6 INTERIOR PAINTING PROCEDURES

6.1 PREPARING THE WORK AREA

The area in which you will be working must be cleared, if possible, of furniture and other items which could be damaged, or would cause obstruction to safe working procedures.

- Remove ornaments, pictures, window dressings or any other decorative items, and store them safely in another area.
- Shift furniture out of the work area.
  - Any items of furniture which are difficult to move may be placed in the centre of the area and covered.
- Cover all floor coverings and surfaces which are not to be painted with drop sheets to protect them from paint spots.

6.1.1 Removal of fittings

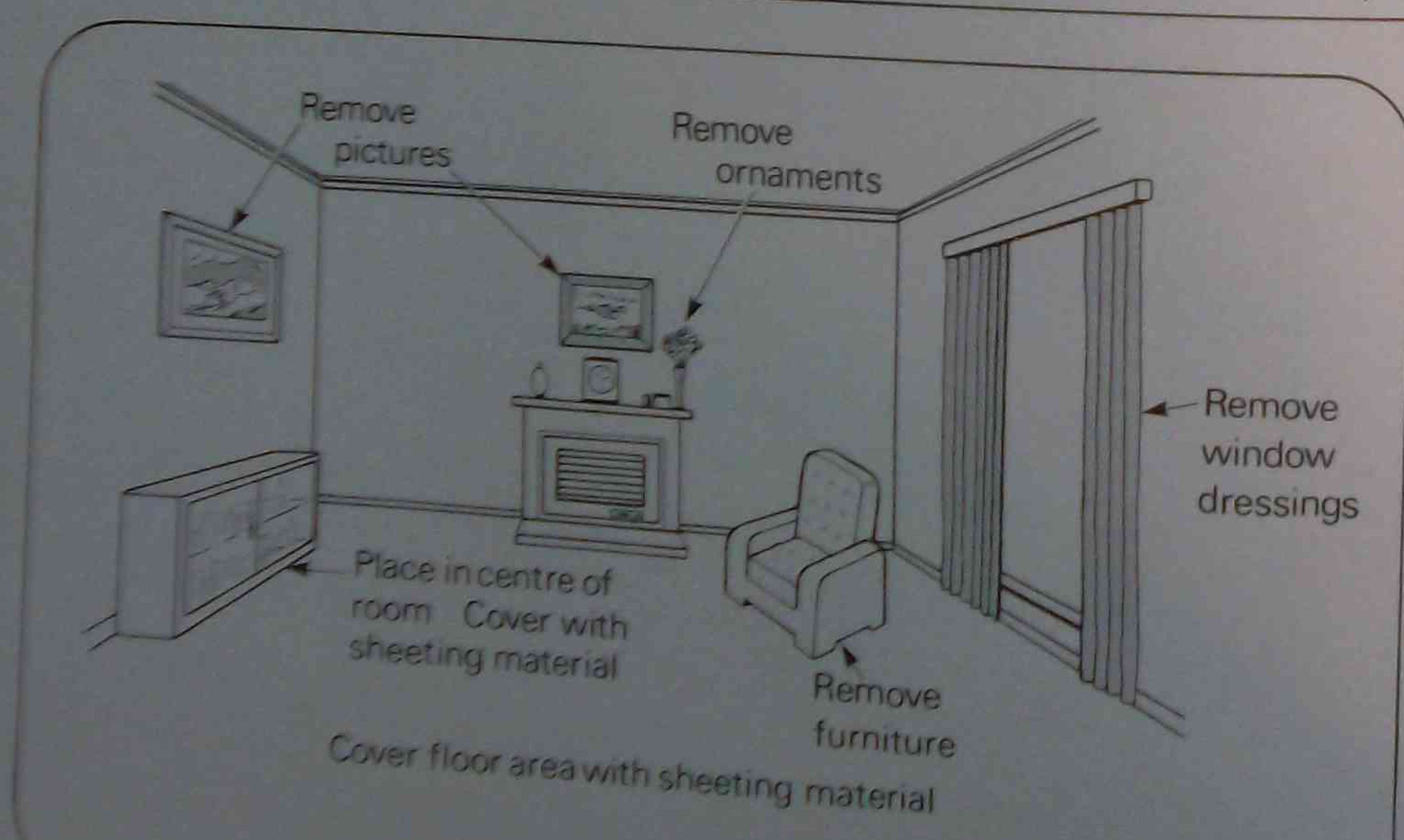
To prevent fittings being damaged or marked with paint, remove them, using a suitable screwdriver, before starting surface preparation.

Fittings that may need to be removed are:

- door handles, push, kick and lock plates, slam plates on architraves
- lightshades
- window fittings

Store the fittings and screws neatly in a box or container.

> **WARNING:**
> Do not interfere with, or remove, electrical fittings. Electrical fittings may be masked with tape.



CLEAR THE WORK AREA

6.1.2 Erecting scaffolding

The erection of scaffolding is best carried out with the help of others to prevent accidents.

For a room 4 metres x 4 metres, two trestle ladders, one plank and one step-ladder should be sufficient for the painting of the ceiling, walls and woodwork.

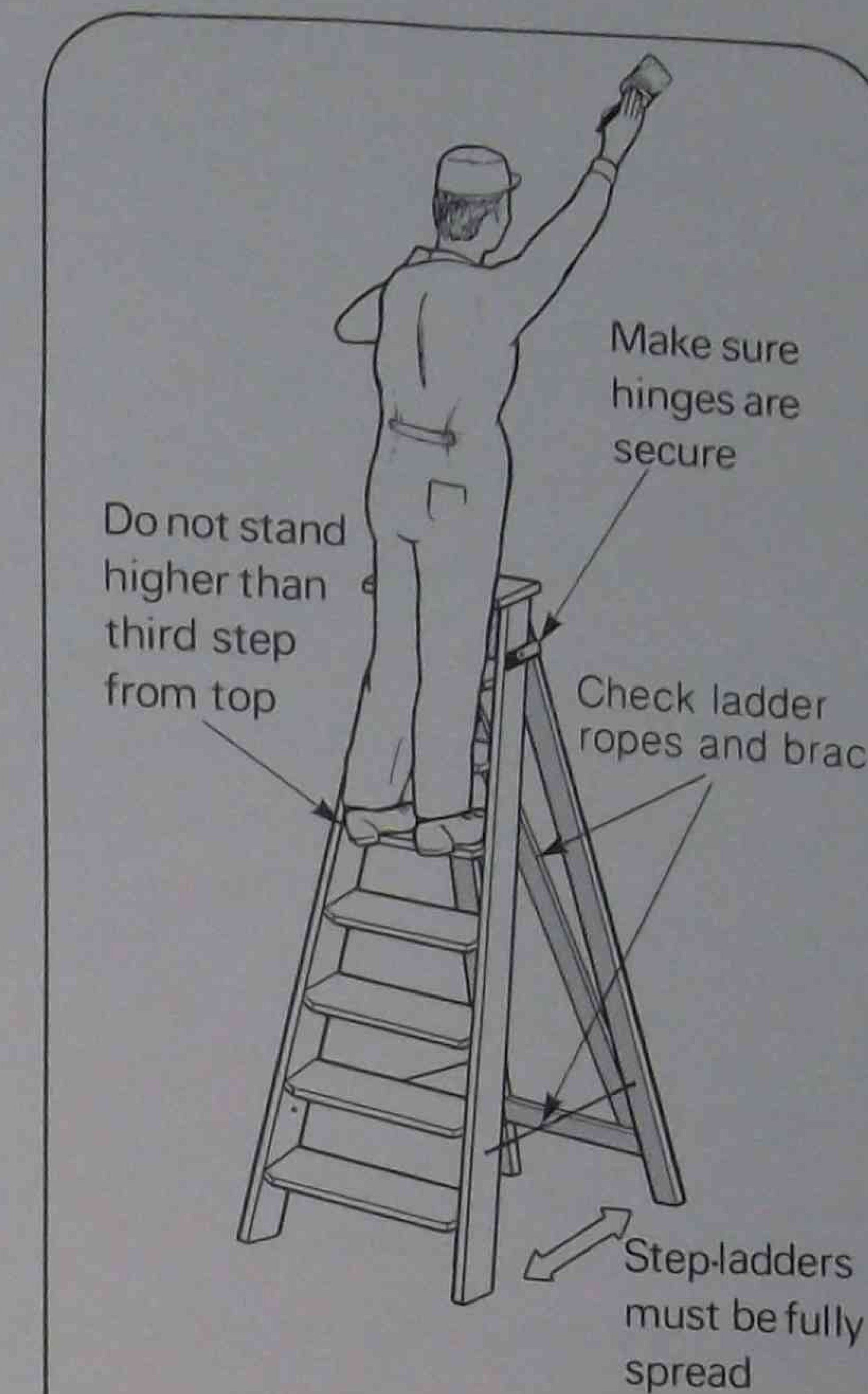
- Select a step-ladder and trestle ladders which are tall enough to allow you to reach the work without standing above the third step from the top.
- Check the ladders before using them for rotting or split timber and make sure the hinges are secure.
  - Ensure that the ladder ropes (if applicable) are in sound condition.

> **WARNING:**
> Do not work on faulty scaffolding.

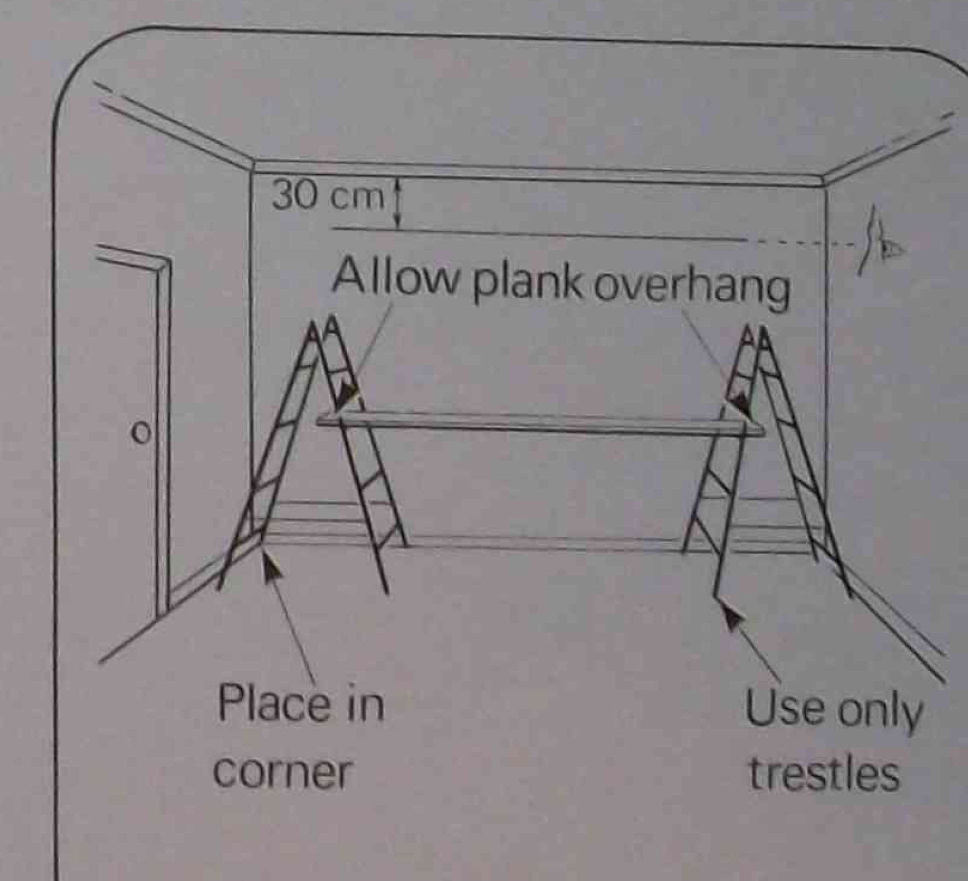
- Place the trestle ladders in two adjacent corners of the room.
  - Make sure they are in a fully extended position.
- Choose a plank which will span from one rung to other, allowing 100 mm minimum overhang at each end.
- Place the plank on the trestle rungs.
  - Choose the trestle rungs so that the ceiling is about 300-400 mm from your eye-level when standing on the plank.
  - Make sure the plank is horizontal and that the ends overhang the rungs on which it is placed, evenly.

NOTE:

Refer to Painting and Decorating Manual Number 2 for details and specifications on the types and uses of various scaffolding equipment.



USING STEP-LADDER



ERECTING SCAFFOLDING

6.2 WASHING DOWN SURFACES

Stained surfaces and surfaces in areas such as kitchens, bathrooms and laundries, will need to be washed down prior to painting.

Smoke deposits, soap, grease, fingermarks on doors and other woodwork must be removed prior to painting.

If surfaces that are to be painted are not thoroughly cleaned, the following faults may occur:

- slowness or lack of drying of the paint film;
- discolouration of the paint film, due to solvent action upon grease, smoke, oil, etc.;
- poor, or lack of, adhesion of the paint film to the surface.

Common types of detergents used for washing down prior to painting are:

- sugar soap
- liquid detergents
- emulsifying liquids
- detergent powders

Follow the manufacturer's directions when mixing detergents. A concentrated or strong mixture may soften the paint on the surface.

When washing down stained surfaces prior to painting, work from the bottom to the top.

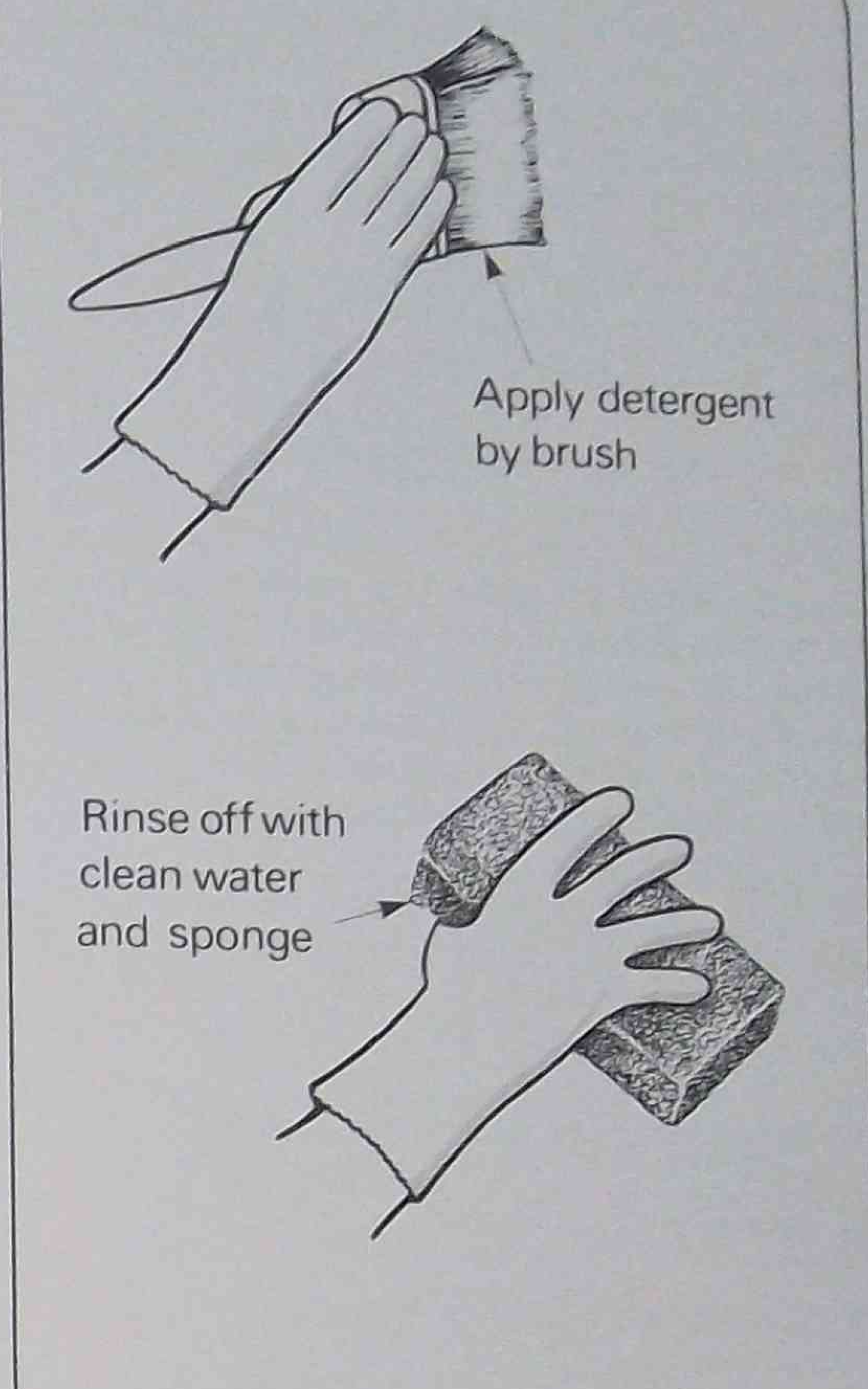
If the upper surfaces are cleaned first, the detergent will run downwards and may cause streaking of the lower surface.

- Mix the detergent solution, to the manufacturer's directions, in a bucket.
- Use an old brush (approximately 150 mm) to apply the detergent, as some solutions are harmful to the bristles.
  - A grass fibre brush is ideal for washing down surfaces, as the fibres are not affected by detergents.
- Apply the detergent, using the brush in a scrubbing motion, to approximately one square metre of surface.
- Rinse this area with a sponge and clean water from a bucket.
- Repeat this process of washing and rinsing over the entire surface to remove the detergent.
- Complete all washing down at this stage of preparation.

WARNING:
Because of the corrosive action of some detergents, do not immerse your hands in the washing solutions. Wear rubber gloves and eye protection whenever washing down.

To avoid accidents when washing down:

- Keep the scaffolding and the surrounding floor area dry.
- Do not overfill buckets and place them where they cannot be knocked over.
- Do not splash the detergent around and work carefully to avoid contact with your skin and eyes.
  - If the detergent does come in contact with your eyes or skin, wash it off immediately with clean water.



WASHING DOWN

REMOVING DETERGENT

6.3 SANDING SURFACES

After the stained surface has been washed down and has dried, all surfaces should then be sanded smooth to remove irregularities and to provide a grip, or key, for the paint to adhere.

Sanding is carried out using abrasive papers which are available in 'grades' from very fine to very coarse.

Abrasive papers are classified as either dry or wet abrasives.

Wet abrasives are used with water to aid in cutting back the surface and to maintain a clean cutting edge on the paper. When used with water to sand previously painted semi-gloss and gloss enamel surfaces, these abrasives give a smooth, scratch-free surface to repaint.

Wet sanding also minimises dust.

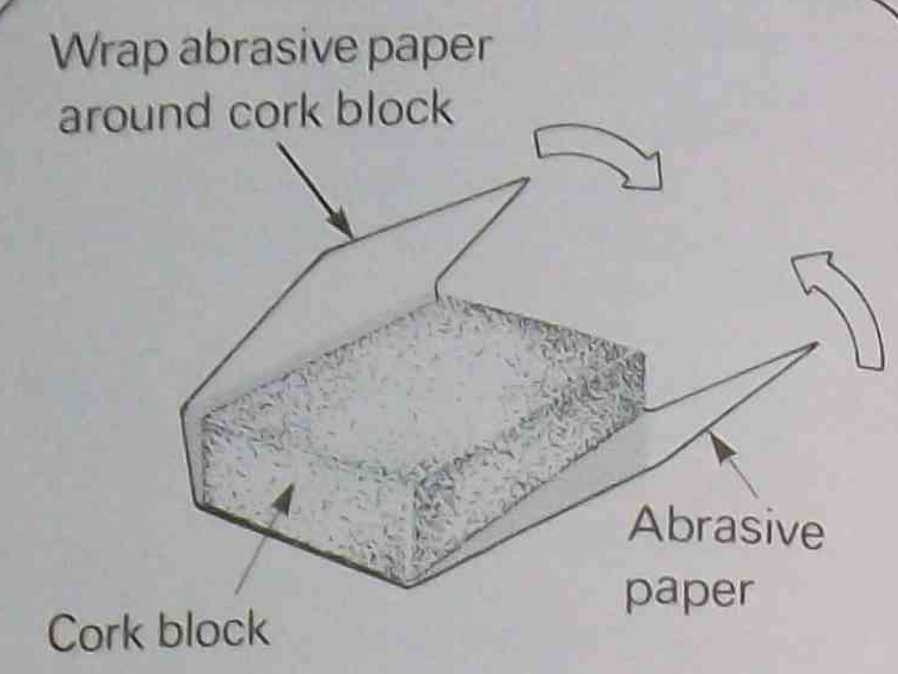
Examples:

- Silicon carbide paper (wet and dry)
- Emery cloth
- Wet abrasive sanding block

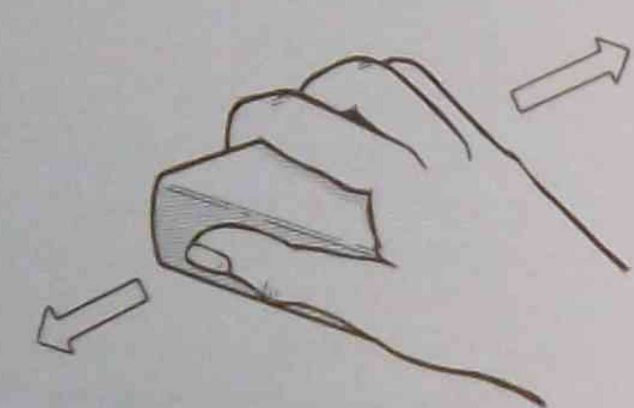
Dry abrasive papers cannot be immersed in water because the adhesive used to fix the grit to the backing paper is water soluble. Also, the backing paper will break up if it is allowed to get wet. Dry abrasives are used to remove irregularities and to provide a level surface for repainting.

Examples:

- Aluminium oxide (open cut) paper
- Glass-paper
- Production paper



SANDING BLOCK



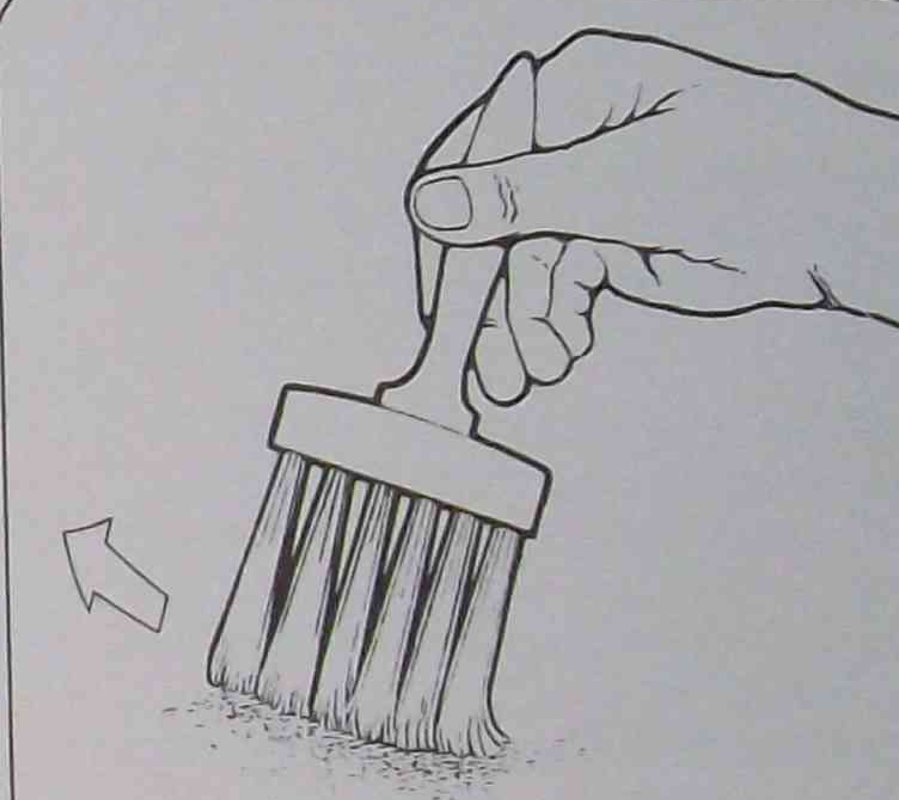
HOLD ABRASIVE FIRMLY ON BLOCK

- Dust caused by sanding should not be inhaled.
  - Wear a dust-mask or a respirator when sanding with a dry abrasive.
- Choose a type and grade of abrasive which suits the surface to be sanded. Your choice of abrasive paper will depend on the condition of the surface.
  - A rough, uneven surface will initially require a coarse-grade abrasive paper.
  - A smooth surface in good condition will require a fine-grade abrasive.
- When sanding flat surfaces, wrap the abrasive paper around a cork block to enable pressure to be applied evenly.
- On previously painted surfaces, work carefully around mouldings and edges to ensure that the timber is not exposed through the paint film.
- Do not allow the abrasive to come in contact with the glass in windows, which can be easily scratched.
- Sand all surfaces to be painted.

NOTE:

Refer to Painting and Decorating Manual Number 2, Surface preparation section, for additional information on abrasive types and uses.

WEAR A DUST-MASK



BRUSH DOWN SANDED SURFACE

6.4 REPAIRING SURFACE DEFECTS

Defects found while sanding the surface will have to be prepared ready for filling.

Cracks

Rake out loose paint and plaster and undercut the crack using a stripping blade to provide a suitable surface for the filler.

Blisters

Remove blistered paint with a stripping blade or shave hook and sand the edges smooth.

Protruding nails

Hammer to surface level and punch below the surface with a nail punch.

Peeling paint

Scrape loose paint back to a sound surface and sand the edges of the remaining paint to merge smoothly into the rest of the surface.

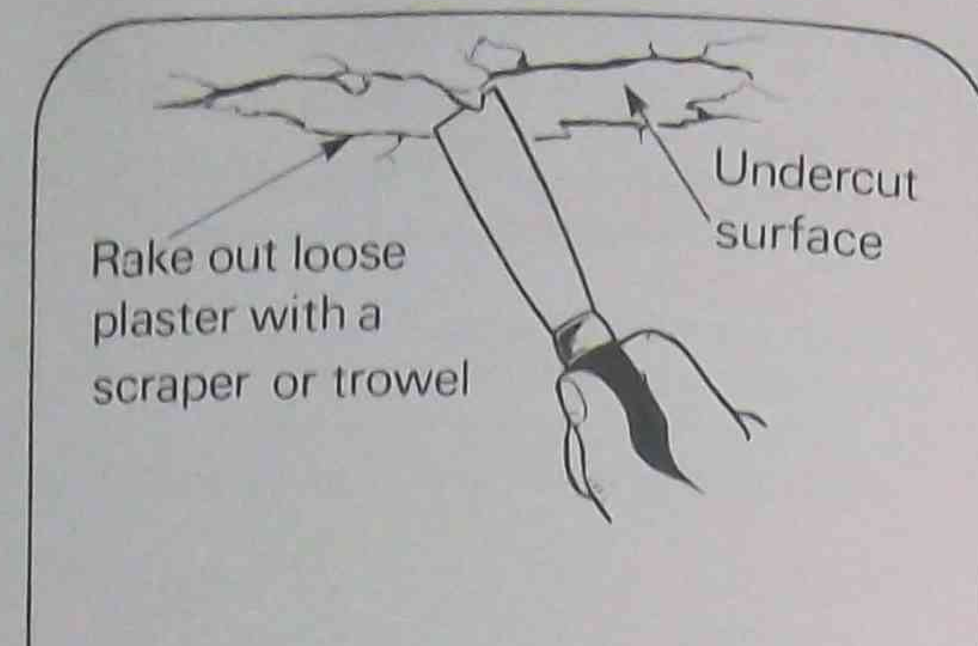
If you have doubts about how well the existing paint is adhering to the surface, test by applying a strip of adhesive tape to the surface and quickly pulling it off again. If the paint comes away with the tape, it is not adhering properly. You will have to remove the affected area by scraping and sanding.

Windows

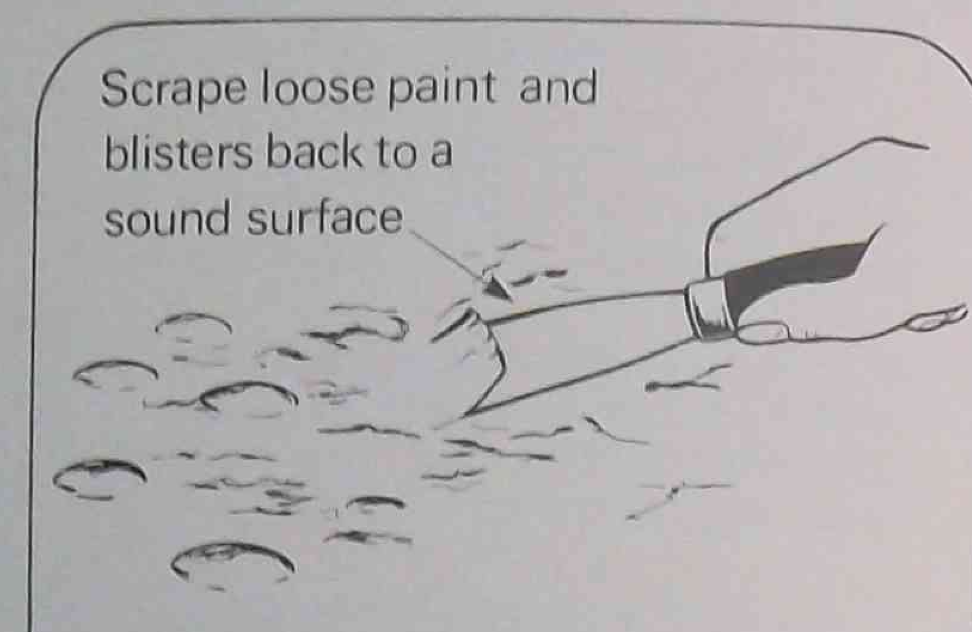
- Replace defective glass and putty.
- Clean and straighten existing putty with a sharp scraper.

NOTE:

Refer to Basic Training Manual Number 4, Glazing.

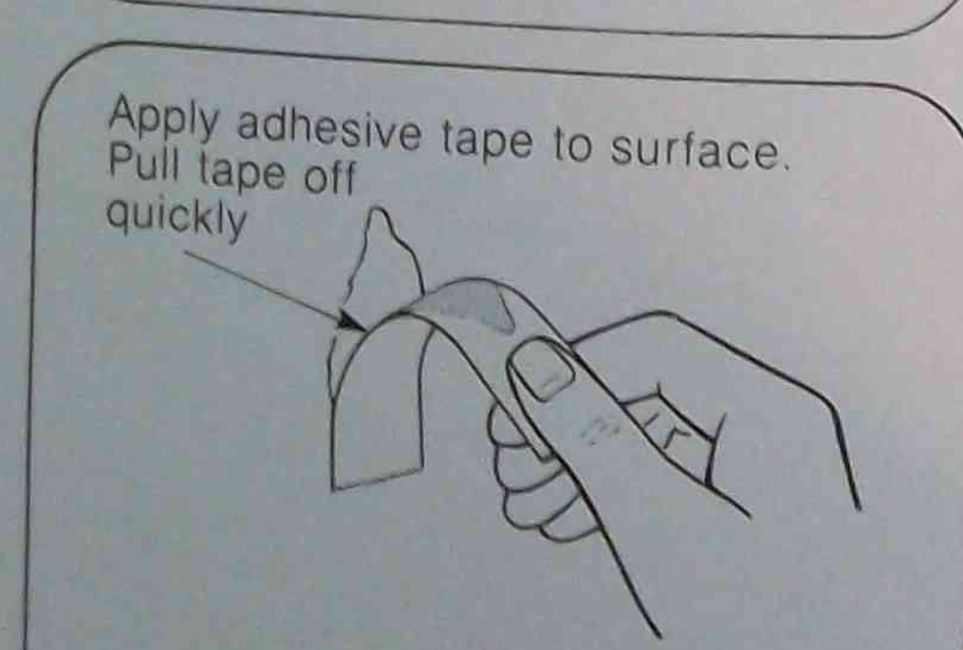


CRACKS



BLISTERS AND PEELING PAINT

PROTRUDING NAILS



TESTING PAINT ADHESION

6.4.1 Filling surface imperfections

When preparing surfaces to receive paint, it is necessary to fill repaired defects and indentations so that they are not seen in the finished job.

Filling

The process of achieving a smooth surface by applying a paste (filler) with a filling knife or blade.

Filling materials:

- Water-mixed cellulose fillers.
- Ready-mixed oil-based fillers.

Stopping up

The process of levelling holes or cavities with a material that dries with a minimum of shrinkage.

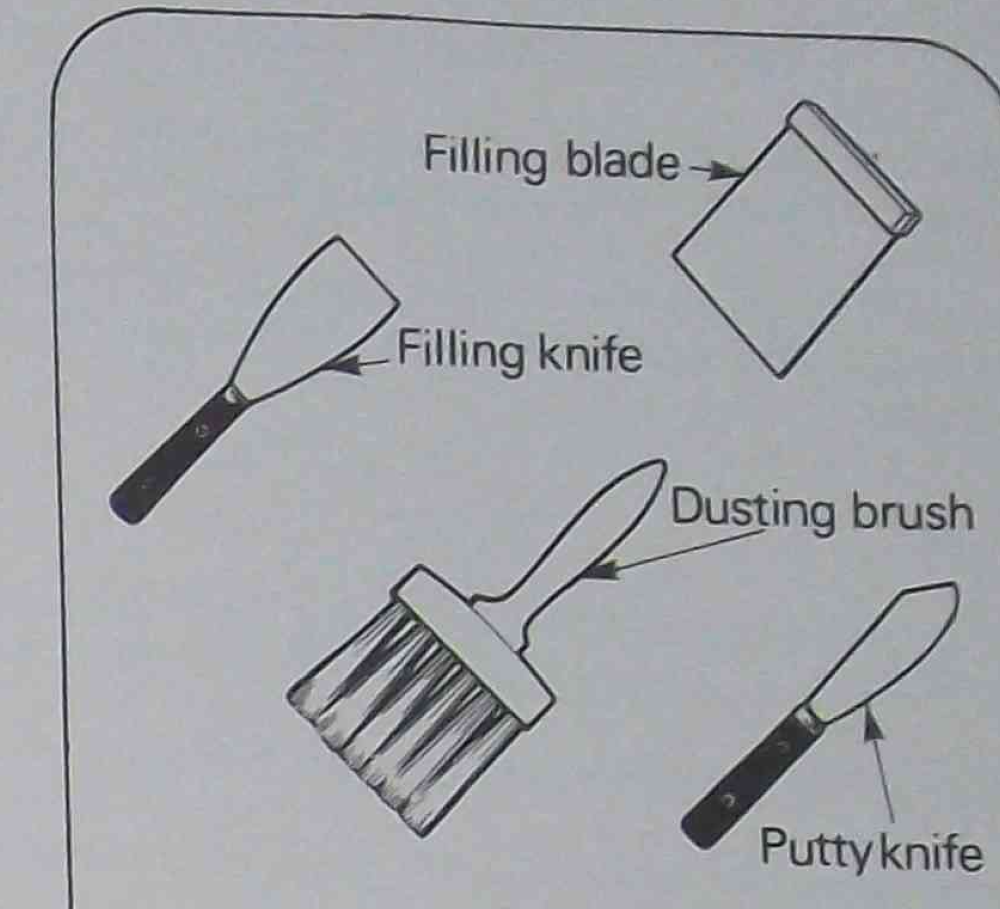
Stopping materials:

Putty, plaster, sand and cement, cellulose stopper, plastic wood, fibreglass and caulking compounds.

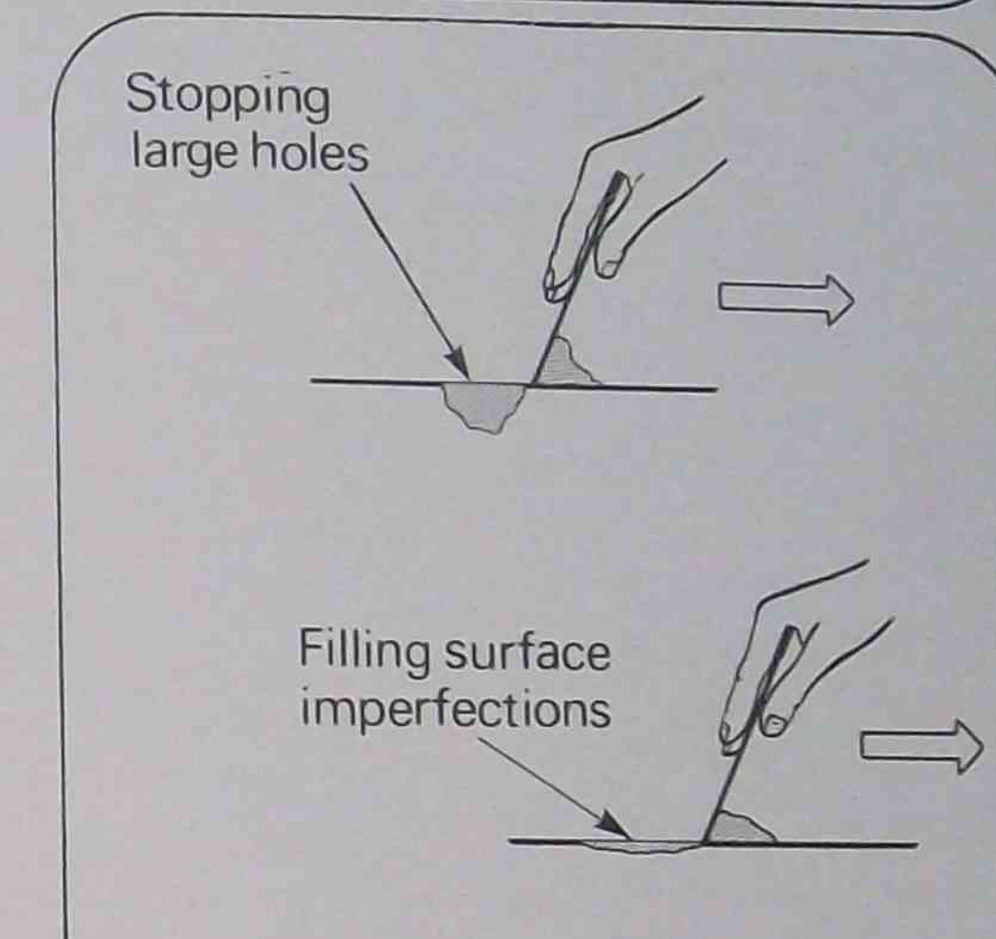
Equipment required:

Filling blades, putty knife, filling knife, water and brush pallet for mixing filler.

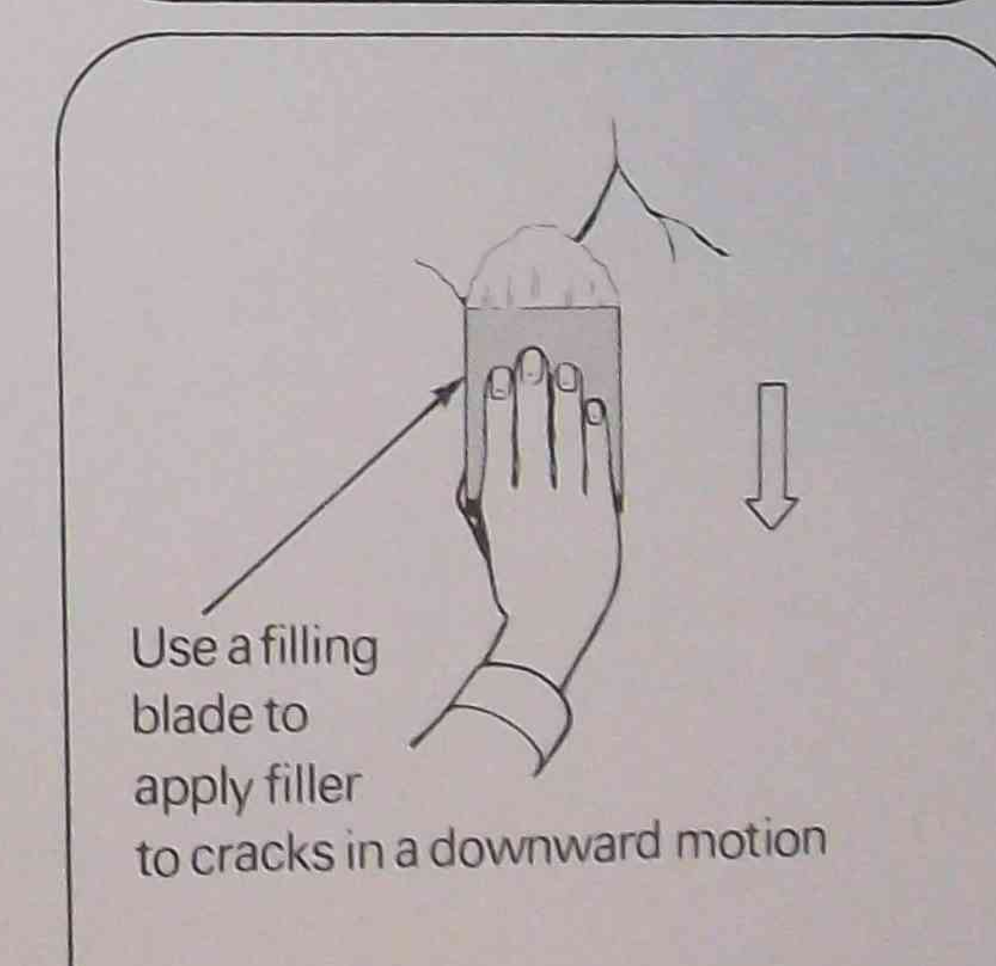
- Make sure your equipment is clean.
- Prepare stopping material to the manufacturer's instructions.
- To avoid wastage of materials, mix only sufficient filler that can be used within the setting time.
- Stop up large cracks or holes first; they may require a second coat and time to dry.
- Work from top to bottom; ceilings, walls and woodwork.
- To minimise the shrinkage of stopping materials on solid plaster surfaces, wet the hole or crack with water before you apply the stopping material.
- To avoid unnecessary sanding, remove excess stopping material from the surface before setting takes place.



FILLING AND STOPPING EQUIPMENT



FILLING AND STOPPING



FILLING CRACKS

6.4.2 Sanding filled surfaces

When the stopped and filled surfaces are dry, use a fine-grade, dry abrasive paper on a cork block to sand the repaired area level with the surrounding surface.

Filling must be sanded at this stage and not left until after the first coat of paint. If left until painted, the surface would be too hard to sand back easily, and the painted surface would be damaged.

NOTE:

Do not use a coarse-grade abrasive to sand the repaired surface as it may scratch the filler and cause the filled surface to appear different from the surrounding area.

Select a fine grade of abrasive to suit the condition of the filled surface.

Do not use a wet abrasive at this stage of preparation, as water will soften most filling and stopping materials.

Use a dusting brush to remove all dust from the repaired surfaces.

6.5 PREPARING PAINT FOR USE

Each colour and type of paint should be prepared just before its use.

- Read the manufacturer's instructions carefully.
- Remove any dust from the lid of the container with a dusting brush or cloth.
- Open the lid, using a manufactured opener or a metal lever.
  - Hand tools can be damaged if used to open containers.

WARNING

Take care when opening the lid as paint may spurt up onto your face or into your eyes.

- Stir the paint thoroughly with a flat stirrer.
  - Move the stirrer up and down with a scooping action until a smooth consistency is achieved.
  - Make sure the stirrer reaches the bottom of the container.

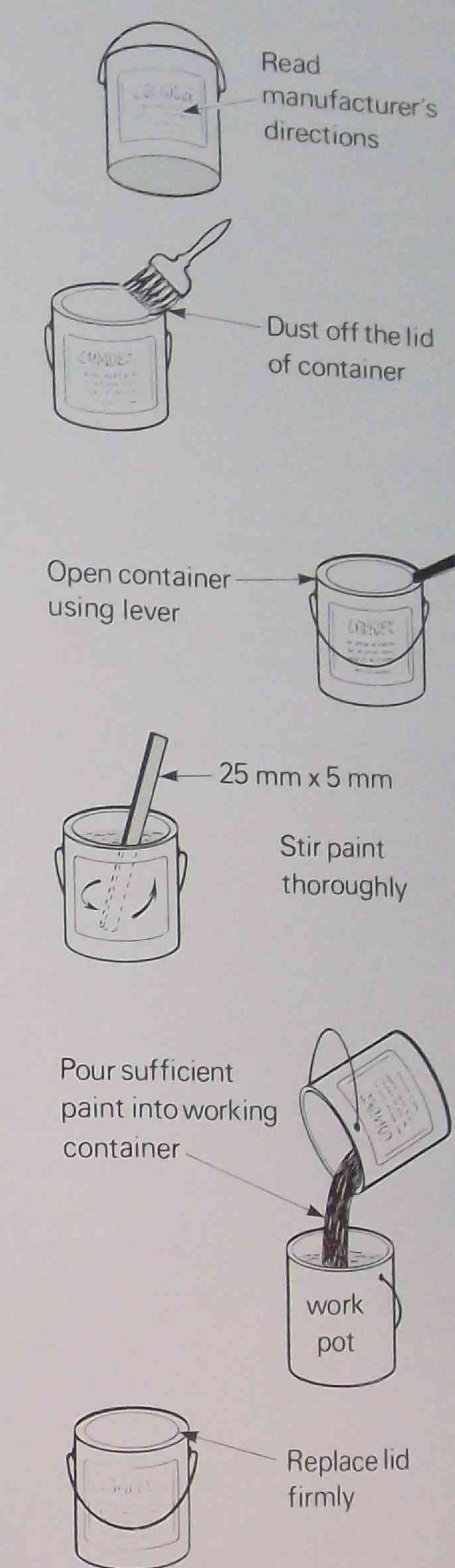
Thin the paint, if required, by adding small amounts of the specified thinner. Stir in the thinner until thoroughly mixed.

- Pour the required quantity of paint into a working container (workpot).
  - Do not pour too much paint into the work container as any paint not used for the first coat, if returned to the manufacturer's container, can add dust and grit to the clean paint.

WARNING

Do not inhale fumes from the paint or thinner.

- Replace the lids firmly on the manufacturer's containers.

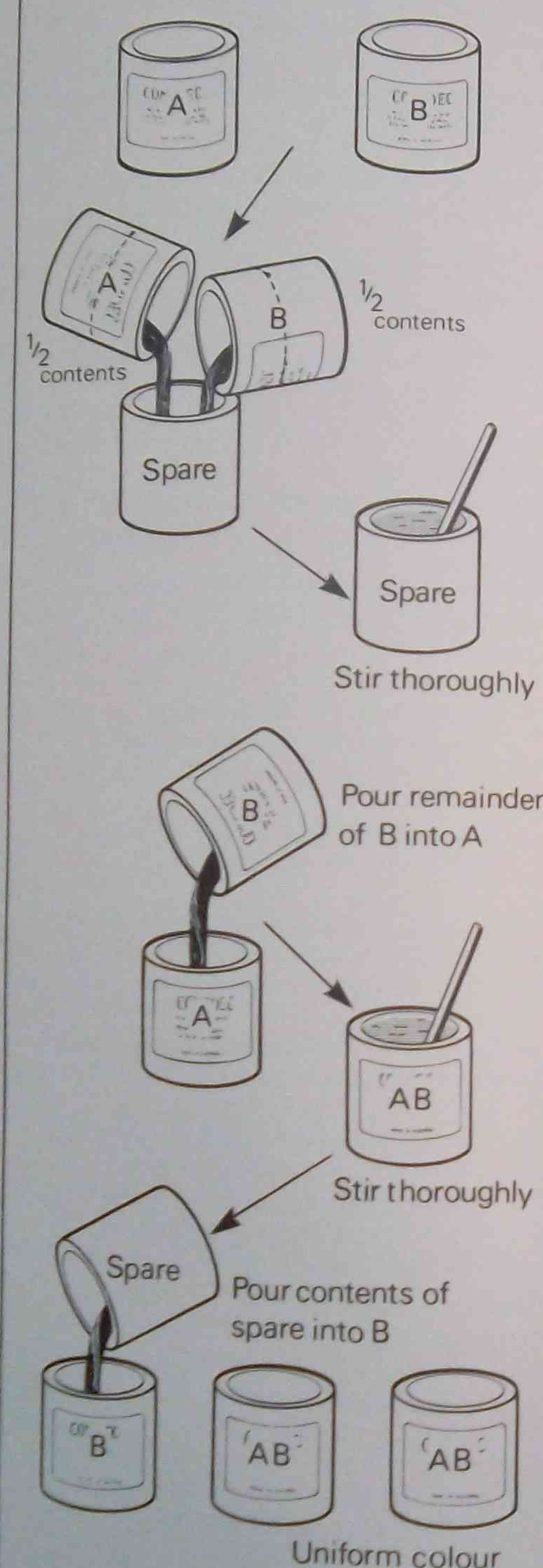


PREPARING PAINT

If you have several containers of the same colour, be aware that there may be a slight difference in colour between them.

To ensure that the colour is uniform:

- Repeat the previous steps with each container.
- Now pour half the contents from each container into a clean spare container.
- Stir the paint thoroughly in the spare container.
- Pour the second half of one container into the other container.
- Stir the paint thoroughly.
- Pour the contents of the spare container back into the original container.
- Repeat the process several times until the colour of the paint is the same in each container.
- Replace the lids firmly on the containers.

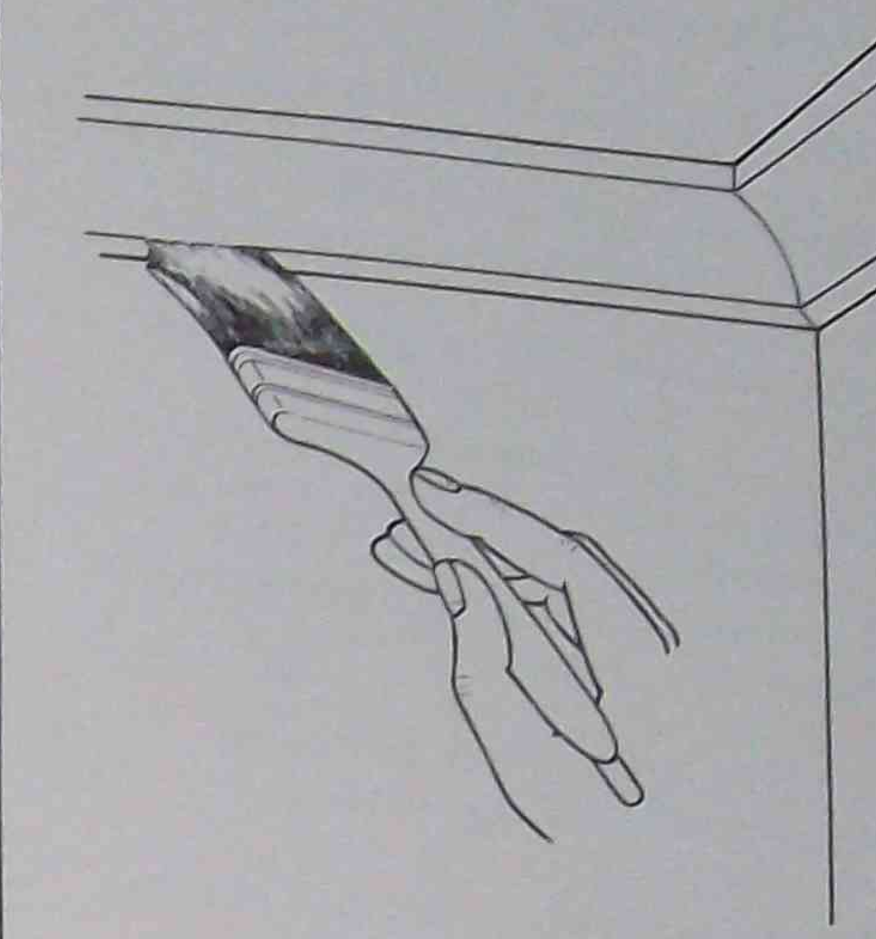


ENSURING UNIFORM COLOUR

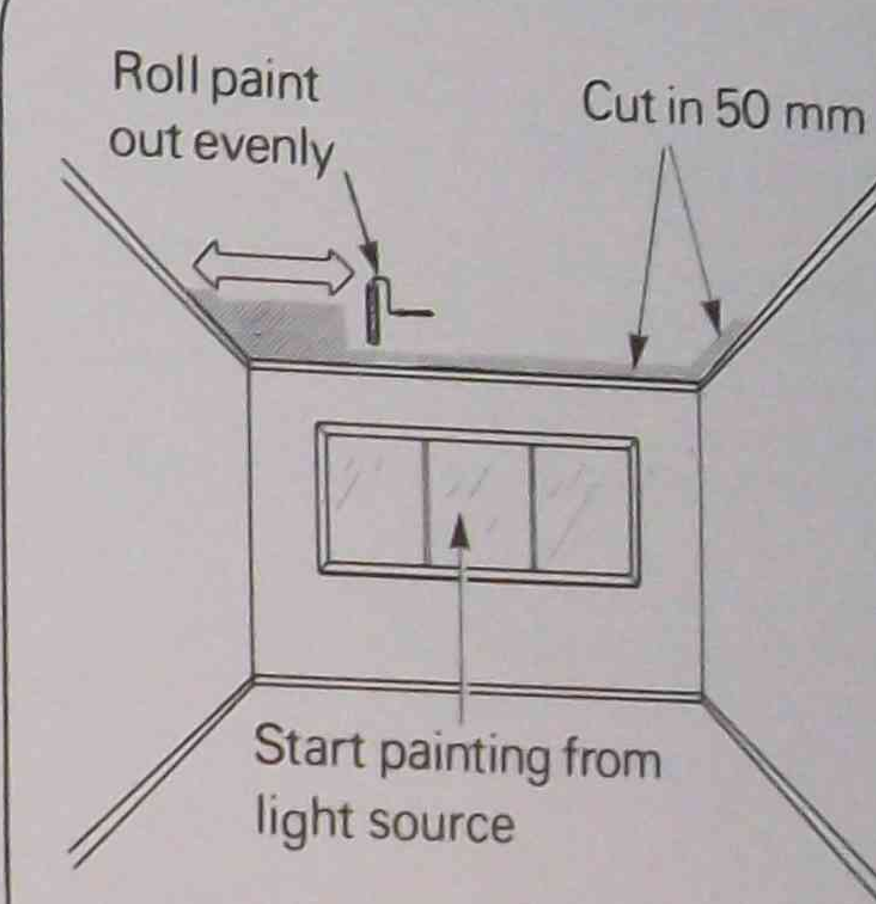
6.6 PAINTING THE CEILING AND CORNICE

After all preparation is complete, begin painting the room. Work from top to bottom, starting with the ceiling and cornice.

- Straighten the protective drop sheets covering the floor and other surfaces.
- Erect the trestle ladders and plank across the width of the room at one end, near a window.
  - Ensure that when standing on the plank your eye-level is 300 to 400 mm from the ceiling.
- Whenever possible start painting from a light source (window) so that completed sections reflect the light, and any areas not coated can easily be seen.
- To avoid discolouration of new paintwork, make sure the brushes and rollers to be used are clean and free of previous paint or thinner.
- Select a 75 mm brush.
- Load the brush by dipping the bristles about 30 mm into the paint.
  - Tap the bristles against one side of the pot to remove excess paint.
- When painting ceilings, work in front of yourself.
- Begin in one corner, paint the underneath edge of the cornice, the cornice surface and about 50 mm of the ceiling surface. This is called 'cutting in'.
- 'Cut in' the full width and sides of the ceiling to a distance that can be safely reached.



CUTTING IN



START IN CORNER

> **WARNING:**
>
> Do not, at any time, overreach when working from scaffolding.

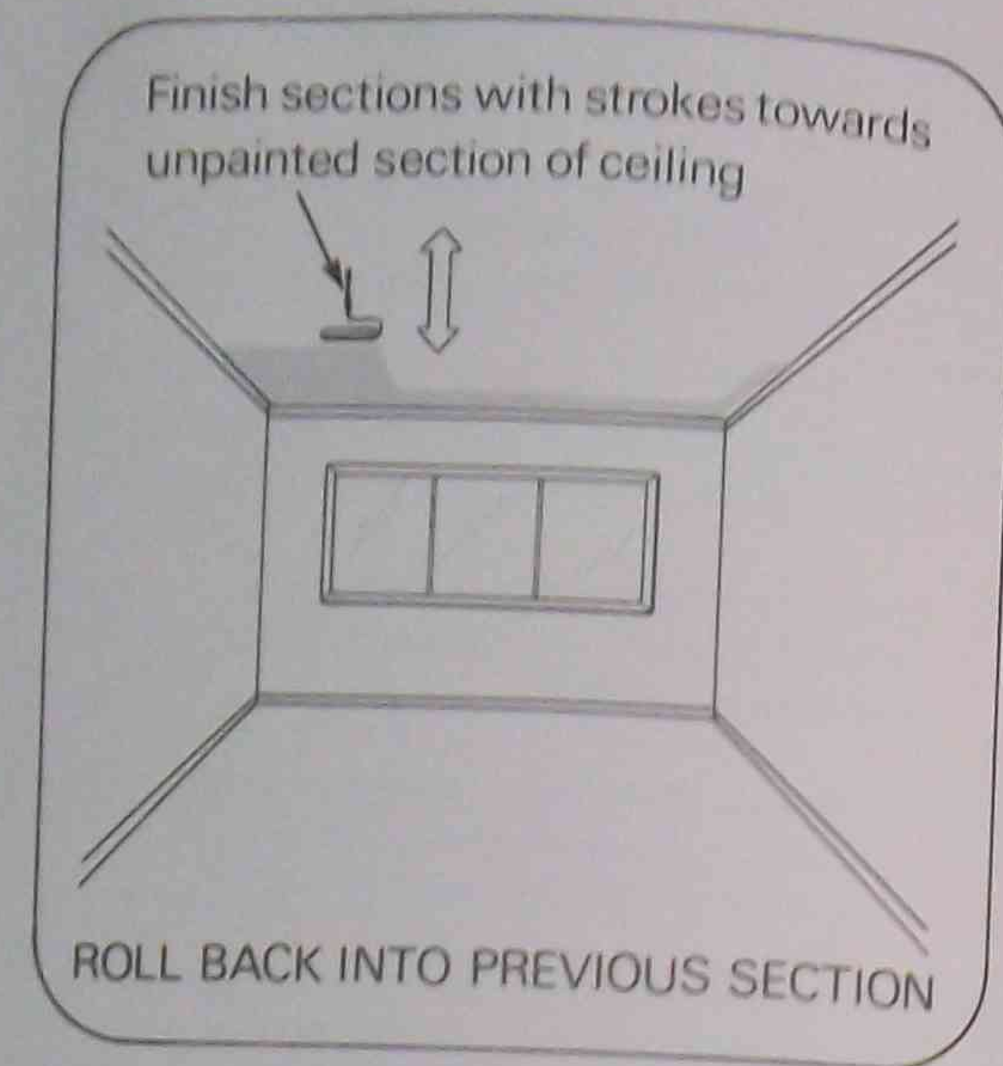
Refer to the manufacturer's specifications to establish which type of roller cover suits the surface to be painted and the type of paint to be used.

For a ceiling measuring approximately 4 m × 4 m wide, a roller 230 mm wide would be suitable and easy to handle.

- Place the roller tray on the floor clear of the trestle ladder.
- Pour about 6 cm of paint into the tray.
- Work the paint into the roller, using the bed of the tray to roll out excess paint.
- Start rolling in a corner of the ceiling.
- Apply the paint to a square section, rolling the paint out evenly, finishing with strokes approximately 1 metre in length towards the unpainted section of the ceiling.
- Finish one strip across the ceiling before moving the scaffolding.
- Shift the scaffolding forward in position for the painting of the next strip.
- Cut in the cornice and ceiling on each side.
- Roll the paint onto the ceiling, finishing with strokes rolled back into the previously painted section.
- Repeat this process until the complete ceiling is coated.

If there are any obstacles on the ceiling, for example a light fitting or ornamental plaster decoration which cannot be removed, 'cut in' a 50 mm strip around it with a brush before rolling the surrounding ceiling area.

Always finish each section of ceiling by rolling in the one direction to ensure that an even coat of paint is applied and to avoid missing any sections of the ceiling.



ROLL BACK INTO PREVIOUS SECTION

ROLL IN ONE DIRECTION

NOTE:

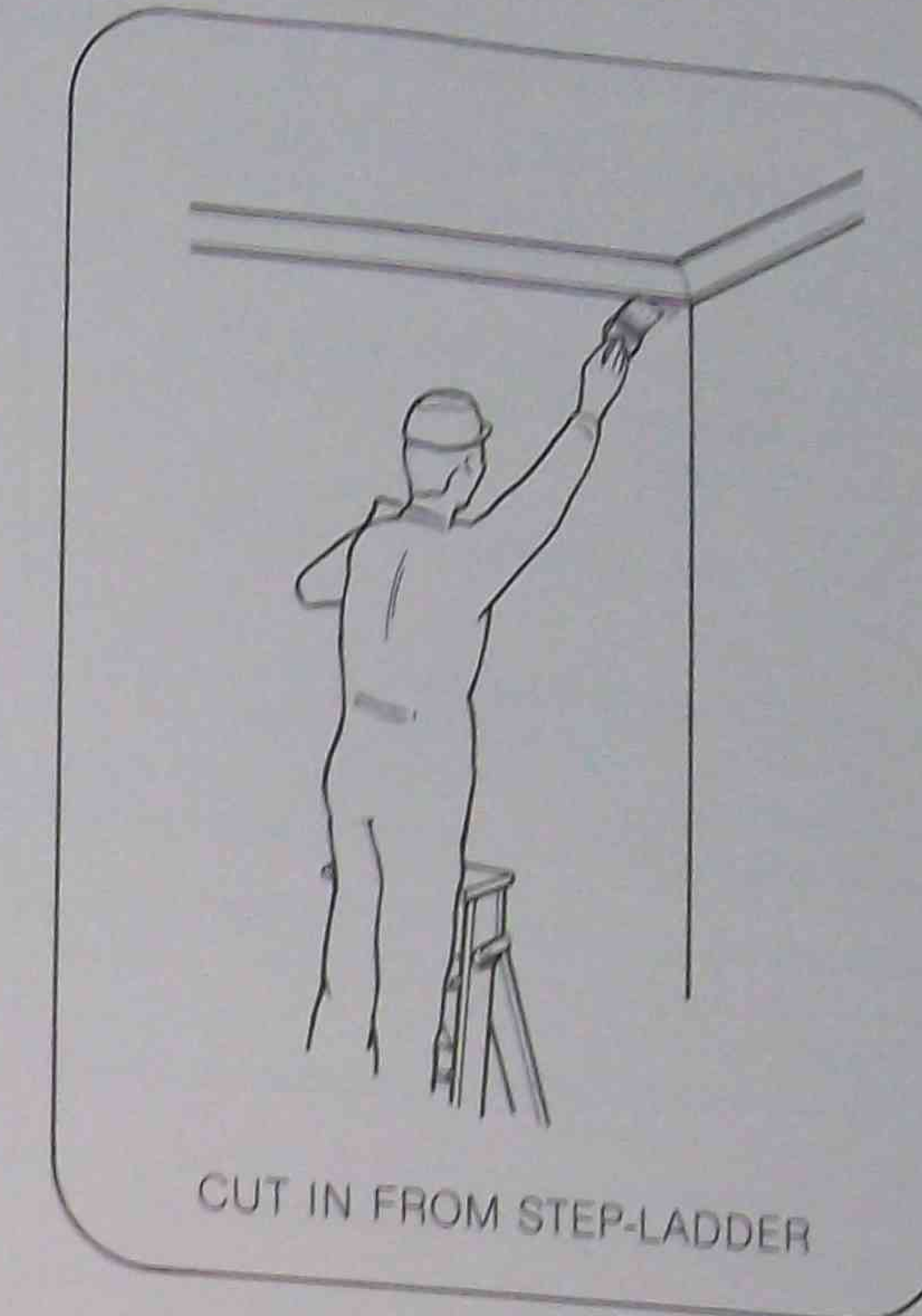
The edge of a previously coated surface must be kept wet while applying paint to the next section. Joining a wet surface to a dried area can cause overlapping to show on the finished work.

6.6.1 Using a roller and extension arm

A roller fitted with an extension arm can be used from the floor instead of rolling the ceiling from scaffolding.

When using this method:

- Paint the cornice and about 50 mm of the ceiling edge with a 75 mm brush.
  - Use a step-ladder to reach the cornice.
  - Do not stand higher than on the third step from the top.
- Place the roller tray on the floor, to one side of the working area, in a position where it is not likely to be knocked over.


CUT IN FROM STEP-LADDER

- Attach the roller handle to the extension arm.
- With the extension arm attached, load the roller by working it into the paint.

The procedure for applying the paint is the same as when working from scaffolding.

- Start painting in a corner of the ceiling at a light source.
- Apply the paint in strips across the width of the ceiling.
- Finish rolling each strip, using strokes towards the unpainted section of the ceiling.


USING ROLLER WITH EXTENSION ARM

NOTE:

This procedure is best carried out by two painters, one painting the cornice ceiling perimeter and the other rolling. This avoids the paint around the ceiling perimeter drying before rolling is commenced, thus causing joins to show.
This method can also be used to paint walls.

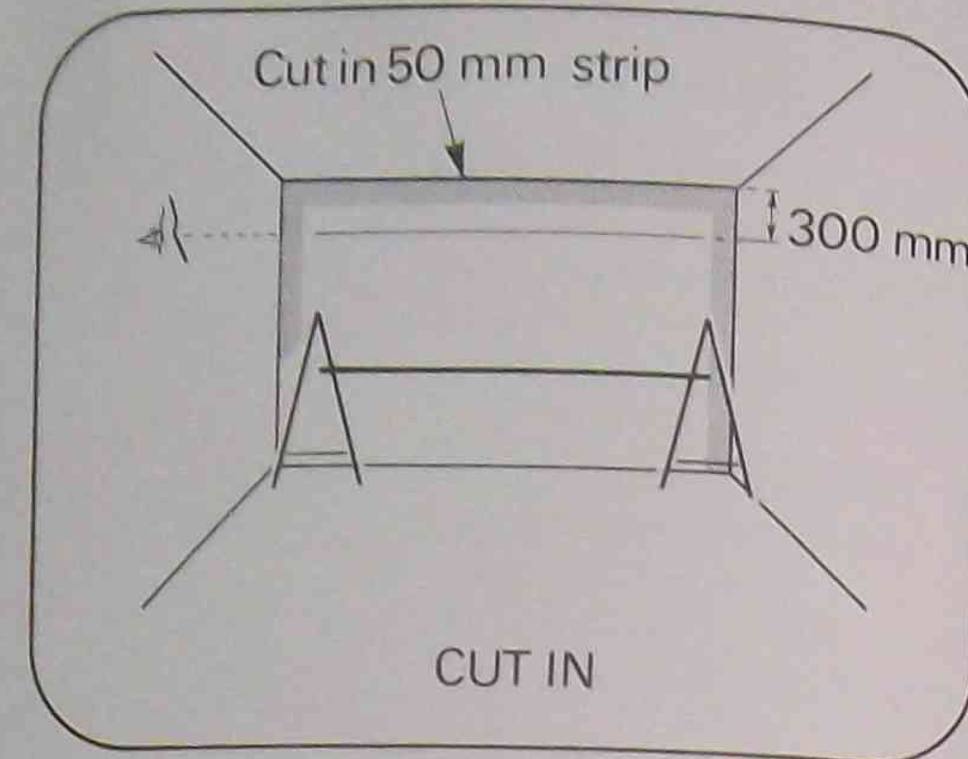
6.7 PAINTING THE WALLS

After all preparation is completed and the ceiling has been given the final coat of paint, the walls are then painted.

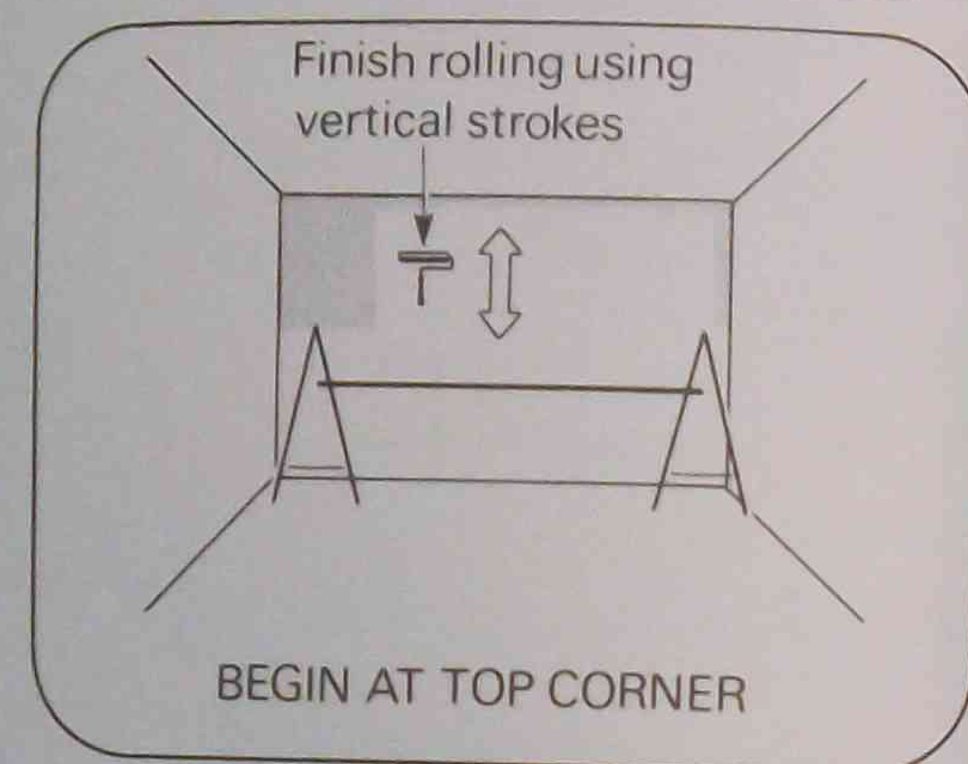
- Mix the paint for the walls, using the same procedure as outlined for the ceiling paint.
- Prepare your roller, tray, paint pot and brush.
- Erect the trestle ladders and plank parallel to the first wall to be painted and with the plank approximately 400 mm from the wall surface.
- Beginning at a top corner of the wall, cut into the ceiling cornice with a brush, painting a strip about 50 mm wide onto the wall.
  - Complete all the cutting in that can be safely reached from the plank.
- When rolling the paint on the wall, start in a corner at the ceiling and paint in sections about 1 metre deep and as wide as your plank will allow.
- Complete the painting of the first strip across the width of the wall before commencing the next strip below.
- For each section, 'cut in' first down corners, along skirting boards and around doors, etc, before you roll the wall surface.
- Complete each wall before you start the next.

NOTE:

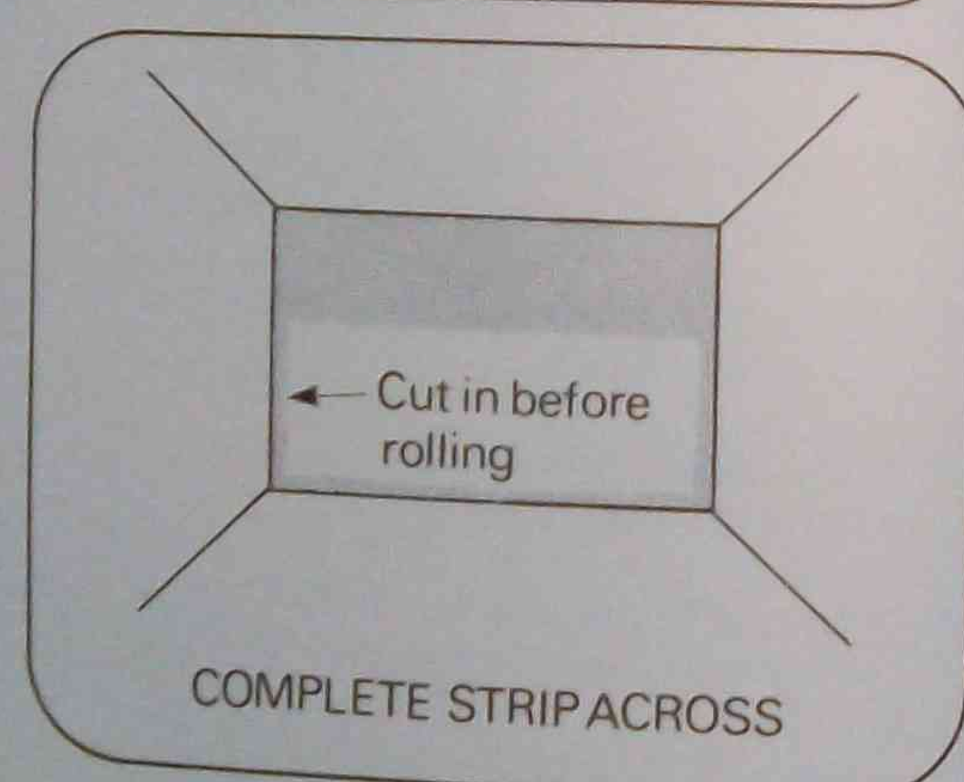
The rolling technique is the same as outlined previously.



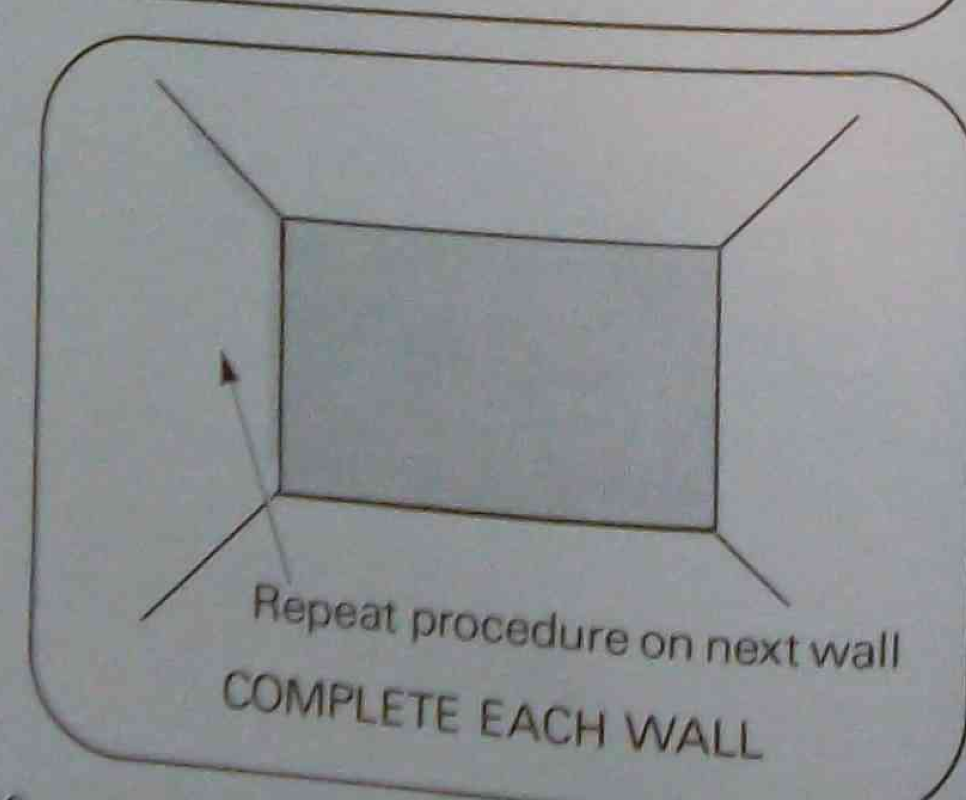
CUT IN



BEGIN AT TOP CORNER



COMPLETE STRIP ACROSS



COMPLETE EACH WALL

6.8 PROCEDURE FOR PAINTING WOODWORK

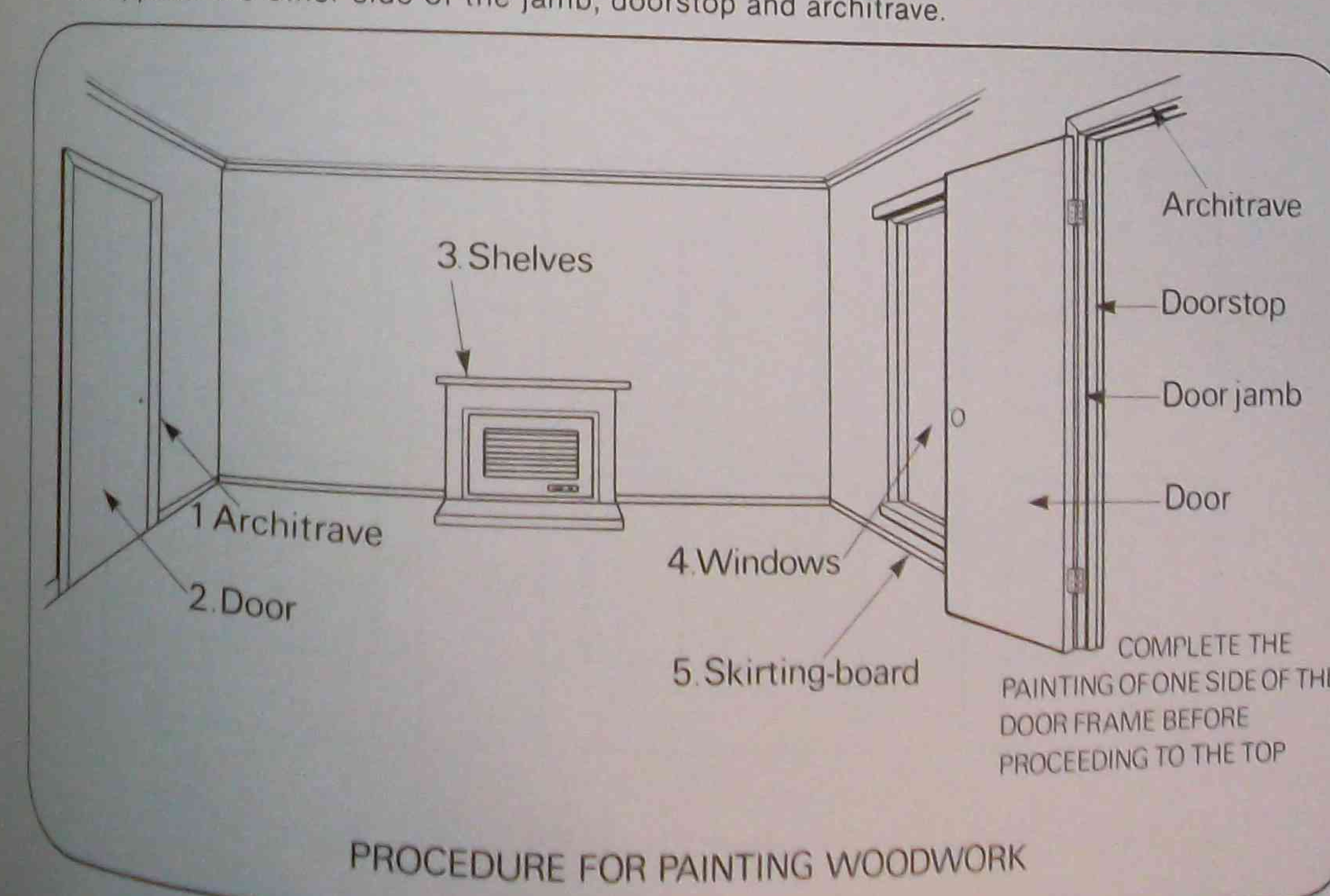
Following the painting of the first coat on the ceiling and walls, the woodwork is painted. The order in which the items of woodwork are painted is as follows:

- door frames (architraves)
- doors
- cupboards, shelves, etc
- windows
- skirting-boards

The reason for painting the woodwork in this order is to ensure that the paint remains clean for a longer period. As the woodwork is painted, the brush picks up dust particles which are transferred to the paint and the painted surface. Therefore, by painting the skirting-board last, dust picked up from the floor area will not be deposited on other more noticeable surfaces, such as doors.

6.8.1 Painting door frames

- Dust down the previously sanded surface and the surrounding floor area.
- Cover the floor area with protective drop sheets.
- Prepare the paint to the manufacturer's directions.
- Select a 50 mm brush.
- Paint the jamb, doorstop and architrave of one side of the frame.
  - Be sure to paint the edge of the architrave before the surface.
- Now paint the top doorstop, jamb and architrave.
  - Do not overload the brush with paint when painting overhead.
- Next, paint the other side of the jamb, doorstop and architrave.



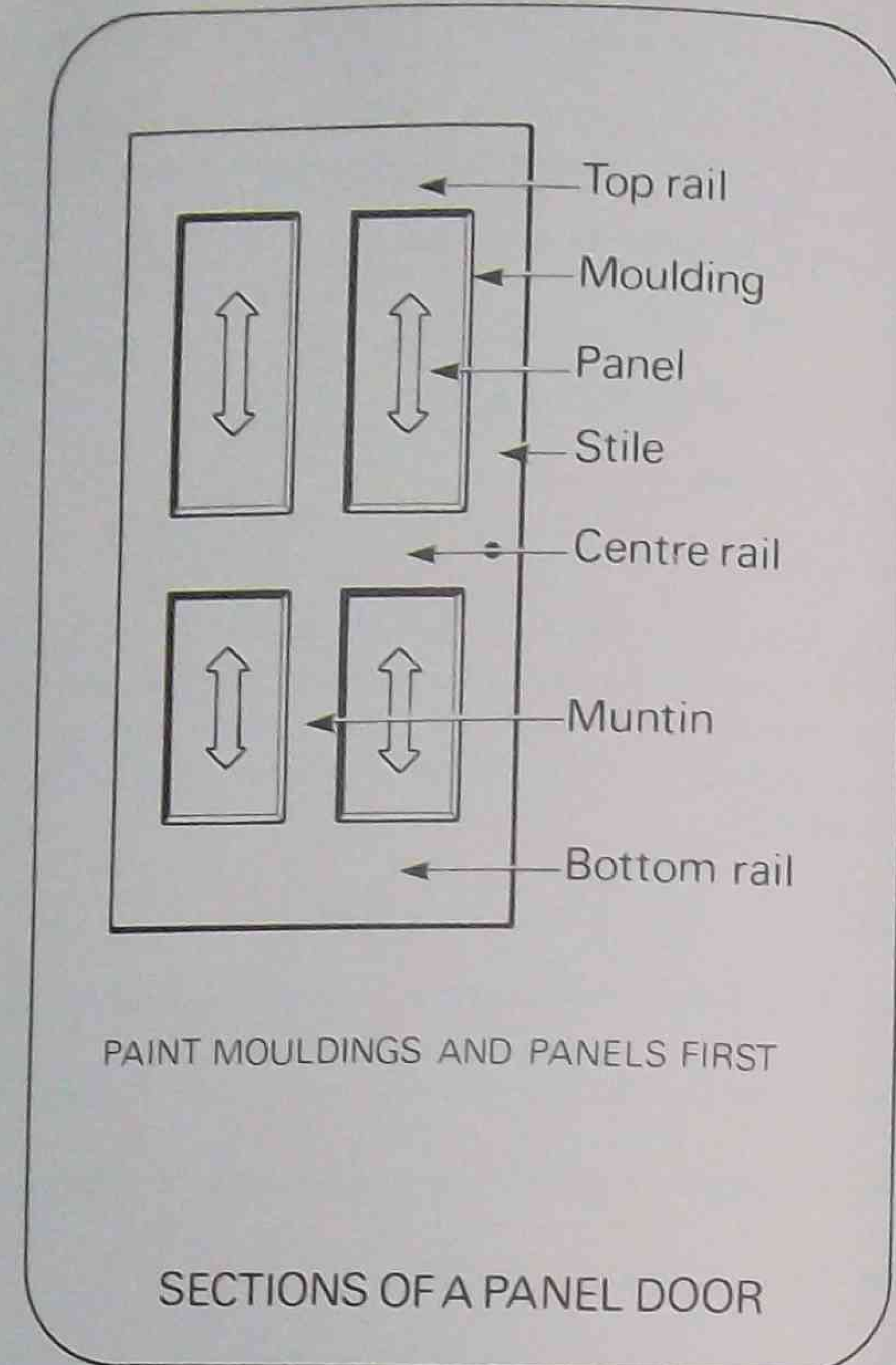
PROCEDURE FOR PAINTING WOODWORK

6.8.2 Painting a panelled door

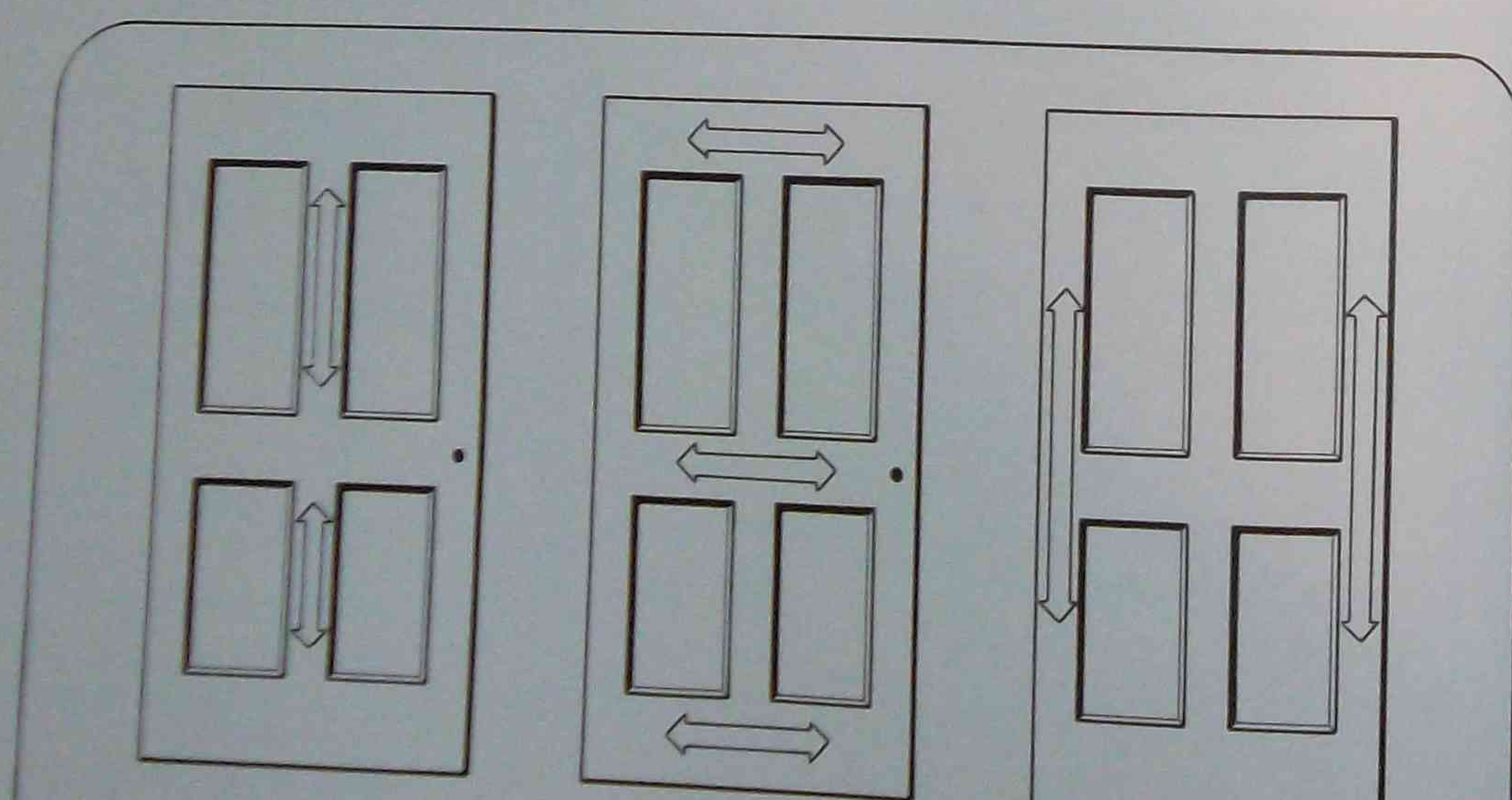
A panelled door is one with a number of sections raised above, or sunk below, the level of the door surface.

Following preparation and dusting down, the painting procedure is as follows:

- Ensure that the floor area is covered with drop sheets.
- Choose one 75 mm and one 50 mm brush.
- Use the 50 mm brush to paint the edge of the door.
  - Be careful not to allow paint to flow onto the door surface.
- Paint the panels and mouldings with the same brush.
  - Be careful not to allow paint to flow onto the stiles and rails.
- Use the 75 mm brush to paint the muntins, rails and stiles.
- Paint the muntins, finishing at the joint with the rails.
- Working from top to bottom, paint the three rails, finishing at the joint with the stiles.
- Paint the stiles.



SECTIONS OF A PANEL DOOR



PAINT MUNTINS PAINT RAILS PAINT STILES

6.8.3 Painting a flush panel door

A flush panel door is one without decorative panels on its surface.

The application of paint to this type of door can be carried out by using a brush, a roller, or a combination of both applicators. A spray-gun is used when a large number of doors are to be painted.

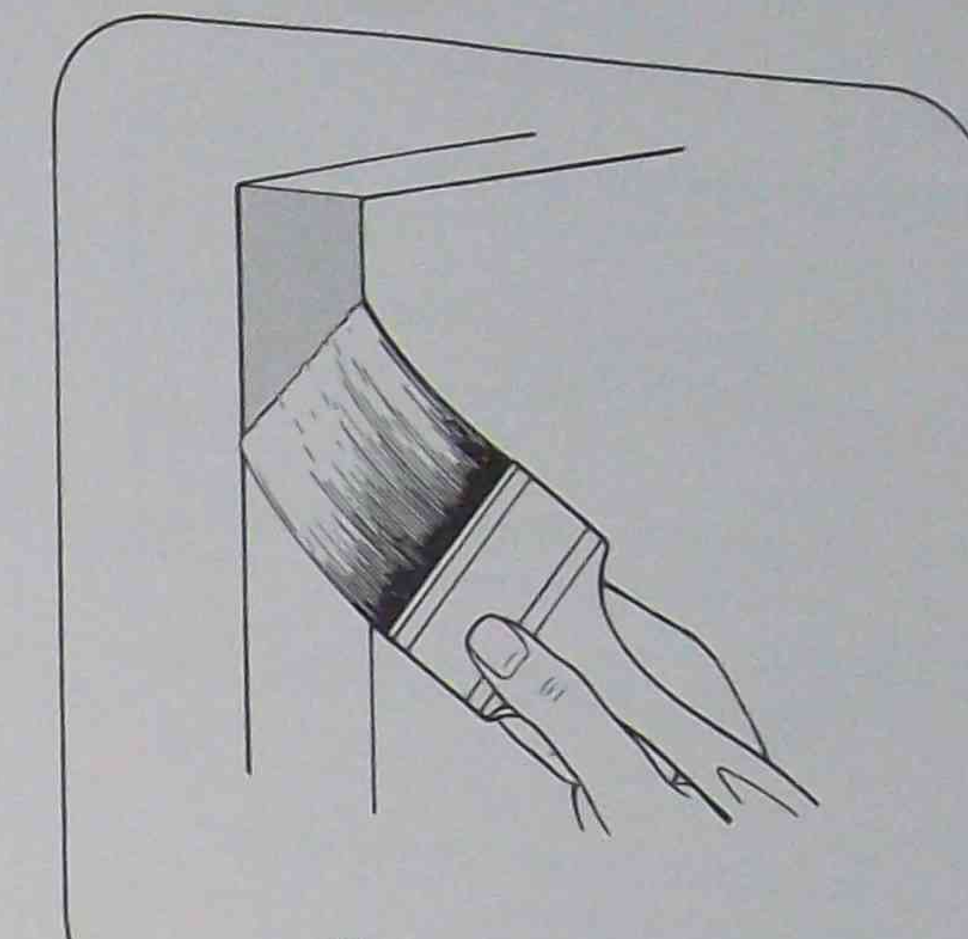
One method of painting small numbers of these doors is with a 75 mm brush and 180 mm synthetic foam roller.

The technique for this application method is as follows:

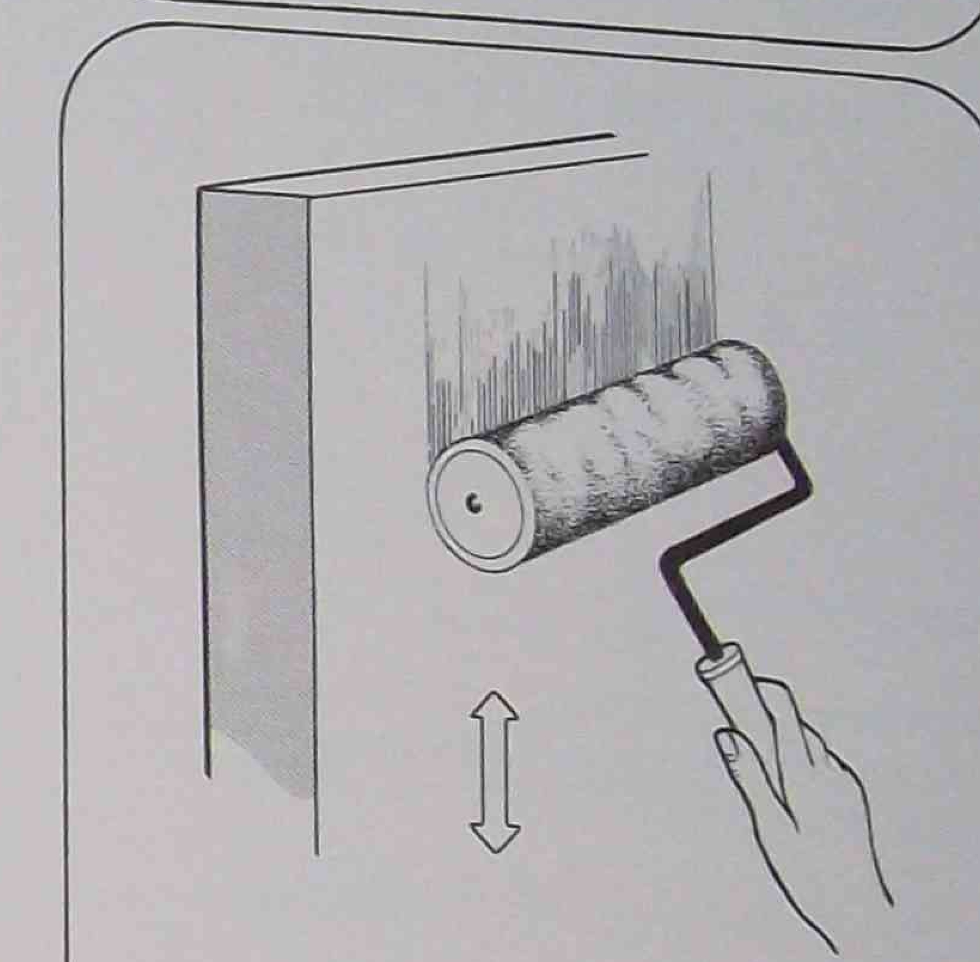
- Prepare and dust down the door and surrounding floor area.
- Cover the floor area with drop sheets.
- Remove door fittings and lock plates.
- Prepare the paint, roller, roller tray and brush.
- Apply paint to the door edge by brush.
- Paint the door surface with the roller.
  - Use vertical strokes and lay the paint onto the surface until an even finish is obtained.

To remove the paint texture left by the roller:

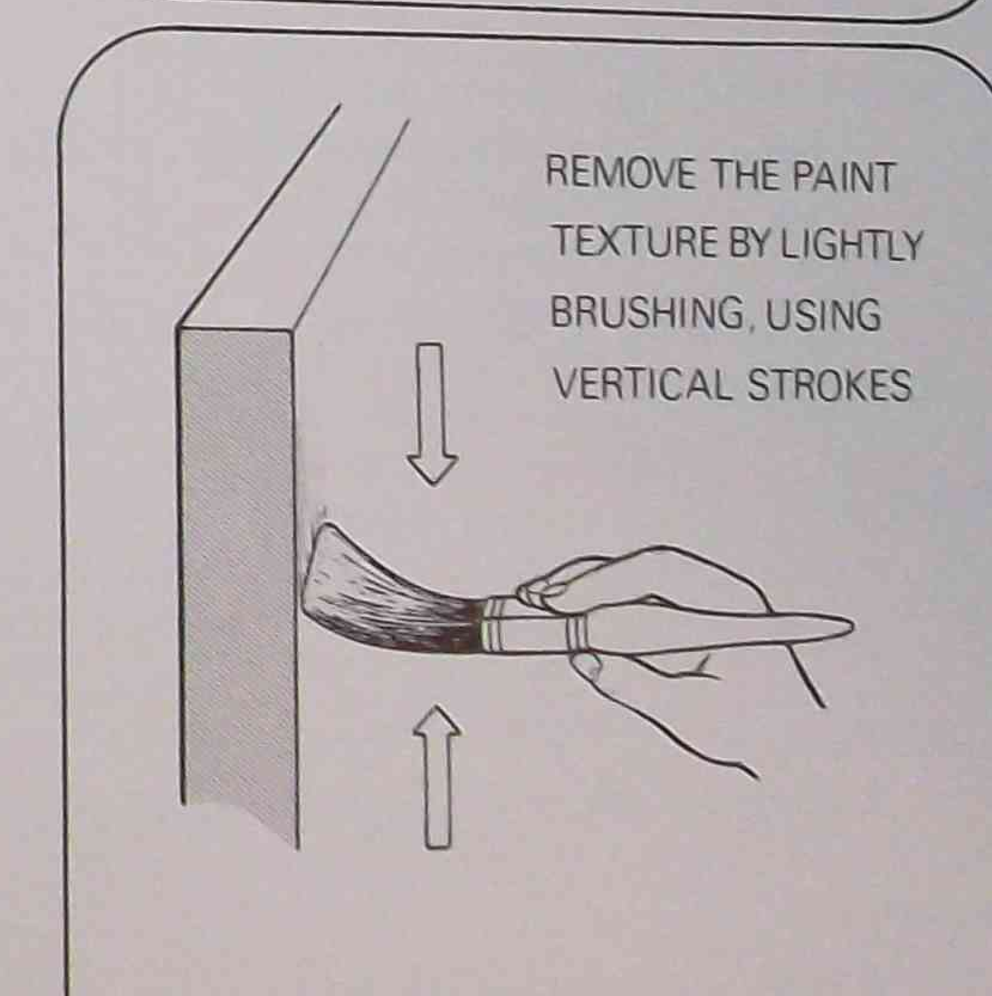
- Lightly brush over the painted surface, using vertical strokes with a dry brush over the full height of the door.
  - This is called 'laying off'.
- Use only the tip of the bristles of the brush to avoid brushmarks on the finished surface.
- Carry out brushing immediately after the door has been rolled.



PAINT EDGES FIRST



ROLL PAINT ONTO SURFACE

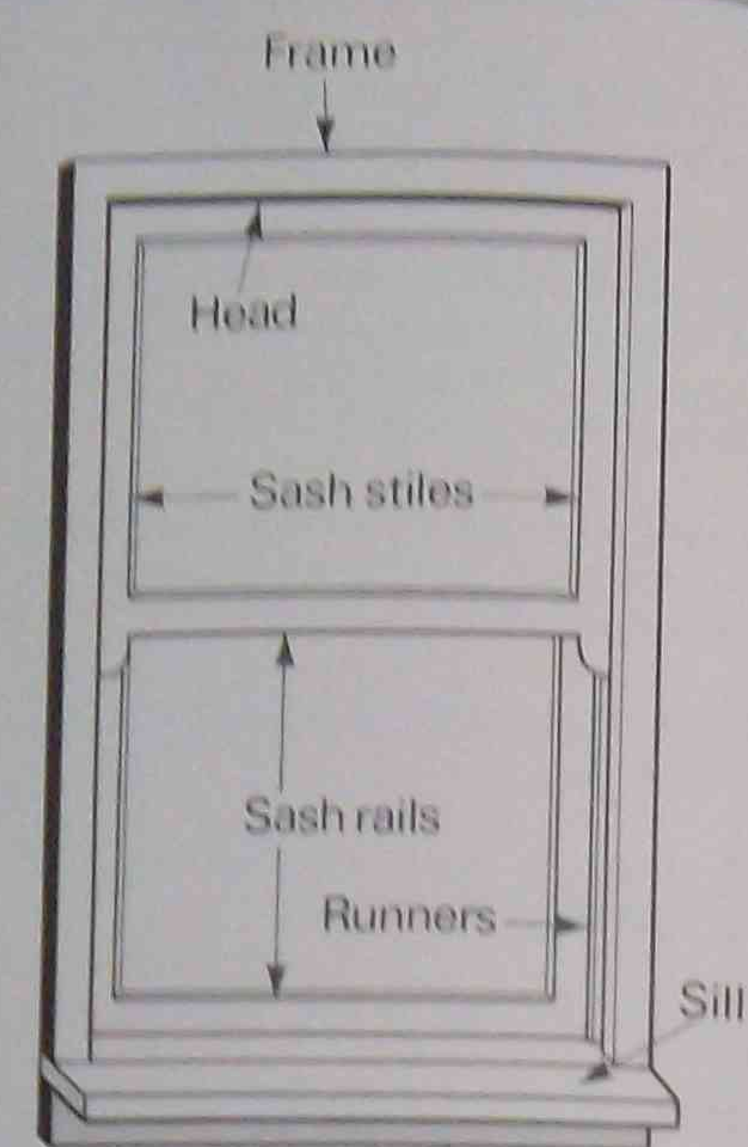


LAYING OFF

6.8.4 Painting windows

Sections of windows

- Sash
  — The section of the window in which the glass is fixed.
- Sash rails
  — The horizontal members of a sash.
- Sash stiles
  — The vertical members of a sash.
- Frame
  — The timber surround to which the window sash is fixed.
- Runners
  — The sections of frame which guide the movement of the sash.
- Head
  — The underside of the top of the window frame.
- Sill
  — The base of the window frame.



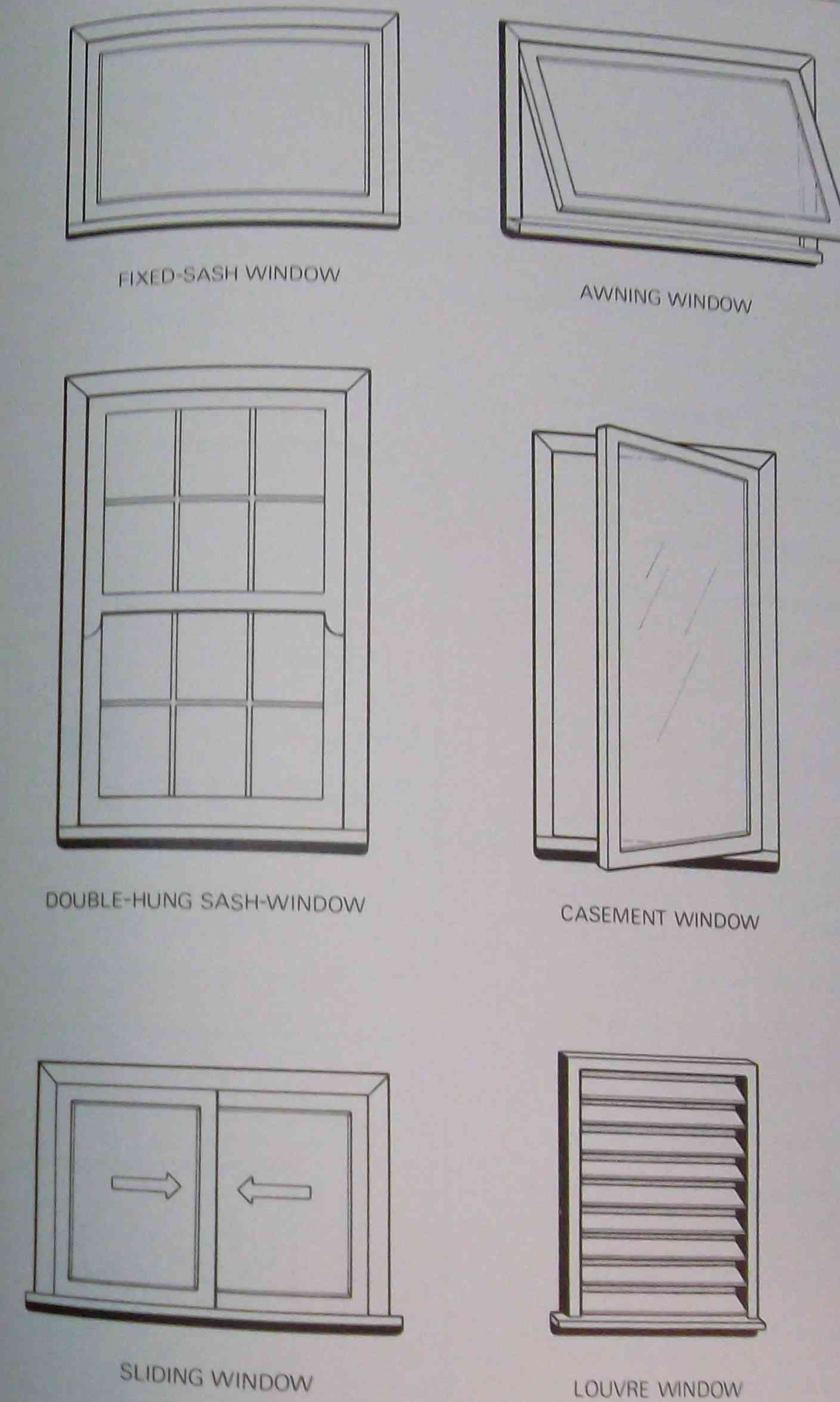
SECTIONS OF A WINDOW

Types of windows

Windows are available in many types and sizes and are manufactured in timber, aluminium or other metals.

The most common types of windows are:

- Fixed sash
  — This type of window has a sash which is fixed in the window frame.
- Double-hung sash
  — A window with two separate sashes sliding vertically up and down in runners.
- Casement
  — A casement window has one or more sashes which are hinged on the side. The sashes swing outwards.
- Sliding
  — A sliding window has one or more sashes sliding horizontally in tracks. Some sets of sliding window have one sash fixed and one sliding sash.
- Awning
  — A window in which the sash is hinged at the top and swings outwards from the bottom.
- Louvre
  — A louvre window has removable glass slats which are inserted into the window frame at an angle of approximately 45°.



TYPES OF WINDOWS

Procedure for painting windows

When painting windows of any type, the general painting procedures are most important.

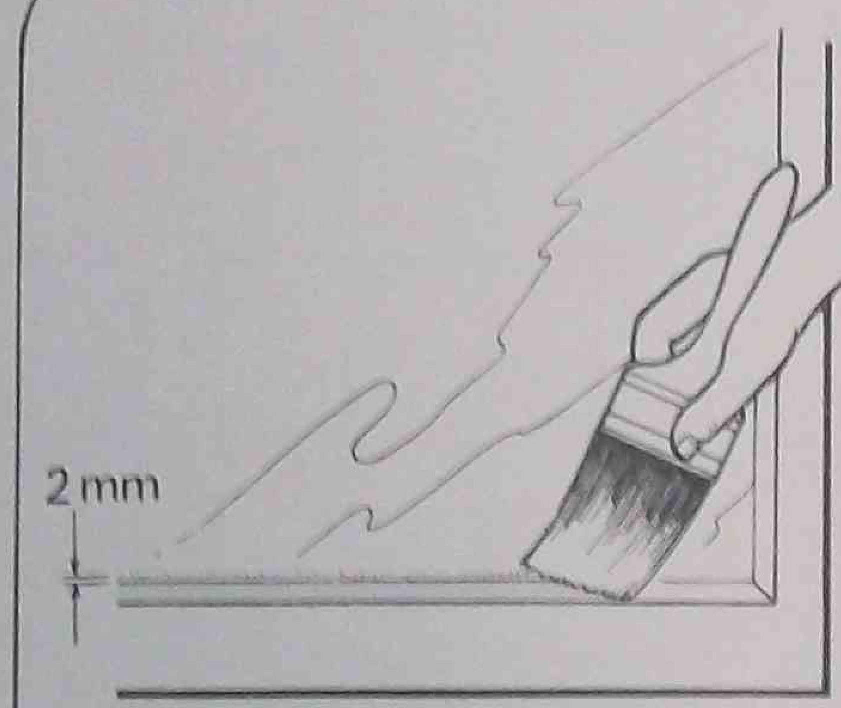
- Work from top to bottom
- Work towards yourself
- Paint edges first

Regardless of the type of window to be painted, a standard order for painting the sections should be used.

- Complete all preparation and dust all surfaces.
- Open the window fully.
  - Remove any glass louvres.
- Prepare the paint and select a 50 mm brush.
- Paint the edges of the sash.
- Paint the window sash in this order:
  - Top rail
  - Stiles
  - Bottom rail

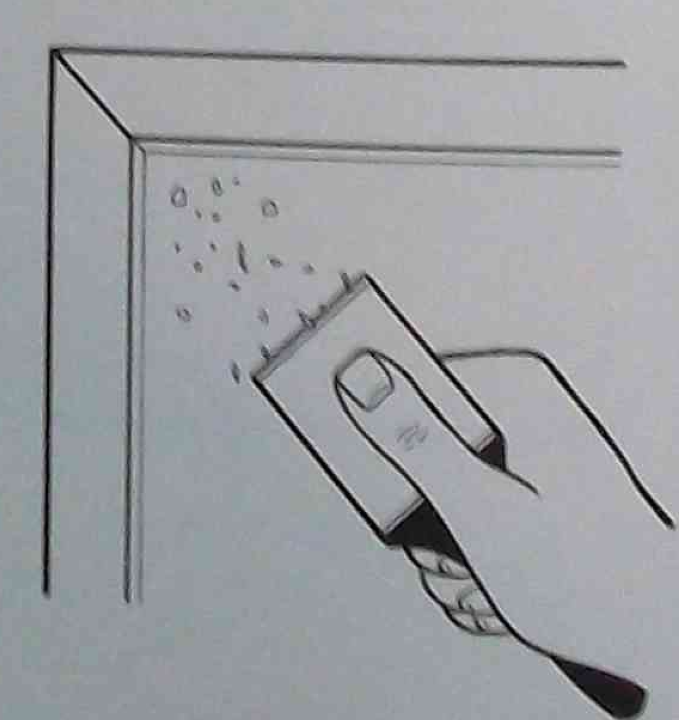
NOTE:

When painting window sashes, apply the paint about 2 mm onto the glass surface to provide a seal.



PAINT ONTO GLASS TO PROVIDE SEAL

- Complete one sash at a time.
  - After painting a sash, leave it slightly open to avoid it sticking to the runner or the frame.
- Paint the top of the window frame.
- Next, paint the sides of the frame, one at a time.
- Paint the runners of the frame.
  - Apply paint sparingly to the runners or the sash may stick when the window is closed.
- Finally, paint the window sill.
- Remove paint spots from the glass with a scraper when the paint has dried.

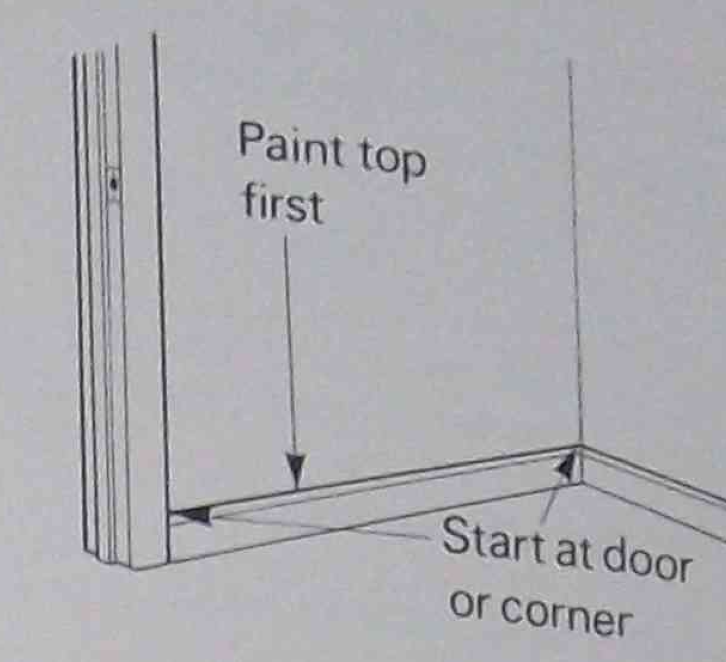


REMOVE PAINT FROM GLASS

6.8.5 Painting skirting-boards

The last item of woodwork which is painted is the skirting-board.

- Dust the previously sanded surface and the adjacent floor area.
- Spread drop sheets on the floor, next to the skirting.
- Start painting at the intersection of the skirting in a corner, or at a door frame.
- Paint the top edge of the skirting before painting the face.
- Complete one section at a time.
- Carefully 'cut in' the lower part of the skirting-board against the floor covering.
  - A flat piece of metal, wood or plastic can be used to hold the drop sheet and floor covering clear of the bottom of the skirting-board to enable you to 'cut in' to the lower edge.



PAINTING SKIRTING-BOARDS

NOTE:

When all woodwork has been given the first coat of paint, wash all brushes and working containers with the appropriate solvent, or with water if the paint is water thinned.

6.9 PREPARATION FOR THE FINISH COAT

When the ceiling, walls and woodwork are dry, and before commencing the application of the final coat of paint, all surfaces must be sanded with fine abrasive paper. Take care and avoid scratching the surfaces.

NOTE:

Care must be taken not to sand through the paint film to the plaster, or the timber surface. Where bare spots are exposed through sanding, these areas should be primed before proceeding.

- Dust down all sanded surfaces.
- Thoroughly clean the work area in preparation for the application of the finish coat of paint.
- Wash and clean all brushes, rollers, trays and containers using the appropriate solvent, or water if the paint was water thinned.

Application of the finish coat

The application of the finish coat of paint is carried out using the same procedure and in the same order as the first coat.

- Ceiling and cornice.
- Walls.
- Door frames and architrave.
- Doors.
- Cupboards, shelves, etc.
- Windows.
- Skirting-boards.

Cleaning the work area.

After the finish coat of paint is dry:

- Remove all paint from any glass with a scraper.
- Clean and replace door and window fittings.
- Clean and replace lightshades.
- Remove sheets from the floor.
- Vacuum clean the floor and the floor coverings.
- Replace furniture, curtains and fittings.
- Wash all application equipment and store it away safely.

REVISION QUESTIONS

1 Place the following tasks in the order in which they are carried out by placing the numbers 1 to 10 in the spaces provided.

Cleaning the work area ☐

Painting the ceiling ☐

Sanding filled surfaces ☐

Erecting scaffolding ☐

Painting the walls ☐

Washing down surfaces ☐

Removing fittings ☐

Sanding all surfaces ☐

Painting the woodwork ☐

Filling surface defects ☐

2 Name the three general painting procedures used to paint surfaces.

A ____________________

B ____________________

C ____________________

3 Each of the following statements may be completed in a number of different ways. Circle the letter, or letters of each answer, that can complete the statement correctly in each of the following cases.

When painting ceilings, begin painting from a window so that:

A Completed sections reflect the light

B The paint will dry faster

C Areas not coated can be easily seen

D Roller marks will not be noticed

Filled surfaces are sanded before painting with:

A A coarse-grade production paper
B A fine-grade wet abrasive
C A fine-grade glass paper
D A fine-grade aluminium oxide paper
E A wet abrasive sanding block

The windows in a room are painted:

A After the door frames have been painted
B Before the doors are painted
C Before the skirting-boards have been painted
D After all other items of woodwork have been painted

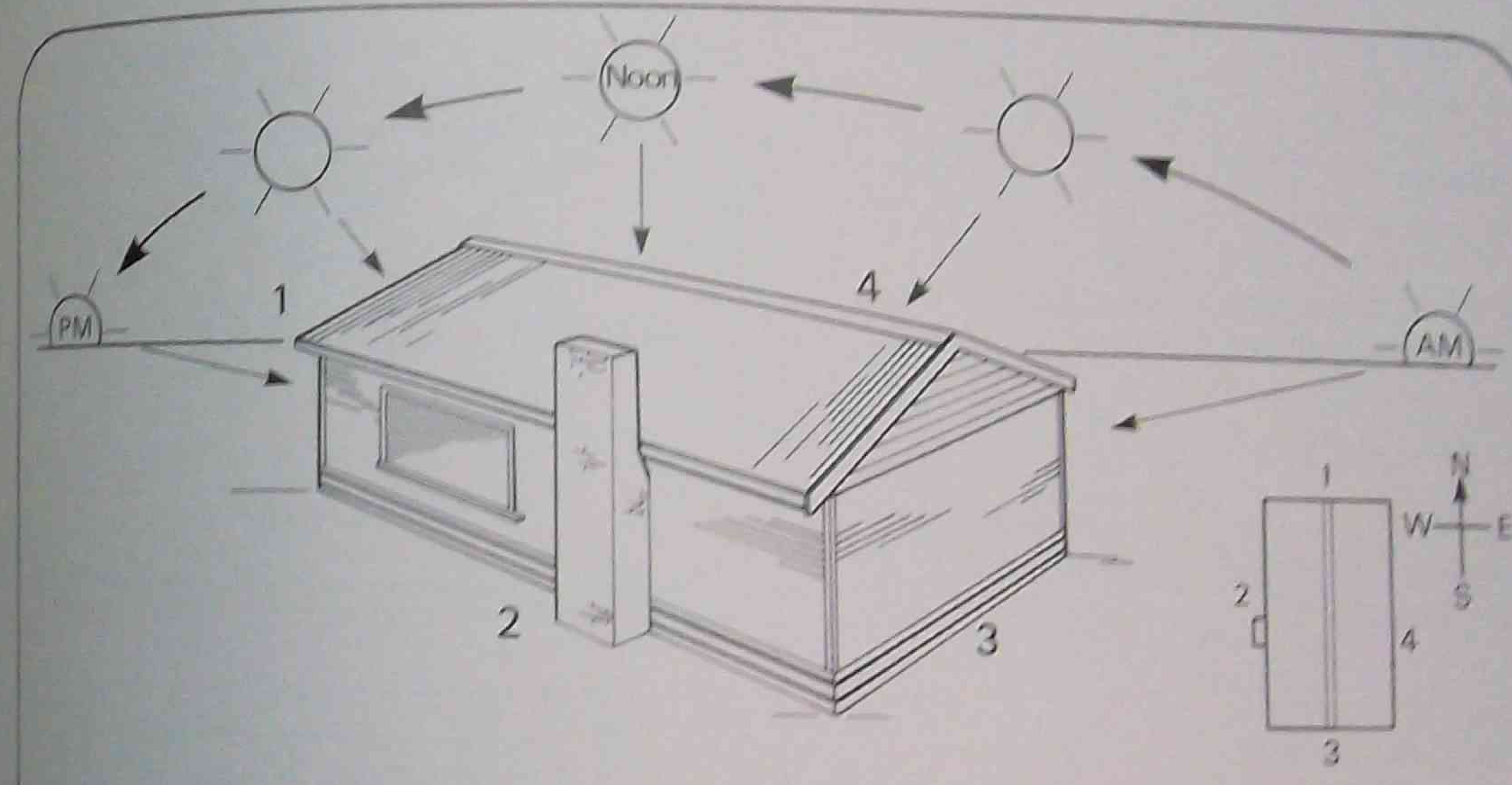
7 EXTERIOR PAINTING GUIDELINES

When painting the exterior of a dwelling, the same procedure as for interior painting applies.

- Work down from top to bottom.
- Work towards yourself.
- Paint edges of surfaces first.

Other guidelines to successful exterior painting are:

- Leave undercover and areas protected from the weather until last. If rain does interrupt work, there will be protected surfaces to paint during inclement weather.
- Complete the preparation and priming of all surfaces before any application of undercoat, or finish coat of paint.
- Plan the painting of surfaces so that painting is not carried out in direct sunlight. Working in the direct sun is not only uncomfortable for the painter (glare, heat, etc) but is not good for wet paint (may cause stickiness, wrinkling). To avoid painting in direct sunlight, work in an anticlockwise direction keeping in the shade.
- Start painting in the morning on the NORTH side. Move to the WEST. Then, as the day progresses, on to the SOUTH. Finish in the afternoon on the EAST side.



PAINT IN SHADE

7.1 REPAIRING SURFACES

Do not apply paint over defective surfaces.

Before preparing surfaces for painting, check for the following defects:

Timber
- rotting
- splits, cracks and holes
- open joins
- protruding nails
- resinous knots

Spouting
- rust holes
- split joins
- blockages

Windows
- loose putties
- cracked or broken glass
- window sashes sticking to frames

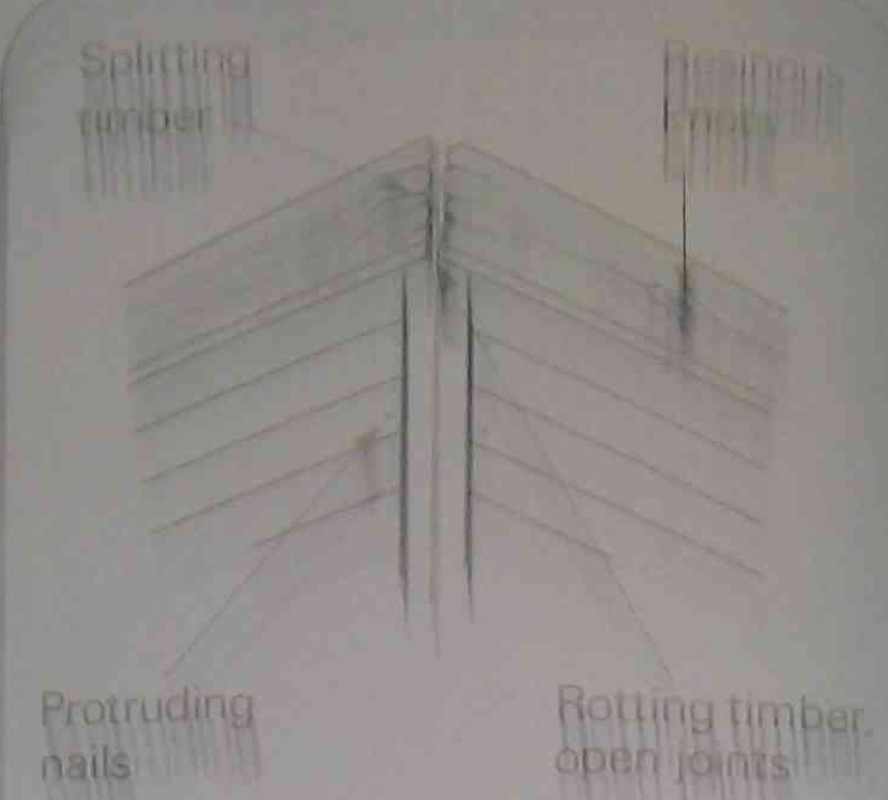
Wrought iron
- rusting

Masonry
- cracks

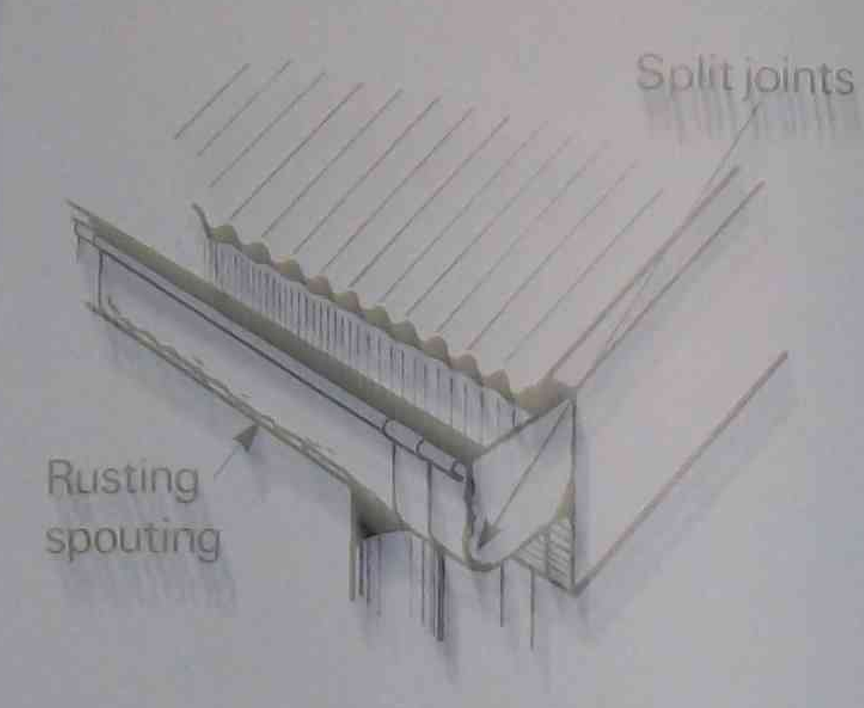
If any of the above defects are found, replace or repair the surfaces.

NOTE:

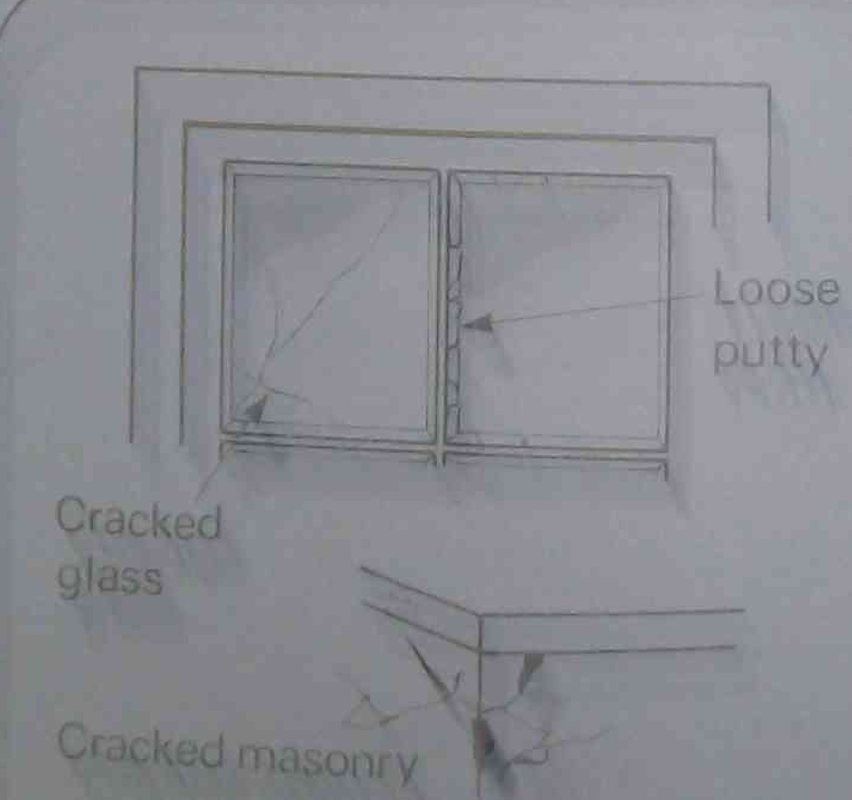
Refer to Painting and Decorating Manual Number 2 for further details on surface preparation.



TIMBER DEFECTS



SPOUTING



WINDOWS AND MASONRY

7.2 PREPARING SURFACES FOR PAINTING

[illegible]

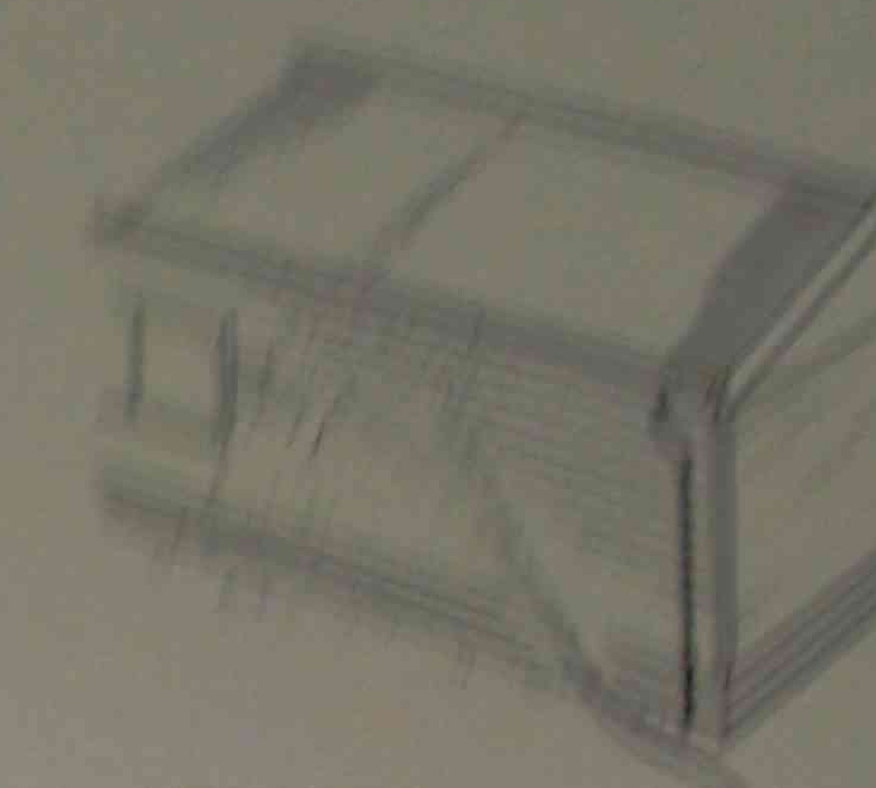
Paint removal

Cracked, blistered or peeling paint will have to be removed back to a sound surface by either:

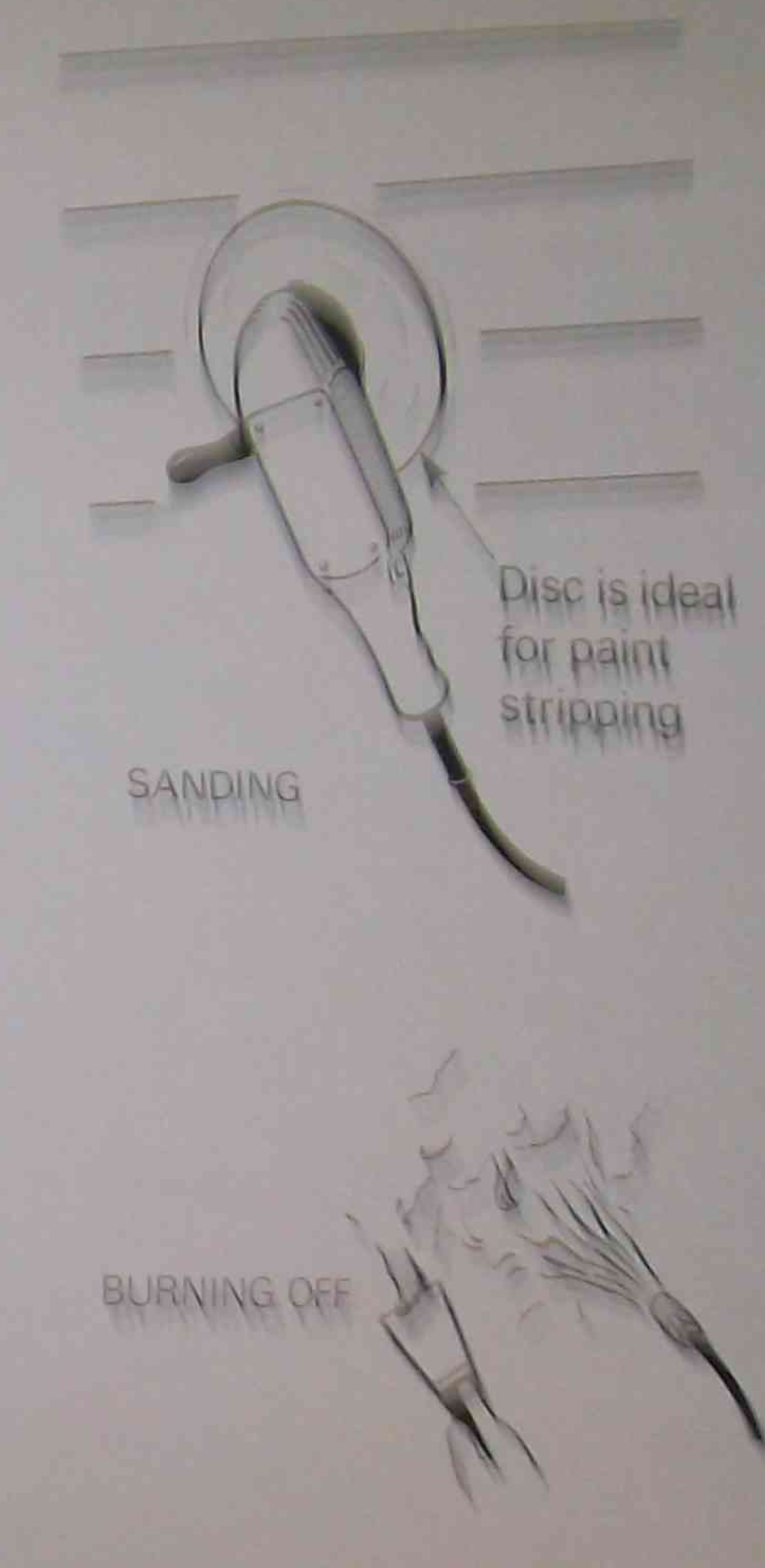
- burning off with a blow-torch and scraping with a stripping blade,
- sanding the surface by hand, or power sander.

NOTE:

Refer to Painting and Decorating Manual Number 2, removal of existing coatings section, for details of equipment to use and safety precautions to be observed.



HOSE DOWN TO REMOVE DUST AND DIRT



REMOVE DEFECTIVE PAINT SURFACE

7.2.1 Priming bare surfaces

Primer

The first coat of paint to be applied to any surface.

Priming

The term given to applying primer to a surface.

For most paint finishes, the priming of timber and metal will have to be carried out to the bare areas.

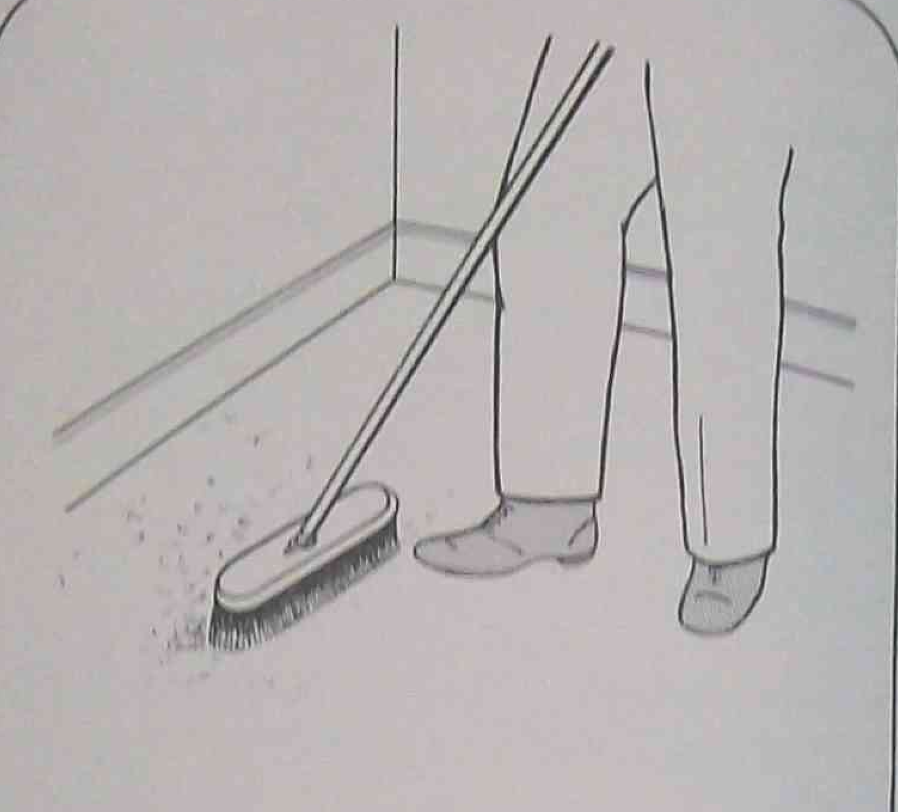
NOTE:

Refer to the manufacturer's specifications for the type of primer required.

- Remove all paint flakes, dirt and rubbish from the ground area surrounding the surfaces to be painted.
- Erect suitable scaffolding.
- Fine-sand previously burnt off, or machine-sanded surfaces in the area.
- Scrape and sand any other cracked or unsound paint films.
- Dust down the sanded surface.
- Prepare the primer to the manufacturer's instructions.
- Make sure the brush to be used is clean.
- Pour about 500 ml of primer into a paint pot.

Working from the top:

- Apply the primer to the bare surface.
- Brush the primer well into the bare timber surface.
- Continue this procedure until all bare surfaces have been primed.
- If oil-based primer is used, allow at least 24 hours before applying the next coat of paint.



CLEAN SURROUNDING AREA

REFER TO SPECIFICATION
PREPARE TO INSTRUCTIONS

7.2.2 Caulking open joints and gaps

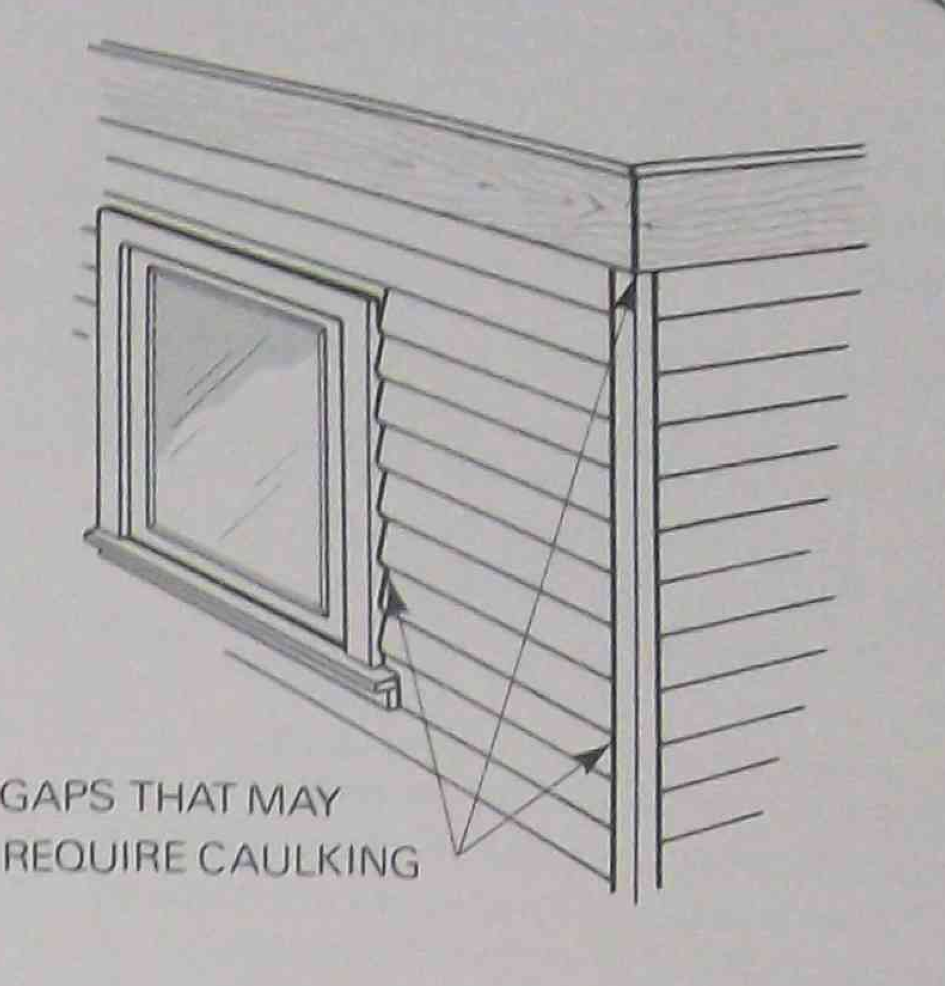
Caulking is the term given to the application of mastic, silicone or acrylic material, in cartridge form, to gaps where water may penetrate and cause structural damage.

Gaps can occur around window and door frames, along window sills, at the corner of fascia boards and at the end of weatherboard planks. If water is allowed to penetrate behind these surfaces, rotting and splitting of the timber may occur.

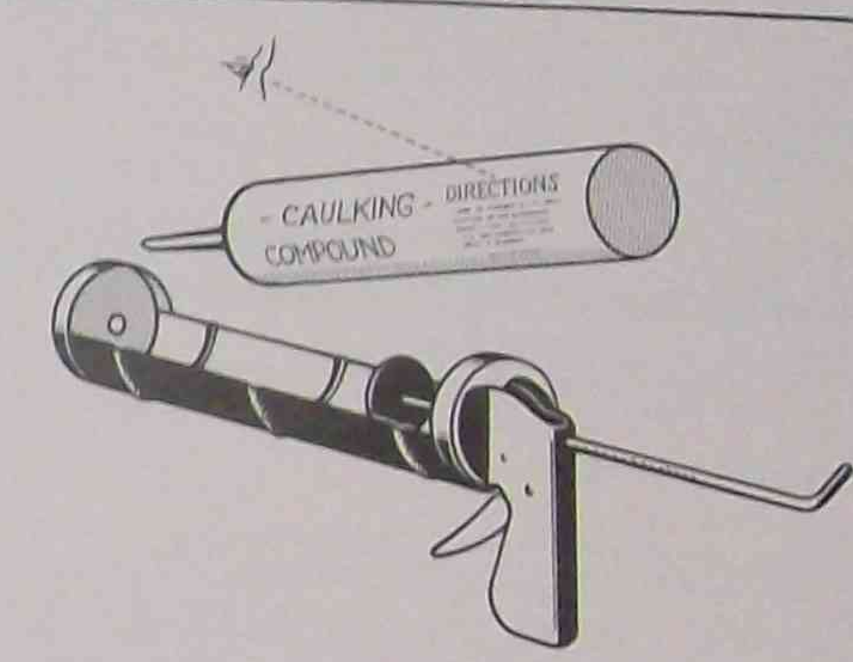
- Ensure that joints to be caulked are clean and dry.
- Prime all bare timber prior to caulking.
- Read the manufacturer's directions on the cartridge regarding the preparation and use of the cartridge and caulking gun.
- Fill all open joints on the surface to be painted.
- Allow the caulking material to form a skin before the application of paint to the material.

NOTE:

Some silicone-based caulking compounds affect the adhesion of acrylic-based paints applied over them. Ensure that the caulking compound and the paint to be used are compatible before use.



AREAS REQUIRING CAULKING



READ DIRECTIONS
ENSURE COMPATIBILITY WITH PAINT

7.3 PROCEDURE FOR PAINTING EXTERIOR SURFACES

Working from the top to bottom, the order in which painting is carried out, after preparation, is as follows:

Chimney

If the chimney is to be painted, do this before the roof to avoid paint spots falling on the finished roof surface.

Roof

Corrugated iron roofs are often spray-painted for ease and speed of application. Whenever possible, finish-coat the roof as soon as practicable to overcome the problem of access to the roof over other painted surfaces.

— When painting roofs, do not stand on wet paint.

> **CAUTION**
>
> Use a roof ladder, or an ordinary scaling ladder adapted for the purpose, to work on steeply pitched roofs.

Spouting and fascia

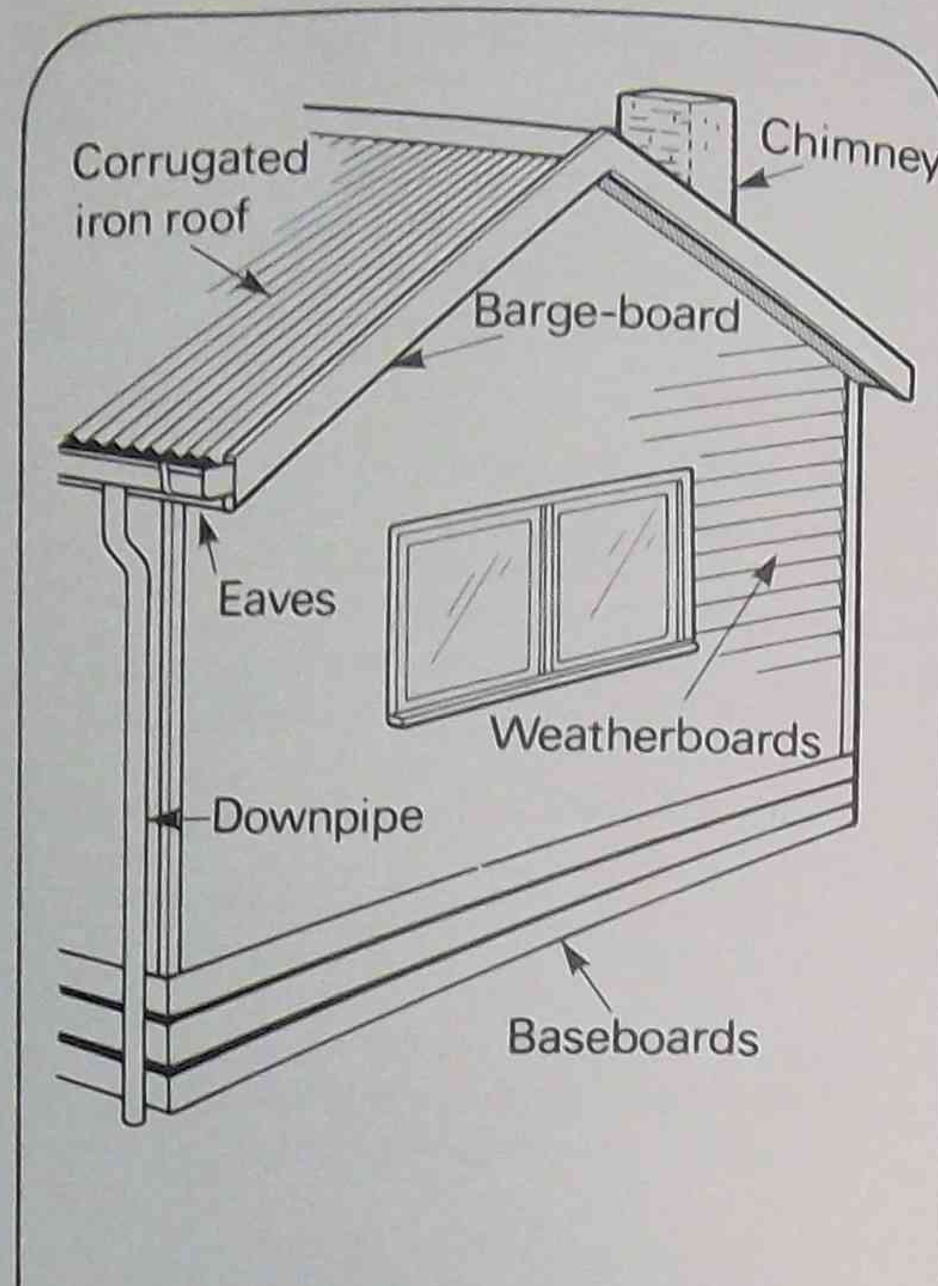
These surfaces are painted next with a 100 mm brush, from a suitable scaffolding.

Eaves

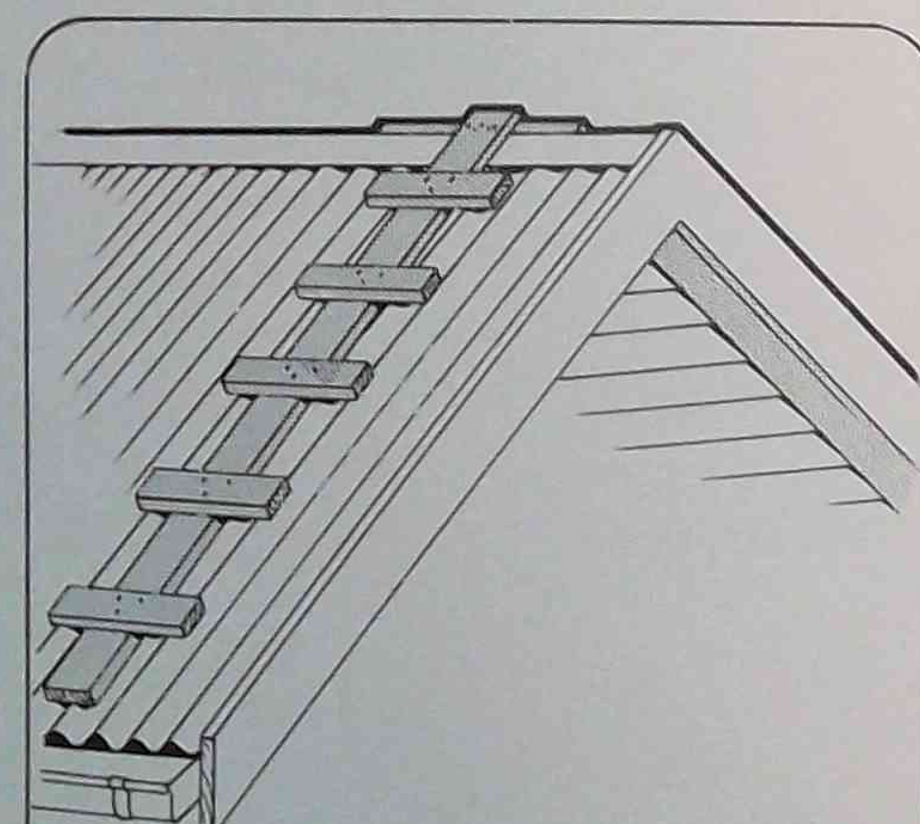
While the scaffolding is erected for the painting of the spouting and fascia, the painting of the eaves can be carried out. If the eaves are flat sheets, the perimeter can be cut in by brush and the surface can be rolled with a paint roller.

Barge-board

The barge-board is painted next along with any adjacent eaves. If the erection of scaffolding is difficult in this area, the barge-board can be painted when scaffolding is erected for the weatherboards below.



EXTERIOR BUILDING COMPONENTS



USE A ROOF LADDER

Weatherboards

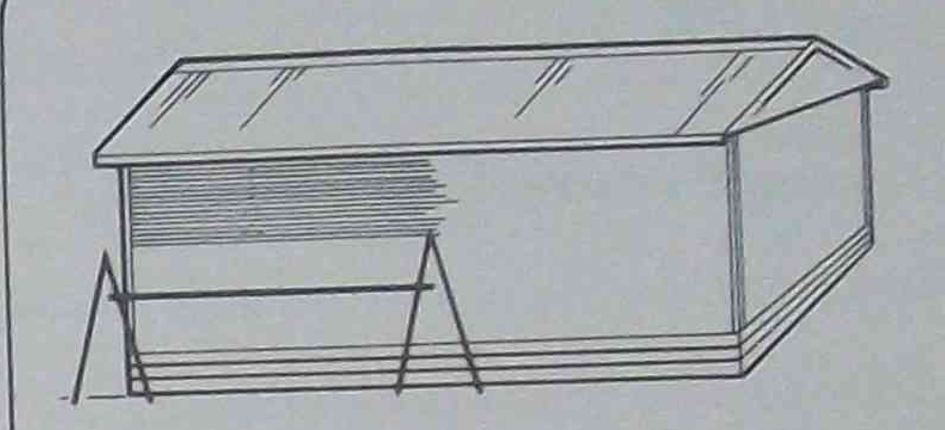
Regardless of the method used to apply the paint, the weatherboards are painted next.

On a solid foundation, erect suitable scaffolding, comprising of trestle ladders and plank.

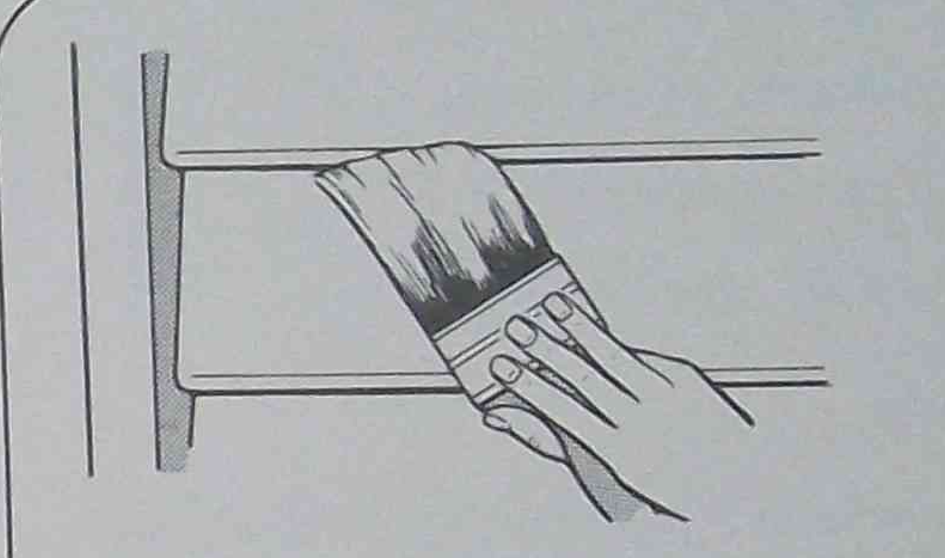
- Sand down as much weatherboard surface as can be reached safely from the scaffolding, then dust down the sanded areas.
- Start application of the first coat of paint to the weatherboards.
  — A 100 mm brush is best suited for the painting of weatherboards.
- Paint the underneath edge of each board before the surface of the board is painted.
  — Remember, edges first.
- To avoid having too many joins in the painted surface, complete the painting of three or four boards at a time for the full length of the scaffolding.
- After painting about ten boards, move the scaffolding along and complete the same boards to the end of the wall.
- Lower the scaffolding and paint another section of boards in the same way until the wall is complete.
- Continue painting the weatherboards until all sides are complete.

NOTE:

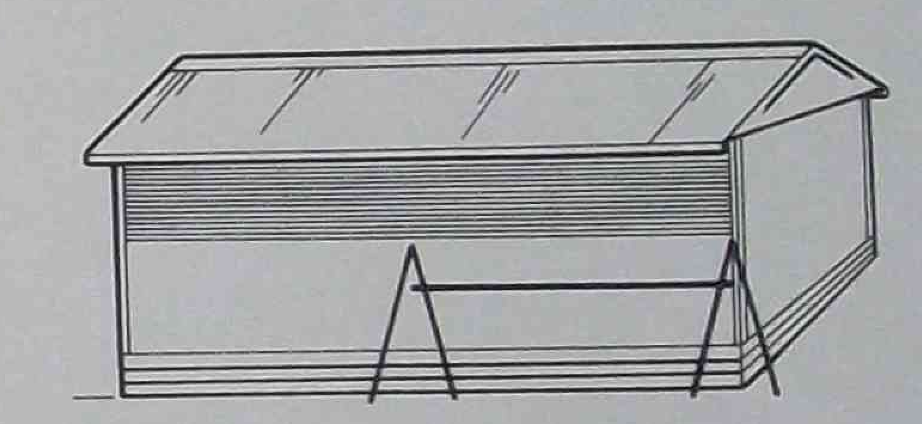
Downpipes are usually painted in the same colour and paint as the weatherboards. Therefore, they can be painted at the same time as the weatherboards behind them.



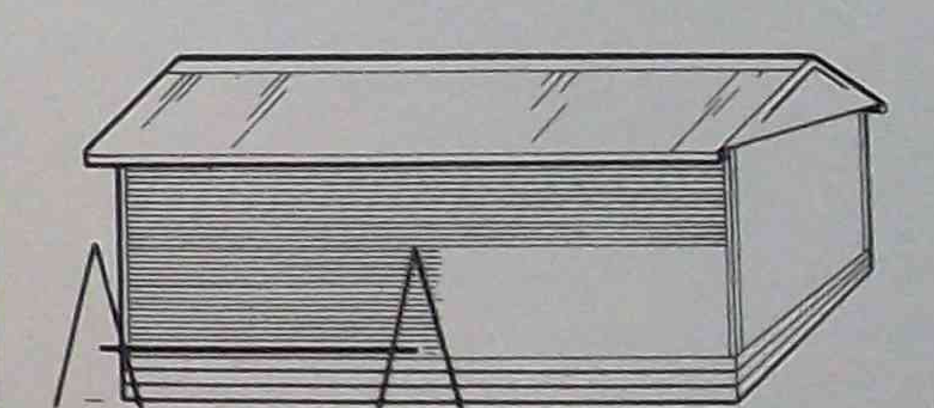
ERECT SCAFFOLDING AND PAINT A SECTION OF WEATHERBOARDS TO THE LENGTH OF SCAFFOLD



PAINT UNDERNEATH EDGE FIRST



SHIFT SCAFFOLDING AND COMPLETE THE SECTION OF WEATHERBOARDS



SHIFT SCAFFOLDING AND COMMENCE THE NEXT SECTION

Windows

After the weatherboards have been painted, the windows are given the first coat of paint.

If the windows are double-hung sash, use the same procedure as outlined for the interior, except only the bottom outside runners are painted.

Regardless of the type of windows to be painted, the general procedure is as follows:

- Sand all surfaces to be painted, taking care not to scratch the glass.
- Dust off the window surfaces.
- Paint the edges of the sash (if accessible).
- Paint the window sash, applying paint about 2 mm onto the surface of the glass to provide a seal.
- Paint the window frame.
- Paint the runners.
- Finally, paint the sill.

NOTE:

The removal of paint from the window glass is completed prior to the application of the finish coat of paint to the windows. A blade can be purchased specifically for this purpose.

Door frames

- Sand the door frame and the adjoining door.
- Dust off the sanded frame and door.
- Paint the section of the frame where the door is hinged.
- Paint the doorstop and the remainder of the frame on the same side.
- Paint the remainder of the frame including the doorstop to the top and other side.

NOTE:

The procedure for painting the door frames is the same as for the interior jambs.

Doors

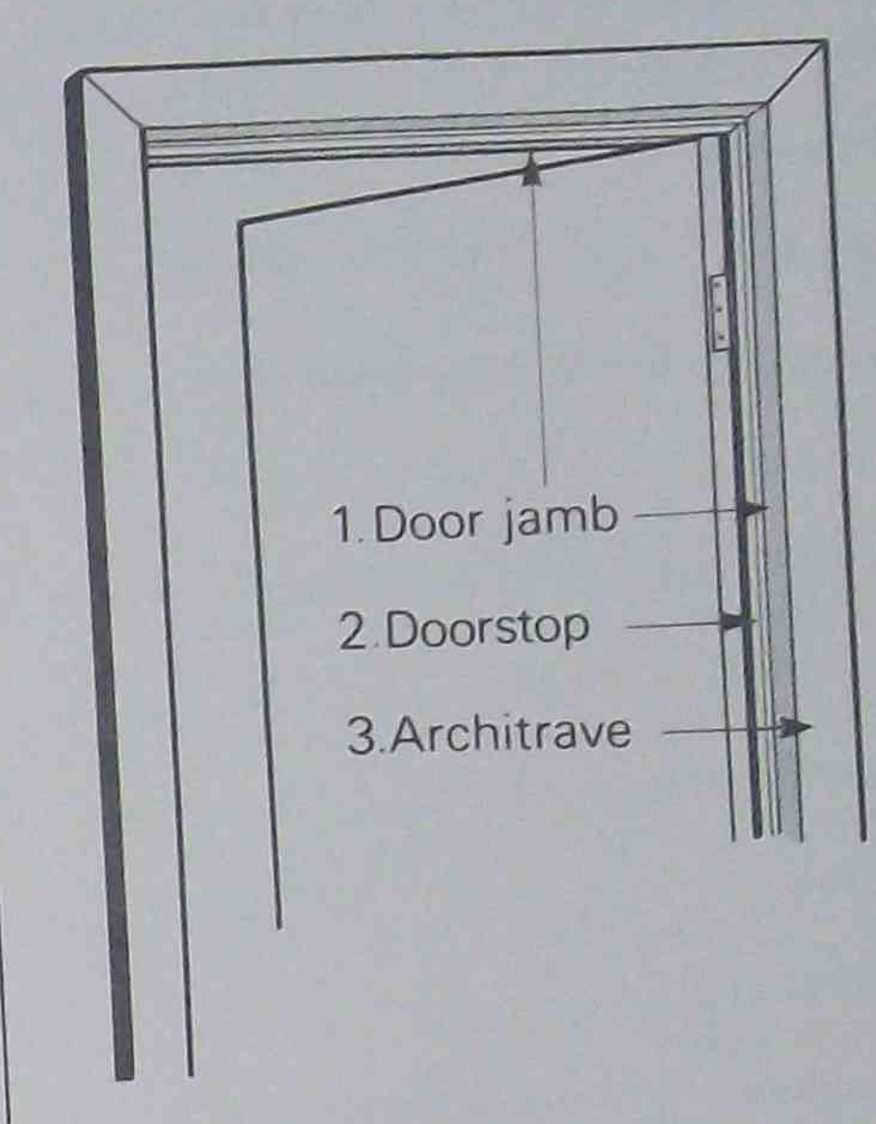
- Open the door fully.
- Cover the surrounding floor area.
- Paint the hinged edge of the door first.
- Paint the surface of the door.
  - If the door is panelled, paint as for the interior panel doors.

NOTE:

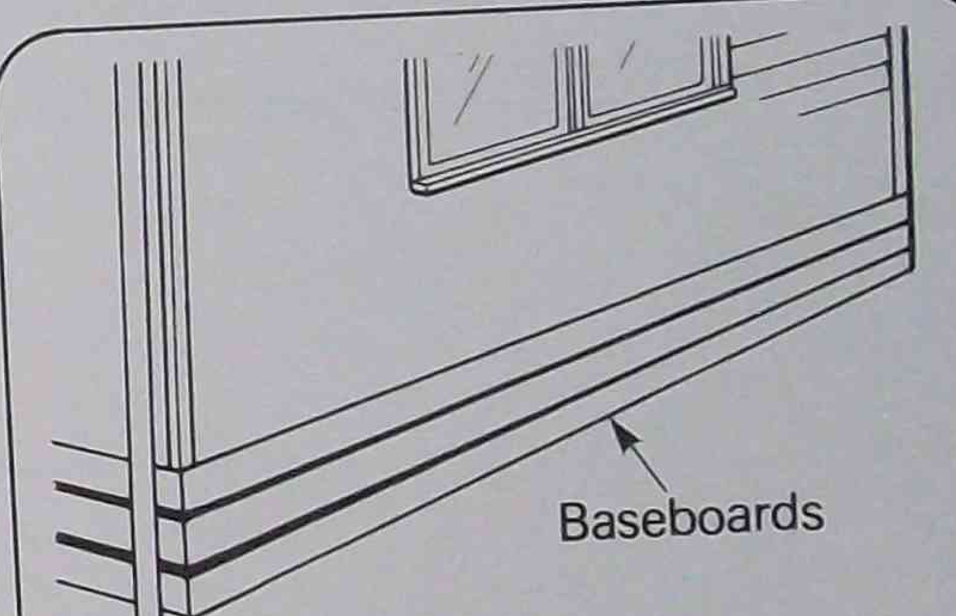
On exterior doors, only one edge (the hinged edge) of the door is painted.

Baseboards

Because the baseboards are at the lowest point of the structure, they are painted last.



PAINTING PROCEDURE FOR A DOOR FRAME



PAINT BASEBOARDS LAST

7.4 APPLYING THE FINAL COAT

After all the surfaces have been first coated, the final coat of paint can be applied to surfaces generally using the same procedure.

- Chimney
- Roof
- Spouting, fascia and bargeboards
- Eaves
- Weatherboards and downpipes
- Windows
- Door frames
- Doors
- Baseboards

The procedure for exterior painting in this text is a general guide only. It will need to be modified by the user to allow for:

- ease of scaffolding to limit the number of shifts;
- a variety of colours in one area;
- the design and construction of the dwelling;
- the number of painters working on the exterior painting.

NOTES FOR THE INSTRUCTOR

In these Training Manuals the term 'instructor' refers to any person who may train or be directly responsible for training individuals.

For example, the task of instructing may be the sole or shared responsibility of:

—skilled tradesmen

—leading hands

—foremen

—instructors

—apprentice masters

—managers

INITIAL PLANNING

A Analyse:

- The training requirements of a newcomer, considering that the person:

  —may have no previous experience in the subject;

  —will need to do productive work as soon as possible.

- What the trainee must learn about:

  —the tools he is to use for the subject;

  —the terminology involved in the subject;

  —basic working methods.

- What will be the first productive work you will be able to give the trainee.

B Decide:

- Whether your trainees need information to supplement that given in this manual.
- Whether or when additional training material or exercises will be required to improve on the skill gained.
- Which other Basic Training Manuals the trainee should use during training.

C Plan:

The explanations, demonstrations and the practice required by the trainee, preferably on an individual basis, if numbers allow.

USING THE MANUAL

It may be of assistance to the trainee to arrange for short periods of learning followed by short periods of practice in applying the knowledge gained.

To keep interest alive, it will be useful to relate, as much as possible, the material treated in this manual with actual practical applications in the field.

BASIC TRAINING MANUAL

15-2

PAINTING & DECORATING

Painting Equipment, Applicators and Scaffolding

NATIONAL BUILDING AND CONSTRUCTION
INDUSTRY TRAINING COMMITTEE

DEPARTMENT OF EMPLOYMENT, EDUCATION AND TRAINING

BASIC TRAINING MANUAL

15-2
PAINTING & DECORATING
Painting Equipment, Applicators and Scaffolding

Australian Government Publishing Service

This manual has been produced at the initiative of the National Building and Construction Industry Training Committee comprising representatives of employers, unions and government. It was prepared and edited by an advisory panel consisting of:

Chairman: Mr. J. T. Ellis — The Operative Painters and Decorators' Union of Australia.

Members: Mr. C. Henzell — The Federation of Master Painters and Signwriters of Australia.

Mr. J. Strang — Education Department of Victoria.

Mr. K. G. Seidel — Department of Employment and Industrial Relations.

Mr. S. J. de Hoedt — Department of Employment, Education and Training.

Material for this manual was written by: Mr. R. Barden — Melbourne College of Decoration.

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CONTENTS

PREFACE

This manual is one of a series that has been developed to progressively increase the practical skills of a trainee in painting, decorating and signwriting.

Other manuals in this series cover:

- Paints: types, reasons for coating, surfaces coated, health and cleanliness, glossary of terms.
- Surface preparation: removal of existing coatings.
- The systematic procedure for the painting of interior and exterior surfaces.
- Colour: simple colour wheel, primary, secondary and tertiary colours, tints, shades and tones.
- Glazing: removal of broken glass, cutting glass, reglazing.
- Staining: filling, clear finishing, opaque and semi-opaque finishes.
- Paper-hanging: drop and set patterns, preparation, adhesives.
- Signwriting: tools and equipment, use and control of the sign pencil, layout of alphabet, design and simple signs.

Each manual is self-contained and is intended as an instructional guide in on-the-job training situations. It may be used by instructors or for self-teaching purposes.

The aim of the manual is to help the trainee to develop a particular skill to the stage where it can be applied productively on the job. Ideally, the manual should be used as part of a course of instruction involving:

- demonstrations of practical skills by instructors or experienced tradespeople;
- planned and supervised practice in handling the tools involved;
- instruction in safe working procedures.

The manuals may be used in any order convenient to the learning needs of the trainee and may be obtained individually or in sets to cover the range of skills in the trade area.

It may be advisable to use part of this manual with sections of other manuals in this series to follow an operation through.

INSTRUCTIONS TO TRAINEE

This manual is a teaching aid to your skill development. It is best used on the job where you can handle the tools and use the equipment shown.

You should follow the directions given by the person training you. To reach the required standard of skill, you must pay particular attention to your instructors' explanations and demonstrations. Supervised practice is essential.

Practice means making repeated efforts to improve your level of skill. Study is making an effort to learn. Every advance in skill depends on study and practice. You will make most progress by co-operating actively in the training arranged for you.

When you are told to study all or part of this manual, try to use a definite plan of study. The following plan is effective.

SURVEY: Read quickly through the headings as you turn the pages. Glance at the drawings. Get an overall view before you read.

QUESTION: Ask yourself: What do I know? What do I need to know? How will this manual help me to learn?

READ: Read right through each section carefully. Be thorough, but do not dawdle. Reading quickly will help you concentrate.

DO: Use all your senses in learning. Getting the 'feel' of any subject is essential in learning it. Follow the directions given to you; they are meant to assist you in the gaining of the skills you need.

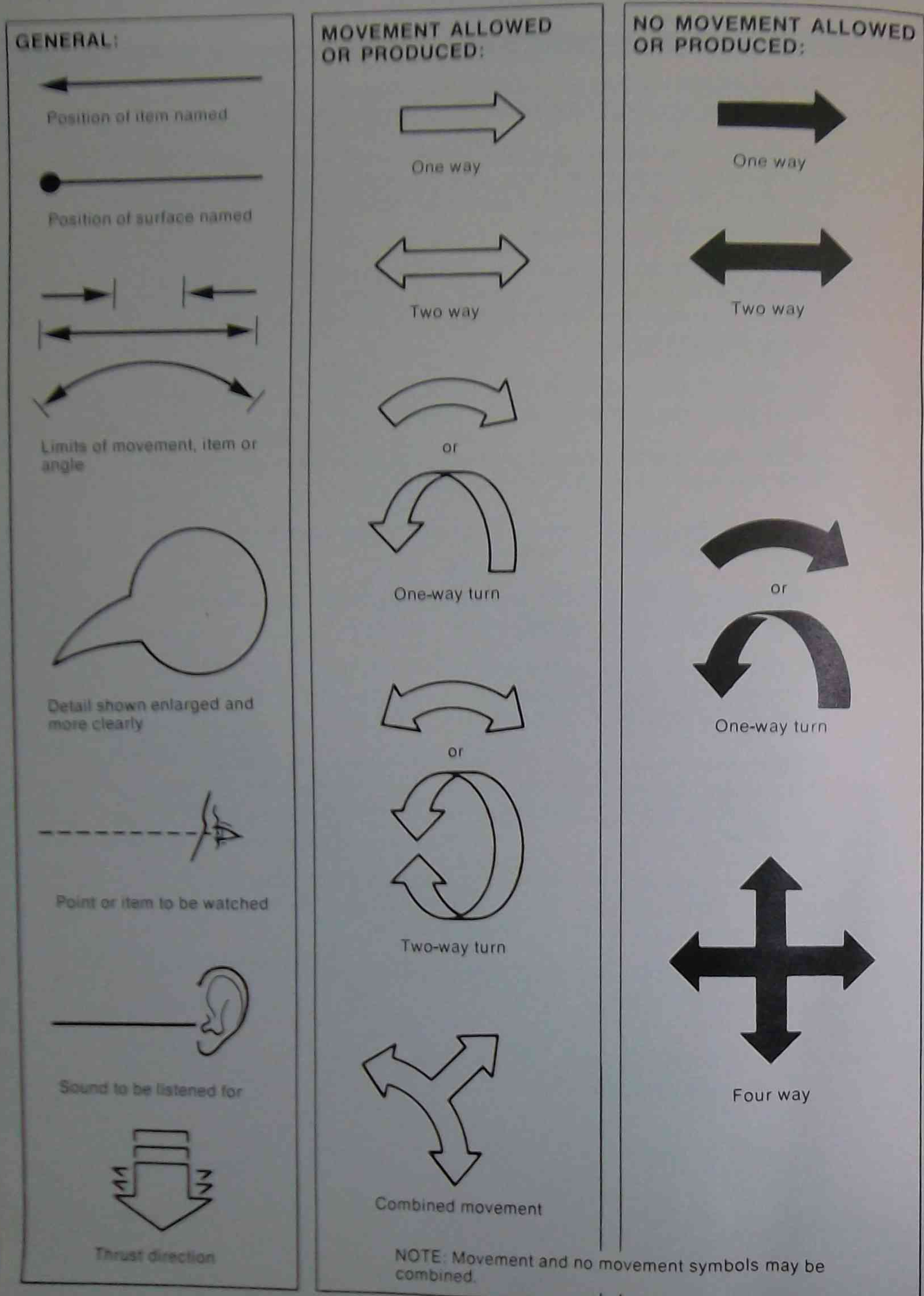
REVIEW: Shut the manual. Try to remember the main points of the section. Check to see that you are right. Revise points on which you are doubtful. Try a few or as many examples as you think you need, without reference to the manual.

One way of fixing important instructions in your mind is to repeat them over and over. Test papers are given in this manual to help you test your understanding of the work. Use them intelligently.

The practical work required of you in this manual will help you develop the skill to work productively.

SYMBOLS

The symbols shown are used in illustrations in these manuals.



1 PAINTERS HAND TOOLS

1.1 SCRAPERS

Paint scraper or stripping knife

A stiff bladed knife, available in sizes from 25 mm to 100 mm blade widths.

Used for:

- The removal of loose and flaking materials.
- Scraping off old paint coatings.
- Stripping off wall coverings.
- Raking out cracks prior to stopping and filling.

Select a good quality knife with a high carbon steel blade riveted to a hardwood handle. The handle should be smooth for a comfortable grip. The blade must be capable of retaining a sharp edge.

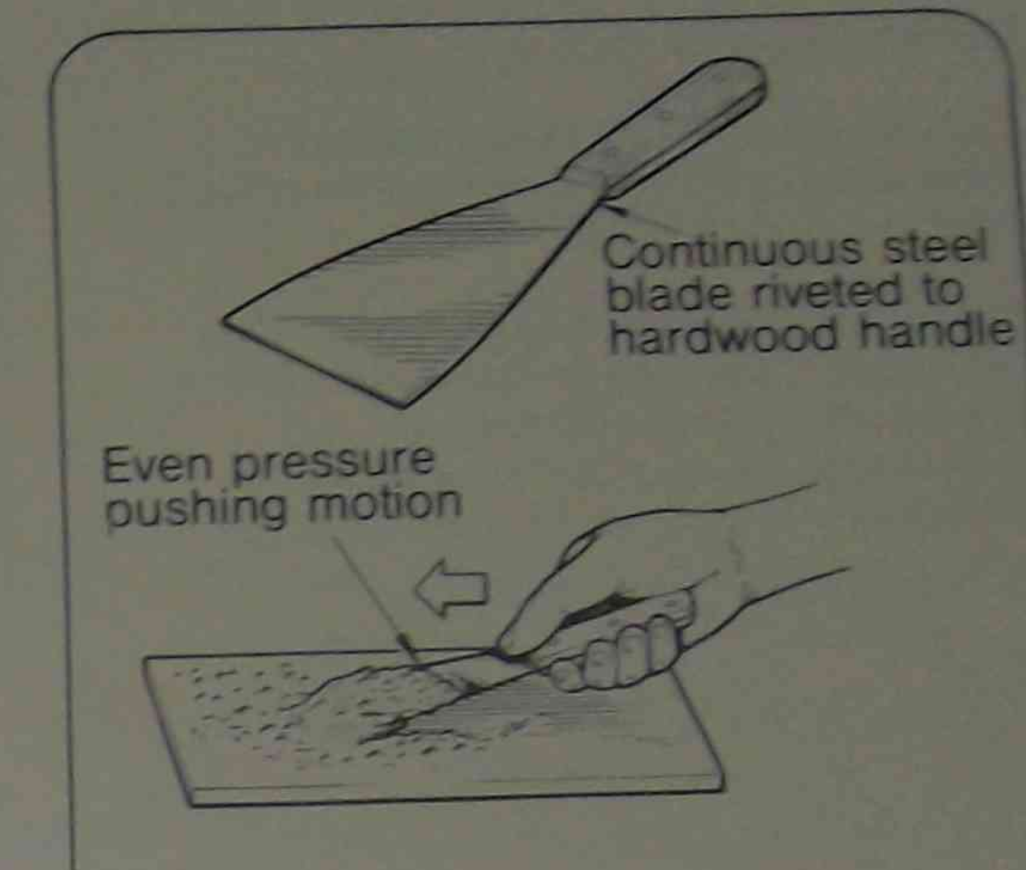
Shave hooks

Steel tool with a sharp bevelled cutting edge. Obtainable with triangular, pear or combination shaped heads.

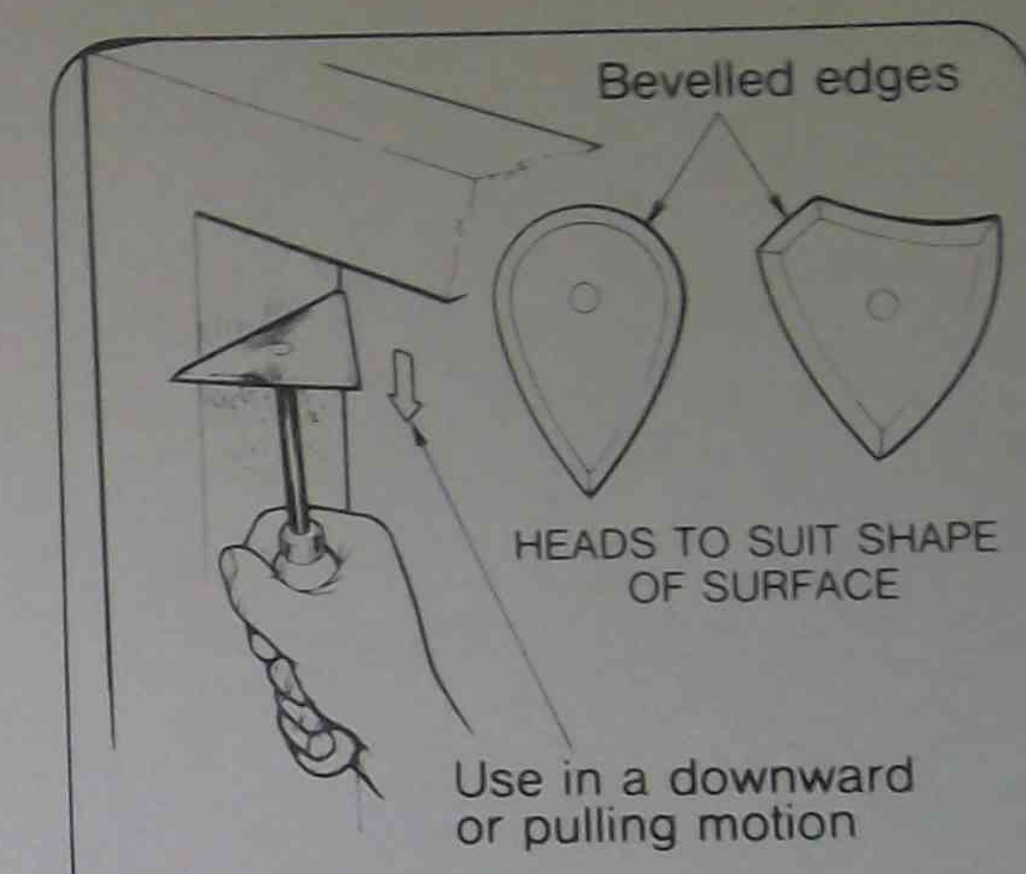
Used in conjunction with a blow torch or liquid paint removers:

- To scrape old paint coatings from ornamental beadings and mouldings.
- To rake out cracks in cornices prior to stopping.

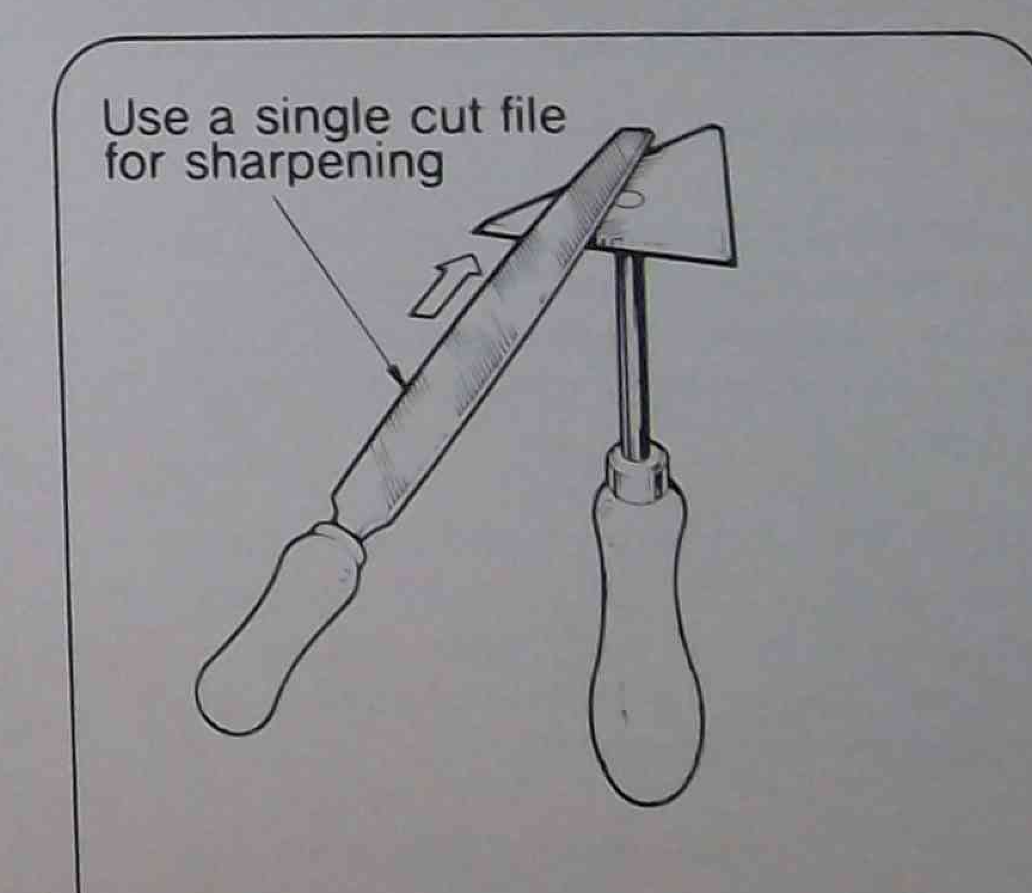
The bevelled edge must be kept sharp by filing.



STRIPPING KNIFE



TRIANGULAR SHAVE HOOK

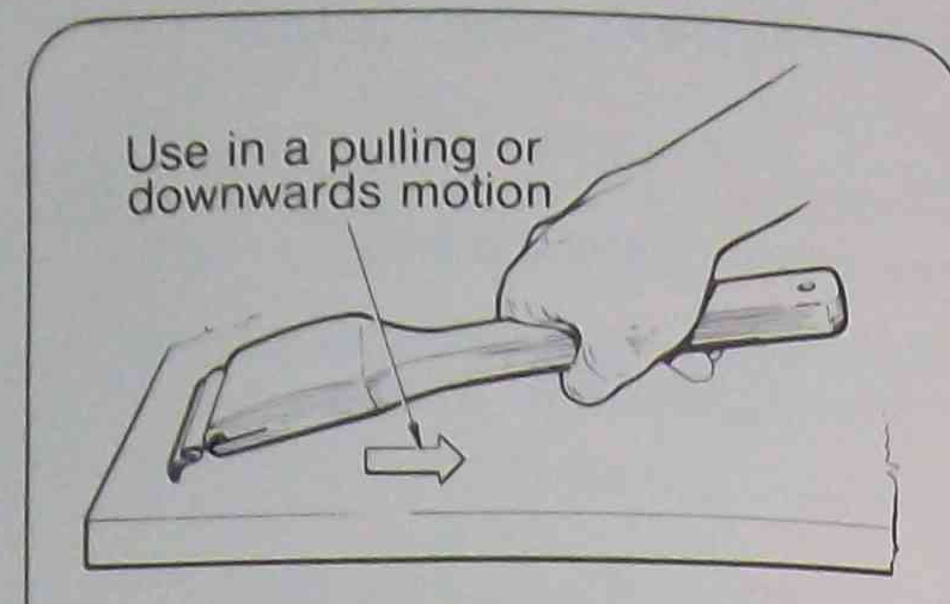


KEEP BEVEL EDGES SHARP

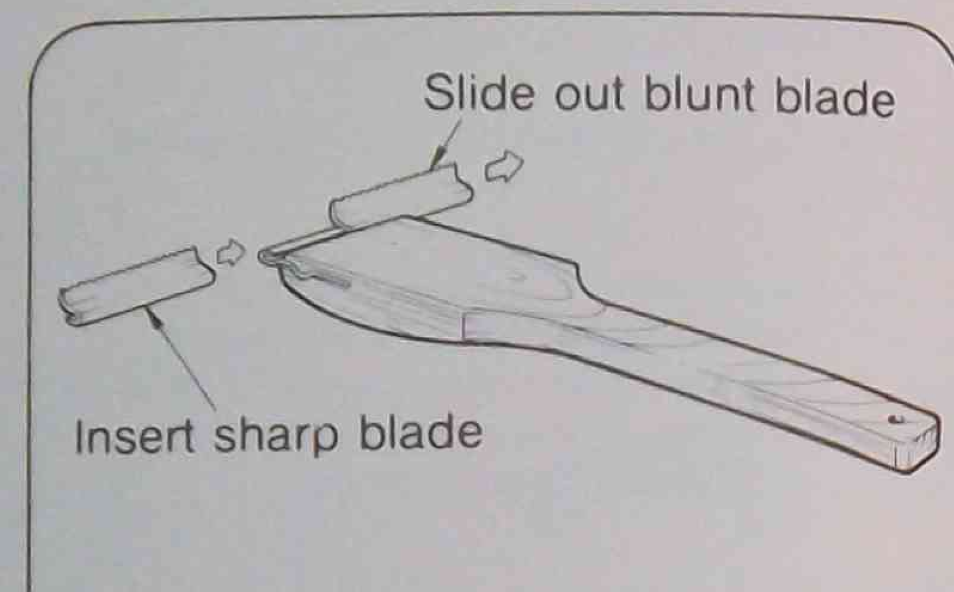
Universal scraper

Serrated steel edged blade attached to large wooden handle. Blade sizes available in 45 mm to 80 mm widths.

Used to remove clear finishes, paint films and imperfections on timber surfaces. The edge must be sharp. Blades are replaceable. When a blade wears dull, remove and replace with a new blade.



UNIVERSAL SCRAPER



REPLACING THE BLADE

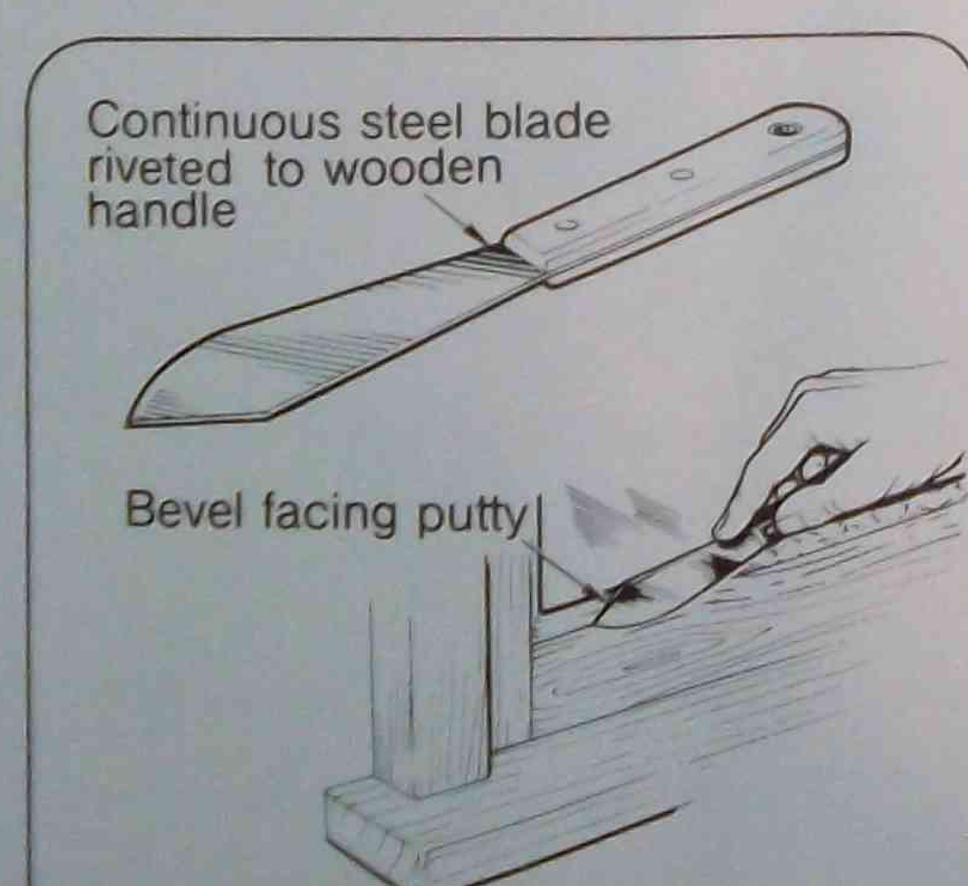
1.2 FILLING AND STOPPING EQUIPMENT

Putty or stopping knife

A stiff steel bladed knife varying in length from 100 mm to 150 mm, available in different shapes. The most common knife used has one straight edge and the other curved.

Used to fill nail holes, cracks and surface imperfections with putty or hard stoppers and to bevel facing putty when glazing windows. The knife edges and point must be free of nicks and burrs.

A good quality knife should have a smooth timber handle for a comfortable grip. The high carbon steel blade must be capable of retaining a keen edge.



PUTTY KNIFE

Filling knife

Similar in appearance to a stripping knife. However, the blade is manufactured from a thinner and more flexible steel.

Knife sizes available 50 mm to 150 mm in width.

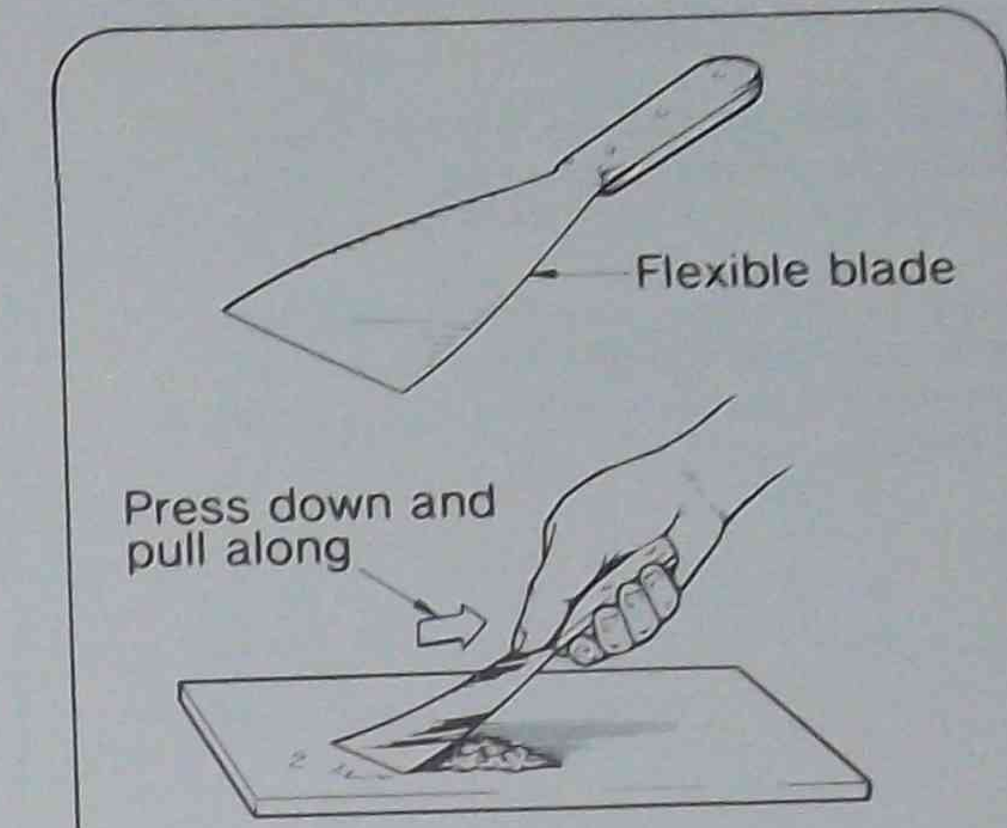
Used to apply oil and water-based fillers to open grained timbers or shallow indentations on broad uneven surfaces.

Blades must be kept free of nicks and burrs to prevent indentations or scratches in the filler being applied.

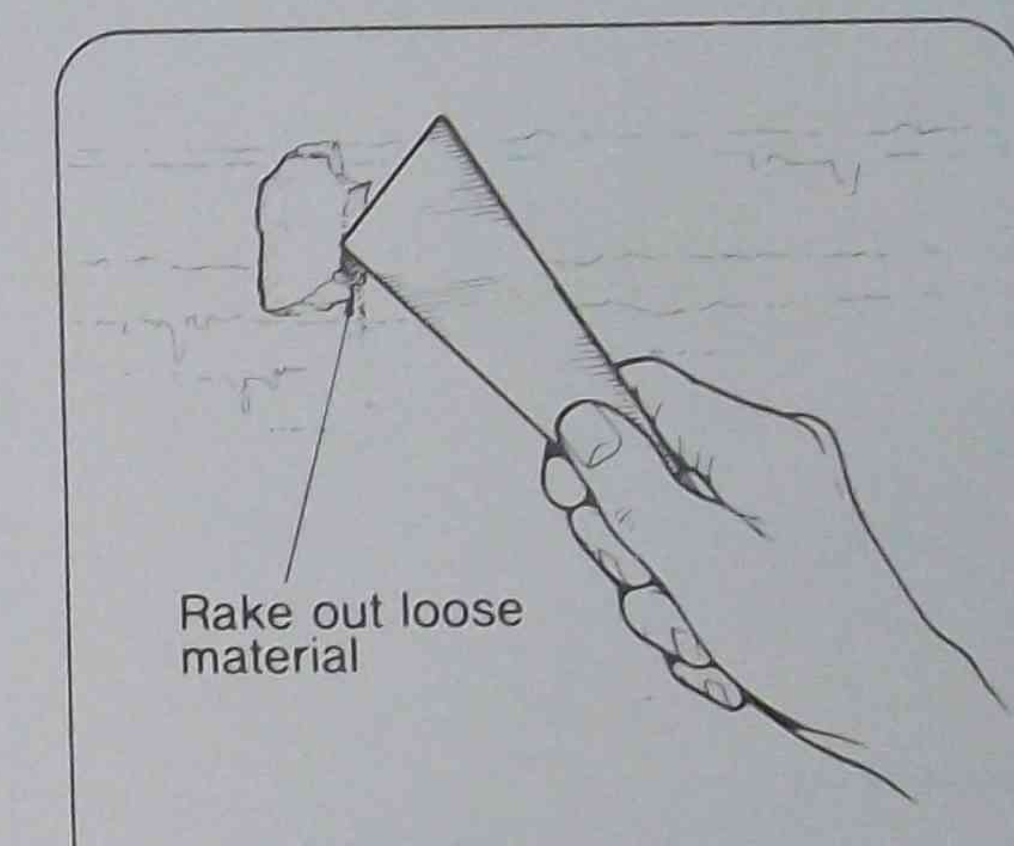
A damaged knife should be replaced with a new knife.

Use a filling knife as follows:

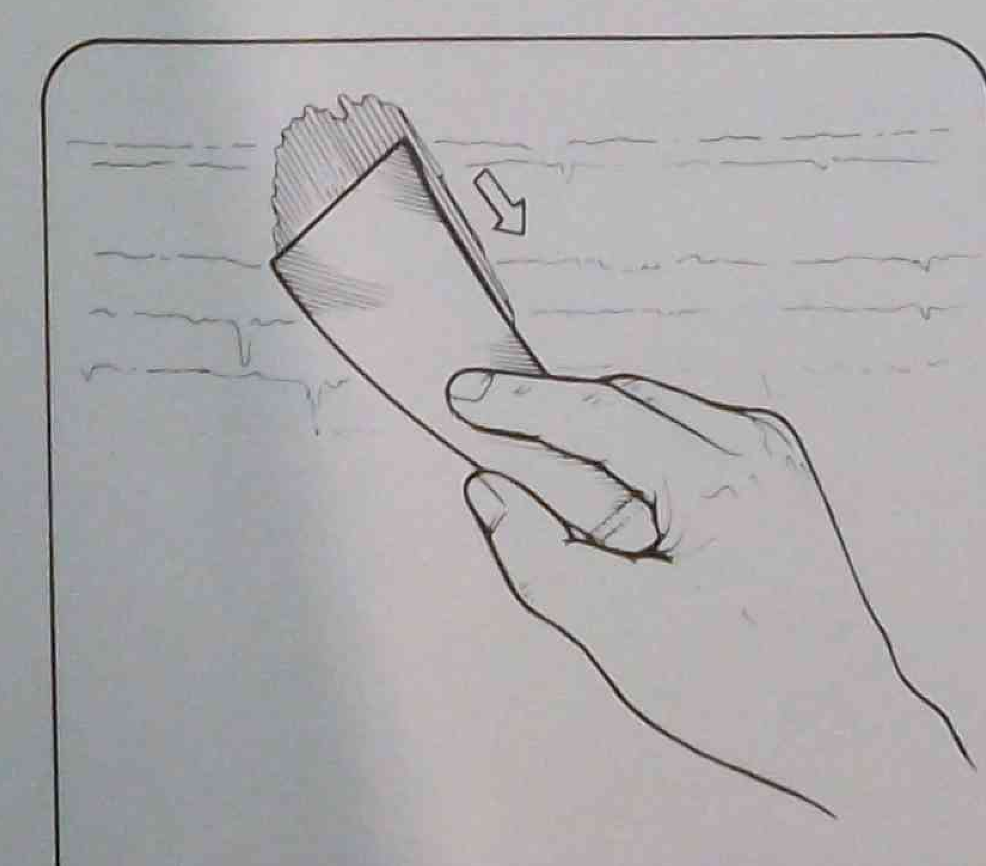
- Rake out loose material.
- Mix up sufficient filler.
- Using the knife, apply the filler.
  - If the indentation is deep, two or three applications of filler may be required.
- When dry, rub down with abrasive paper to smooth off the surface.

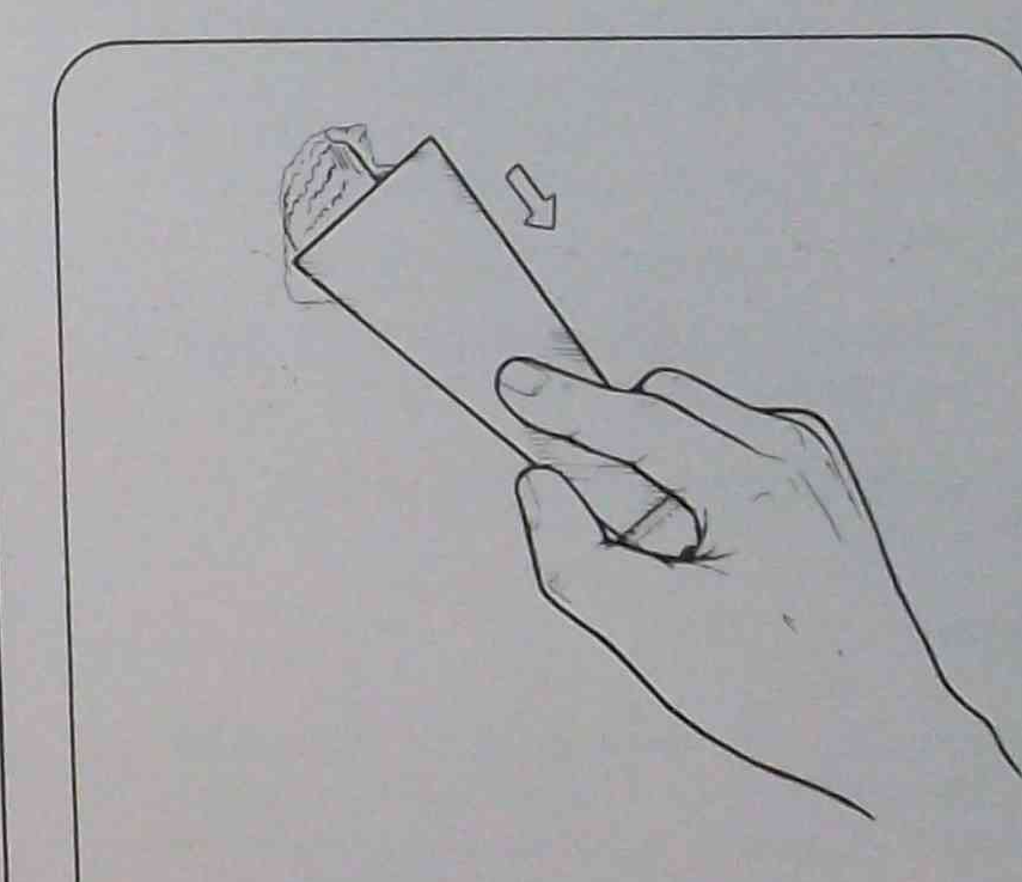


FILLING KNIFE



RAKE OUT LOOSE MATERIAL

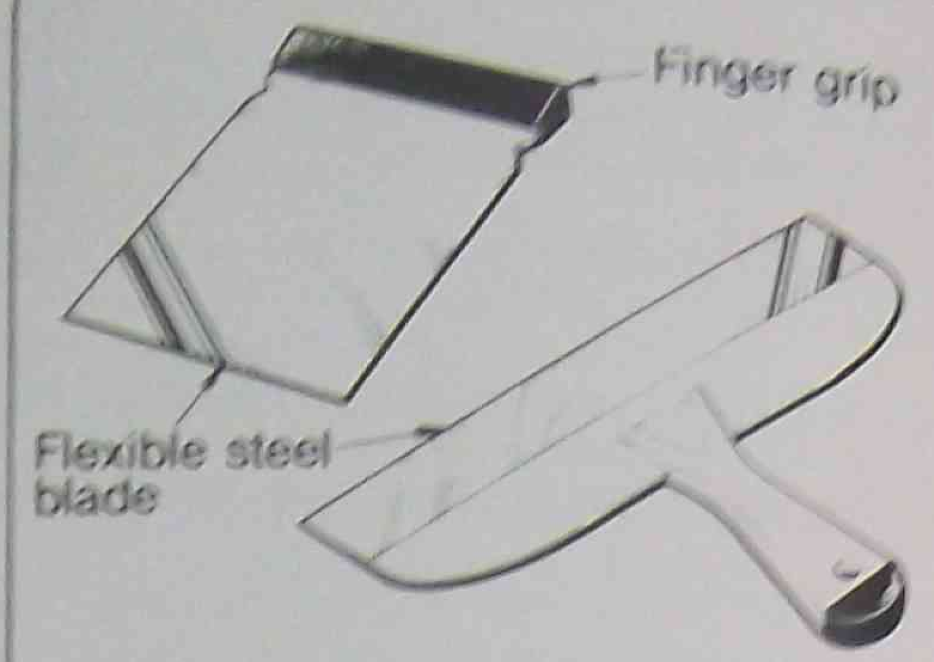

FILL FLUSH WITH EXISTING EDGE


APPLY FILLER

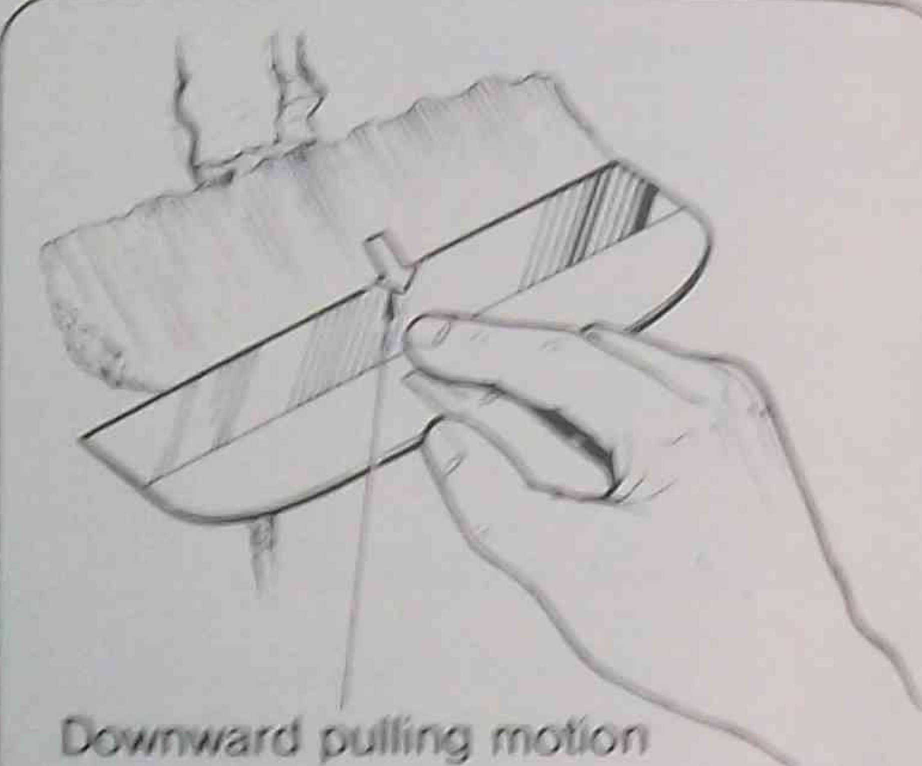
Flexible filling blades

A fine steel flexible blade fitted with a plastic or wooden finger grip. Blade has greater flexibility than a filling knife.

Used for the same purpose as a filling knife. Available in sizes from 50 mm to 120 mm. For broad areas a blade 250 mm is available.



FLEXIBLE FILLING BLADES



FILLING BROAD AREAS

Maintenance

All filling blades and knives should be cleaned after each use and kept free of rust.

- Remove hardened excess filler from the blade with a paint scraper.
- Clean the blade with a fine abrasive paper.
- Coat with a rust preventative oil, such as Vaseline, to prevent rust.
- Store in a container to protect the edges.

NOTE:

Before use, remove oil from the blade with a cloth dampened in turpentine, this will prevent oil being placed on the surface which could cause defects to applied coatings. For example non-drying, cissing or crazing and discolouration.

MAINTENANCE OF FILLER BLADES

Float

Flat flexible steel blade attached to a wooden handle.

The size most commonly used is 115 mm by 285 mm.

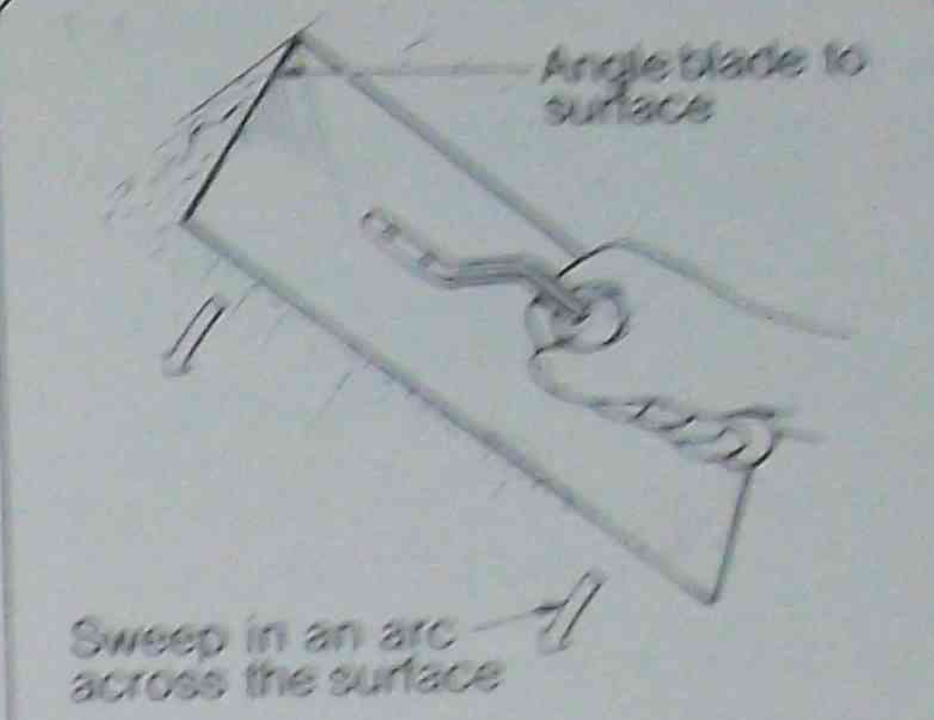
Used to flush fill plaster joins or surface imperfections and to make repairs to large holes or cracks. Also used to create decorative effects when texturing.

NOTE:

The blade must be flat and free of nicks and dents.

After use:

- Clean with water.
- Dry off.
- Coat with anti-rust protective oil.
- Store in a dry place.



FLOAT

Pointing trowel

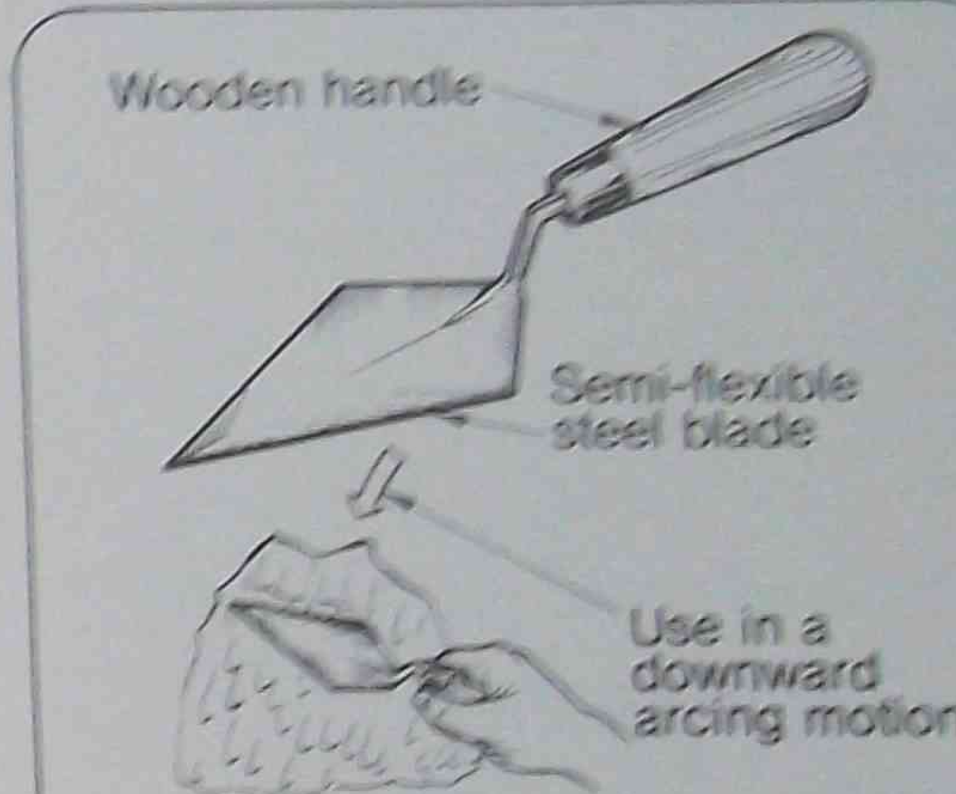
A triangular shaped semi-flexible steel blade with a wooden handle. Blade sizes available are 125 mm to 150 mm wide.

Used to:

- Repair broken mortar in brickwork.
- Stop up large cracks and holes on cement or plaster surfaces prior to painting.
- Rake out loose material.
- Mix filler for the job at hand.

Apply filler to the damaged area and spread evenly with the trowel. Keep the edge of trowel at approximately a 30 degree angle.

When the filler is dry, repeat the process until filling is flush with the surrounding surface.

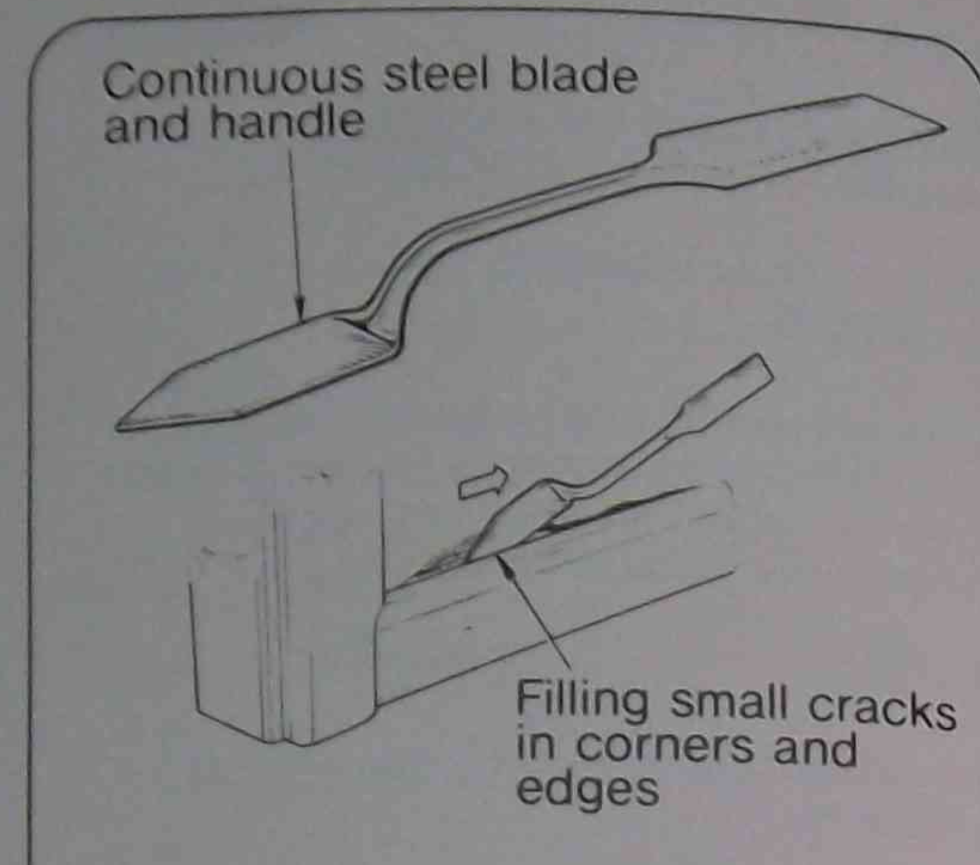


POINTING TROWEL

Plasterers small tool

A flexible steel tool, triangular shaped at one end and rectangular at the opposite end.

Used to fill small holes and cracks in ornamental surfaces, such as cornices, and for filling cracks in corners and the top edge of skirting boards adjoining the base of a wall.



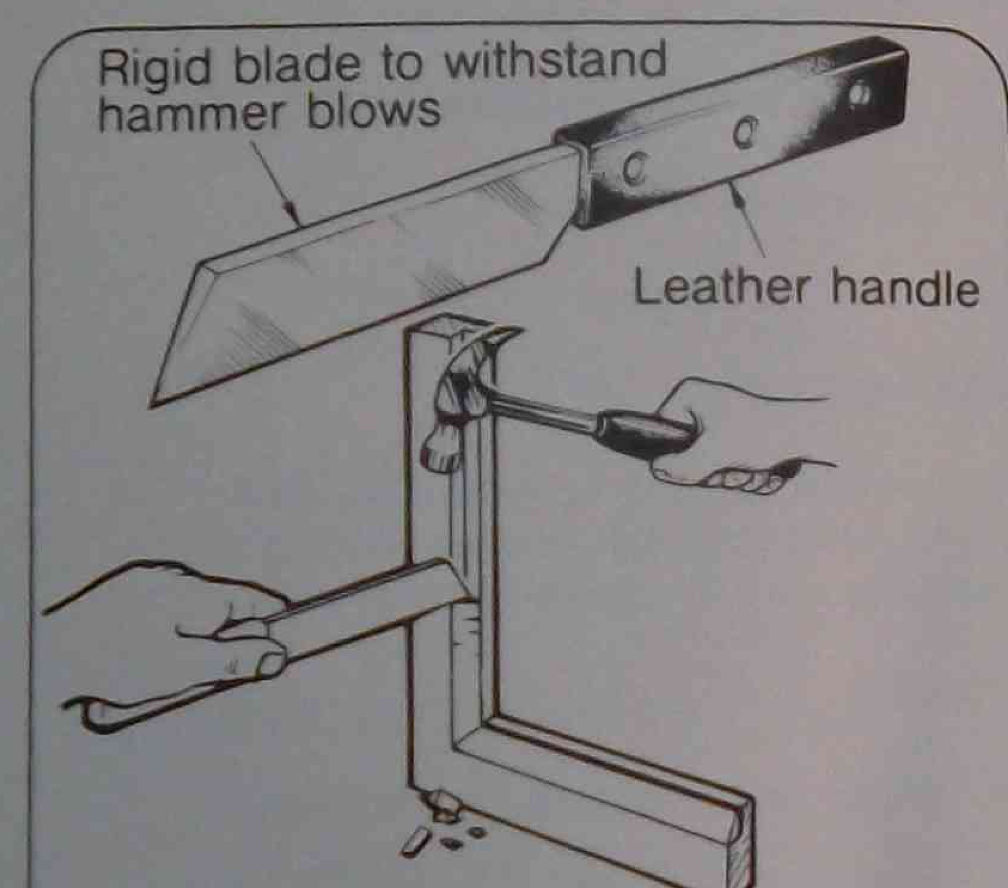
PLASTERER'S SMALL TOOL

Hacking knife

A heavy rigid steel blade with a leather handle.

The back edge of the blade is flat and is designed to withstand hammer blows. The blade is 100 mm to 125 mm long.

Used to remove old hard putties from window rebates prior to glazing.



HACKING KNIFE

1.3 GENERAL TOOLS

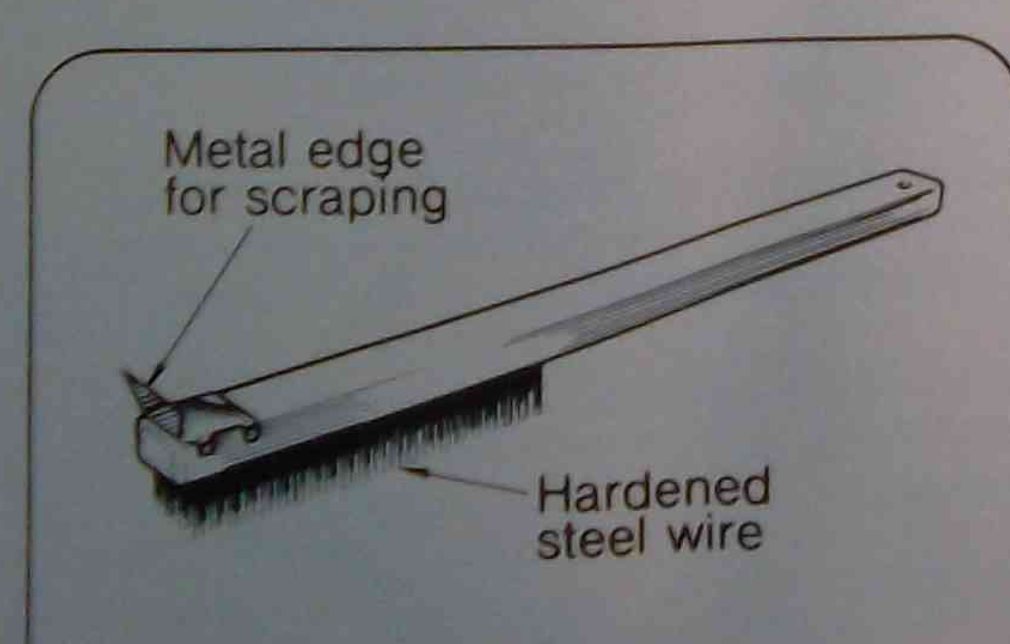
Wire brush

Made from hardened and tempered steel wires fixed to a wooden handle. Various types are available with long or short flexible wires.

Bronze wire brushes are available for safe use in high fire risk areas. Bronze wire will not create a spark.

The main use is to remove surface rust and foreign deposits from metal and masonry surfaces whilst preparing for painting.

Wire brushes are also used to clean brushware.

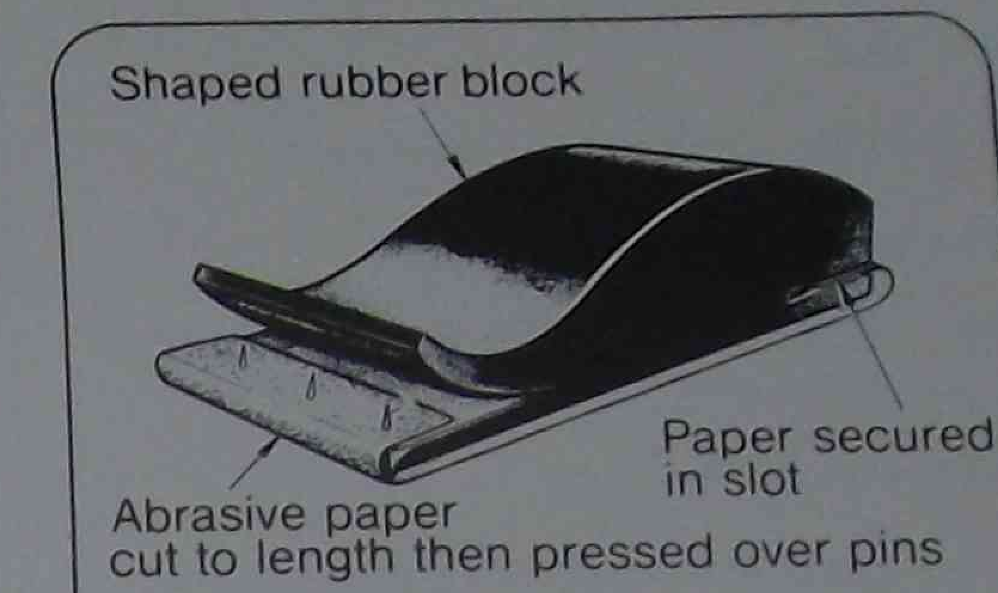


WIRE BRUSH

Sanding block

Made from wood, cork or rubber. The base is approximately 50 mm by 110 mm.

Used to hold and keep the abrasive paper firm and flat on surfaces when rubbing to achieve a smooth even surface. It protects the users hands from abrasive paper and provides a more comfortable grip.



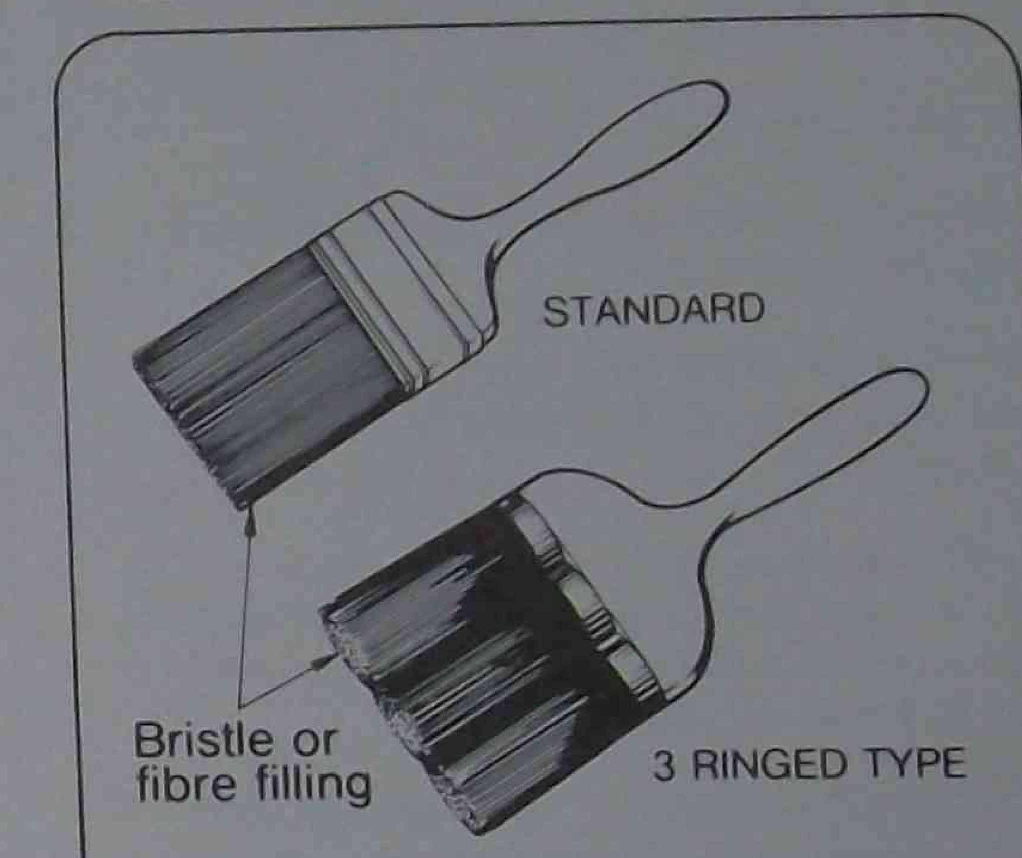
SANDING BLOCK

Dusting brush

A brush with stiff bristles or synthetic fibre filling.

A standard 75 mm brush may be used, or a three-ringed type dusting brush 100 mm or 110 mm width. The width of the brush should fit the hip pocket of overalls for easy access.

Used to brush dust and dirt from surfaces prior to painting.



DUSTING BRUSH

Roller spinner (cleaner)

A tubular shape with a spiral plunger. Made from alloy or galvanised metal.

An efficient and practical tool for cleaning roller covers and brushware.

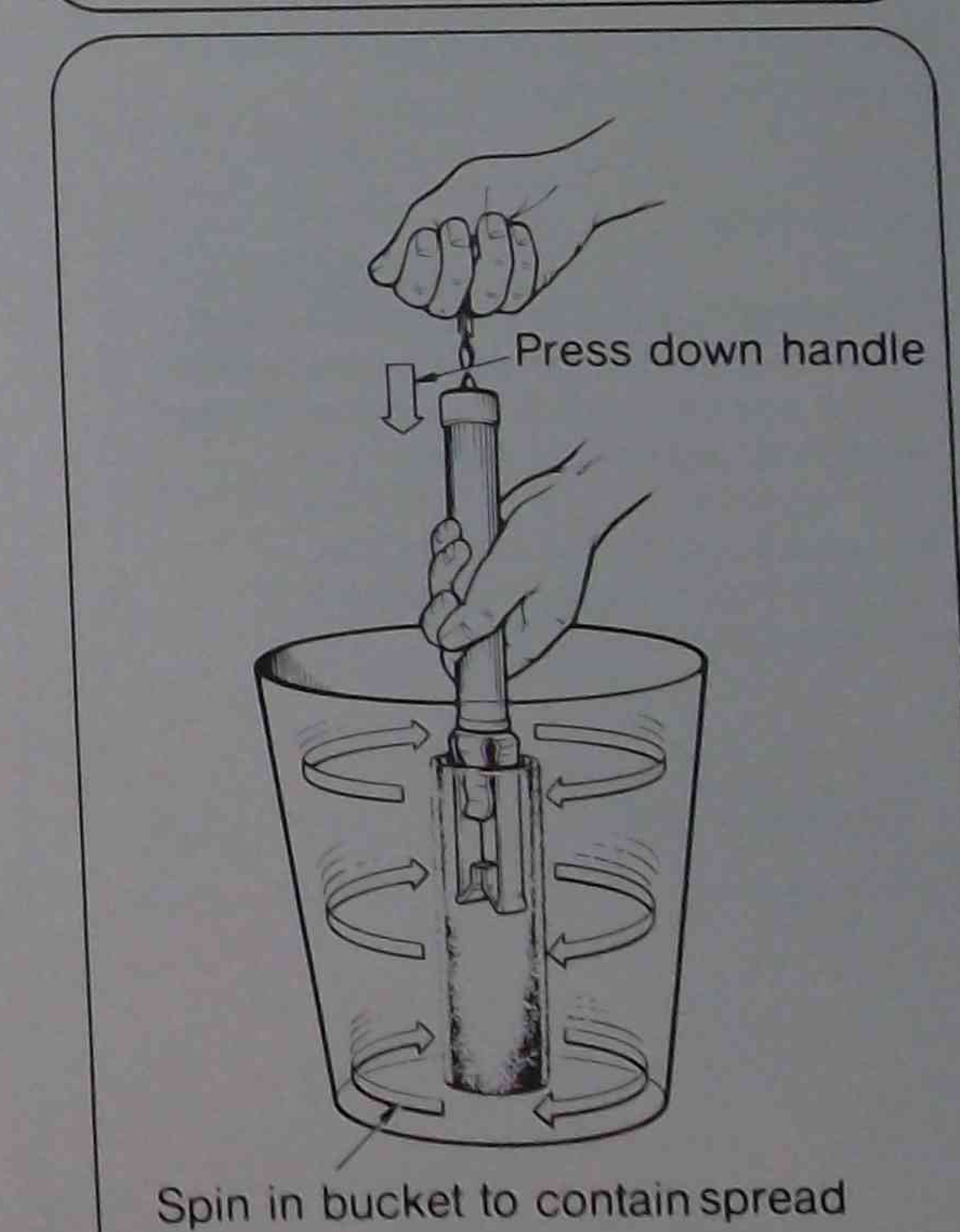
The roller cover is slipped over the lower prongs. The plunger is depressed, causing the lower section to revolve rapidly, spinning off solvent and paint residue, leaving the cover or brush clean and ready for use.

Paint pot

Made from black or galvanised sheet iron. Various sizes are available 150 mm to 200 mm diameter.

Used to hold a convenient quantity of paint for the job at hand.

After each use, wash the pot out with a brush and appropriate solvent, such as turpentine or water, then wipe clean with a cloth.



ROLLER SPINNER

Pot hook

Made from strong wire or steel plate.

Used to support paint pots when working on a ladder or scaffolding. This enables free use of both hands. The hook should be offset to ensure the pot hangs straight.

Window scrapers

A light metal tool which has provision for a single-edged razor blade. The cutting edge is fully retractable for safety. The blade must be retracted when not in use.

To retract the blade:

Depress the lever and slide the blade back into the holding slot.

When required for use, depress the lever and push forward. The blade will then be exposed.

Used to remove paint spots, transfers, posters and foreign materials from window panes, mirrors or flat glass surfaces. Used in a pushing or forward motion.

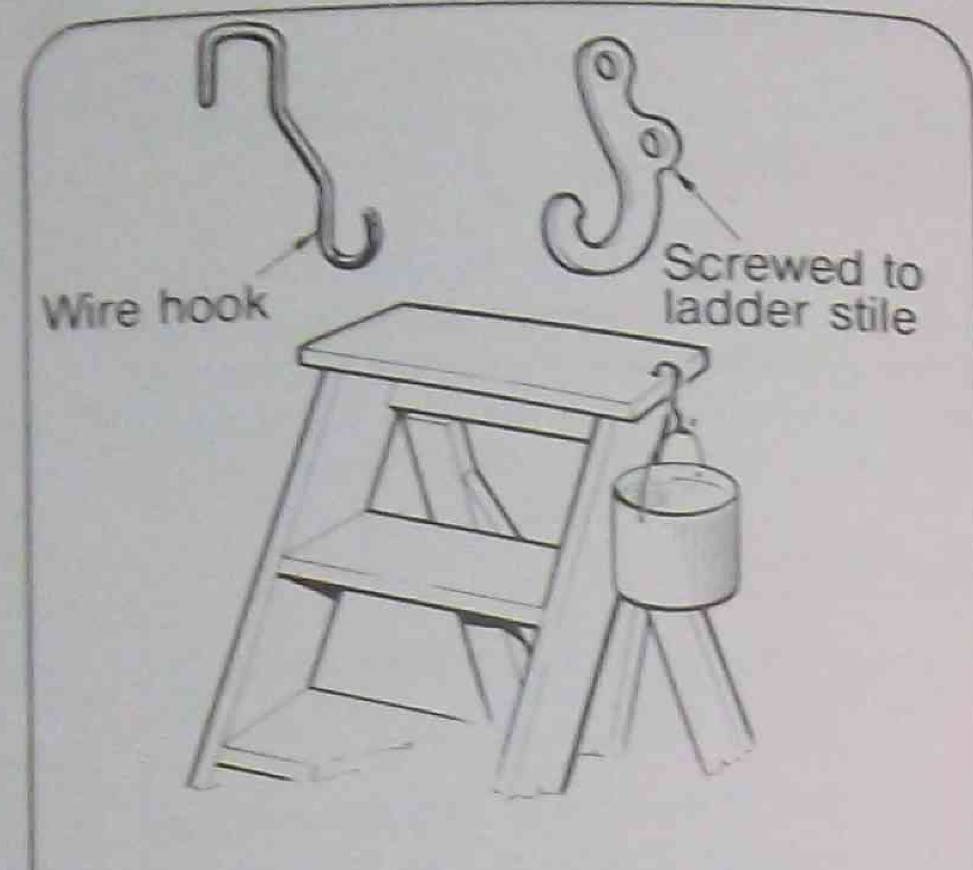
A larger type scraper is also available with a replaceable single-edged 50 mm wide blade.

When not in use the blade is reversed to expose the back edge.

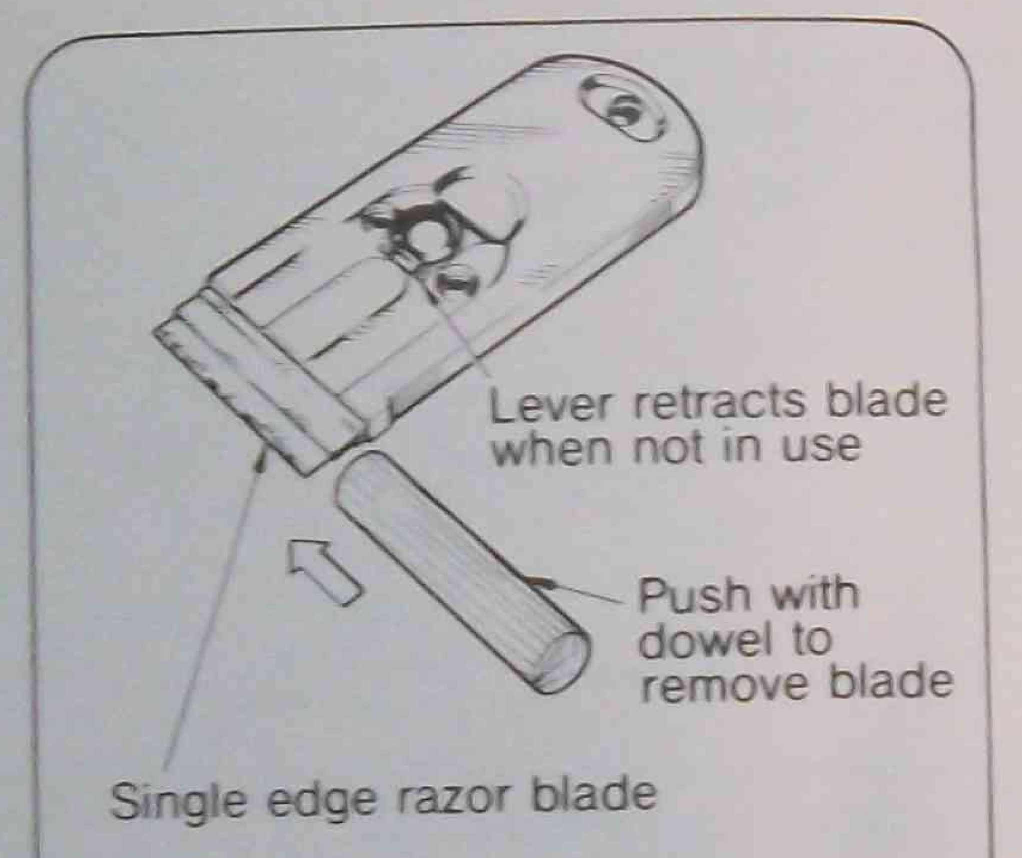
WARNING:

The blade is extremely sharp; therefore, it is essential to reverse the blade when not in use for maximum safety to prevent gashes or cuts to the hands.

These scrapers have a limited use; however, they are essential tools in a painter's tool box.



POT HOOKS



WINDOW SCRAPER

WINDOW SCRAPER

Measuring tape

Tapes are available in metal, fibreglass or PVC coated cloth in lengths from 3 m to 30 m.

Used for measuring areas to estimate quantities of material and labour costs for painting or paper hanging.

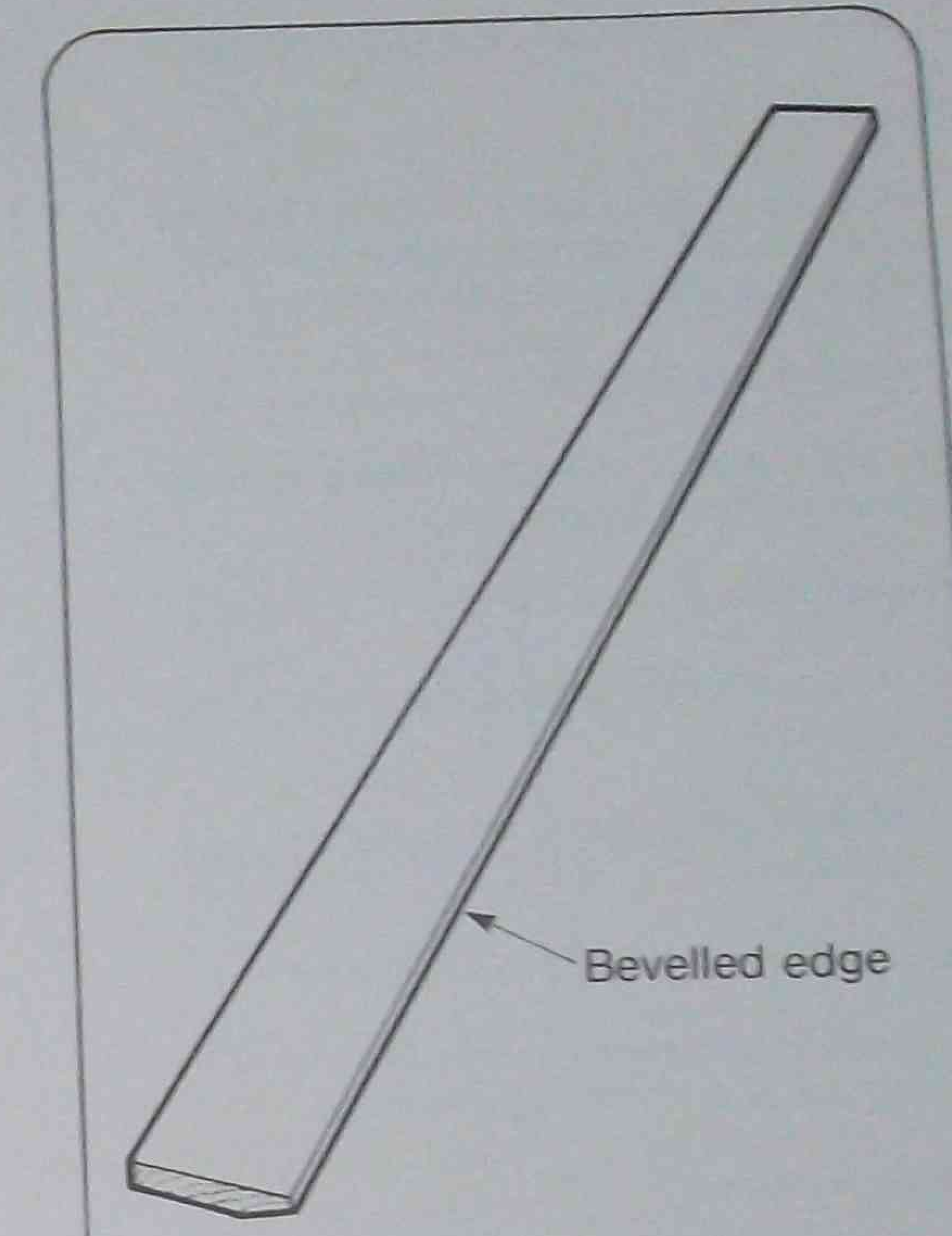
Straight edge

A piece of straight timber 1 metre long, with a bevelled edge.

Used to guide a lining fitch when running lines onto a surface.

Claw hammer

Has many uses in painting and decorating. Used in conjunction with a hacking knife for removing putty. To drive home nails, brads and clouts protruding from surfaces. For general repair work carried out prior to painting.



STRAIGHT EDGE

Nail punch

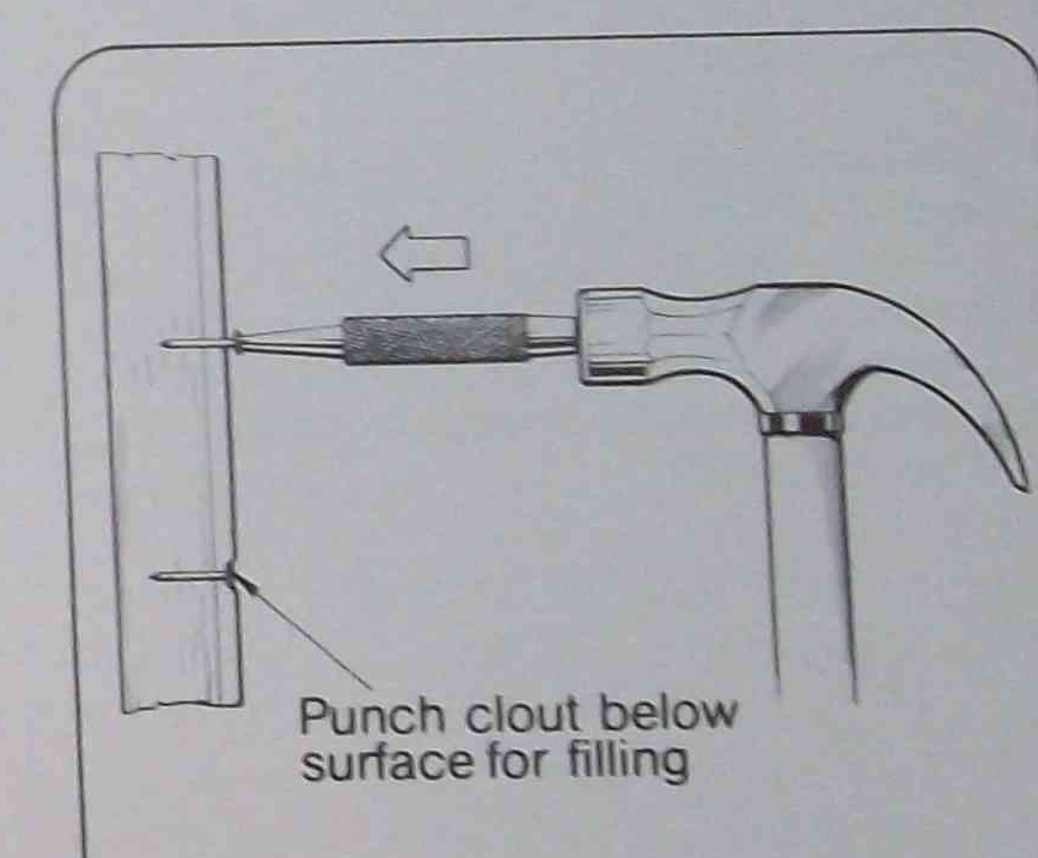
A tapered hardened steel punch.

Used to punch nail heads, brads and clouts below the surface prior to stopping and filling. Tip size available 2 mm to 5 mm.

Screw drivers

Standard type and Phillips head.

Used for removal and replacing of fittings prior to painting or paper hanging. Door fittings, window fittings, furnishings, blinds, curtain racks etc.



NAIL PUNCH AND CLAW HAMMER

1.4 PROTECTIVE EQUIPMENT

Overalls

Two pairs of clean white overalls either bib and brace or combination. Alternate each week whilst one pair is being washed.

Protective eye glasses

Eye protection is essential when preparing various surfaces for painting.

Glasses must be worn:

- When stripping flaking materials from a surface.
- Wire brushing metal or masonry surfaces.
- While using solvent paint removers.
- When dusting down, especially in industrial or overhead situations.

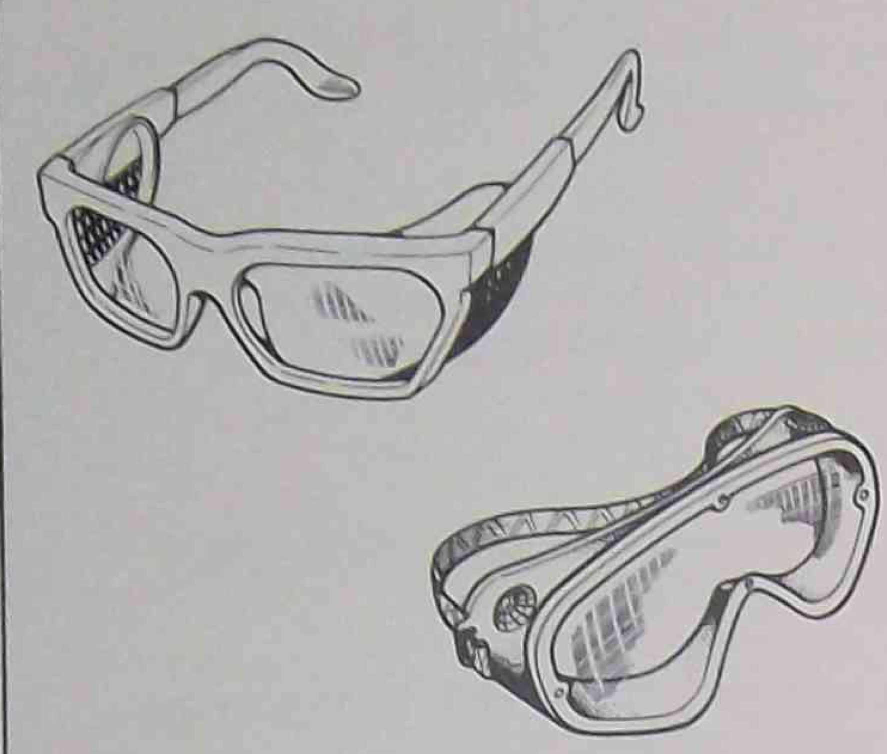
Protective gloves

Two pairs are required. One pair of cloth gloves. One pair of rubber gloves.

Rubber gloves must be worn when:

- Handling liquid paint removers, acids or strong alkalis.
- Bleaching timber stains with oxalic acid.
- Washing down surfaces with solvents or caustic-type materials to avoid burns and skin dermatitis through handling these materials.

Canvas or cloth gloves should be worn when handling or removing glass when glazing to avoid cuts, splinters etc.



USE EYE PROTECTION WHEN PREPARING SURFACE

WEAR RUBBER GLOVES WHEN USING SOLVENTS, ACIDS OR ALKALIS

WEAR CLOTH GLOVES WHEN REMOVING BROKEN GLASS

2 PAINT APPLICATORS

2.1 BRUSHES

Section of a brush

There are basically four main sections of a paintbrush.

Handle

Usually made of hardwood which is sealed to prevent moisture soaking in and to make cleaning easier.

Stock

The means by which the handle is fixed to the filling. Usually, a ferrule made from copper or nickel-plated steel. The ferrule is riveted or pressed onto the handle.

Setting

An adhesive which cements the filling together at the root.

The main types of settings used are epoxy resin and vulcanised rubber. These materials are resistant to paint solvents.

Filling

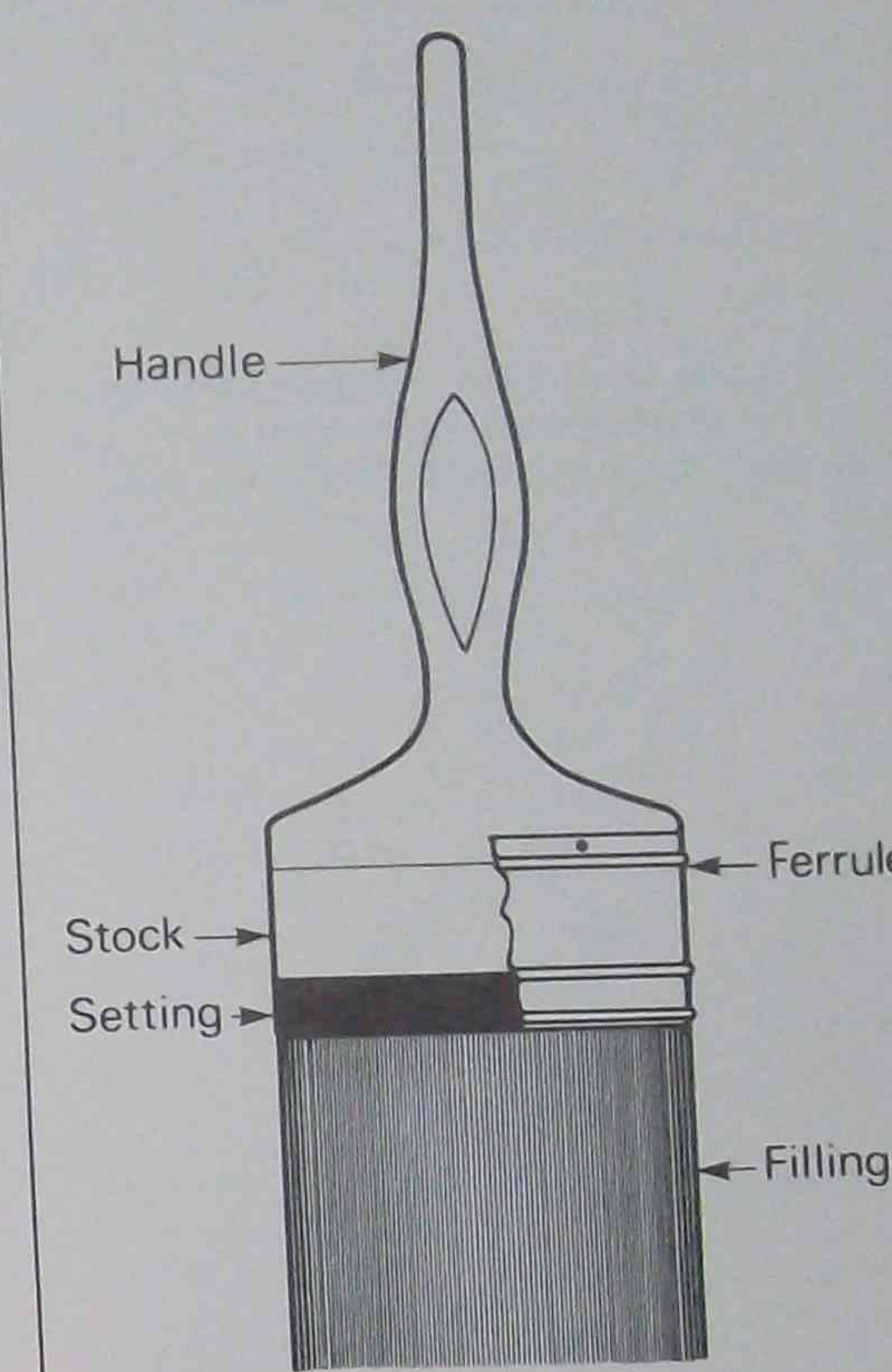
The filling is the section of the brush which holds the paint.

There are four main types:

- pure bristle
- synthetic fibres, such as nylon
- natural fibres obtained from grass and plants
- a mixture of bristles and fibres

NOTE:

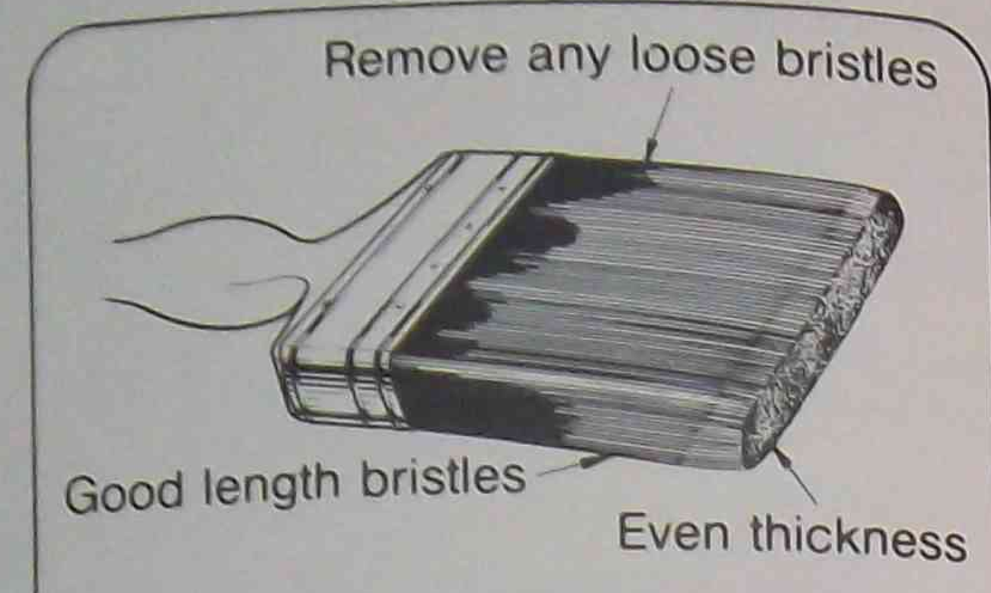
Cheaper brushes may have plastic handles and short thin bristles which lack the ability to hold a good load of paint. This in turn makes it harder to flow paint onto the surface.



SECTIONS OF A BRUSH

2.1.1 Care and maintenance of brushware

Before using a new brush inspect the bristles for good length and thickness. This gives the brush the ability to hold more paint and provide easier paint flow. Remove any loose bristles.



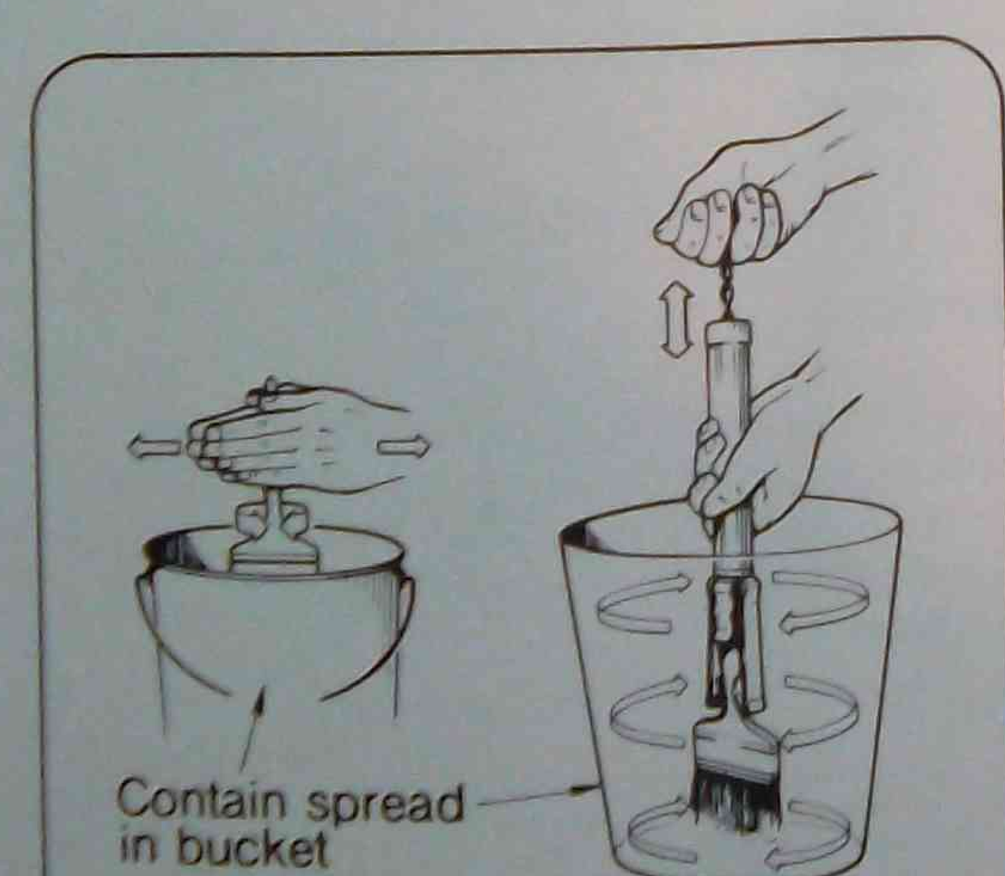
INSPECTING A NEW BRUSH

A brush used in oil alkyd type paint may be stored for short periods suspended in water. Spin the water out before using the brush.

STORE BRUSH OVERNIGHT IN WATER

Should the brush be out of use for several days:

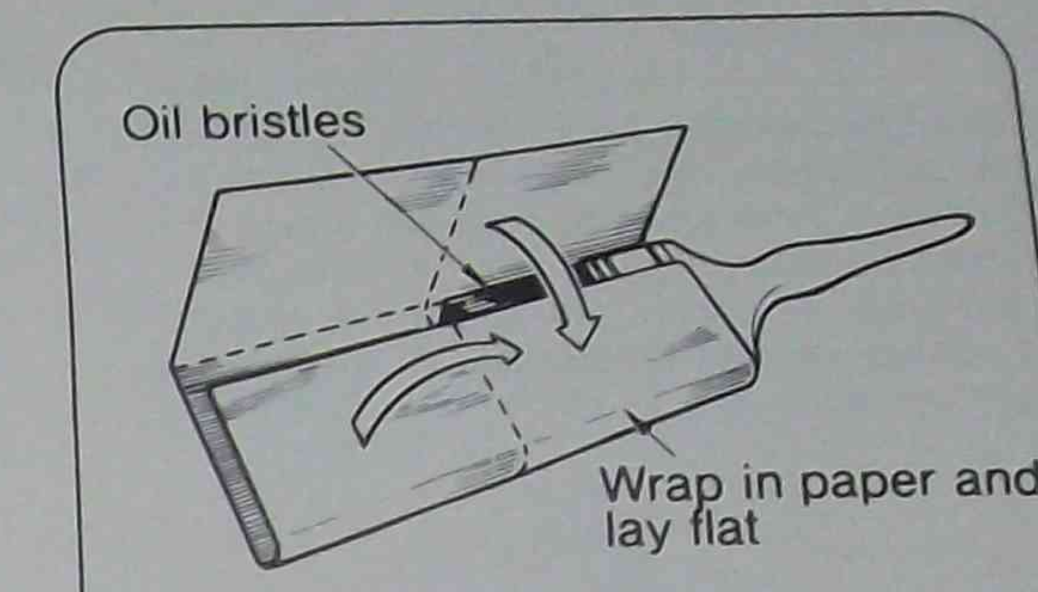
- Clean the bristles thoroughly with a suitable solvent to remove all traces of paint.
- Wash out the solvent with warm water and detergent.
- Rinse thoroughly in clean water.
- Hang to dry in a well ventilated area.



REMOVE SOLVENT OR WATER BY SPINNING

After cleaning, brushes can be stored by dipping the bristles into neat's-foot or linseed oil, then suspended in a container. Brushes dipped in oil may also be wrapped in paper and laid flat in a suitable container.

These methods of storage will ensure the bristles maintain their flexibility and shape.



STORING BRUSHES

Brushes used in water-based coatings such as acrylics must be thoroughly cleaned on completion of use. Remove all traces of paint by washing in water. Oil residues may be removed with turpentine or methylated spirits. Lather bristles in soapy water then rinse thoroughly with clean water. Store brushes by laying them flat in a container or suspended in a well-ventilated area.

NOTE:

Neat's-foot oil is non-drying; therefore, the brush should be washed in turpentine before use to remove the oil.

If oil from the brush is deposited on the surface, defects or breakdown of paint being applied will occur, e.g. non-drying, crazing.

WASH OUT BRUSH

2.1.2 Brush types and their uses

100 mm flat brush

Used for applying coatings to broad areas such as walls, ceilings, weatherboards, panelled doors and most surfaces.

100mm FLAT BRUSH

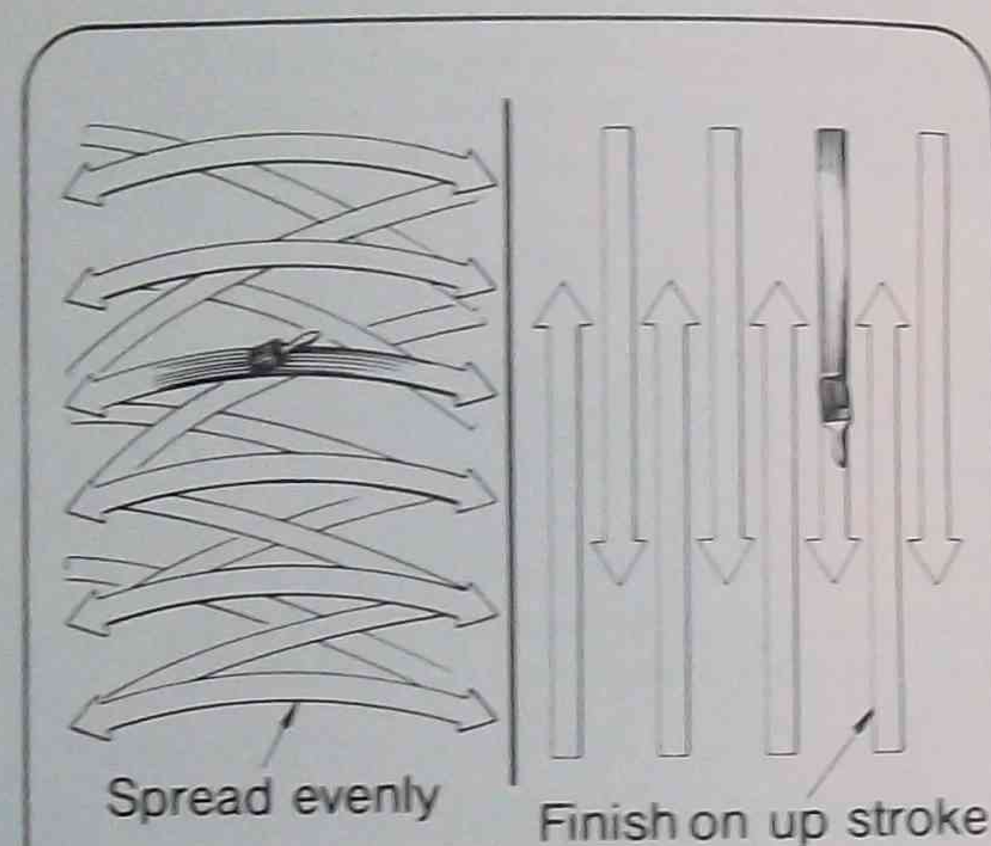
75 mm flat brush

Used for painting a variety of surfaces such as architraves, spoutings, facias, cornices, furniture, skirtings and panelled doors. Flush panelled doors coated with a roller will leave a stippled effect or roller marks. To eliminate this defect, lay off the surface with a 75 mm brush.

75mm FLAT BRUSH

Laying off procedure

Paint is spread evenly by horizontal brushing, or arcing. The paint is then brushed up and down, always finishing on the upstroke. This will eliminate brush marks left from spreading the paint.



LAYING OFF

Paint applied on a vertical surface has a tendency to sag and run, the final upstroke when laying off prevents this problem.

HOLDING THE BRUSH CORRECTLY

50 mm flat brush

Used to paint small areas, staining of timber, furniture, painting of table legs, chairs, also for application of varnish and clear finishes.

Sash cutter fitch

Flat pure bristle, long-handled brush. Sizes available from 10 mm to 75 mm. Handle 200 mm in length.

Uses

75 mm sash cutter turned on edge is used for cutting in around architraves and trim work. Brush is then turned flat to paint flat and broad areas.

50 mm sash cutter turned on edge is used to cut in window sashes. Cutters are also used to cut in straight lines on a surface, such as where the walls meet the ceiling. The long handle enables the brush to reach otherwise awkward areas.

Definitions of the term 'cutting in':

Finishing off a section of paintwork in a neat line.

Finishing the paintwork with a neat edge, where it meets the glass of a window pane by overlapping the glass one millimetre, to seal the putty from the weather.

Cutting in skirtings neatly without encroaching on the flooring or walls.

Cutting to another colour. Care should be taken where a sharp line is formed in multi-colour work.

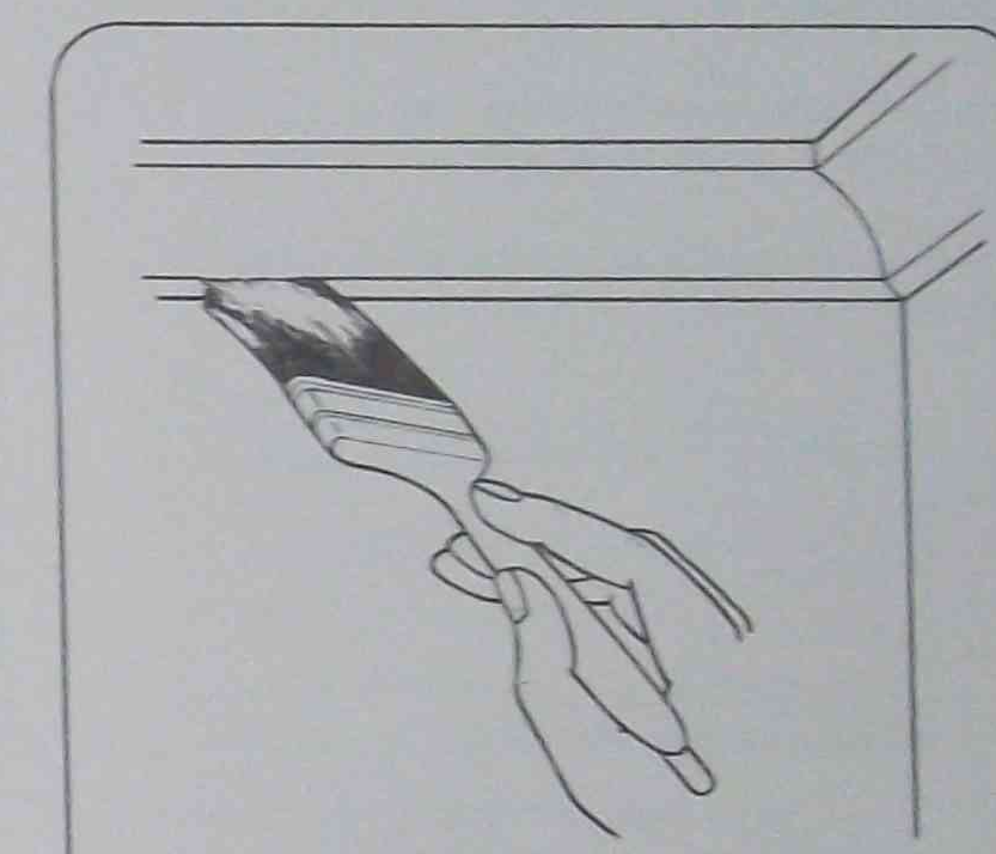
Flat wall brush or paste brush

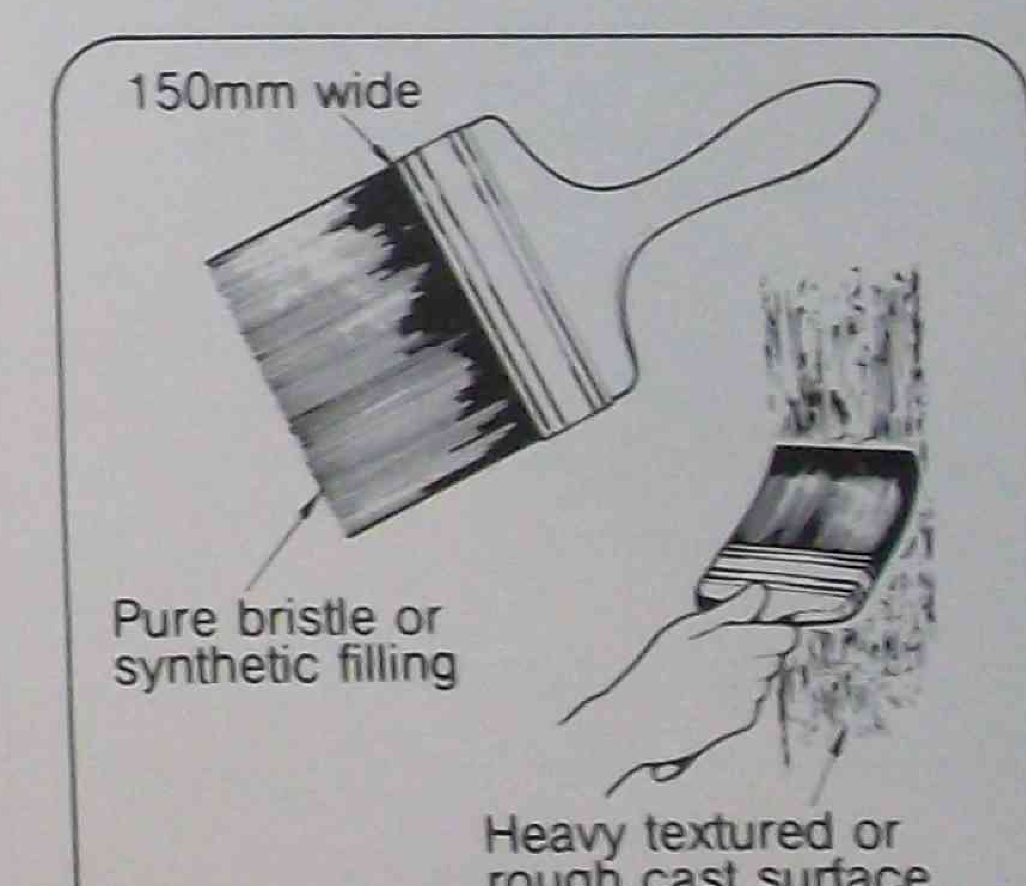
A pure bristle or synthetic filling. 150 mm wide brush.

Used for:

- Applying paint coatings to heavily textured and broad areas.
- Washing down greasy surfaces with detergent prior to painting, such as kitchens and bathrooms.
- Applying adhesives to wall coverings.

SASH CUTTER


CUTTING IN

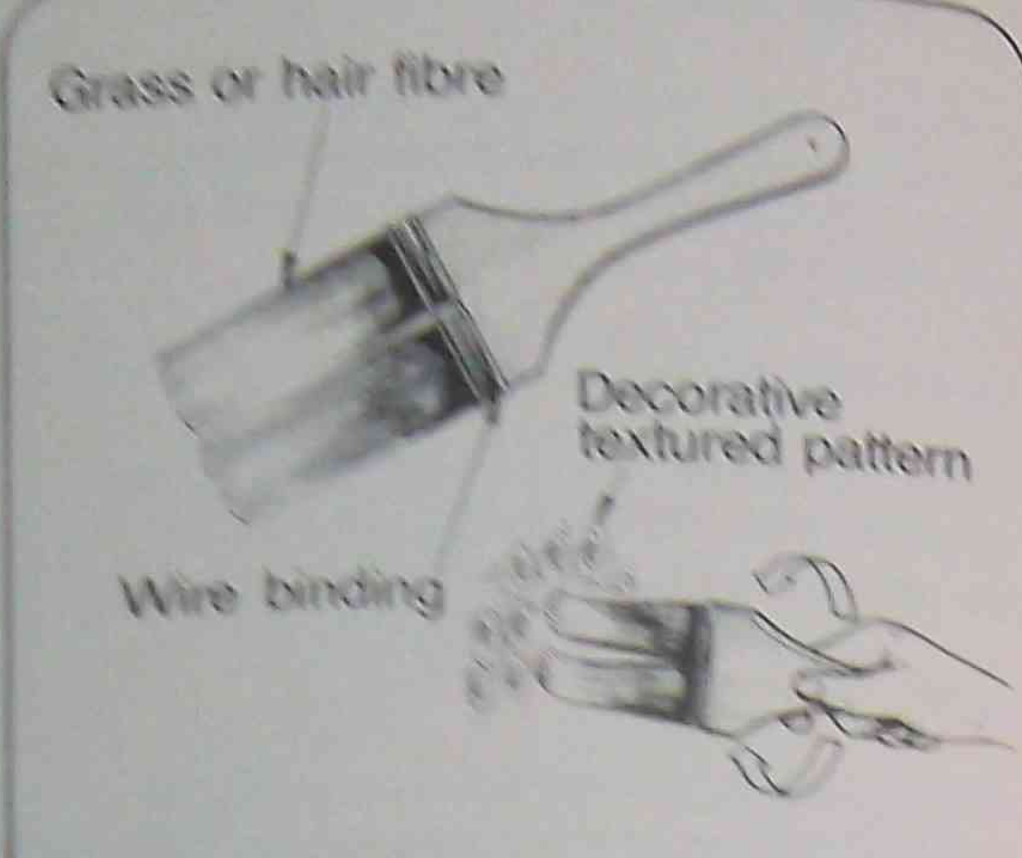


FLAT WALL BRUSH

Two tie brush

Filling of grass or hair fibres 200 mm in length. Each knot is bound by copper wire creating two round knots of filling 60 mm in diameter.

Has similar uses as the flat wall brush. This brush may be used to develop decorative effects when texturing.



TWO TIE BRUSH

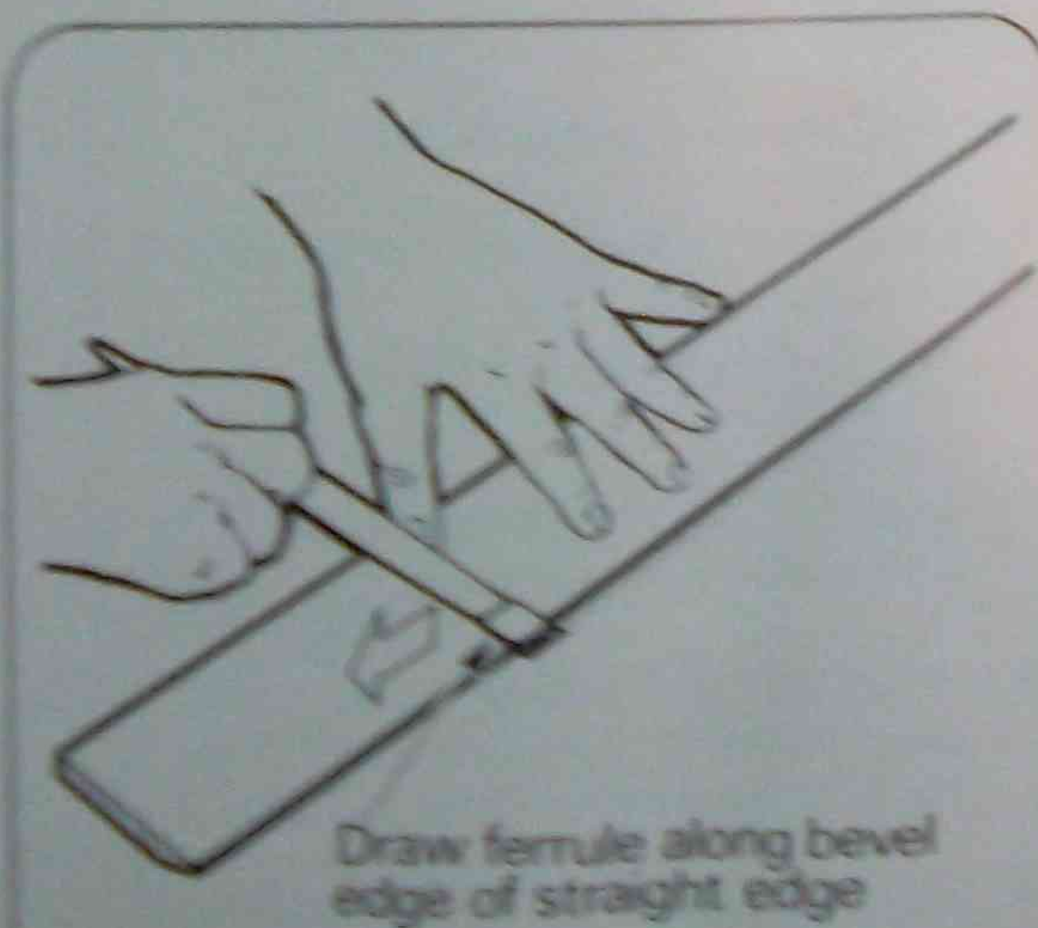
Lining fitch

A brush with bevelled edge bristles. Available in sizes from 6 mm to 37 mm.

Used for touching up. Good all purpose brush.

LINING FITCH

Used with a straight edge to paint straight lines on a surface. For fine lining, a metal "keeper" is placed over the bristles of the brush to maintain a firm shape.



USING A FITCH AND STRAIGHT EDGE

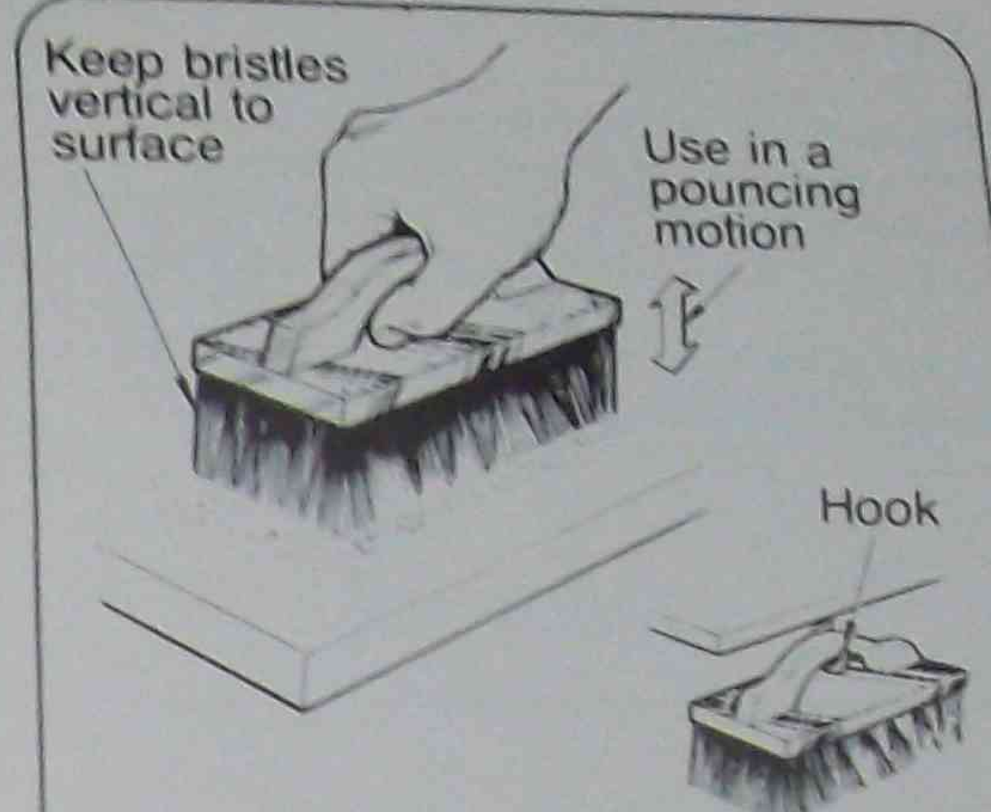
Stipple brush

A pure bristle brush, with bristles 75 mm in length. A wooden handle grip is attached to a flat stainless steel top. Sizes available are 100 mm × 75 mm, 125 mm × 100 mm and 150 mm × 100 mm.

Used when frosting on glass, colour blending, decorative glazing and creating soft decorative effects. Paints and materials used for decorative effects are applied initially by brush or roller. The stipple brush creates a soft even surface free of brush or roller marks.

The brush is used in a pouncing motion keeping the bristles vertical to the surface.

After each use, wash the brush in a suitable solvent. Remove all traces of solvent by washing the brush in warm soapy water. Rinse the bristles thoroughly in clean water to remove the soap. Shake out residue water, then suspend the brush by the handle in a well-ventilated area for storage.

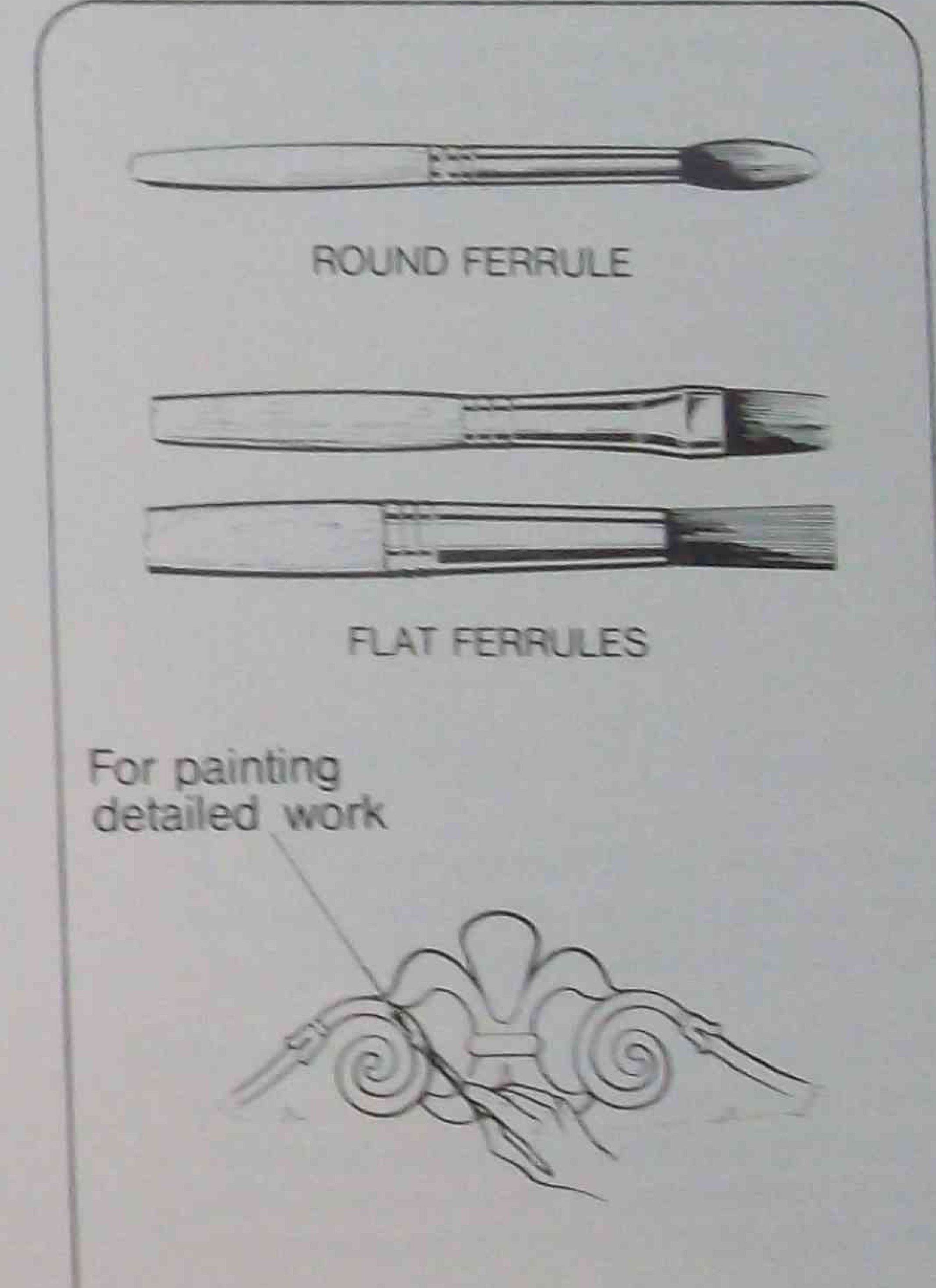


STIPPLE BRUSH

Fitches

Fitches have a bristle filling which is set in either a flat or rounded ferrule. Available sizes 3 mm to 20 mm.

Used to apply paint coatings to delicate, detailed work. May also be used to paint small areas that are difficult to reach.

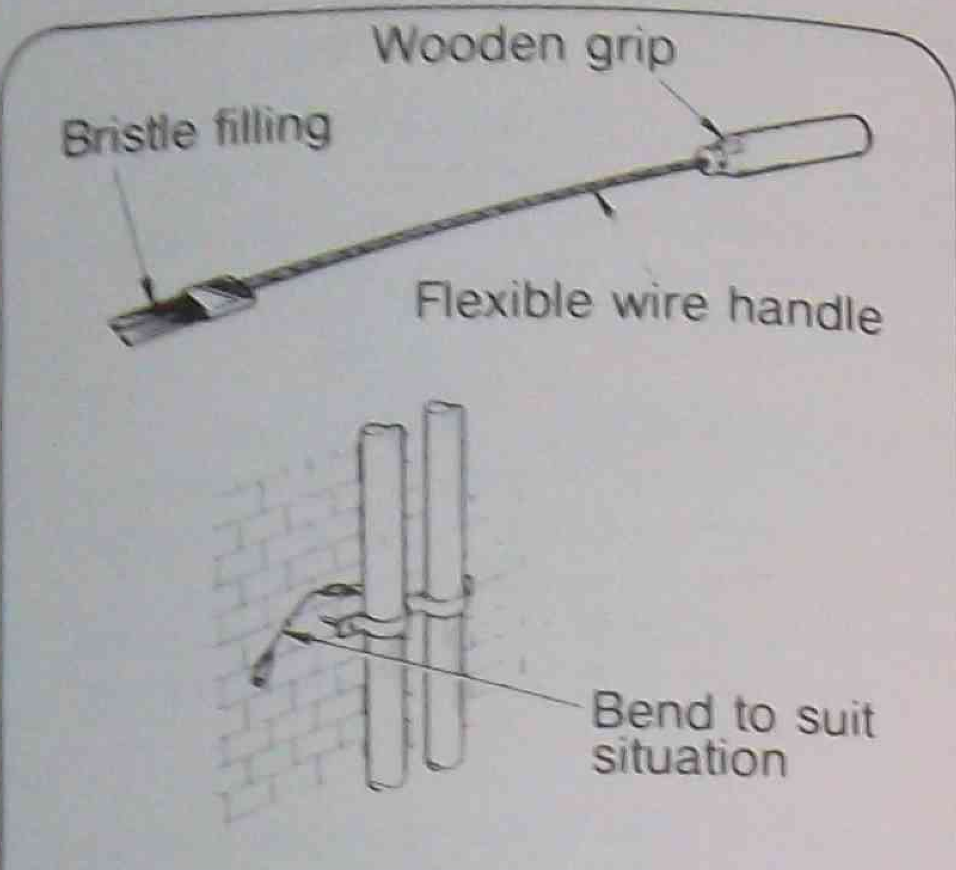


FITCHES

Flag or radiator brush

Bristle filling with a flexible wire handle and a wooden grip. Available brush size 25 mm to 50 mm. Handle may be bent to suit the shape of the object being painted.

Used for applying coatings to areas difficult to reach: radiators, behind drainpipes, etc.

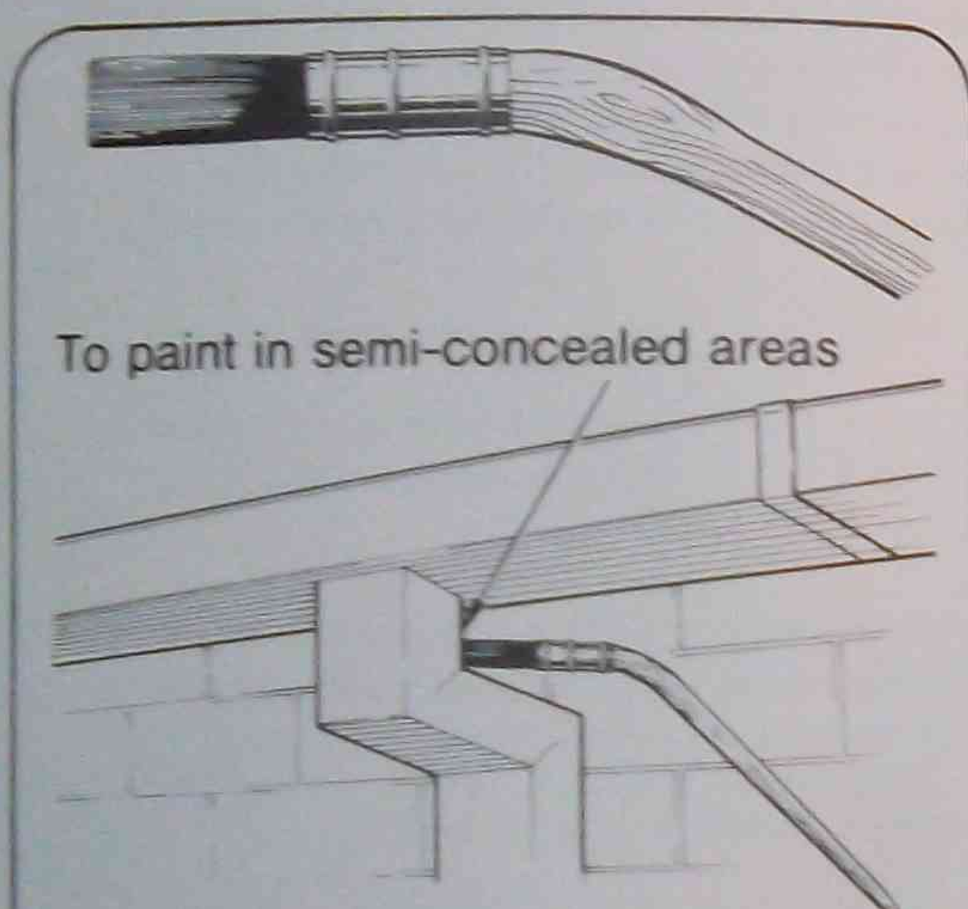


FLAG BRUSH

Bent or crevice fitch

Similar to a lining fitch with flat or rounded filling.

The handle is angled to assist when applying paint to areas visible to the eye but awkward to reach. Areas such as the rear side of drainpipes or waste pipes. It enables these areas to be coated without splashing paint onto surrounding areas.

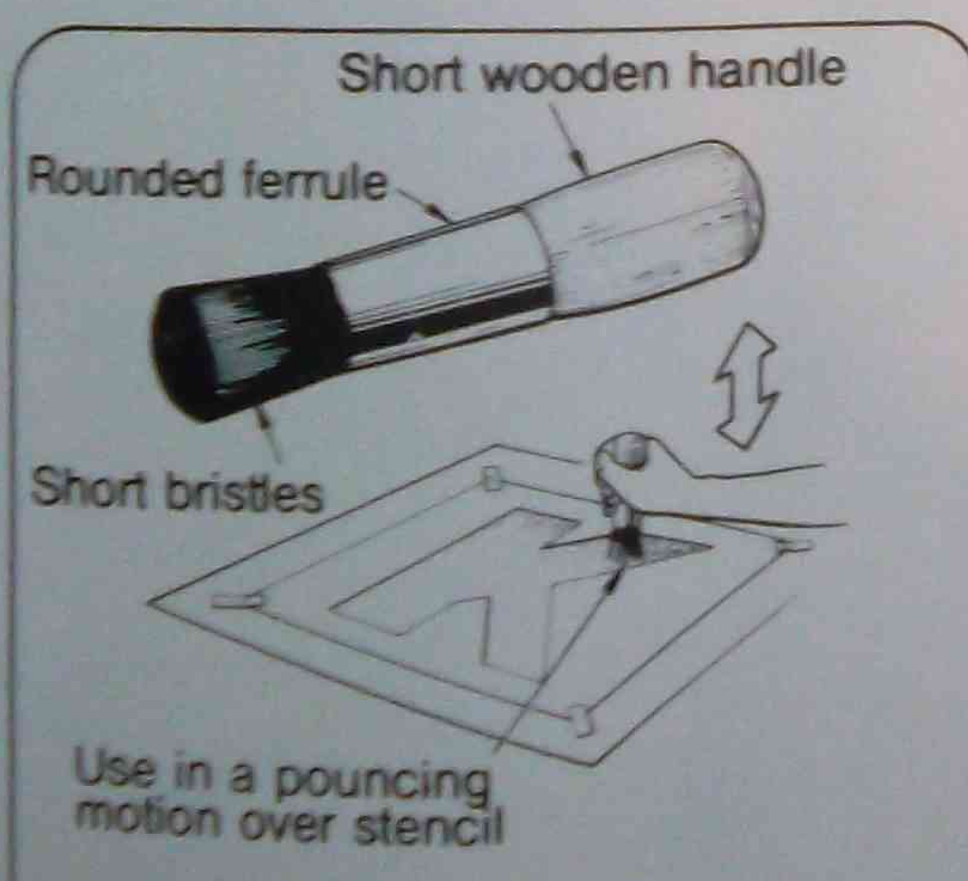


BENT OR CREVICE FITCH

Stencil brush

A stiff short rounded bristle brush with a short wooden handle. Sizes available from 7 mm to 80 mm diameter.

Used to apply decorative stencils. With the use of a template or cut stencil, numerals or lettering may be applied. For example, pipeline identification, various signs, exits, decoration, identification and safety signs.



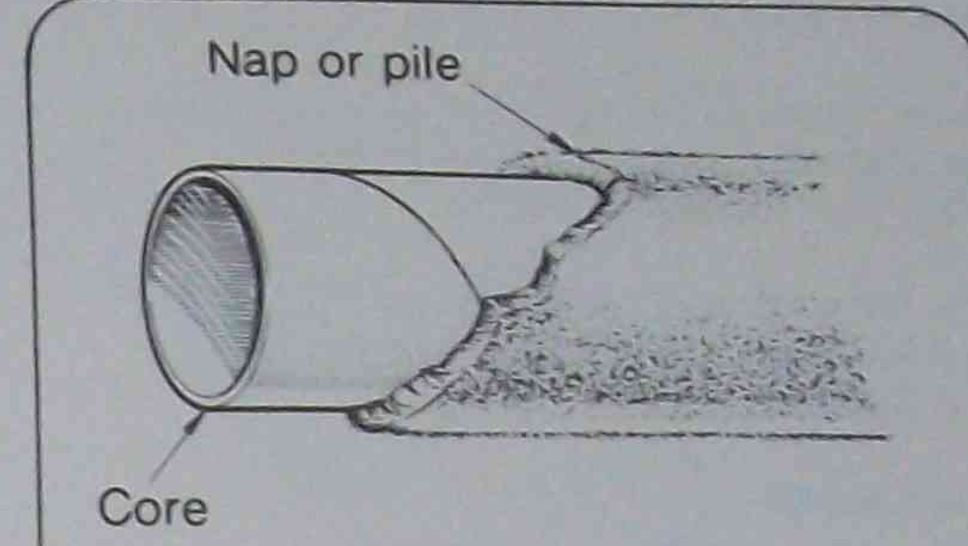
STENCIL BRUSH

2.2 PAINT ROLLERS

2.2.1 Roller covers

Roller covers consist of a central core covered with selected fabrics. Each fabric has its own characteristics which will produce the required finish on a selected surface with a particular paint system.

The core is made from heavy-duty cardboard tube impregnated with phenolic resin to resist solvents used in paint coatings, enabling the cover to retain its strength and rigidity under workload conditions.



ROLLER COVER

The pile or nap fabrics can be natural fibres, such as wool, mohair or cotton. Synthetic fibres produced from chemical composition, such as acrylic, polyester and nylon, are also used.

Rollers are used to paint a wide variety of surfaces, both internal and external, such as walls, ceilings, furniture, corrugated surfaces, pipes, heavily textured surfaces and wire fences.

A wide variety of covers are available for various surfaces. The selection of the correct cover for the type of paint and surface is essential to obtain the desired finish.

NOTE:

Refer to the manufacturer's specifications and recommendations to select which type of roller would be suitable for the surface to be painted and the type of paint to be used.

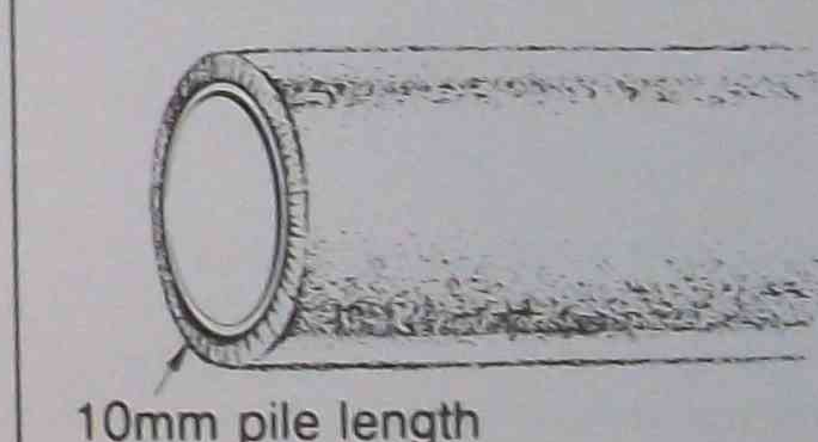
2.2.2 Types of covers

Lambswool

Natural wool pile fabrics processed for roller painting. Pile size or thickness 10 mm. Available in sizes from 130 mm, 180 mm, 230 mm to 460 mm wide. Most common size in use 230 mm.

An all-purpose cover used to apply PVA and acrylic coatings, alkyd primers, undercoats and some industrial enamels.

Most common use is to paint ceilings and walls with water base coatings and wallpaper size prior to hanging wallpaper. This cover is resistant to harsh solvents.



LAMBSWOOL COVER

Mohair blend

Ideal cover for applying undercoats, gloss and semi-gloss enamels to smooth surfaces. 7 mm pile length.

The short mohair fibres lay out the paint evenly with minimum stipple effect left on the surface.

Foam rubber

Used to apply gloss and semi-gloss enamels and clear finishes. Excellent for obtaining a smooth finish on doors.

Orlon soft pile

Used to apply acrylic, gloss and semi-gloss paints to bathrooms, kitchens, toilets etc. 7 mm pile length.

Long nap 100 per cent polyester

20 mm pile length. Designed to hold more paint for coverage over textured or semi-rough surfaces with all paints other than gloss enamels.

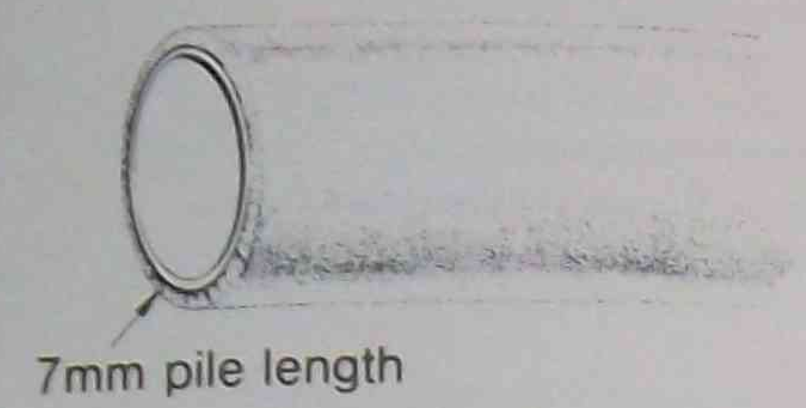
Textured foam

10 mm pile length. The open mesh texture is used to apply heavy bodied decorative texture finishes, creating a high-build even-pointed decorative texture finish.

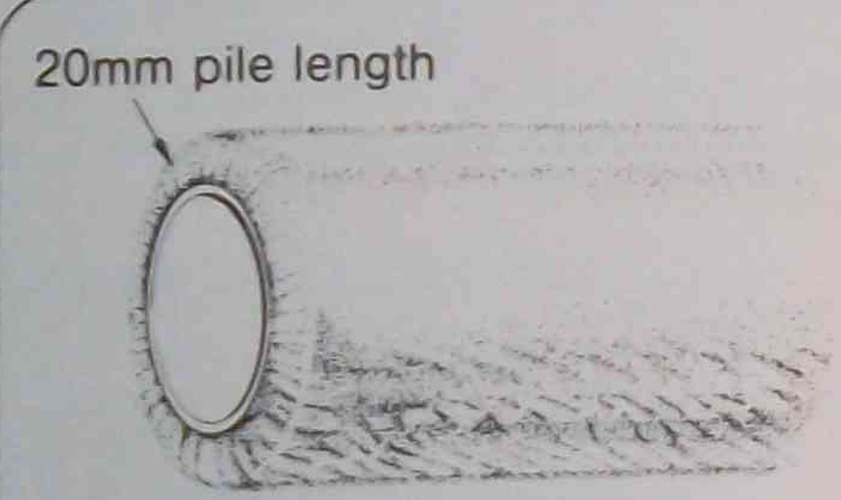
Summary of roller covers

These six covers are adequate for the most common surfaces encountered in painting and decorating.

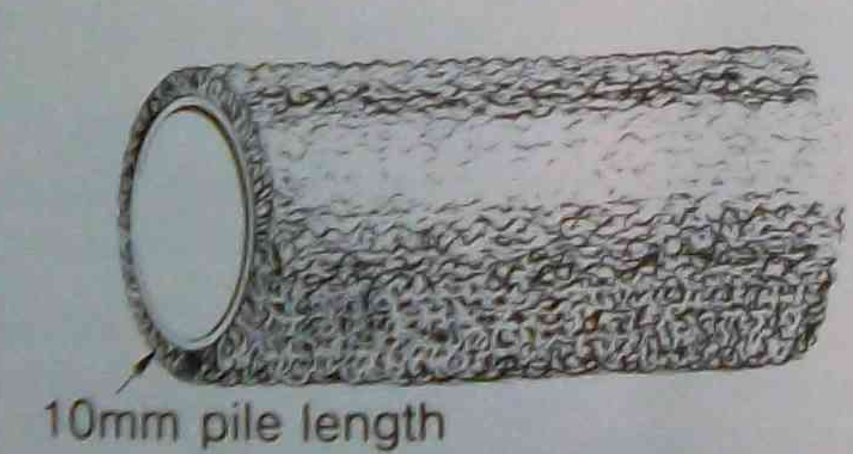
For specialised surfaces such as heavy texture, wire fences, contoured surfaces, pipes, etc., a suitable roller cover is available.



MOHAIR BLEND COVER



LONG NAP POLYESTER COVER



TEXTURED FOAM COVER

2.3 ROLLER FRAMES

Standard roller frame

Consists of a pressed-steel cylinder rotating on a 6 mm diameter zinc-plated rod which extends from the frame to a strong plastic handle. An internal thread at the base of the handle is for attaching an extension pole.

Available in sizes from 80 mm to 230 mm wide.

Used for general purpose work with a variety of covers.

Caged roller frame

Constructed from heavy nickel-plated wires to ensure smooth fitting and removal of the covers. Nickel plating ensures strength and easy cleaning. The plastic handle has an 8 mm chrome-plated rod which is attached to the cage. The handle has an internal thread for attaching an extension pole. An attachment to connect a timber-type extension pole is also available.

Available in sizes from 230 mm to 270 mm wide.

Used for general purpose work with a variety of covers.

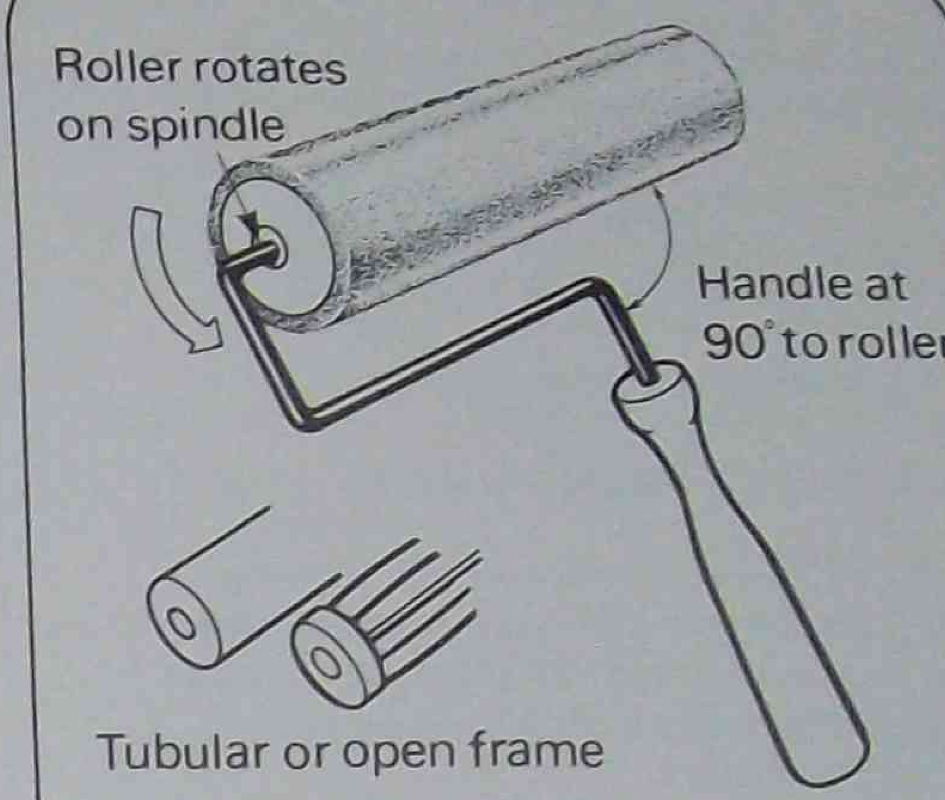
Twin T frame

Made from the same heavy-duty materials as the caged frames. The frame is designed to take either two 180 mm or two 230 mm covers.

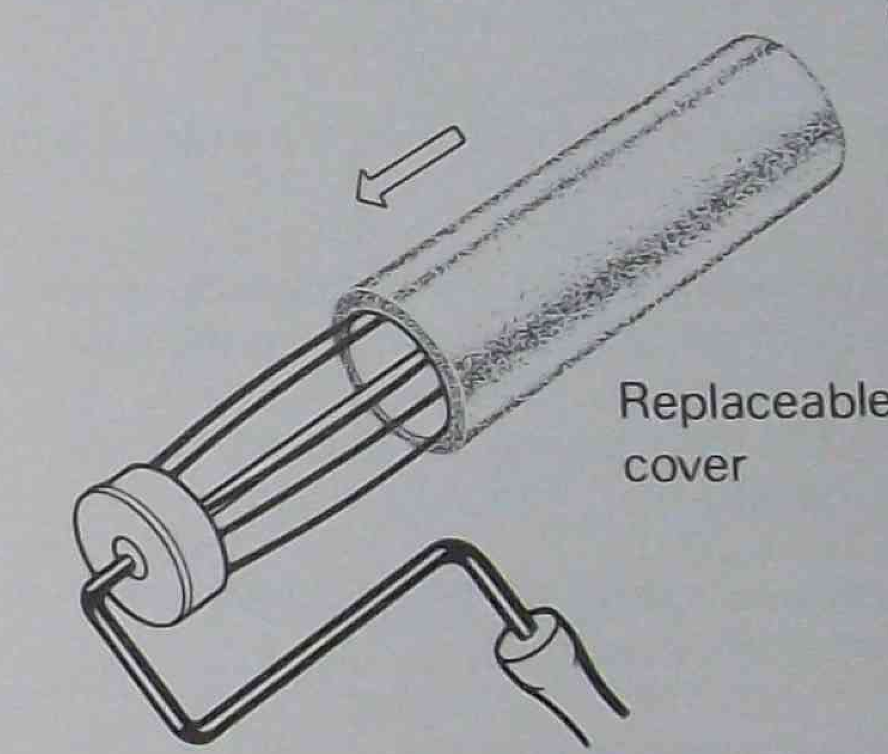
Twin frames are used on large, broad areas for speed of application.

In general, roller cages or frames are available for an assortment of special job situations.

Sizes available are from 80 mm to 460 mm.



PAINT ROLLER



ROLLER COVER

2.3.1 Extension poles

Aluminium telescopic extension poles made from a heavy-duty aluminium alloy.

Available in lengths

- 0.6 m which extends to 1.2 m
- 1.2 m which extends to 2.4 m
- 1.8 m which extends to 3.6 m

The pole features a heavy-duty, non-slip locking device which holds the pole firmly at the selected height position. The thread on top of the extension will fit all roller frame connections.

To adjust the pole:

- Pull the locking pin outwards to release the telescopic extension.
- Hold the pin out, then pull out the extension to the required height for the job.
- Release the pin to lock the extension in position for use.

To lower the extension, lift the locking pin and pull the extension back into the pole.

Used for painting any surface that cannot be reached from floor or ground level.

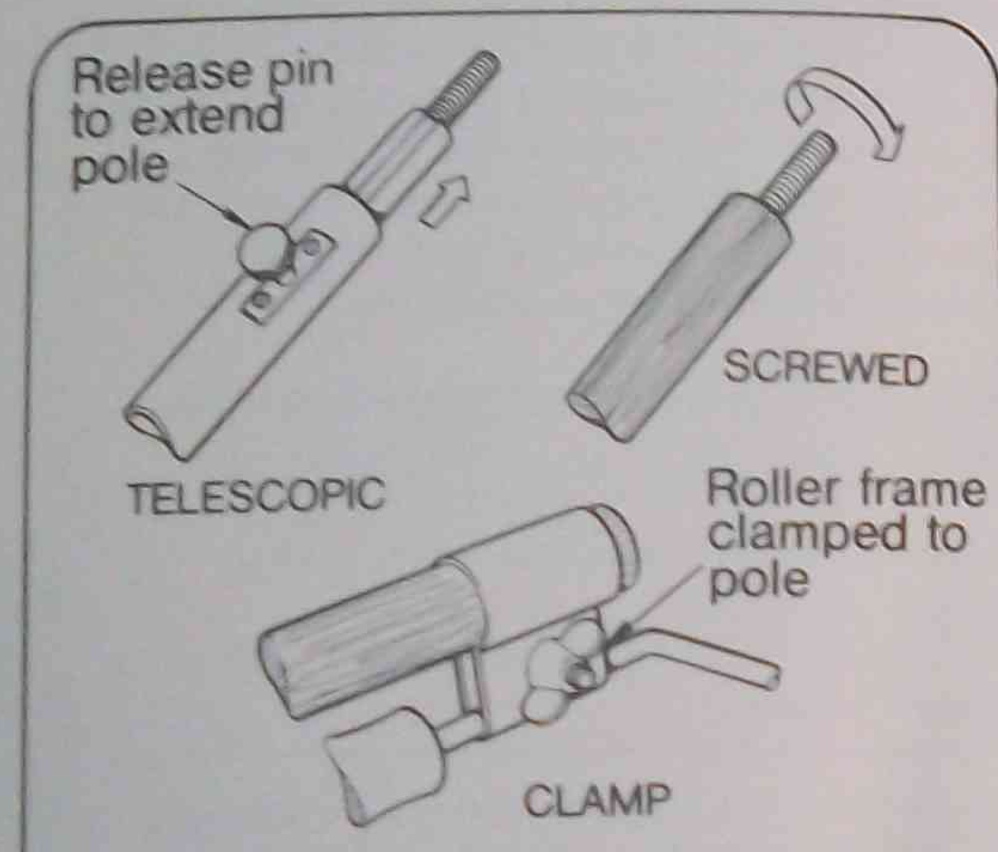
Extension poles save time as there is no need to erect scaffolding.

Timber extension poles

38 mm diameter timber poles are designed to fit all roller frame handles. Timber poles cannot be extended. An extension clamp may also be used to attach broom handles to the frames. Available in lengths of 1.8 and 2.3 metres.

Used for painting floors, pathways, roofs, etc.

PAINTING THE WALL WITH AN EXTENSION ROLLER



ROLLER EXTENSION POLE FITTINGS

FITTING A ROLLER EXTENSION POLE

2.4 ROLLER TRAYS

Standard roller tray

Made from pressed steel or moulded plastic with a heavy-ribbed, non-skid, sloping bottom.

A wire stand beneath one end holds the tray level, so that the paint runs down the sloping bottom to a well that holds approximately 1.5 litres of paint.

The wire stand also fits onto a step ladder top plate allowing free use of both hands.

NOTE:

When moving a paint tray always keep it horizontal to prevent spillage of paint. Never leave a tray at the bottom of steps, ladders or any position where it can be knocked over or stepped into.

Trade tray, or hooded tray

Similar to a standard tray but fitted with a press steel hood over the paint well.

A carrying handle and step grip enables this tray:

- to be carried as a bucket;
- hung from a pot hook; or
- supported from a ladder ring.

Hooded trays can hold up to 3 litres of paint.

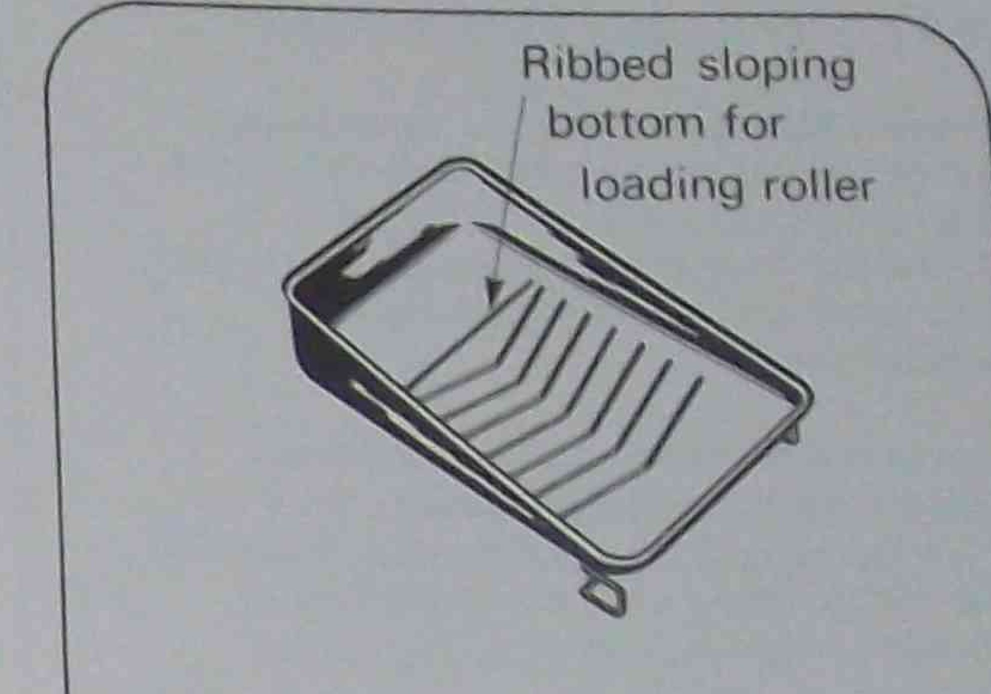
It is the most suitable tray used for painting when using 230 mm roller frames.

Roller buckets with a grid

Constructed from heavy gauge, rust resistant, zinc-plated steel and fitted with a removable mesh grid for loading the roller with paint.

The bucket can hold up to 8 litres of paint.

Used for large jobs as the bucket is wide enough to take twin-frame rollers.



ROLLER TRAY

HOODED TRAY

ROLLER BUCKET

2.5 ROLLING PROCEDURE

Rollers have a tendency to spray paint particles, especially with flat-finish paints. Use dropsheets to cover all areas to be protected from paint spray. Drapes, curtains and other soft furnishings should be removed.

If woodwork or trim, such as skirting boards, are to be clear finished, run masking tape along the top edge to prevent the timber being covered in paint spray from the roller.

- Select a suitable roller cover.

NOTE:

Refer to the manufacturer's specifications and recommendations to select which type of roller would be suitable for the surface to be painted and the type of paint to be used.

- Slide the roller cover onto the roller frame.
- Pour the required amount of prepared paint into a clean roller tray.
  - After pouring, wipe the excess paint from the side of the can with a brush, this will prevent paint dripping or running down the sides.

Always work in a clean and tidy manner.

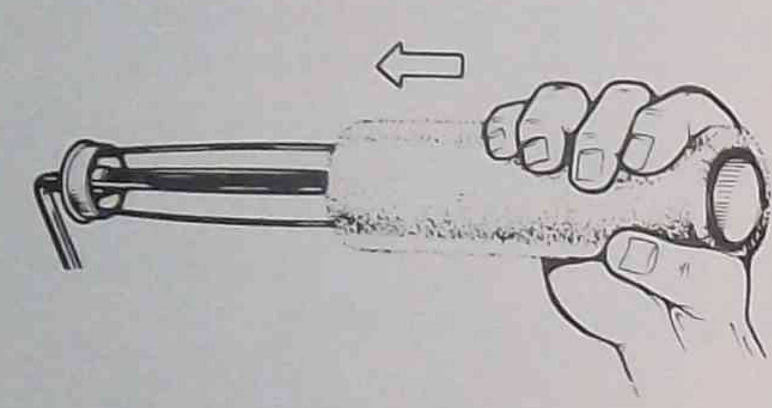
Areas not accessable by roller should be "cut in" with a brush.

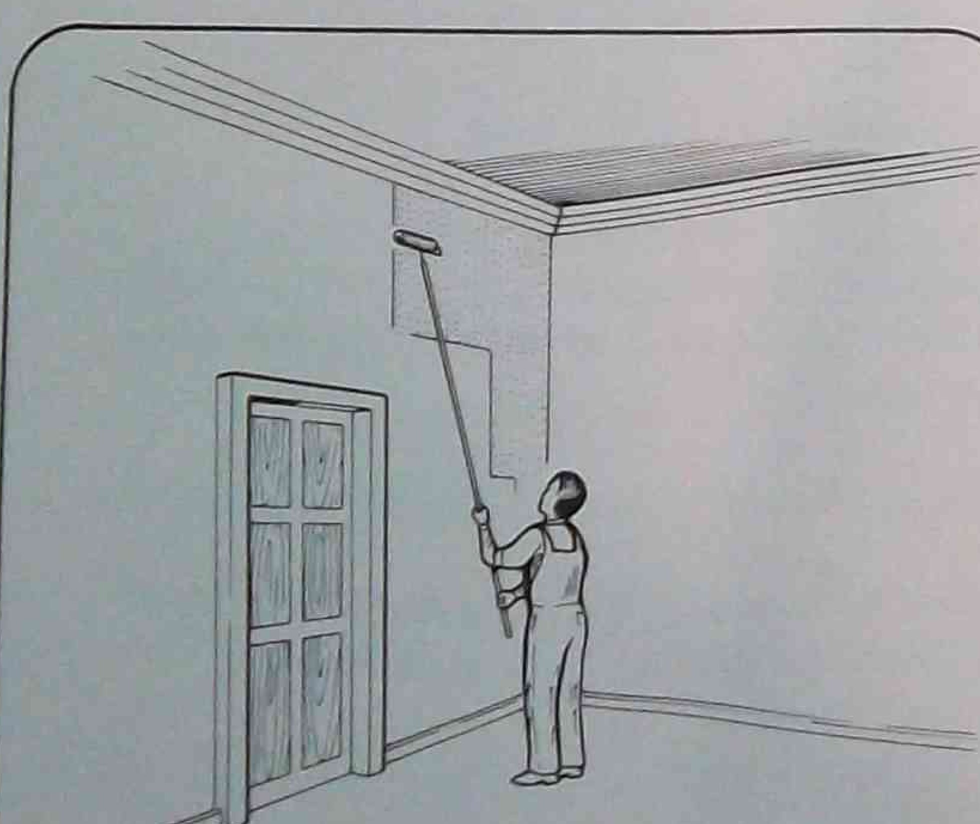
Attach an extension pole to the roller frame handle, and extend to the required height.

NOTE:

With the extension pole connected, take care not to knock or break any household fittings with the pole.

USE MASKING TAPE TO PROTECT EDGES FROM SPRAY


SLIDE ROLLER COVER ONTO FRAME


AN EXTENSION POLE ALLOWS ACCESS TO HIGH WALLS AND AWKWARD PLACES

Applying paint with a roller:

- Place the roller tray in a convenient position.
- Pour the required amount of paint into the tray.
- Load the roller cover by placing it into the paint, then roll it up and down firmly on the ribs in the tray to fill the cover evenly with paint.

NOTE:

The roller must be loaded evenly, if this is not done correctly paint will drip from the roller as it is lifted from the tray. Also when the roller is placed on the surface and pressure is applied to rotate the roller, the sleeve will skid on the surface squeezing large droplets of paint from the roller.

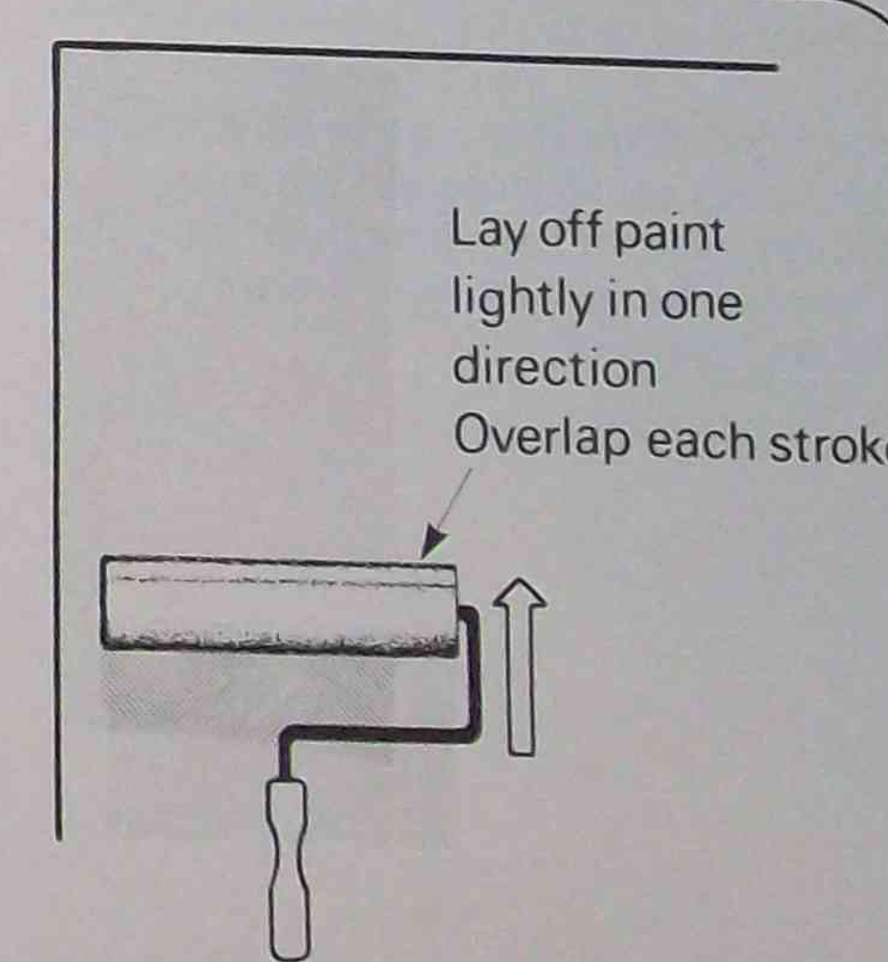
- Remove the loaded roller from tray and roll it onto the surface. Take the roller as close as possible to the edges that have been "cut in" to eliminate join marks of brush and roller.
- Spread the paint out evenly. Refill the roller with paint and continue to spread an even layer onto the surface.
- With a dry roller, roll back over the painted area to remove any thick edges of paint left by the roller.
- Reload the roller and continue spreading and laying off the paint until the surface is completely covered.
- On completion of the work, disconnect the extension handle and place it in a safe position to prevent accidents.

NOTE:

Before cleaning the equipment check all work for defects. Look for runs, sags, misses or scuffs. Rectify if necessary.

POUR PAINT INTO TRAY

LOADING THE ROLLER



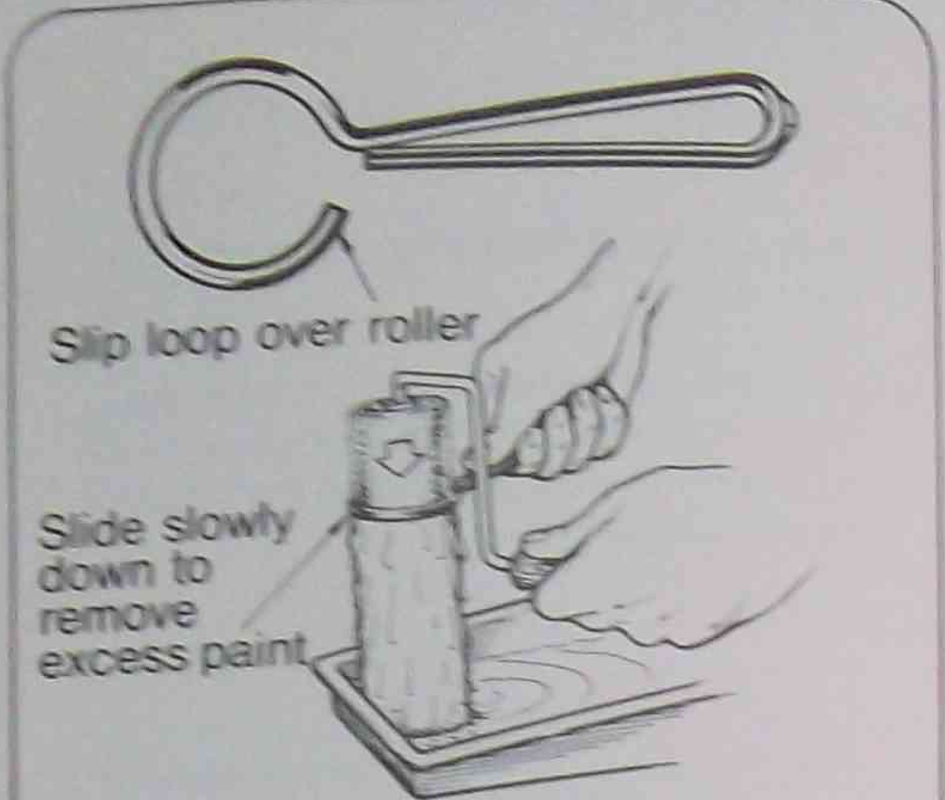
LAY OFF IN ONE DIRECTION

2.6 MAINTENANCE OF ROLLERS

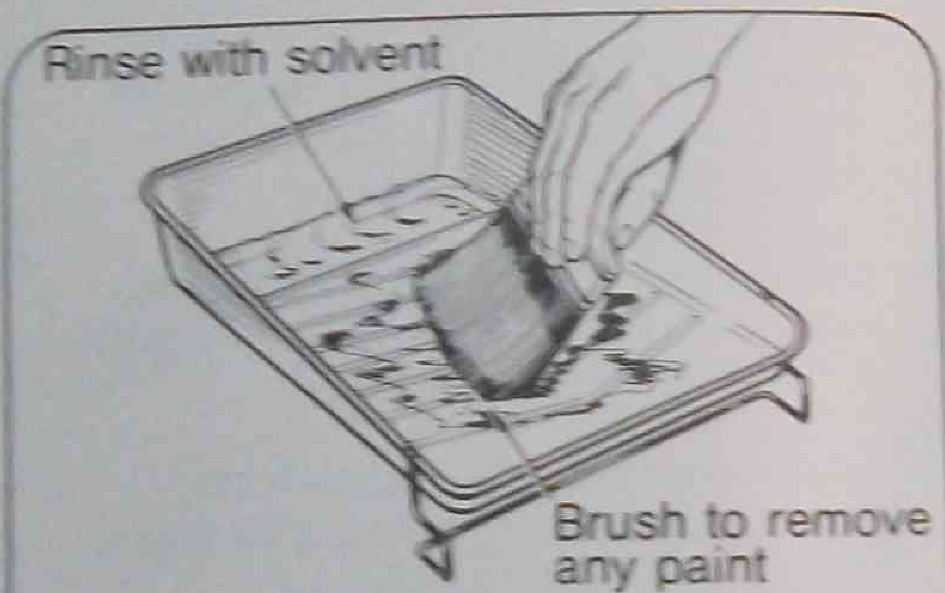
At the completion of a job clean the equipment.

- Hold the roller frame vertically. Place the bottom of the roller cover into the tray.
- Slip a roller cleaning loop over the cover. Hold the frame firmly and slide the loop down slowly over the cover. This removes excess paint from the cover into the tray.
  - — If a loop is not available, use a putty knife or stripping knife on its side edge, and scrape down the cover.
- Pour the remainder of the paint from the tray back into the paint can, then wipe out the tray with a brush.
- Pour a small amount of appropriate solvent into the tray.
  - — Turpentine for oil base paint. Water for acrylic paint.
- Place the roller in the tray and let it soak.
- Roll the cover up and down the tray ribs.
  - — Repeat this procedure with clean solvent until the roller is free from paint.
- Remove the cover from the roller frame and, using a roller spinner, spin off excess solvent.

If the roller cover is to be stored, wash it in warm soapy water, rinse out the soap thoroughly with clean water, then spin off the excess. Store the cover in a well-ventilated area.



WIRE LOOP FOR CLEANING THE ROLLER



CLEANING THE TRAY

STORING THE COVER

2.7 AIRLESS CUP GUN

An airless cup gun has the ability to spray paint onto a surface without any air pressure.

The gun is driven by a small powerful electro-magnetic motor. This motor drives a high-speed piston which draws paint up from a container, or 'cup', then forces the paint under pressure through the spray nozzle onto a surface.

WARNING

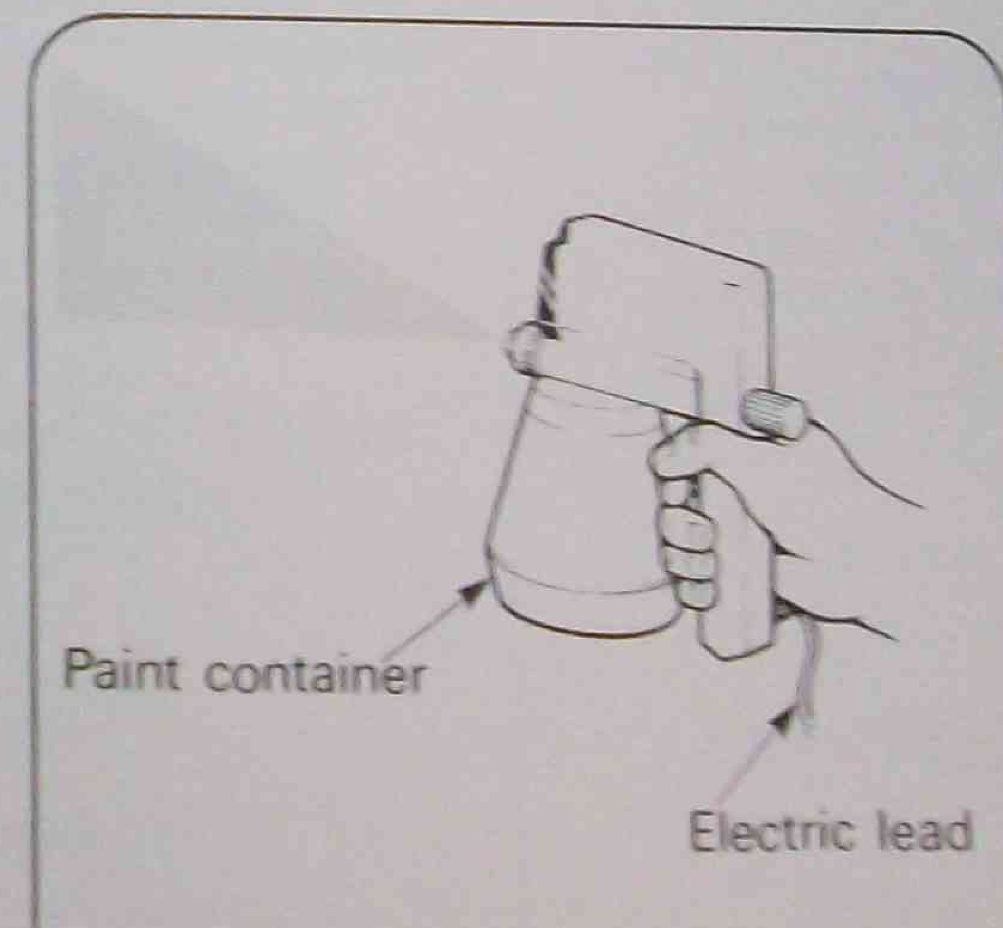
The maximum pressure available is 160 bars or 2300 lbs per square inch. Because of the extremely high pressure developed at the spray tip never place a finger or any part of your body over the tip. Should body contact occur, the material being sprayed at pressure will penetrate the skin causing serious injury.

Advantages of airless spraying

- Up to 30 times faster than a brush on suitable surfaces.
- No brush marks.
- Very little over spray.
- Large spray patterns.
- Has the ability to 'cut in' within 15 mm.
- Applies a thick coat with minimum passes.
- No contamination from air line impurities.
- Ideal for coating large or heavy-textured areas.
- Ideal for awkward and irregular-shaped surfaces.

Cup guns are capable of spraying a wide variety of oil, alkyd, and water-type paints and are suitable for coatings such as, primers, undercoats, semi-gloss, gloss, stains, flat finishes, and clear finishes.

Many of these coatings are not formulated for spraying, and must be adjusted to a suitable viscosity (consistency) for spray application. As these materials differ in viscosity they are sprayed onto surfaces at different pressures.



AIRLESS CUP GUN

Cup guns have a variety of interchangeable spray nozzles or tips each designed for spraying a certain paint type. Refer to the manufacturer's specifications for viscosity, gun pressure and correct tip selection.

2.7.1 Viscosity of the paint

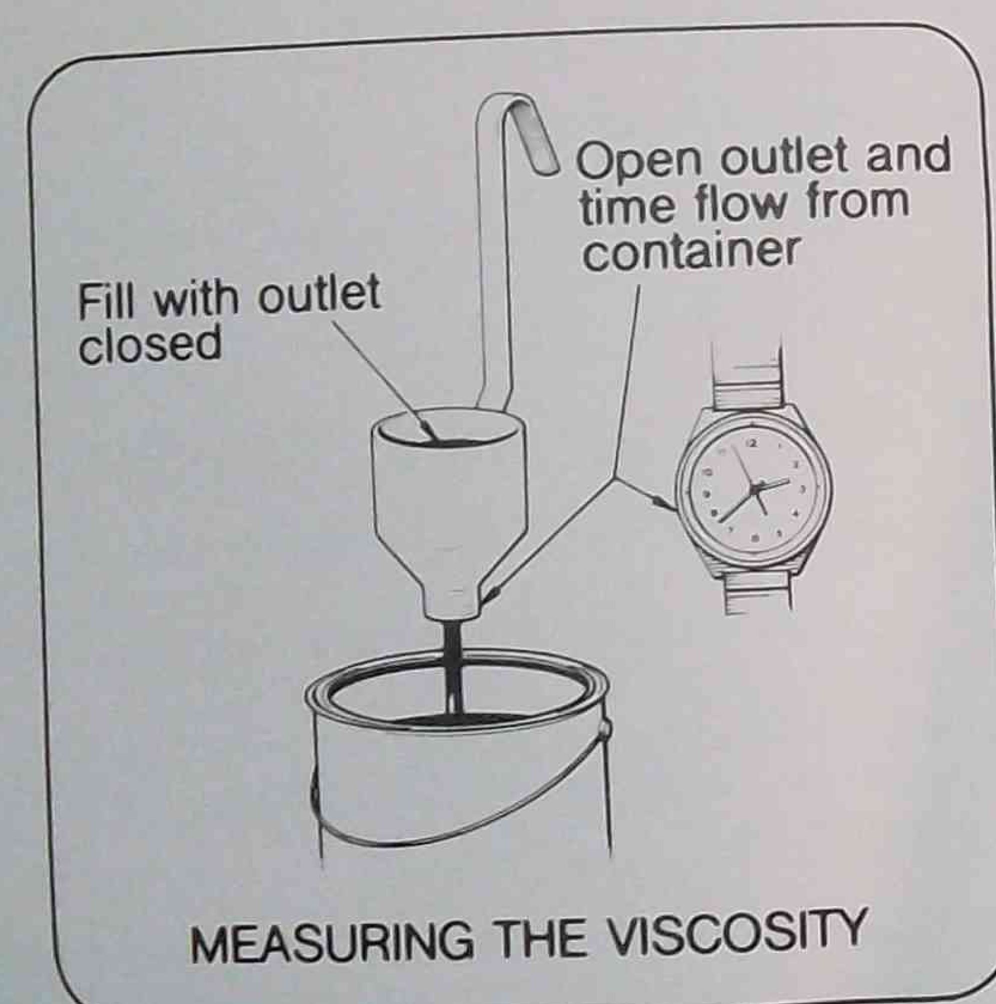
Viscosity is determined by the rate in seconds that a measured quantity of paint runs completely through a viscosity cup.

To determine the viscosity of the paint:

- Fill the viscosity cup with paint, with the outlet closed.
- Open the outlet and the paint starts to drain from the cup.
- Check the time in seconds it takes for the paint to completely drain from the cup.
- Add thinner until the paint runs through the cup in the number of seconds recommended by the manufacturer for airless cup gun application.

— Use only the manufacturer's recommended thinner to adjust the paint to the correct viscosity.

VISCOSITY MEASURING CUP

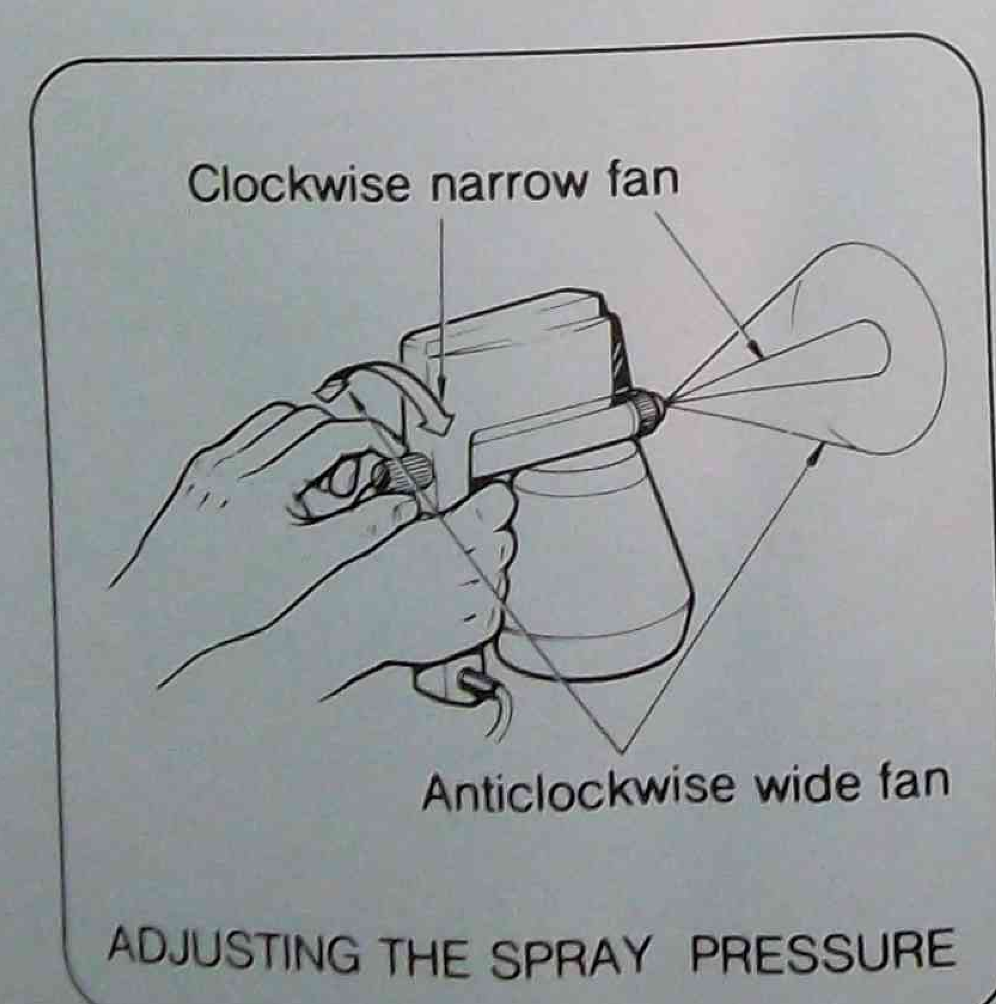


MEASURING THE VISCOSITY

To adjust the pressure of the gun turn the pressure control knob until recommended pressure is obtained. Turn the knob clockwise to produce a narrow fan (width of spray from tip). The recommended pressure is recognised by the spray pattern and volume of paint being delivered from the tip.

The specified nozzle or tip will produce the correct fan or spray pattern.

Refer to manufacturer's specifications for tip size and pressure.



ADJUSTING THE SPRAY PRESSURE

Many surfaces can be painted with an airless cup gun. They can apply coatings to all surfaces that can be coated by brush, or roller:

- Faster and easier.
- With a high standard finish.
- With little or no overspray.

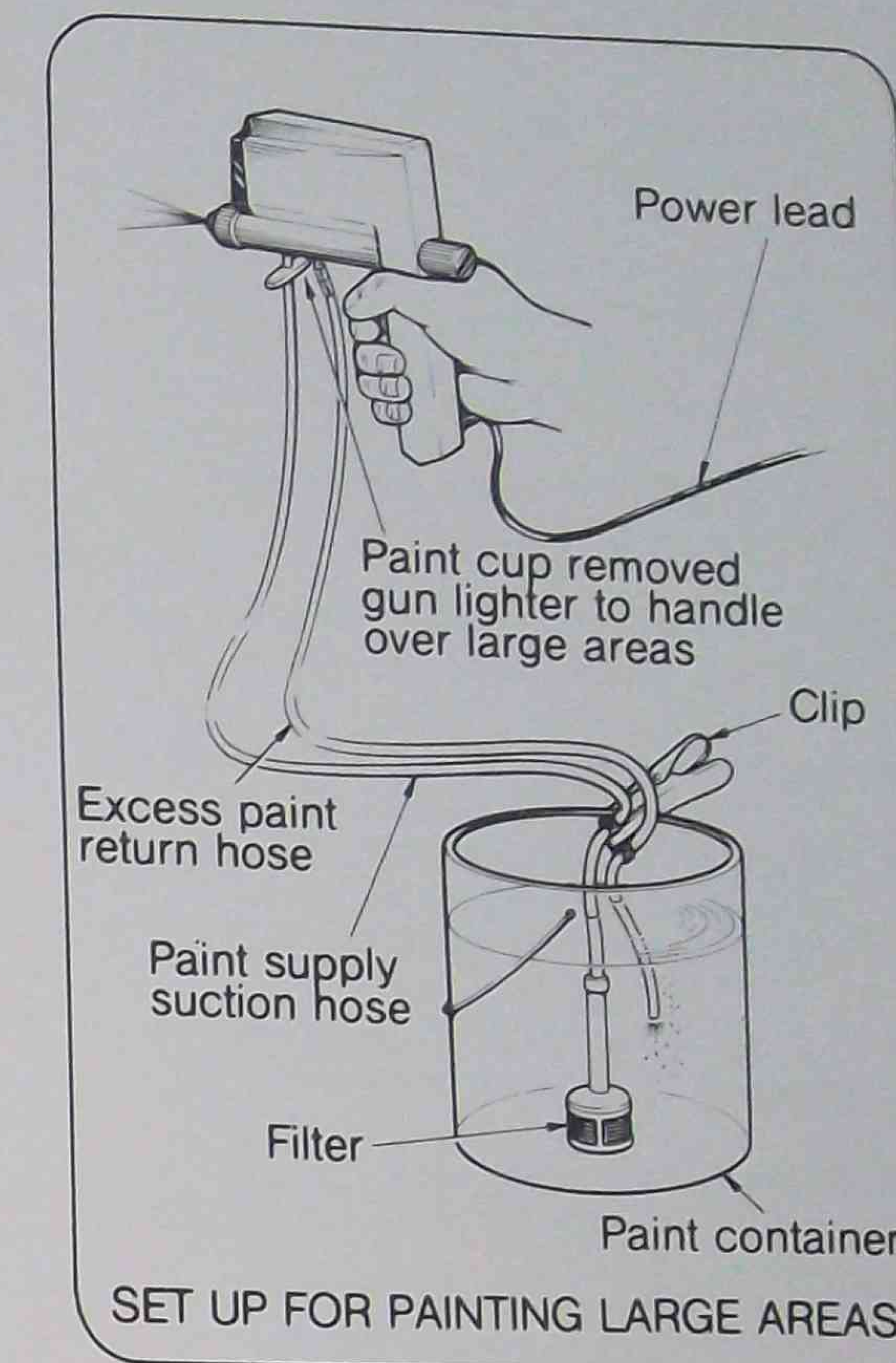
2.7.2 Extension kit

The cup or container of the gun only holds one litre of paint. This is adequate for small jobs. For painting large surfaces an extension hose kit is available which can be placed into the original or a larger paint container.

The extension kit consists of two clear plastic hoses, one being a suction hose for the paint supply, the other a paint return hose.

One end of the suction tube is placed over the paint supply fitting on the gun, the opposite end with the filter attached is submerged into the container of paint.

The return tube is attached to the paint return fitting on the gun, the opposite end is placed into the paint container. A clip holds the hoses onto the side of the paint container to prevent them lifting out of the paint.



SET UP FOR PAINTING LARGE AREAS

Flexible nozzle extension

All electrical components are located in the handle housing of the gun, therefore the gun should not be tilted back as paint may flow back through the gun into the housing affecting the electrical components. For this reason a flexible nozzle extension is available. The extension may be bent in any direction for spraying of awkward areas whilst keeping the gun level.

As the gun cannot be tilted back to paint a ceiling the flexible nozzle extension must be used.

SPRAYING AWKWARD AREAS

2.7.3 Safety precautions

- Never under any circumstances point the gun at anyone.
- Do not place or point the gun in direct contact with any part of the body.
- Wear a spray mask and protective clothing.
- Use a protective cream on your hands and exposed skin.
- Always spray in a well ventilated area.
- Before spraying, make sure that all fittings are tight and secure.
- Check all electrical leads and plugs and ensure they are in good condition.
- Keep electrical leads out of wet areas.
- Do not tilt the gun upwards, causing the paint to run into the handle housing and affect electrical components.
- If spraying flammable materials, do not smoke or use in a confined area.
- Follow the manufacturer's recommendations for correct use of the gun.

PAINT SPRAY RESPIRATOR

DRESS SAFELY – WEAR SUITABLE PROTECTIVE CLOTHING

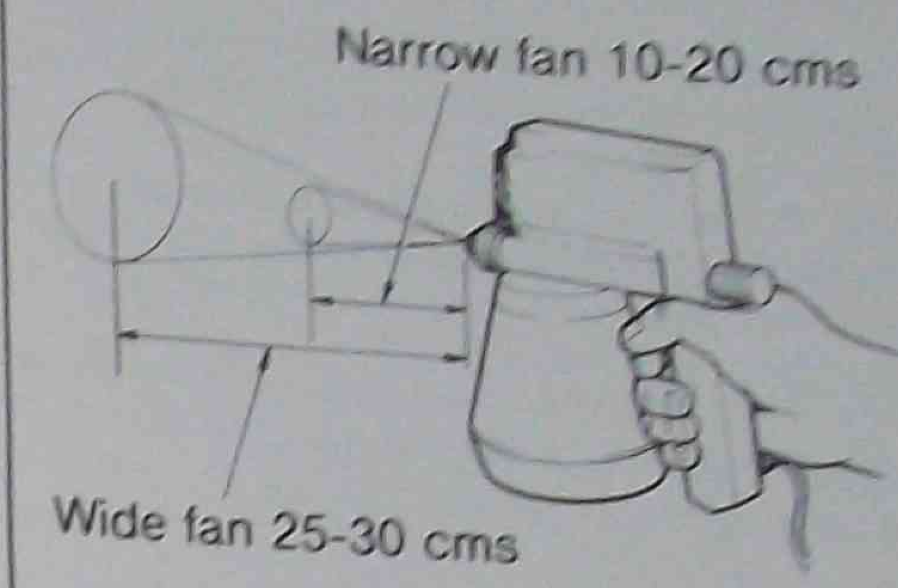
2.7.4 Spraying procedures

- Test the viscosity of paint using a viscosity cup.
- Fill the container with paint.
- Plug in the electrical cord and switch on the power.
- Hold the gun level. Press the trigger and adjust the spraying pressure.
- Commence spraying. Keep the gun moving steadily and evenly at a constant distance from the surface being sprayed.
  - Any interruption or irregular movement of the gun will be reflected in the irregularity of the finish.

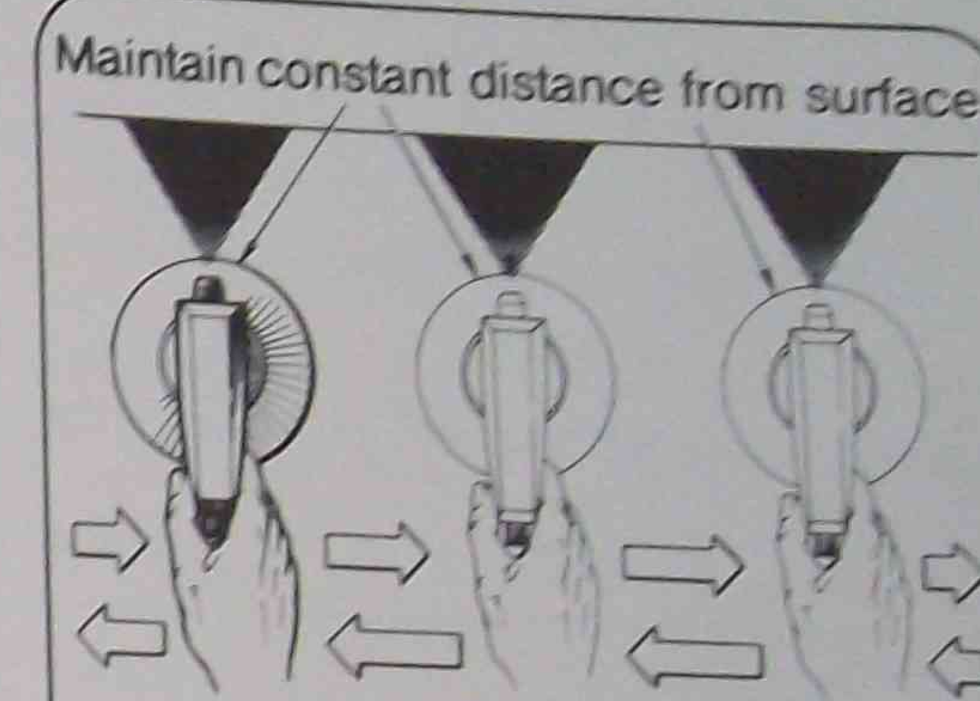
NOTE:

For spraying horizontal, vertical or irregular-shaped surfaces refer to the manufacturer's recommendations.

> **WARNING**
>
> **Do not let any part of the body come into contact with the spray. Never point the gun at any person in the area where spraying is taking place.**



DISTANCE FROM SURFACE FOR FAN WIDTH

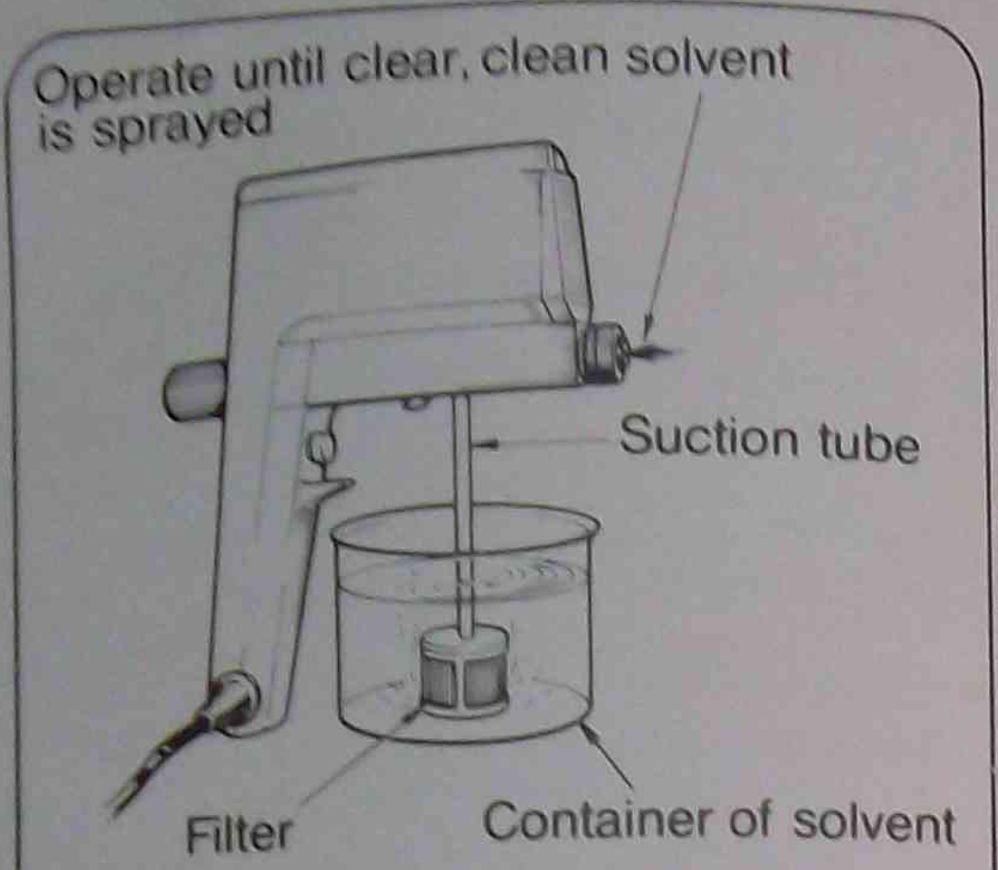


MOVE GUN AT A STEADY SPEED

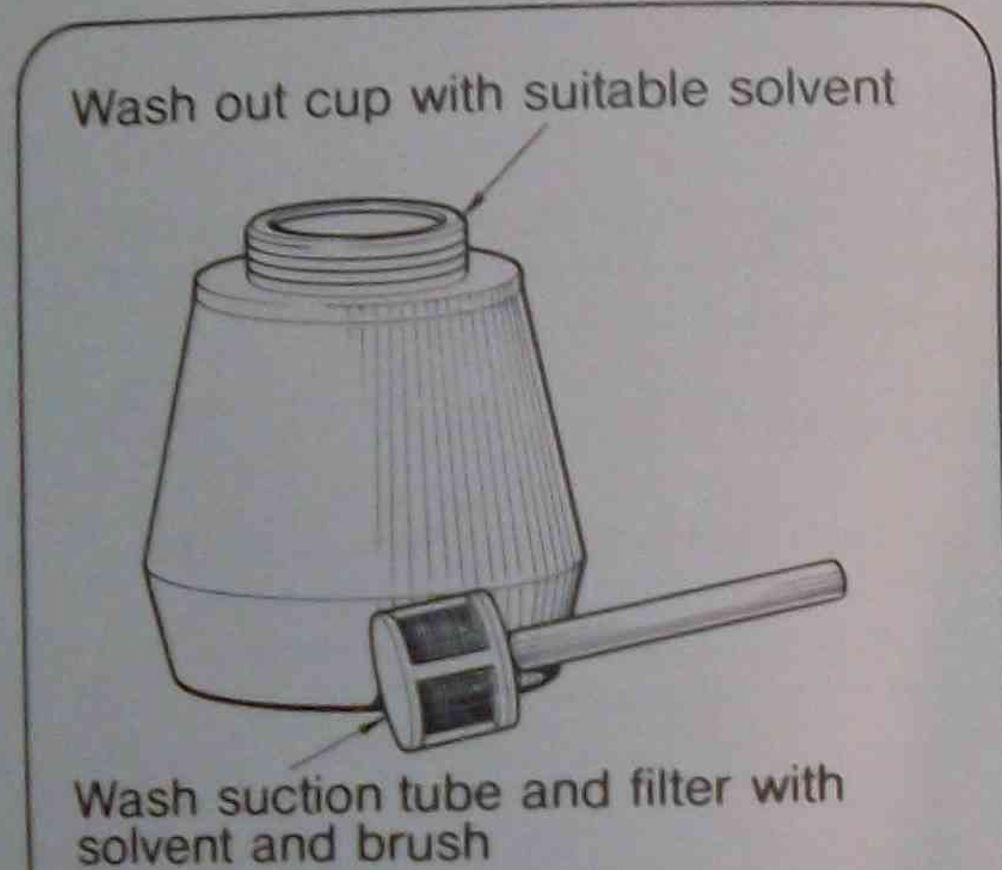
2.7.5 Cup gun maintenance

Cleaning

- Unscrew the cup container from the gun exposing the suction tube and filter.
- Dip the tube into a clean container of suitable solvent and operate the unit until the solvent comes through the gun tip clear, and clean.
- Clean the suction tube, filter, and nozzle with solvent and a brush.
- Thoroughly clean out the paint cup with a suitable solvent.



CLEANING THE GUN



CLEANING THE CUP

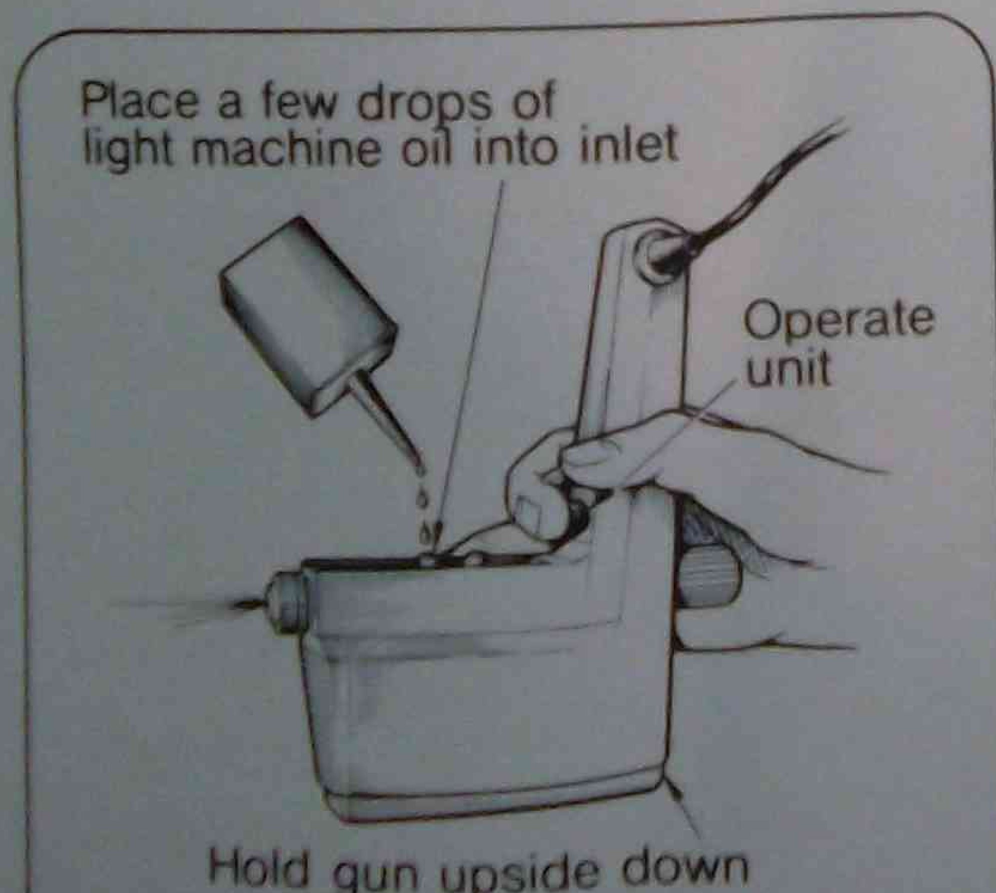
Storage

Turn the gun upside-down, place a few drops of light machine oil into the suction fitting and operate the unit. This will draw oil through the gun to coat all the metal components with a film of oil preventing rust occurring at the pump and nozzle when not in use.

Switch off electrical power and roll up the electrical cord. Store the equipment in a well-ventilated area.

NOTE:

Before using the equipment again, spray a small quantity of solvent through the gun to remove any machine oil. This will prevent machine oil being mixed with paint and sprayed onto a surface causing paint defects such as crazing, non-drying and discolouration.



PREPARATION FOR STORAGE

3 SCAFFOLDING

A large variety of surfaces requiring painting or decorating, cannot be reached from the ground or floor level, therefore ladders or some form of scaffolding is needed to reach and carry out the work. To perform the work with maximum safety, a knowledge of scaffolding is essential to enable the correct ladder or scaffolding to be selected for each job situation.

NOTE:

Regulations govern the safe use of scaffolding. For maximum safety when using scaffolding it is essential to adhere to these regulations.

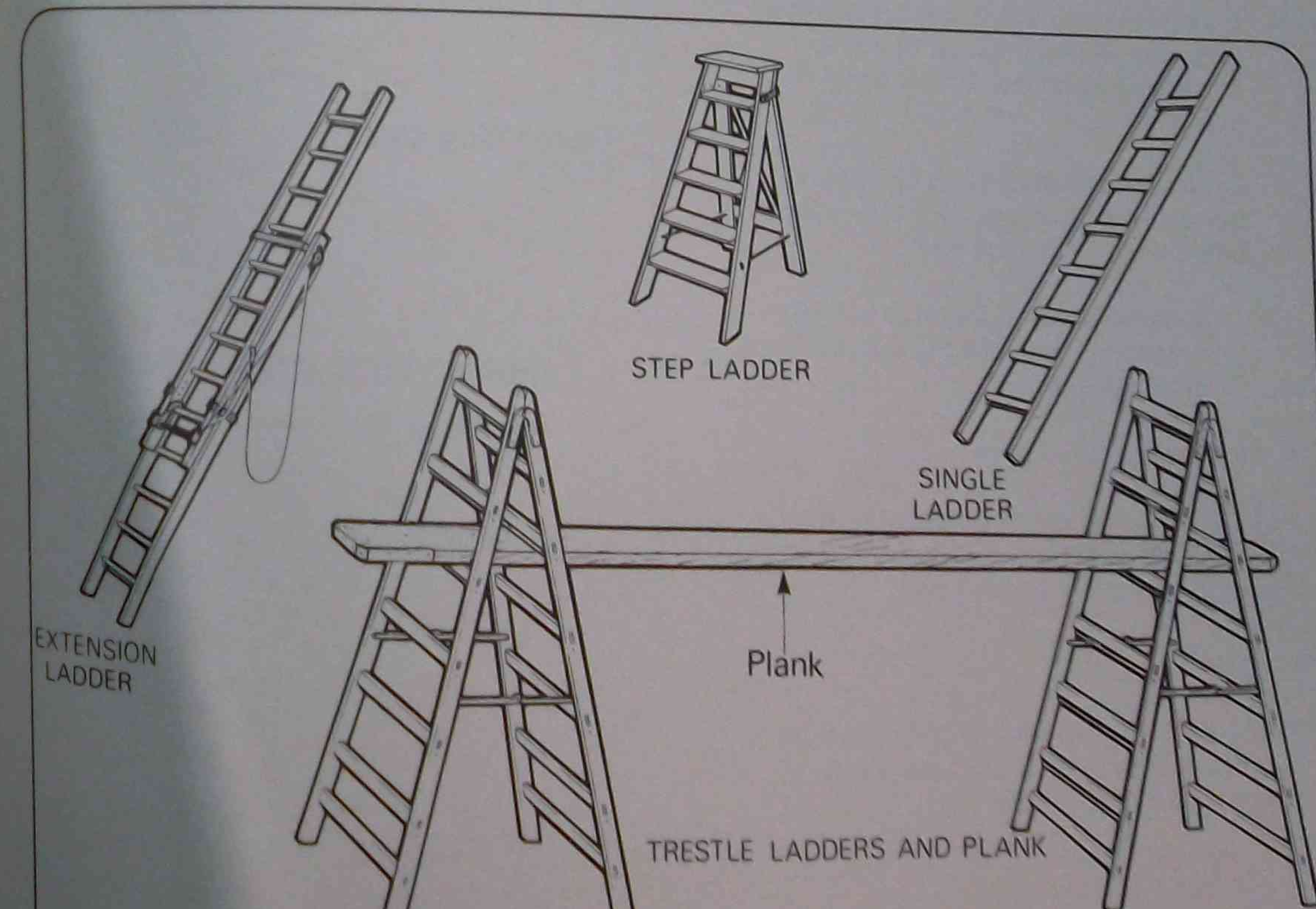
Scaffolding regulations vary from State to State. The regulations applying in any particular State can be obtained from the appropriate State Authority.

3.1 TIMBER SCAFFOLDING

Step ladders, single ladders, extension ladders, trestle ladders and planks.

These appliances are constructed from selected timbers, douglas fir, alpine ash, mountain ash and silver ash.

- All timbers used must be free of knots, fungi attack, and seasoned to the correct moisture content.
- All timber must be straight grained for strength.
- Timber must be dressed on all sides, and corners rounded or chamfered, for safe handling.
- Timber scaffolding must not be painted with opaque paints.
  - Opaque paints will cover defects, such as splits, cracks, etc. and can make ladder rungs, treads, and planks slippery.
  - Timber may be protected with a coat of clear finish.



TIMBER SCAFFOLDING

NOTE:

The above scaffolding is also available in aluminium. Although lighter in weight they are required to be equal in strength to timber components.

3.2 SWING BACK STEP LADDERS

Step ladders are self-supporting portable ladders, not adjustable in length, having flat steps, or treads and hinged back legs. Available in sizes from 1 m to 5.4 m in height.

Components of step ladders:

- Stiles

  Sides of the step ladder which taper to the top and support the treads.

- Treads

  90 mm in depth for safe footing and spaced at 250 mm for safe ascent and descent.

- Spreader ropes

  Two ropes fitted to check the opening distance of the steps and prevent their collapse. Ropes must be of equal strength and no less than 6.5 mm in diameter.

  Ropes are securely fitted by passing through the front and back stiles and firmly knotted at each end.

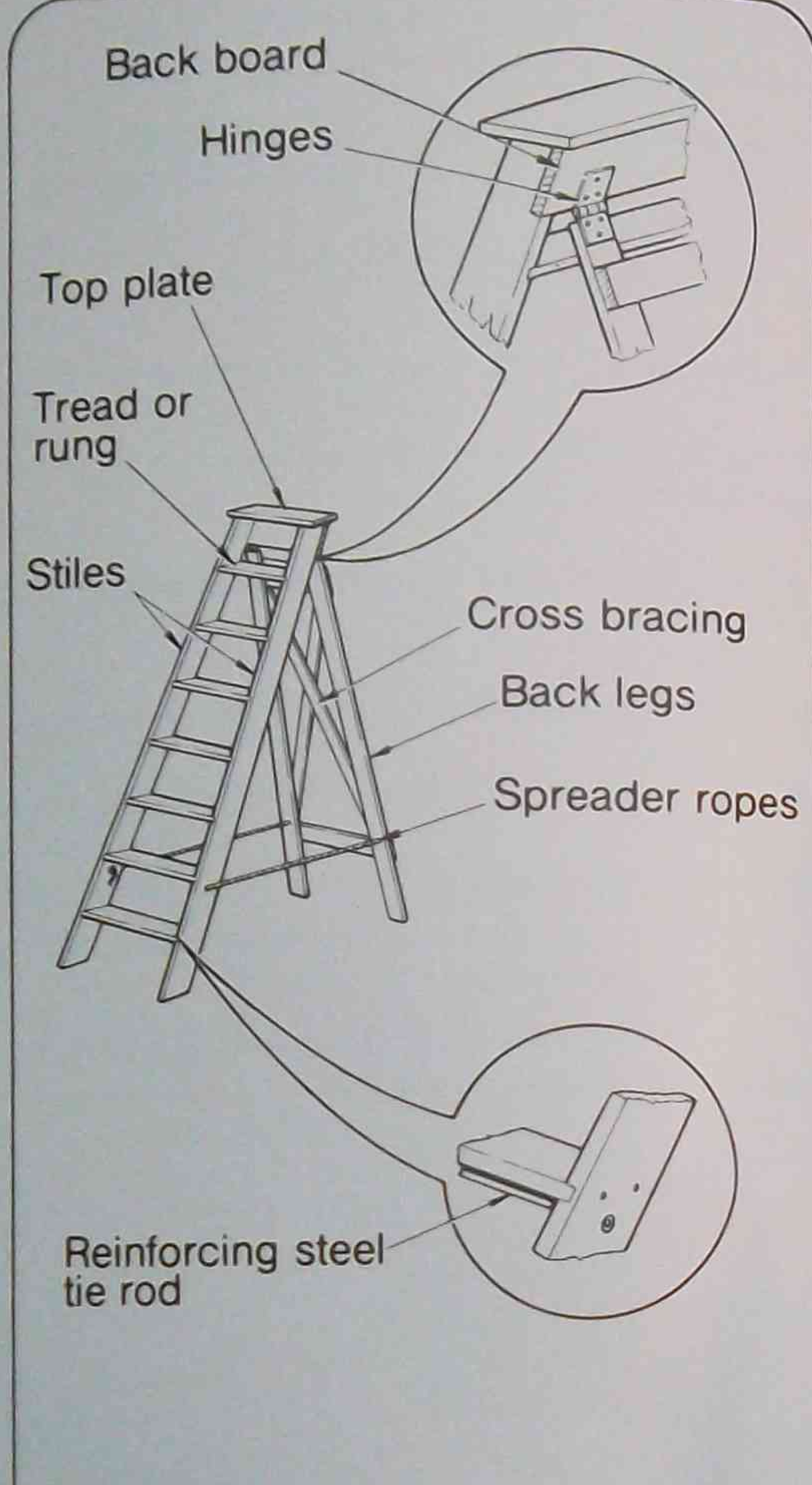
  — A metal locking device to prevent spreading and collapse may be used in lieu of ropes.

- Reinforcing steel rods

  5 mm steel reinforcing rods are fitted below the second tread from the bottom and below every fourth tread.

- Braces

  The back legs of step ladders must be cross braced with the braces firmly screwed to the legs.



SWING BACK STEP LADDER

Step ladders are designed for light duty work which allows one person working from steps at any one time.

Scaffolding planks must not be supported by step ladders.

Steps are widely used for painting in restricted room areas such as bathrooms, toilets, laundries and many other overhead job situations.

Aluminium swing back steps

Similar in design to timber step ladders.

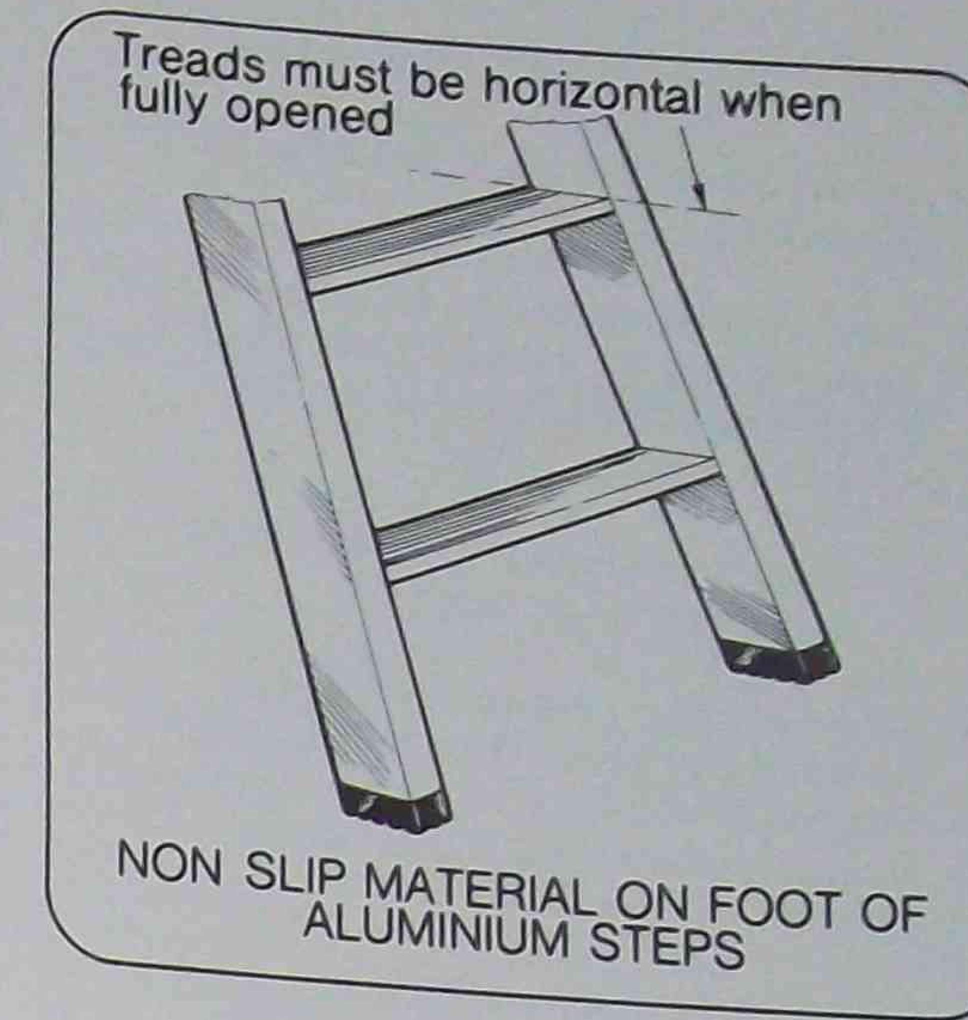
Lighter in weight than timber, but equal in strength.

Will not twist, warp, or rot.

Aluminium steps are fitted with a heavy locking bar in place of spreader ropes to prevent spreading and collapse of the steps.

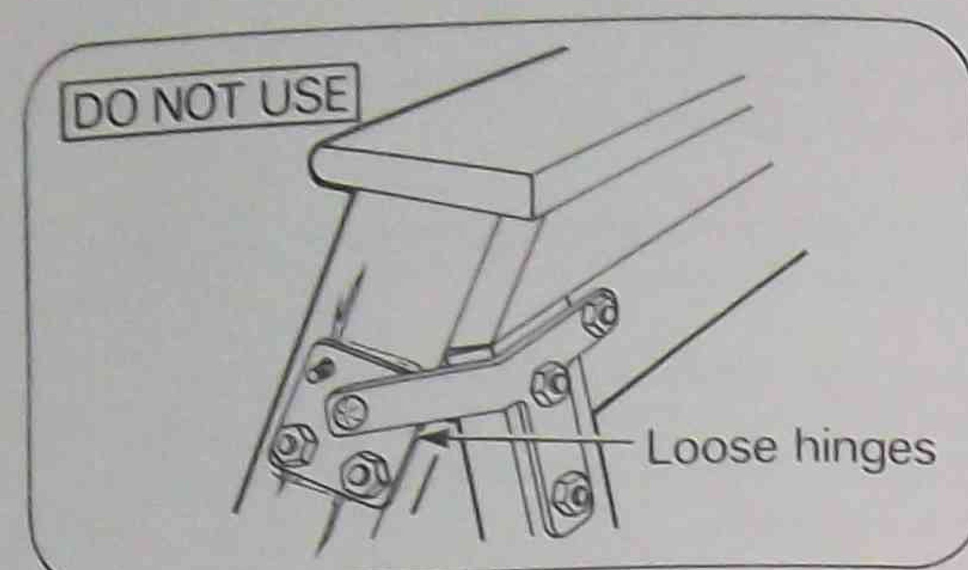
The foot of each stile is fitted with a pad of non-slip material such as rubber, nylon or timber. These non-slip materials are securely fixed; however, they are easy to replace once worn.

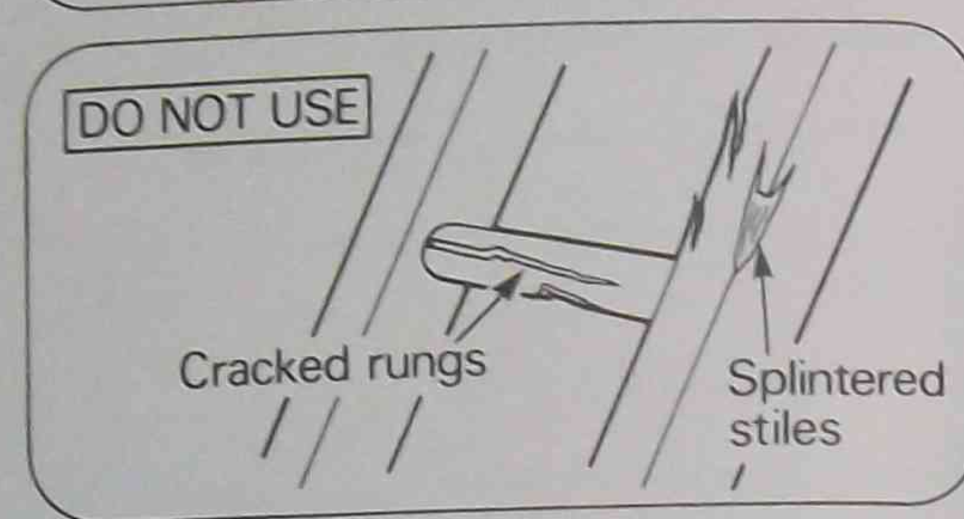
Treads on aluminium steps must also have a non-slip surface.



3.2.1 Safe use of step ladders

- Select steps that are suitable for the job situation.
- Inspect all components for defects. Look for cracks, splits, broken treads, loose screws or bolts and damaged spreader ropes.
  - Damaged steps should be tagged for repair, or replaced.
- When carrying or erecting steps be aware of any obstructions such as light fittings, furnishings, windows, overhead wires, tree branches and building fixtures.
- Step ladders must be placed on firm level ground.
- Step ladders must be in the fully opened position, to prevent sudden slip movement.
- When ascending or descending always face the step ladder.
- Ascend and descend one step at a time.
- Do not erect a step ladder where the movement of a door could cause interference with steps, unless the door is fixed in an open position, locked, or guarded.
- Never stretch or overreach when working from steps.
- Do not stand any higher than the third tread from the top plate of steps.
- Step ladders greater than 5.4 m in length must not be used.
- When not in use, lower the step ladder and store it in a safe place.
- To avoid injury to others, never leave erected step ladders unattended.





SAFE USE OF STEP LADDER

3.3 LADDERS

A ladder is a non-self-supporting portable appliance which consists of two side rails known as stiles, joined at regular intervals by cross pieces called rungs on which a person may rest or step when ascending or descending.

Extension ladders are adjustable in length, they consist of two or more sections travelling in guides or brackets so arranged as to permit length adjustment.

3.3.1 Components of a ladder

- Stiles

  The sides of the ladder.

- Rungs

  Round or rectangular.

- Guide brackets

  Fitted at top of lower section to keep the sections together.

- Extension lock

  Fitted to the bottom of extension to hook over a rung of the section below.

- Pulley wheels

  For the smooth running of ropes when raising or lowering rope-operated ladders.

- Ropes

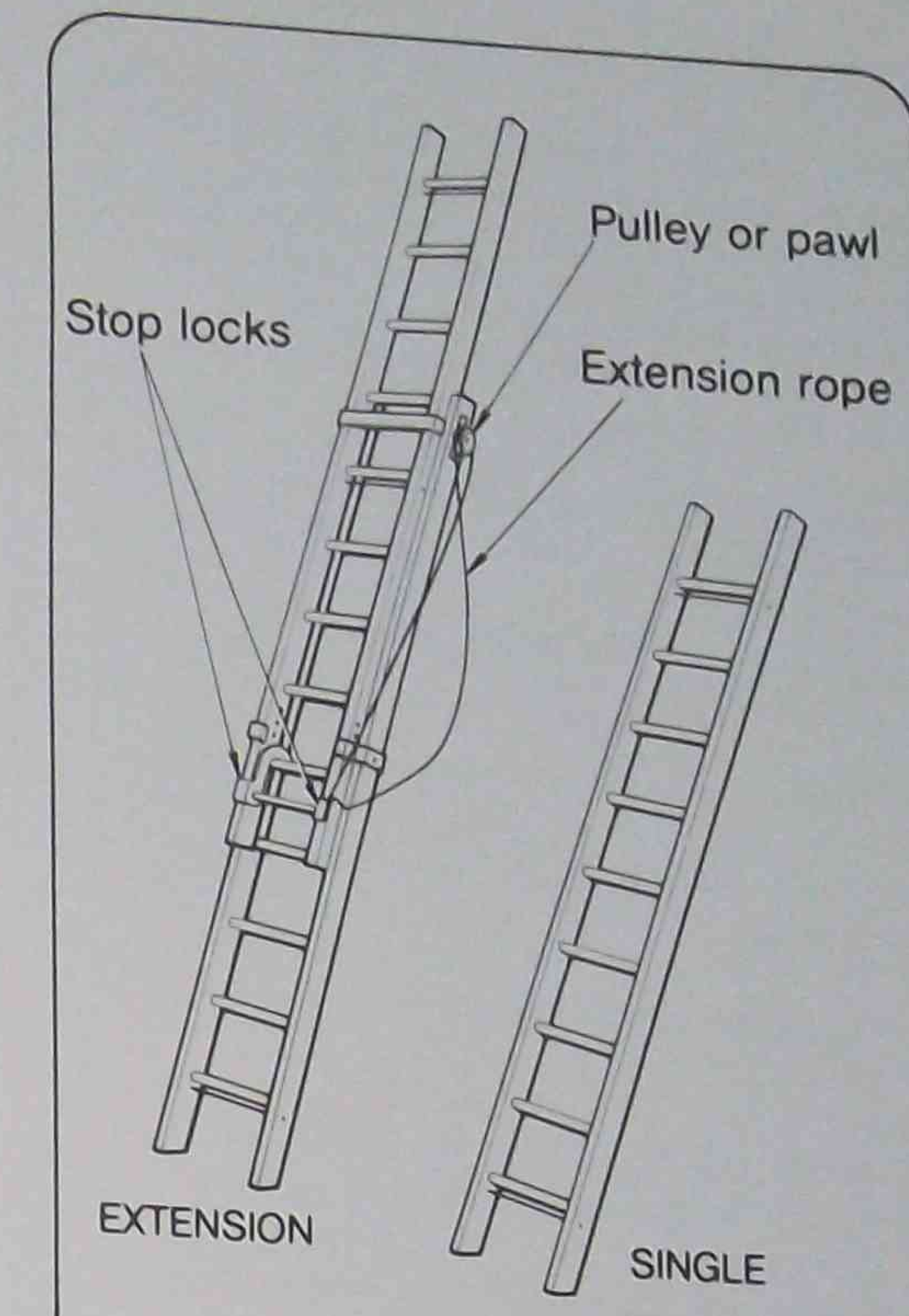
  Sash cord or material of equal strength. Fibre rope must have adequate hand grip.

- Ties

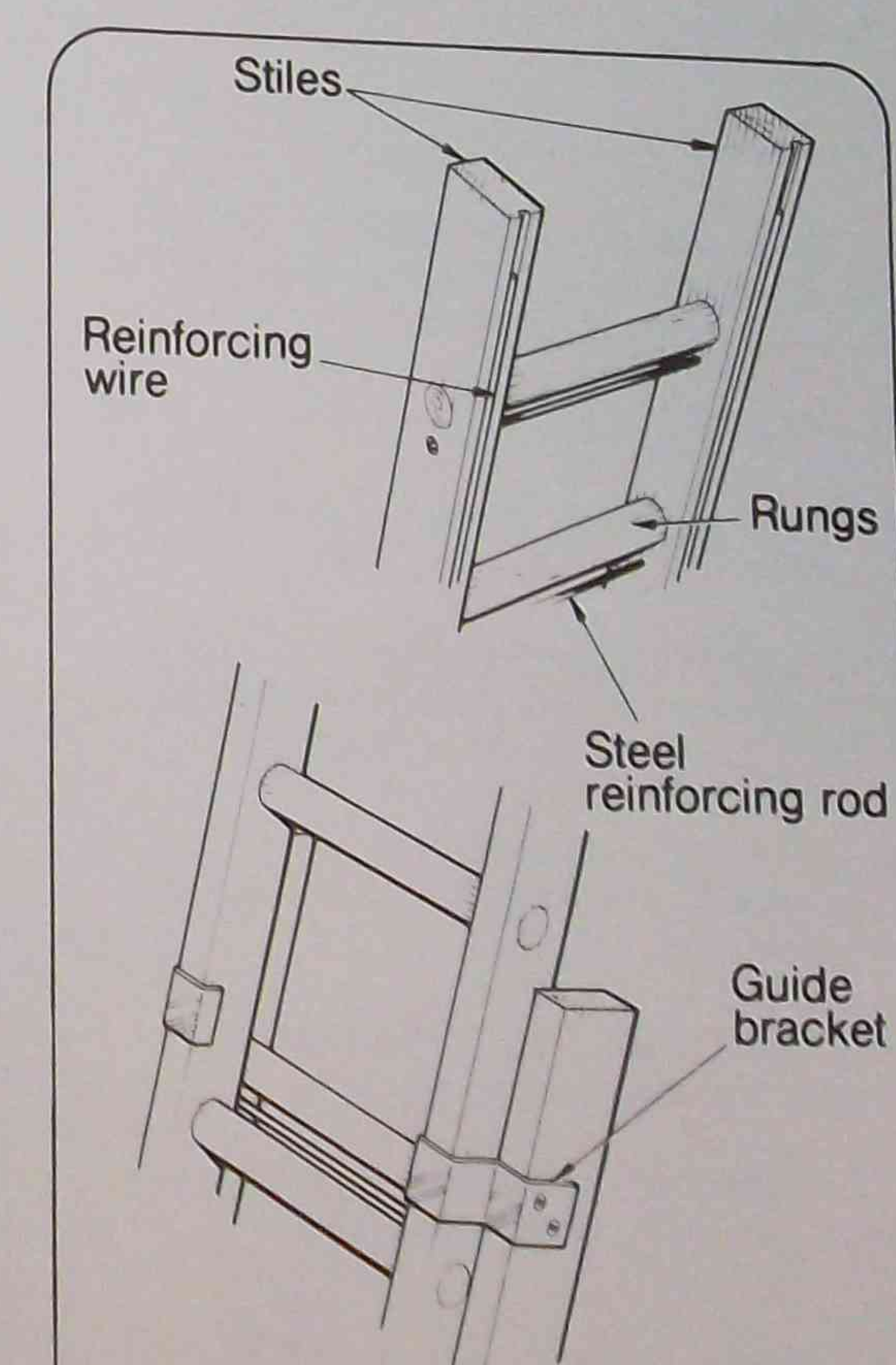
  5 mm steel rods fitted below the second rung from each end and not less than at 6-rung intervals.

- Reinforcing wires

  To give the ladder strength, galvanised steel wire is fitted into a groove running the full length of the stiles.



LADDERS



EXTENSION LADDER COMPONENTS

3.3.2 Safe use of ladders

Check all components of ladders prior to use for weakened or broken stiles and rungs; defective ropes, pulley wheels, guide brackets and latching hooks. If faulty, tag for repair, or destroy damaged gear to prevent others from accidently using unsafe scaffolding.

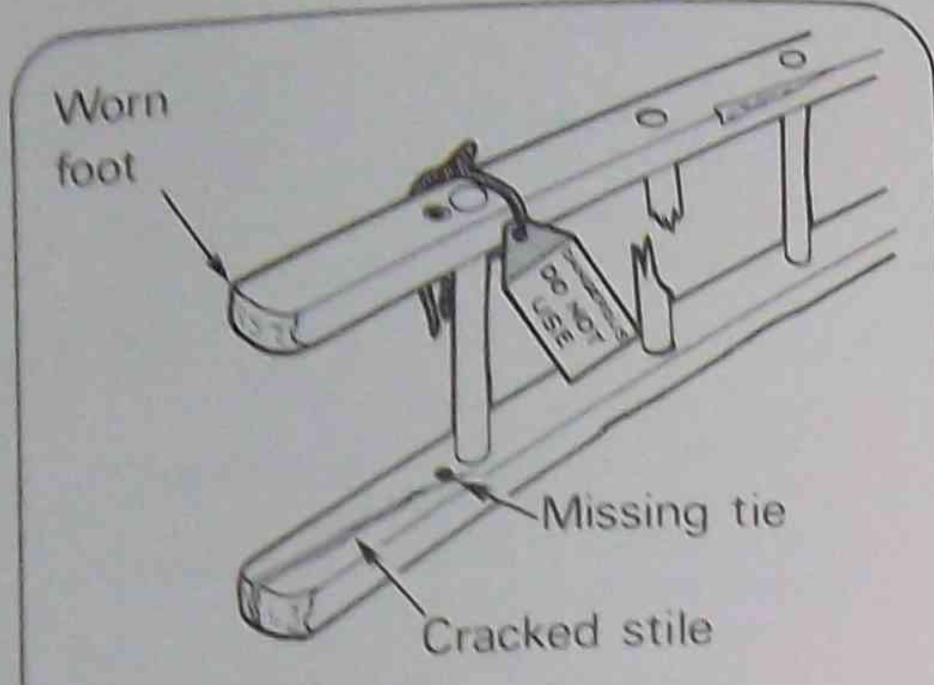
- Select a ladder to suit the height of the job at hand.
- Carry the ladder to the position of erection.
- Check for any overhead obstructions.
- Check that the ladder is on firm level ground.
- Raise the ladder with the sections closed.
- Adjust the position of the ladder by tilting the top half across the surface approximately .5 m, then lift the lower section across to vertically line up the ladder. Continue until the ladder is in correct position.
- Raise the sections to the required working height.

Extending a large ladder

To safely extend a large ladder two people are necessary. One person stands behind the ladder, the other in front.

Extend a large ladder as follows:

- Place the ladder in position against the wall with the sections closed.
- The person behind steadies the ladder and pushes the top away from the wall until the ladder is almost vertical.
- The person in front releases the extension lock by pulling the back end of the rope.
- Pull on the front end of the rope to raise the ladder sections.
  - Maintain light tension on the back rope to hold the lock clear.



SEND DEFECTIVE LADDERS FOR REPAIR

ADJUST POSITION OF LADDER IN SMALL CAREFUL MOVEMENTS

SAFETY ON LADDER

- When the required height has been reached, slacken the back rope to allow the lock to automatically engage over the rung.
- Release all tension on the rope.
- Gently lower the ladder against the wall.

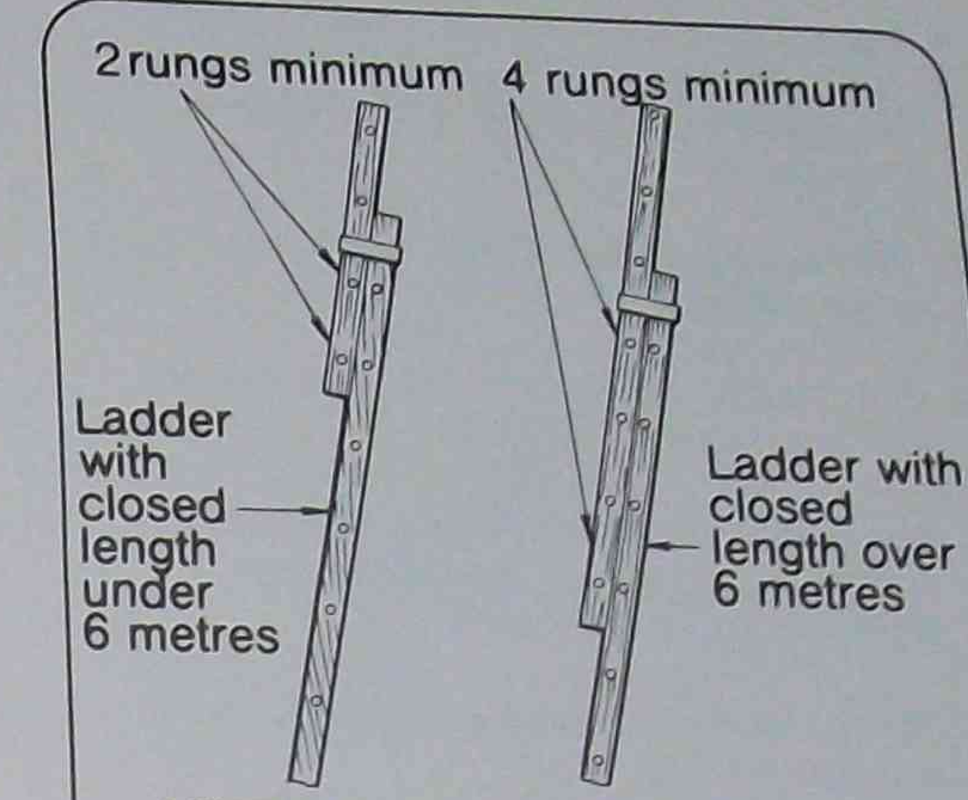
NOTE:

Never over-extend extension ladders.

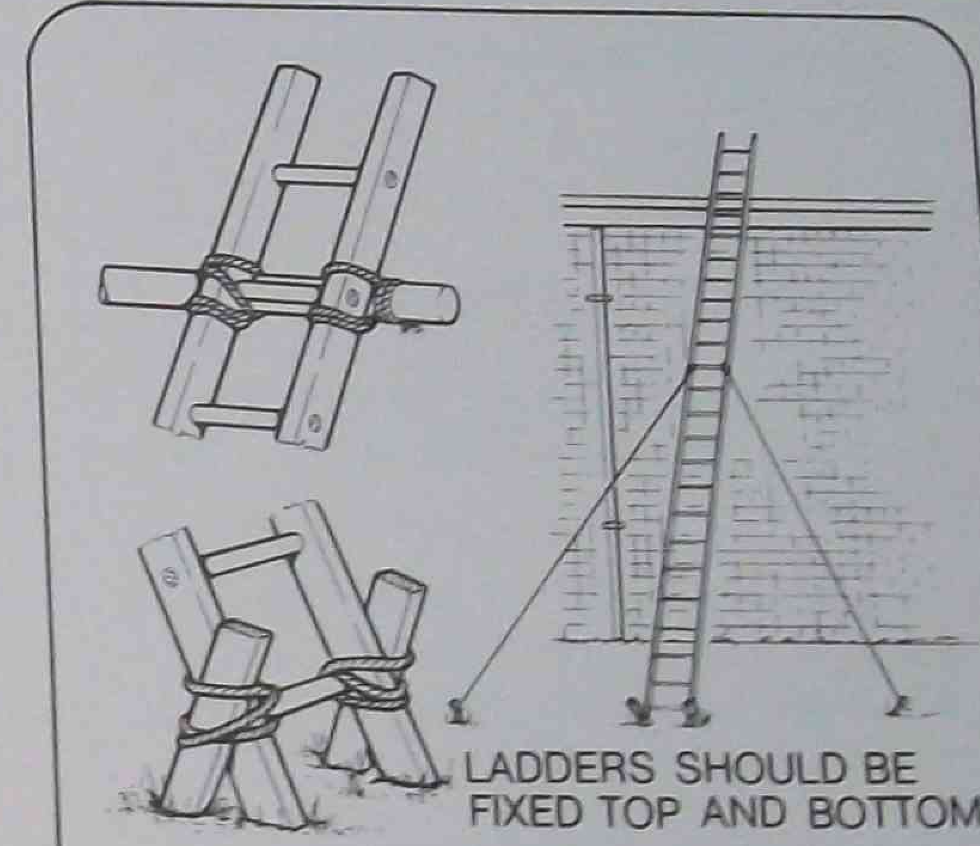
The minimum overlap on each section on extension are:

- Two rungs for ladders with closed length of 4.8 metres.
- Three rungs for ladders with closed length of 6 metres.
- Four rungs for ladders with closed length over 6 metres.

Ladders should be fixed at the top and bottom. If this is not possible, they must be held firmly with both hands on the stiles, about shoulder height and with both feet against the base.



MINIMUM ALLOWABLE OVERLAP ON EXTENSION



SECURING LADDERS

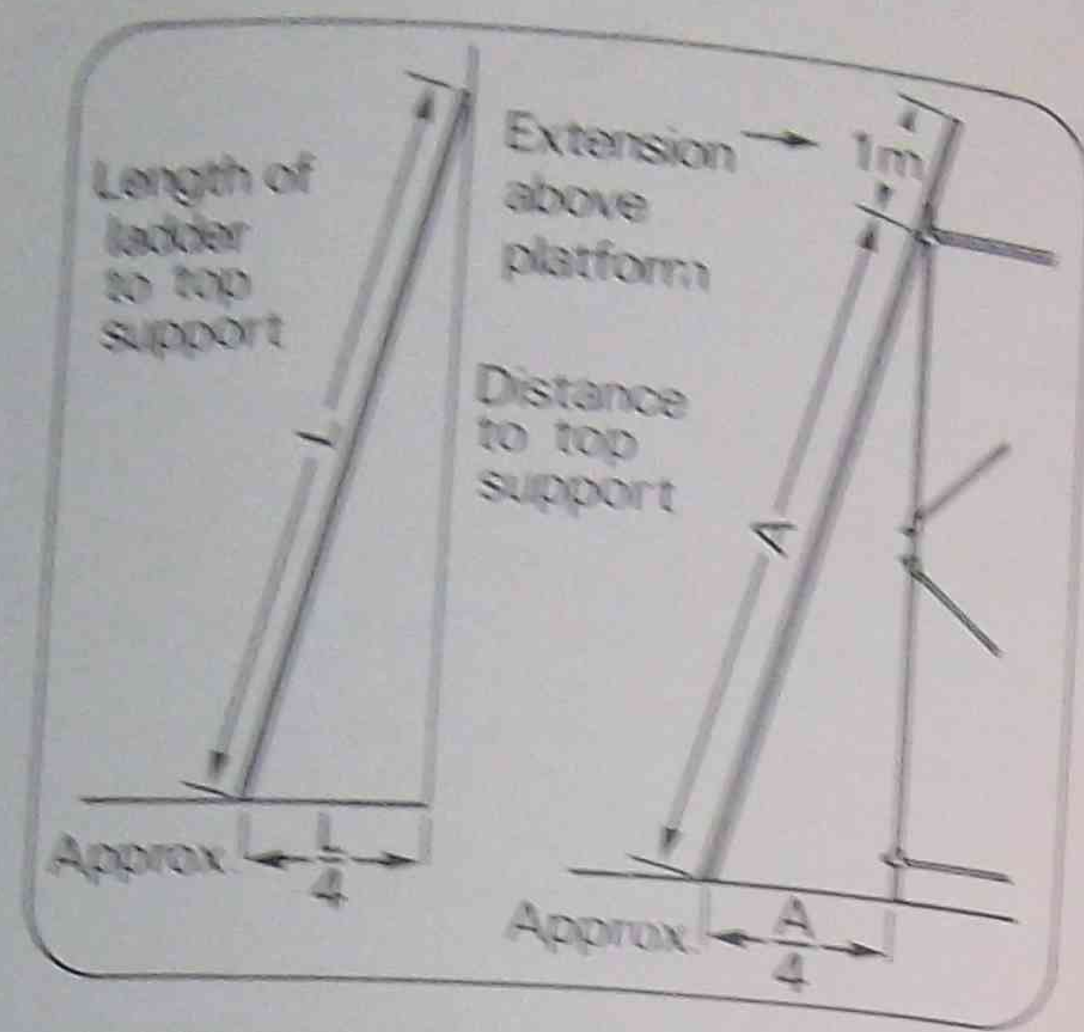
BOTTOM OF LADDER HELD SECURELY

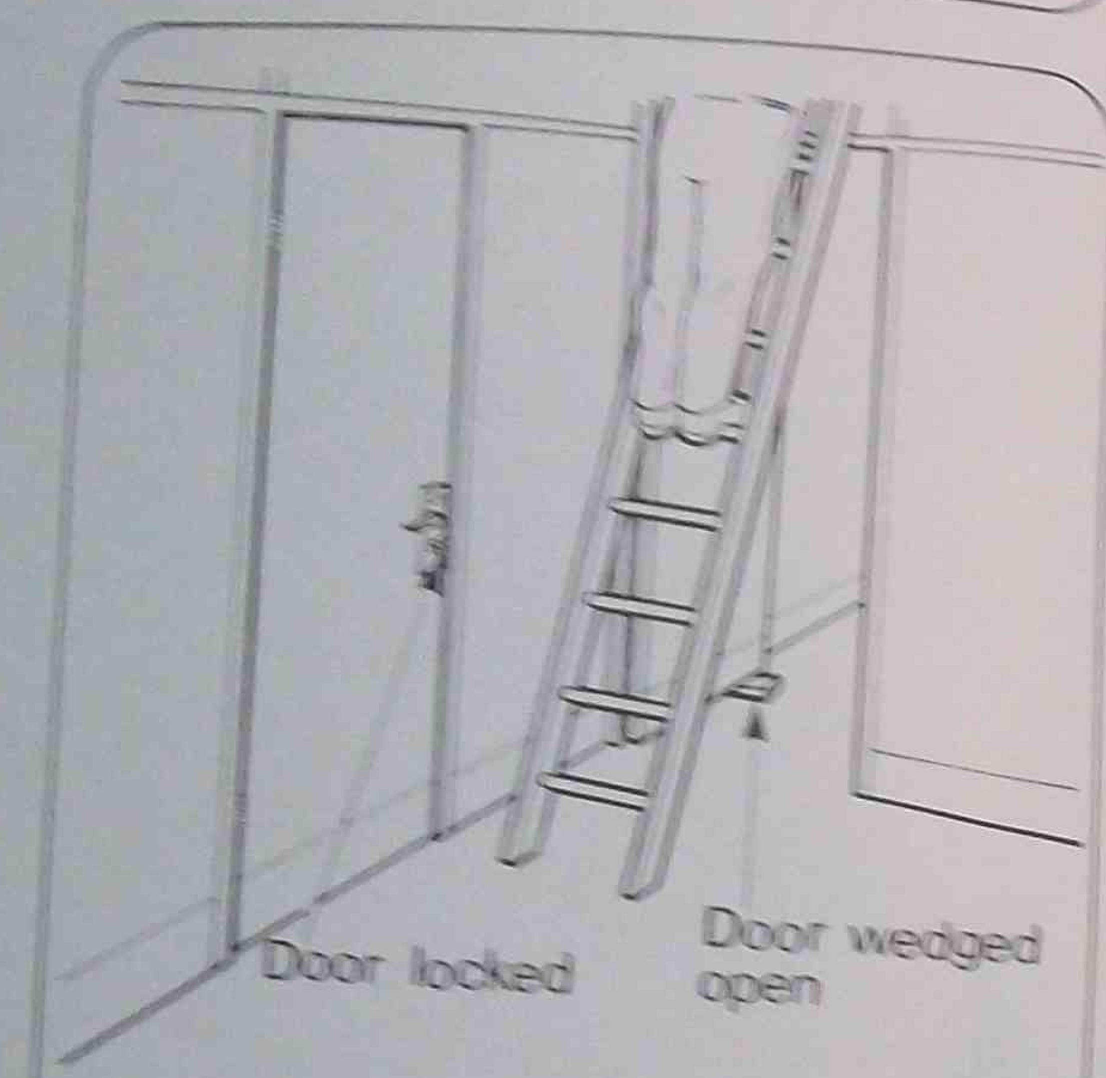
- The ladder must extend 1 metre above the working platform. This enables ease of access to the ladder and adequate hand grip.
- The ladder should be at a slope no greater than 4:1.
- Only one person to work off a ladder at any one time.
- The person using the ladder must not work any higher than the third rung from the top of the ladder.
- Always face the ladder when ascending and descending.
- Do not rest the ladder on a wet painted surface.
- Use a pot hook to hold the paint pot. Leaving one hand free for holding onto the ladder.
- Work in comfort.
- Do not stretch or overreach.
- To move a ladder, lower the sections, then two people move the ladder across.
- Do not place ladders in dangerous positions, such as unattended doorways, unless the doors are blocked open or locked closed.
- Never leave an unsecured ladder unattended.
- To lower a ladder, reverse the erecting procedure.
- Store ladders in a dry, well-ventilated area.

3.3.3 Carrying ladders

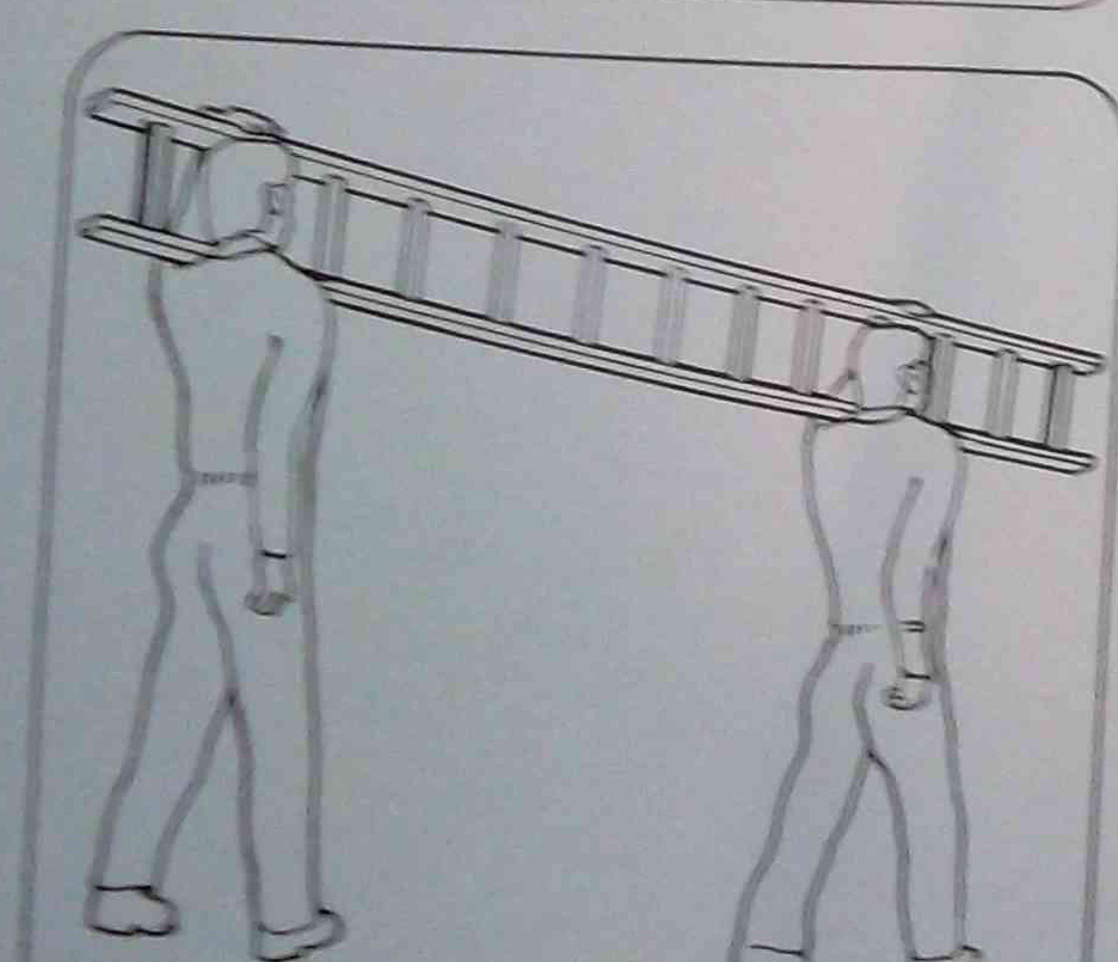
To carry a small ladder over a short distance, lift it vertically by grasping the rung just below normal reach and resting the stile on your shoulder. Find the correct balance and angle before moving.

When moving ladders more than a few metres, the ladder should be lowered and carried on the shoulders by two persons; one at each end.





SECURE UNATTENDED DOORS

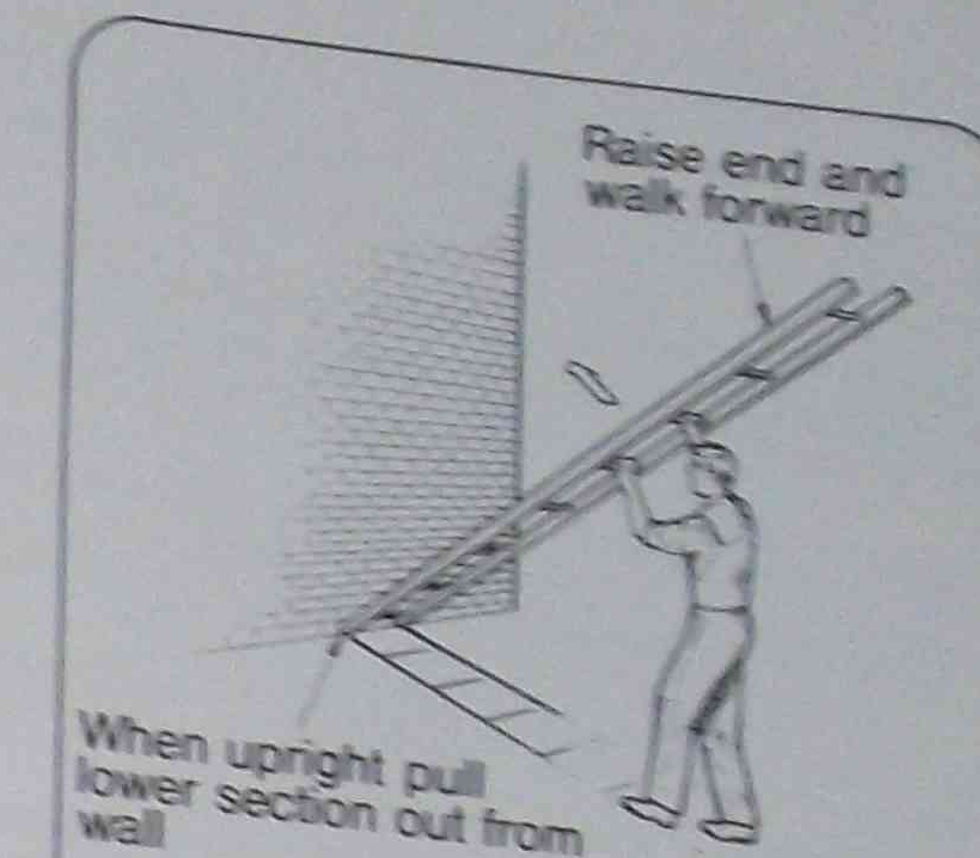

CARRYING LONG LADDERS

3.3.4 Erecting ladders

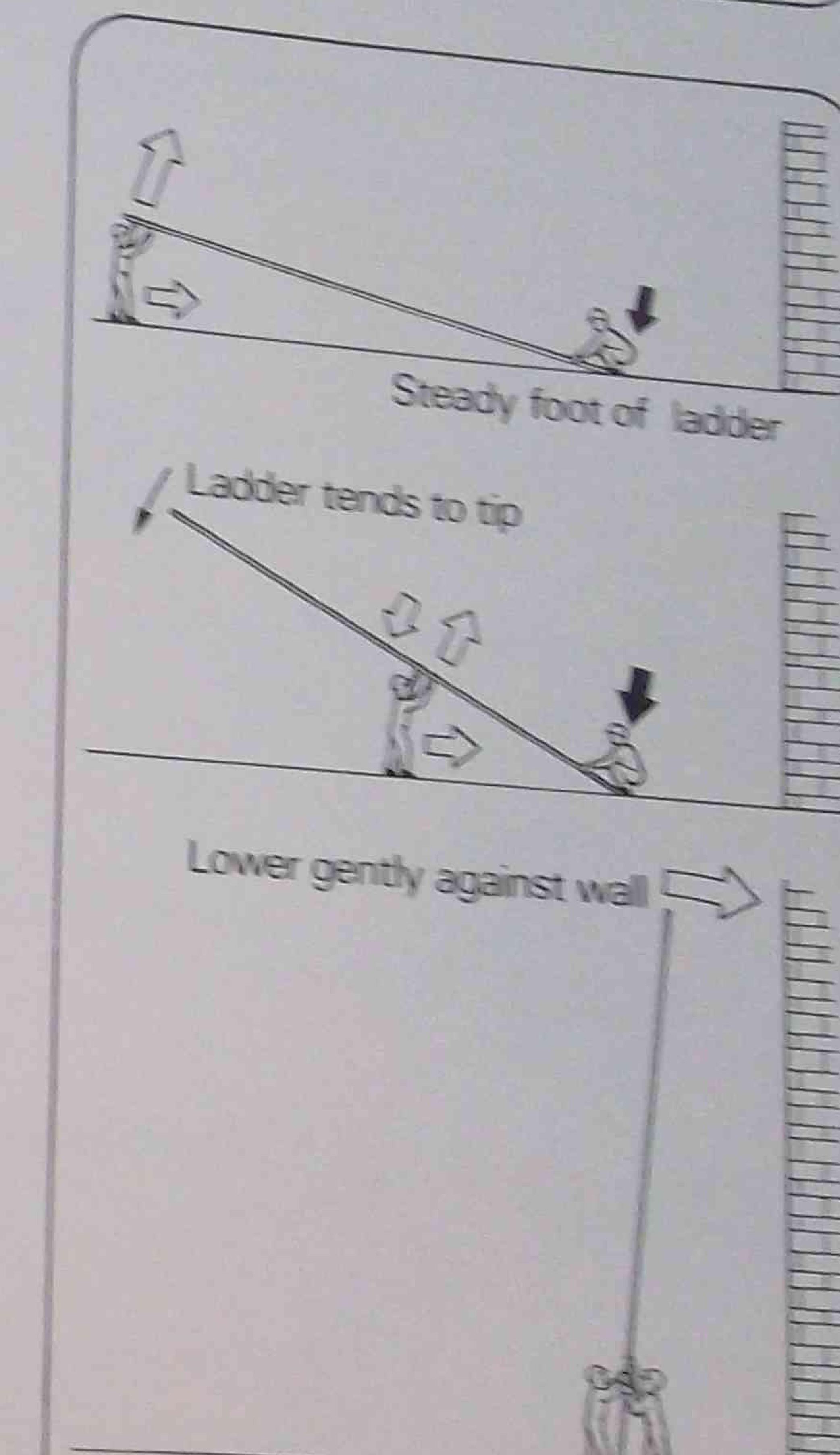
Extension ladders are raised and lowered with the sections closed.

Two people are required to erect heavy ladders.

- Lay the ladder flat with the foot about one-quarter of the ladder length from the wall.
- One person places their feet against the foot of the ladder and holds the stiles to steady the ladder as it is being raised.
- The second person stands at the other end of the ladder. Lifts it over his head and moving hand over hand, walks towards the foot. Raising the ladder until it is upright.
- Once upright, the ladder is lowered gently against the wall.
- To lower the ladder, reverse this procedure.



RAISING A SINGLE LADDER



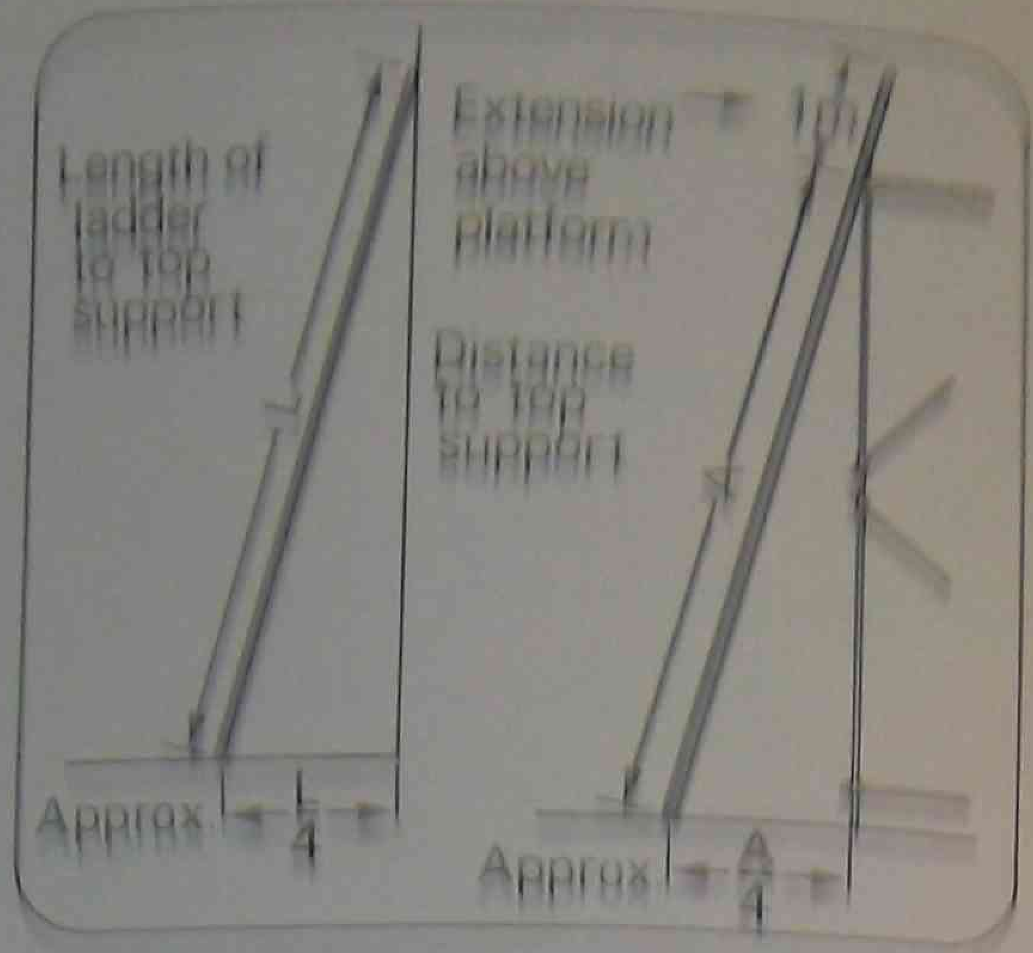
ERECTING LONG AND HEAVY LADDERS

- The ladder must extend 1 metre above the working platform. This enables ease of access to the ladder and adequate hand grip.
- The ladder should be at a slope no greater than 4:1.
- Only one person to work off a ladder at any one time.
- The person using the ladder must not work any higher than the third rung from the top of the ladder.
- Always face the ladder when ascending and descending.
- Do not rest the ladder on a wet painted surface.
- Use a pot hook to hold the paint pot. Leaving one hand free for holding onto the ladder.
- Work in comfort.
- Do not stretch or overreach.
- To move a ladder, lower the sections, then two people move the ladder across.
- Do not place ladders in dangerous positions, such as unattended doorways, unless the doors are blocked open or locked closed.
- Never leave an unsecured ladder unattended.
- To lower a ladder, reverse the erecting procedure.
- Store ladders in a dry, well-ventilated area.

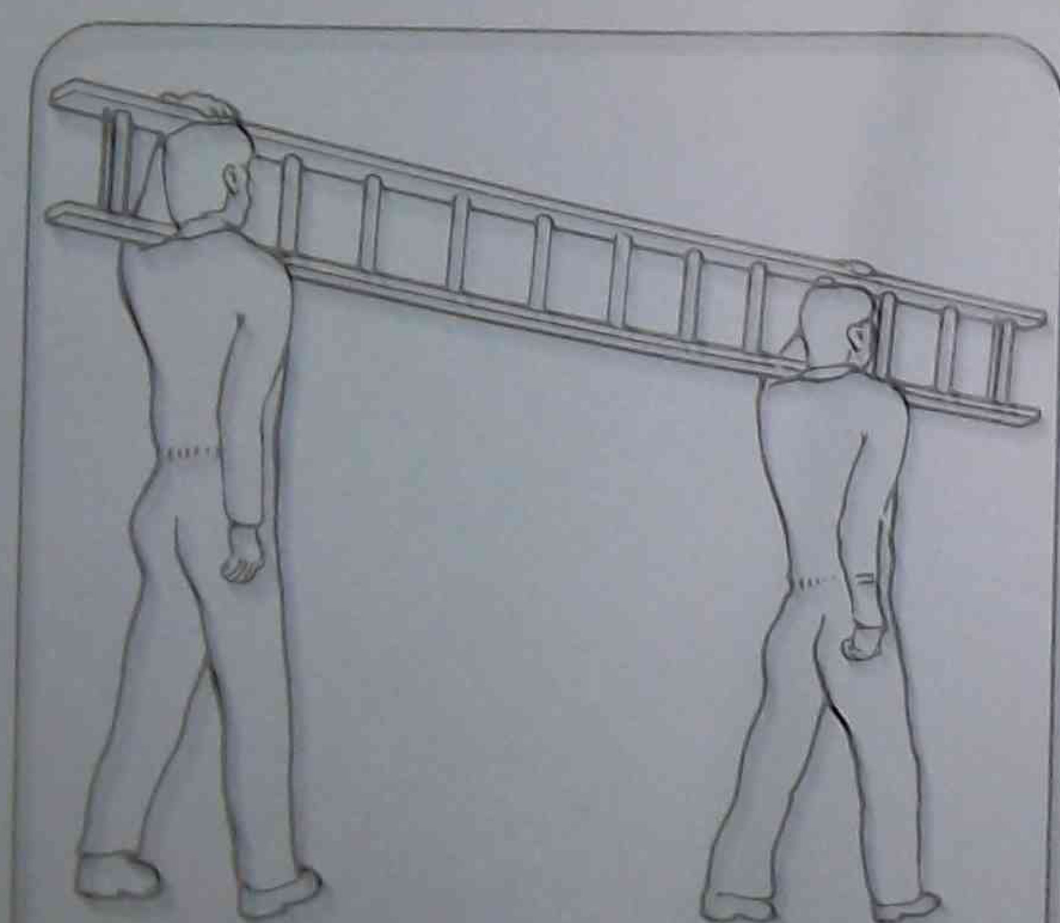
3.3.3 Carrying ladders

To carry a small ladder over a short distance, lift it vertically by grasping the rung just below normal reach and resting the stile on your shoulder. Find the correct balance and angle before moving.

When moving ladders more than a few metres, the ladder should be lowered and carried on the shoulders by two persons; one at each end.



SECURE UNATTENDED DOORS



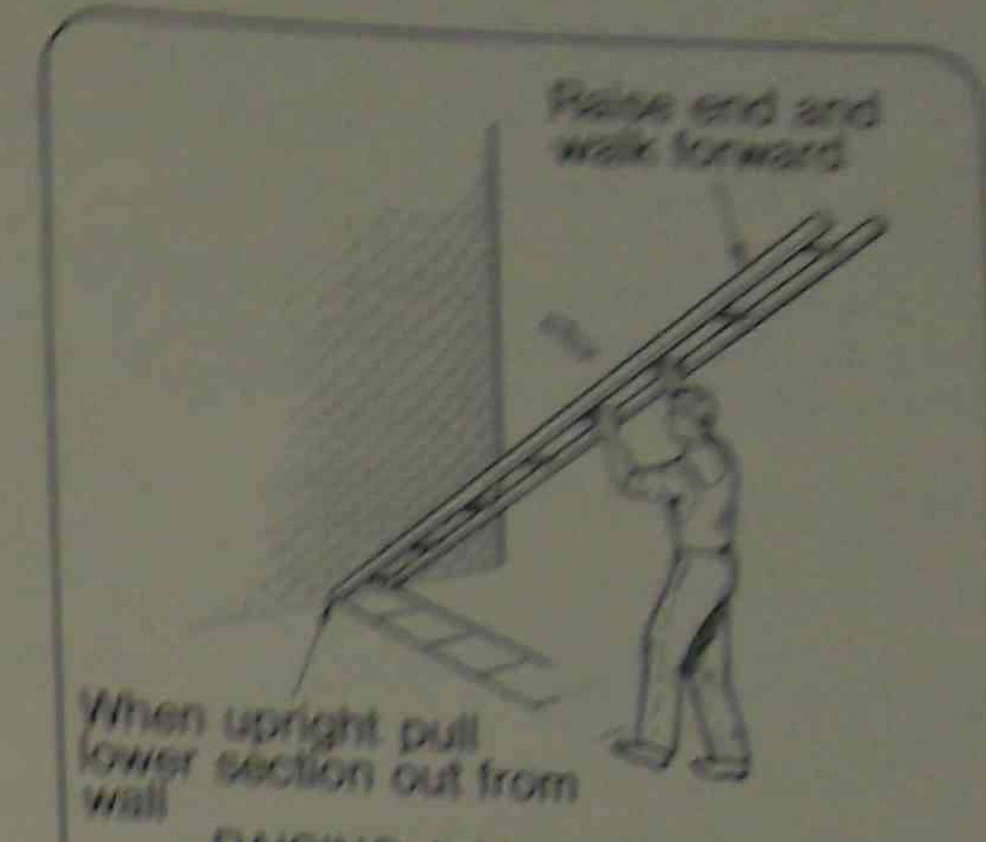
CARRYING LONG LADDERS

3.3.4 Erecting ladders

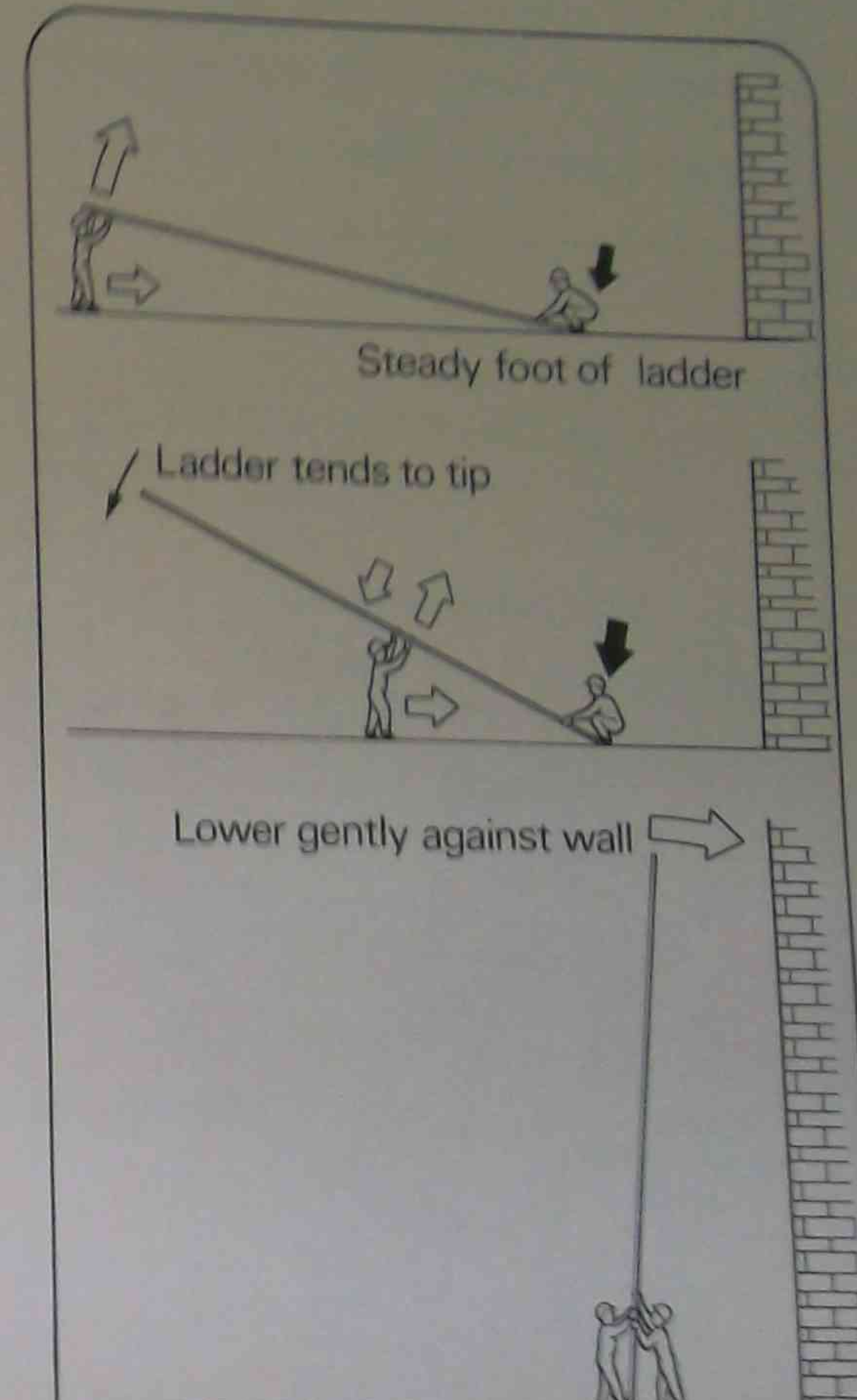
Extension ladders are raised and lowered with the sections closed.

Two people are required to erect heavy ladders.

- Lay the ladder flat with the foot about one-quarter of the ladder length from the wall.
- One person places their feet against the foot of the ladder and holds the stiles to steady the ladder as it is being raised.
- The second person stands at the other end of the ladder. Lifts it over his head and moving hand over hand, walks towards the foot. Raising the ladder until it is upright.
- Once upright, the ladder is lowered gently against the wall.
- To lower the ladder, reverse this procedure.



RAISING A SINGLE LADDER



ERECTING LONG AND HEAVY LADDERS

3.4 TRESTLE LADDERS

Trestle ladders are self-supporting structures capable of holding one or two horizontal scaffolding planks to form a working platform.

Trestle ladders and planks are widely used when painting ceilings, walls, windows, the preparation and painting of exterior walls, guttering and fascia boards. All these surfaces may be reached and worked upon with safety from trestle ladders and scaffolding planks.

Trestle ladders will support a maximum of two planks and two men.

Folding trestles are available in timber or aluminium.

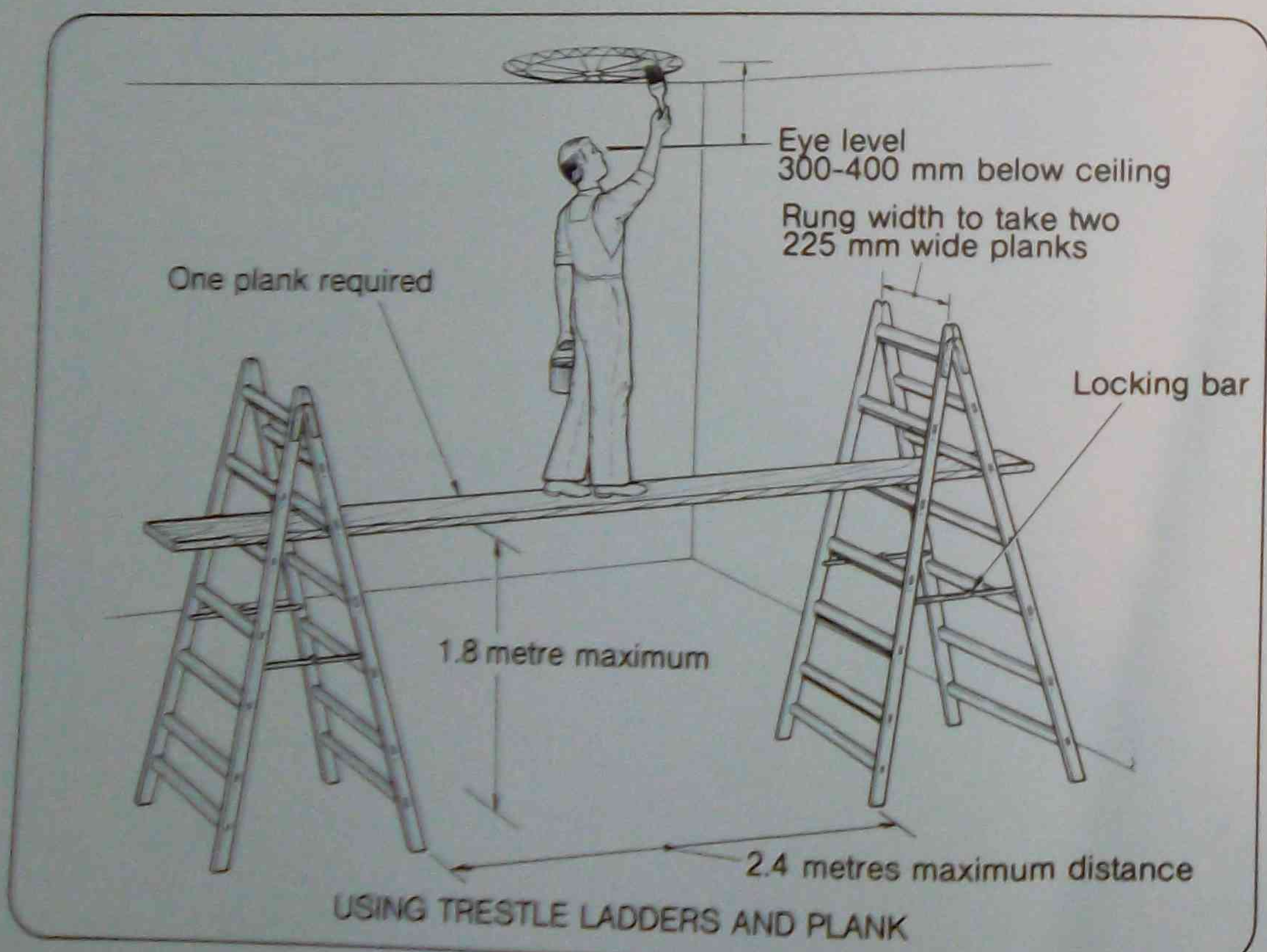
Stiles are tapered towards the top and should be wide enough apart to take two 225 mm scaffold planks.

Rungs are staggered on each side to give a platform rise of 225 mm.

— Rungs on both sides should have at least two 5 mm steel reinforcing rods fitted to give added strength.

The trestle is prevented from over-opening and collapse by a specially formed lipped trestle hinge. When the hinge is fully opened the angle should not be less than 24° or more than 36°.

Spreader ropes may also be used as in step ladders.

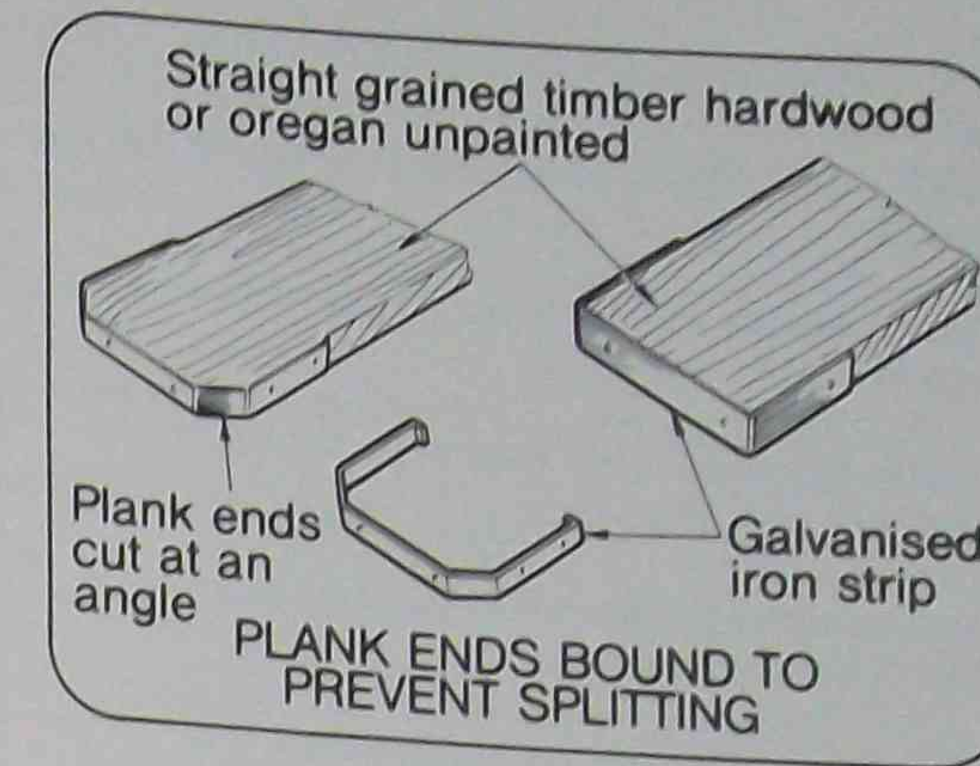


USING TRESTLE LADDERS AND PLANK

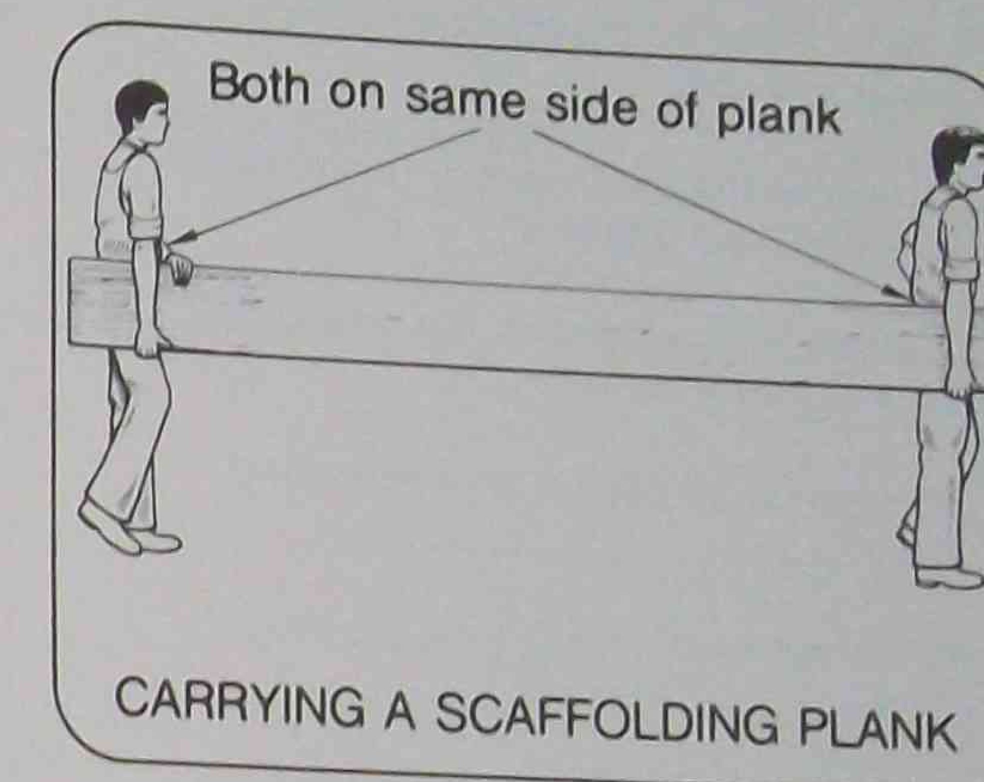
3.4.1 Scaffolding boards (planks)

Made from hardwood or oregon straight-grained timbers. Planks up to 4 metres are available. Planks are also available in aluminium.

- Planks must be free of knots, splits, decay and with no twists or warps.
- Hardwood planks must not be less than 225 mm wide × 37 mm thick.
- Oregon planks must not be less than 225 mm wide × 32 mm thick.
- Planks must not be painted with opaque paints.
- Planks should be free of grease and oil, to prevent slipping.
- To prevent planks from splitting they should be bound at each end with a galvanised iron band.
- To minimise damage to planks, the corners are cut at an angle then bound with a metal strip.
- Planks should not be dropped.
- Planks must be stored in a dry, well ventilated area when not in use.



PLANK ENDS BOUND TO PREVENT SPLITTING



CARRYING A SCAFFOLDING PLANK

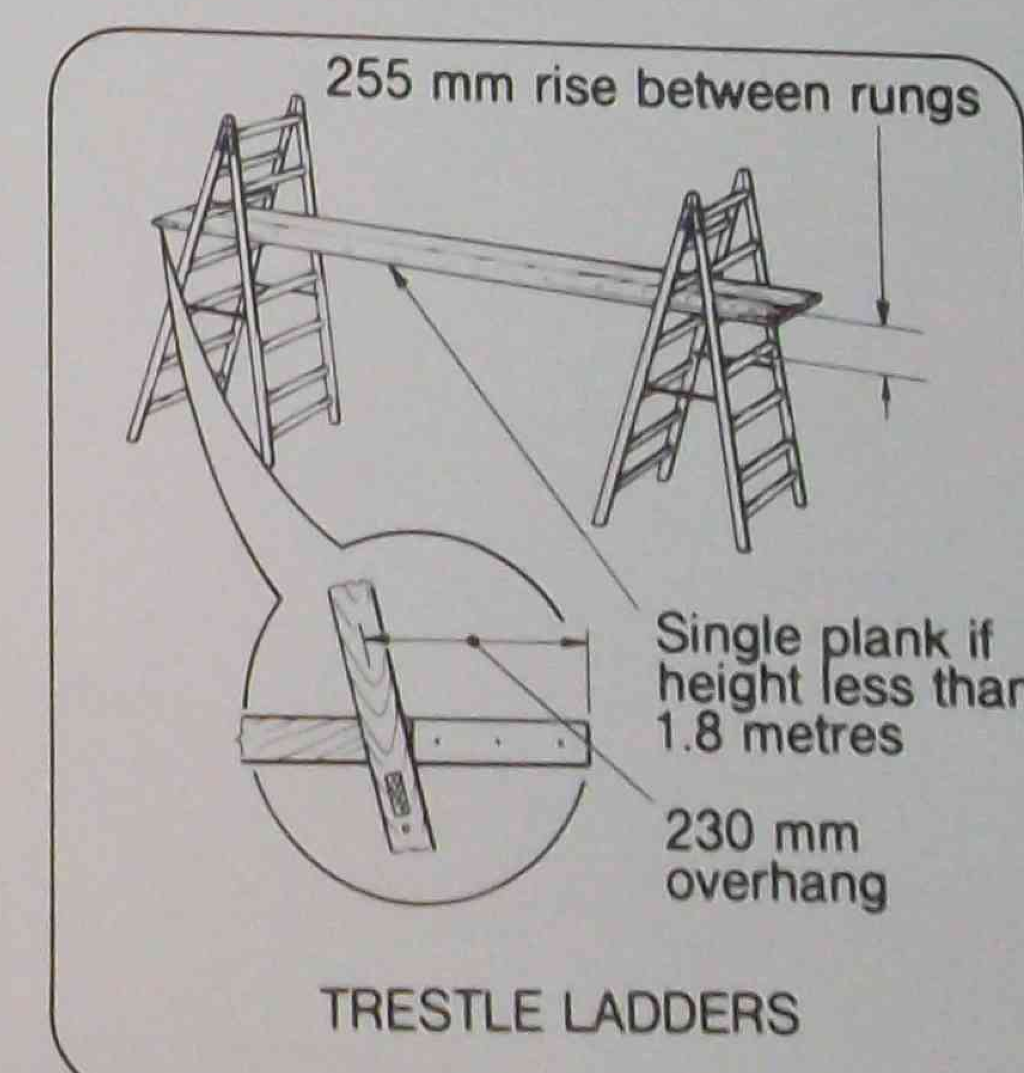
3.4.2 Trestle ladder scaffolding

Safe use of trestle scaffolding

Check all scaffolding for defects before erecting.

Fully open the trestles. If a stay bar is fitted it must be correctly locked.

If the working height does not exceed 1.8 metres, one plank may be used to form the working platform.



TRESTLE LADDERS

If the working height exceeds 1.8 metres and less than 3.66 metres, two planks of equal strength laid side by side must be used.

Trestle planks must not be placed above 3.66 metres.

Trestle ladders higher than 4.25 metres must not be used.

Trestle ladders must not be spaced more than 2.4 metres apart.

All work must be performed between the trestle ladders. Never overreach.

No more than two persons can work on the plank at any time.

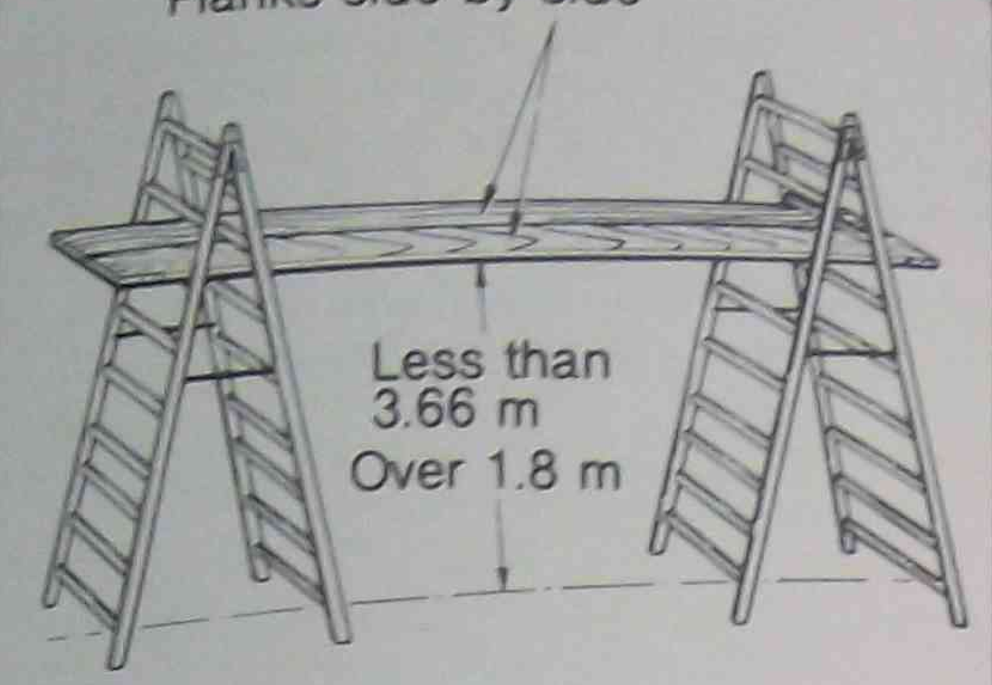
Overhang of the plank on the trestle rungs must be at least 230 mm.

No person is to remain on the scaffolding while it is being moved.

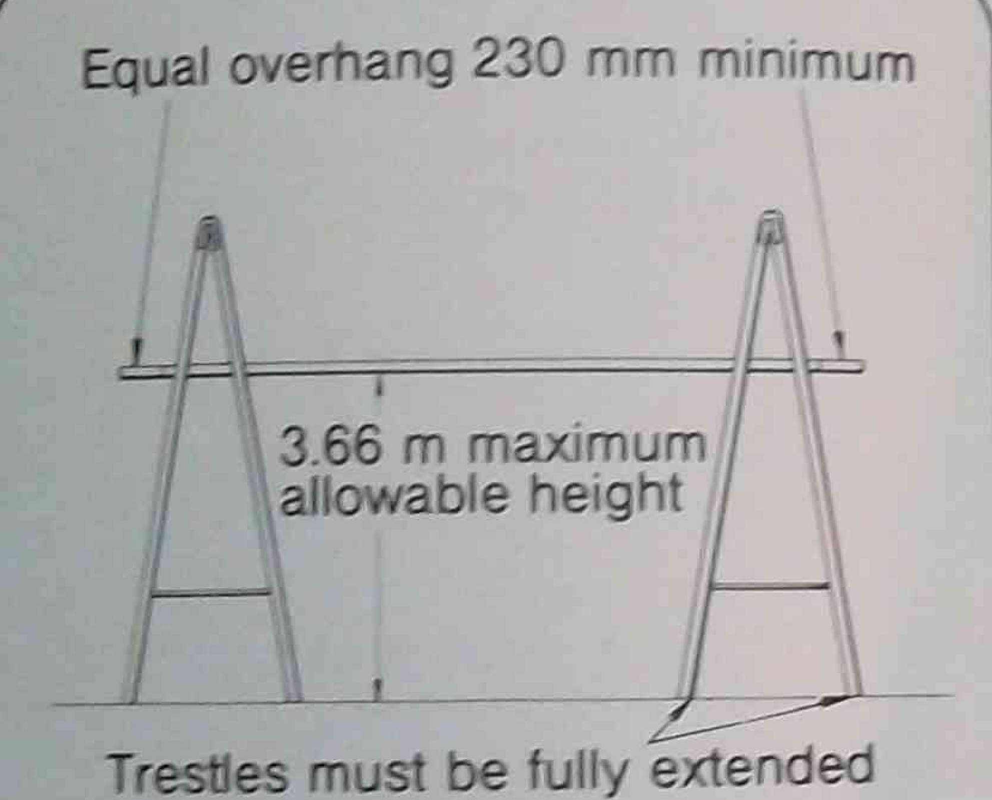
Trestles must be placed on a firm solid footing.

Planks must form a horizontal working platform.

Aluminium trestles and planks must have equivalent working capacity to timber.



TWO PLANKS REQUIRED ABOVE 1.8 METRES



SAFETY REQUIREMENTS FOR TRESTLES AND PLANKS

3.5 LADDER BRACKET SCAFFOLDING

Ladder bracket scaffolding consists of two rung-type ladders, each of which is fitted with an approved ladder bracket to hold a scaffolding plank.

Brackets must be approved by the appropriate State Authority.

Planks when secured to the brackets must have a minimum overhang of 230 mm each end.

Distance between brackets must not exceed 2.44 m.

Each bracket must be connected to the underside (back) of the ladders.

Maximum height of the working platform must not exceed 3.66 m.

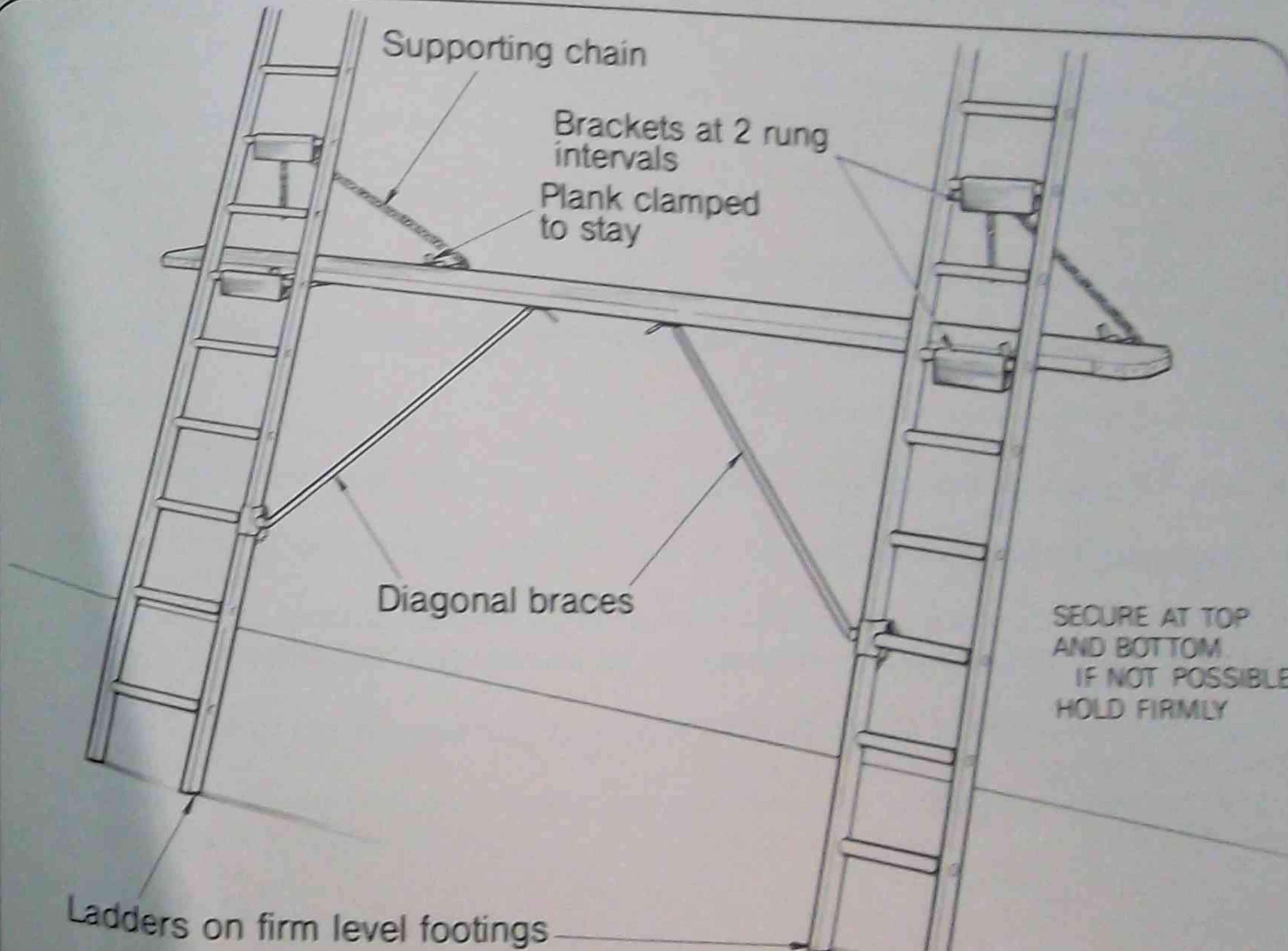
No more than two persons can work on the scaffolding at any one time.

All work must be performed between the ladders.

Ladder brackets must have a diagonal brace to form a rigid working platform.

NOTE:

Before erecting any scaffolding check all components for defects.

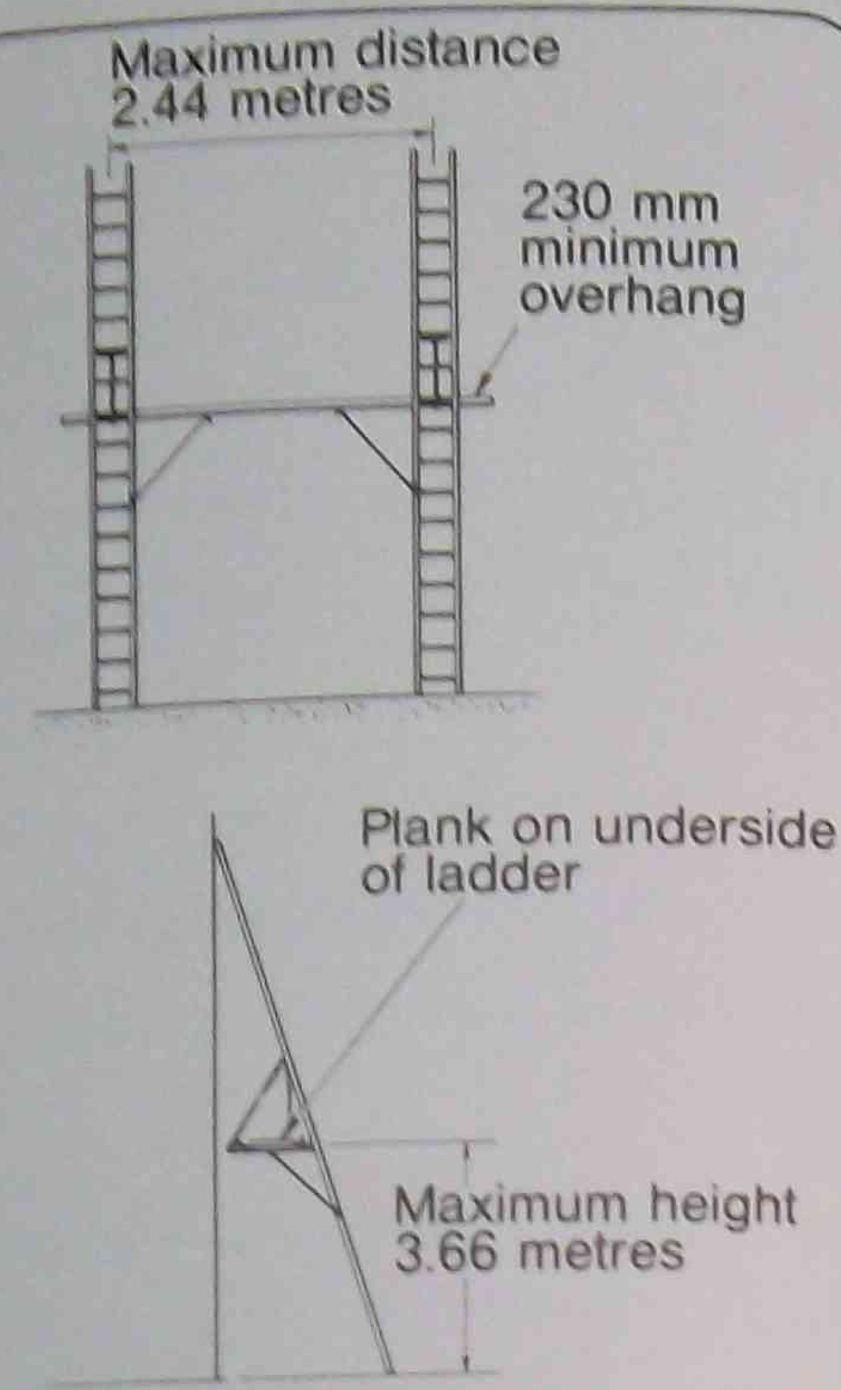


LADDER BRACKET SCAFFOLDING

3.5.1 Erecting ladder bracket scaffolding

To erect ladder bracket scaffolding, two people are required as follows:

- Check the ladders, plank and brackets for defects.
- Place the ladders in position against the wall.
- Fix the brackets at the required height on the ladder rungs.
- Adjust the supporting chains until the support bars are horizontal.
- With one person on each ladder, support the plank on edge behind the ladder in the crook of the elbows.
- Keeping the plank level, climb the ladders together to reach the bracket position.
- Slip the plank one end at a time onto the brackets.
- Lay the plank flat, then tighten the clamp to secure the plank in position.
- Fit and tighten the diagonal braces.



SAFE USE OF LADDER BRACKET SCAFFOLDING

3.6 SPECIALISED SCAFFOLDING

For special or unusual job situations there are several scaffolding systems available:

- Suspended swing stage platforms.
- Interlocking tubular scaffolding.
- Tubular metal mobile towers.

To erect, dismantle or work on scaffolding other than steps, trestles, ladders and planks a scaffolding permit or licence may be required from the appropriate State Authority.

A licence can be obtained by attending a scaffolding and riggers course run by the State Licencing Authority.

NOTES FOR THE INSTRUCTOR

In these Training Manuals the term 'instructor' refers to any person who may train or be directly responsible for training individuals.

For example, the task of instructing may be the sole or shared responsibility of:

—skilled tradespeople

—leading hands

—supervisors

—instructors

—apprentice supervisors

—managers

INITIAL PLANNING

A Analyse:

- The training requirements of a newcomer, considering that the person:

  —may have no previous experience in the subject;

  —will need to do productive work as soon as possible.

- What the trainee must learn about:

  —the tools to use for the subject;

  —the terminology involved in the subject;

  —basic working methods.

- What will be the first productive work you will be able to give the trainee.

B Decide:

- Whether your trainees need information to supplement that given in this manual.
- Whether or when additional training material or exercises will be required to improve on the skill gained.
- Which other Basic Training Manuals the trainee should use during training.

C Plan:

The explanations, demonstrations and the practice required by the trainee, preferably on an individual basis, if numbers allow.

USING THE MANUAL

It may be of assistance to the trainee to arrange for short periods of learning followed by short periods of practice in applying the knowledge gained.

To keep interest alive, it will be useful to relate, as much as possible, the material treated in this manual with actual practical applications in the field.

PRACTICAL EXERCISES AND PROJECTS

There may be areas and tasks in actual situations where the developing skills of the trainee can be put to effective productive use at any stage during the period spent learning the subject. Such possibility should be carefully considered and used to the full for the trainee's benefit as well as that of the firm.

Give the trainee as many opportunities as possible to use the whole range of hand tools on suitable small jobs to enable speedy acquisition of the manual dexterity required.

Small projects and exercises to suit particular work situations may be devised, but they must take into consideration the limits of skill and knowledge of the trainee.

Whatever form of exercise is used to develop practical skill, it must be carefully planned. A suggested course of instruction is:

- Prepare the working area, the materials and the hand tools to be used.
- Make the aim of the project clear to the trainee.
- State how you intend to assess the proficiency of the trainee.
- Stress key points in the project, paying particular attention to safety precautions.
- Explain clearly and thoroughly any new steps in the project.
- Check that the trainee can use the hand tools correctly.
- Assess the finished project, record the results and discuss with the trainee your appraisal of the performance.
- If you are satisfied with the performance, direct the trainee to the next exercise or project.

TRAINING RECORDS

Simple training records will help in planning systematic training.

Record:

- the parts of the manual learnt by the trainee;
- your assessment of the general skills developed;
- the practical exercises undertaken and completed.

Use your record to measure the trainee's performance and to assess readiness for undertaking actual operations.

Draw up a simple record card to suit your needs.

Using records helps to pinpoint the trainee's strengths and weaknesses. They ensure that training in essential skills is not missed. Training records can be used to help co-ordinate on-the-job training and technical school learning. Where trainees have to serve a probationary period, records assist when the trainee's progress is being assessed.

PUBLICATIONS IN BASIC TRAINING MANUALS PAINTING, DECORATING AND SIGNWRITING

Title	
15.1	PAINT TYPES AND SURFACE PREPARATION
15.2	PAINTING EQUIPMENT, APPLICATORS AND SCAFFOLDING
15.3	PAINTING TECHNIQUES
15.4	COLOUR
15.5	GLAZING
15.6	STAINING
15.7	PAPER-HANGING
15.8	SIGNWRITING EQUIPMENT AND USE OF SIGN PENCIL
15.9	SIGNWRITING DESIGN AND LAYOUT
15.10	FRENCH POLISHING (IN PREPARATION)

OTHER PUBLICATIONS IN BASIC TRAINING MANUALS
(Available at date of printing)

PRACTICAL GEOMETRY	3 MANUALS
LATHE WORK	7 MANUALS
SHAPING AND SLOTTING	3 MANUALS
GRINDING	3 MANUALS
MILLING	4 MANUALS
SANITARY PLUMBING	4 MANUALS
WATER SUPPLY	4 MANUALS
BRICKLAYING	2 MANUALS
WELDING (ARC)	4 MANUALS
SOLDERING	1 MANUAL
ELECTRICAL	13 MANUALS
ROOF PLUMBING	6 MANUALS
MOTOR VEHICLES	10 MANUALS (4 MORE IN PREPARATION)
FITTING	10 MANUALS
PANEL BEATING	2 MANUALS (8 MORE IN PREPARATION)
WORKSHOP SAFETY	1 MANUAL
CARPENTRY AND JOINERY	14 MANUALS (2 MORE IN PREPARATION)
FURNITURE REMOVALS	4 MANUALS
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BASIC TRAINING MANUAL

15-5

PAINTING & DECORATING

Glazing

NATIONAL BUILDING AND CONSTRUCTION
INDUSTRY TRAINING COMMITTEE

...itiative of the National Building and Construction Industry ...ttee comprising representatives of employers, unions and government. It was ...ited by an advisory panel consisting of:

— The Operative Painters and Decorators' Union of Australia.

— The Federation of Master Painters and Signwriters of Australia.

— Education Department of Victoria.

— Department of Employment and Industrial Relations.

...dt — Department of Employment and Industrial Relations.

...manual was written by:

...t — Melbourne College of Decoration.

— Department of Employment and Industrial Relations.

...dt — Department of Employment and Industrial Relations.

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CONTENTS

PREFACE

This manual is one of a series that has been developed to progressively increase the practical skills of a trainee in painting, decorating and signwriting.

Other manuals in this series cover:

- Paints: types, reasons for coating, surfaces coated, health and cleanliness, glossary of terms.
- Surface preparation: removal of existing coatings.
- The systematic procedure for the painting of interior and exterior surfaces.
- Colour: simple colour wheel, primary, secondary and tertiary colours, tints, shades and tones.
- Staining: filling, clear finishing, opaque and semi-opaque finishes.
- Paper-hanging: drop and set patterns, preparation, adhesives.
- Signwriting: tools and equipment, use and control of the sign pencil, layout of alphabet, design and simple signs.

Each manual is self-contained and is intended as an instructional guide in on-the-job training situations. It may be used by instructors or for self-teaching purposes.

The aim of the manual is to help the trainee to develop a particular skill to the stage where it can be applied productively on the job. Ideally, the manual should be used as part of a course of instruction involving:

- demonstrations of practical skills by instructors or experienced tradesmen;
- planned and supervised practice in handling the tools involved;
- instruction in safe working procedures.

The manuals may be used in any order convenient to the learning needs of the trainee and may be obtained individually or in sets to cover the range of skills in the trade area.

It may be advisable to use part of this manual with sections of other manuals in this series to follow an operation through.

INSTRUCTIONS TO TRAINEE

This manual is a teaching aid to your skill development. It is best used on the job where you can handle the tools and use the equipment shown.

You should follow the directions given by the person training you. To reach the required standard of skill, you must pay particular attention to your instructors' explanations and demonstrations. Supervised and individual practice is essential.

Practice means making repeated efforts to improve your level of skill. Study is making an effort to learn. Every advance in skill depends on study and practice. Progress is obtained by co-operating actively in the training arranged for you.

When you are told to study all or part of this manual, try to use a definite plan of study. The following plan is effective.

SURVEY: Read quickly through the headings as you turn the pages. Glance at the illustrations. Get an overall view before you read.

QUESTION: Ask yourself: What do I know? What do I need to know? How will this manual help me to learn?

READ: Read right through each section carefully. Be thorough, but do not dawdle. Reading quickly will help you concentrate.

DO: Use all your senses in learning. Getting the 'feel' of any subject is essential in learning it. Follow the directions given to you; they are meant to assist you in the gaining of the skills you need.

REVIEW: Shut the manual. Try to remember the main points of the section. Check to see that you are right. Revise points on which you are doubtful.

One way of fixing important instructions in your mind is to repeat them over and over.

Practical exercises are given you in this manual. Do not be satisfied by doing them once. Repeat the exercises as often as possible as this will enable you to develop your skills.

OLS

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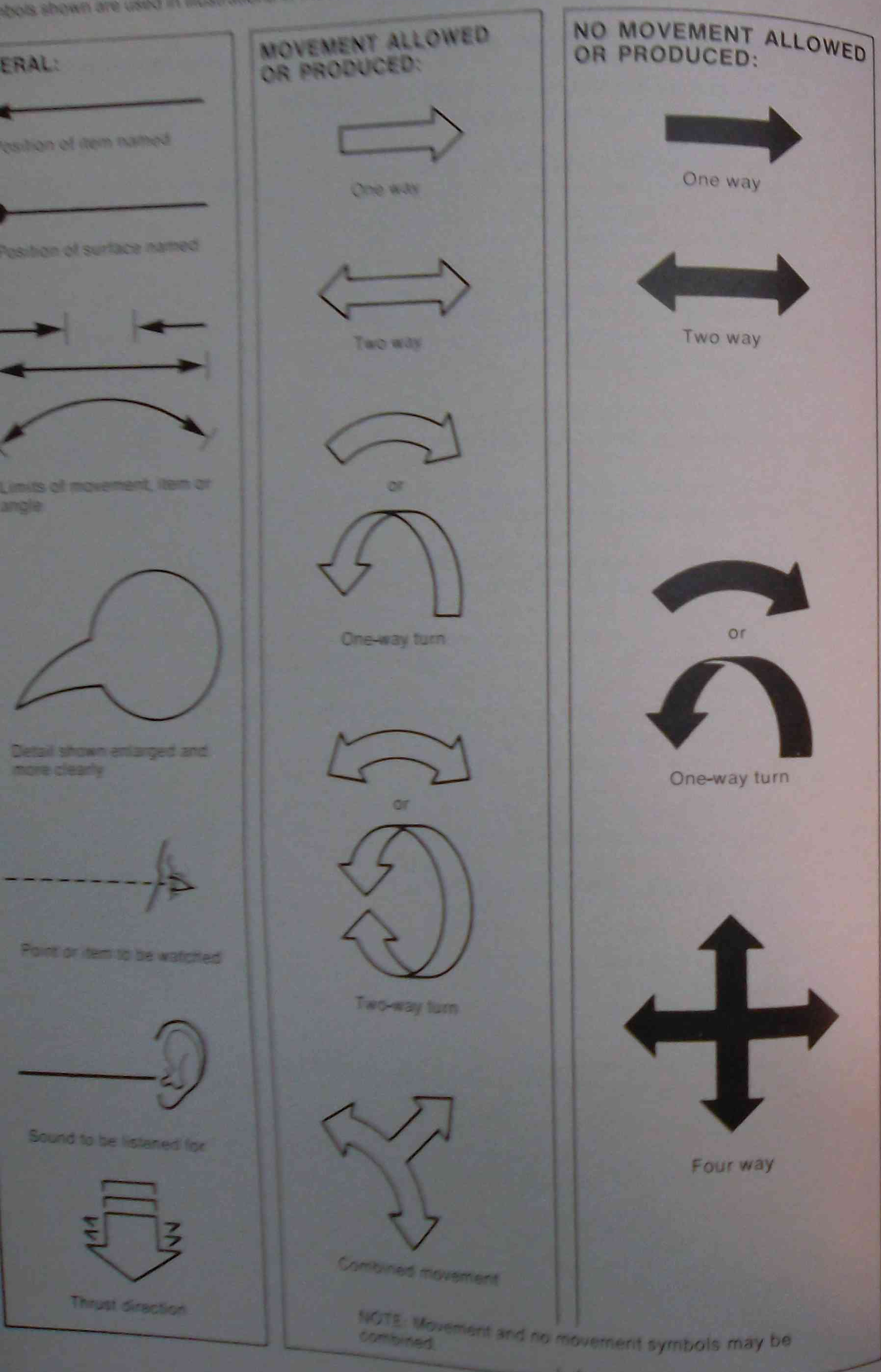


1 OBJECTIVES OF THIS MANUAL

The aim of this manual is to help you develop the skills needed to successfully and safely glaze a window.

To do this you will need to learn how to:

- Recognise and use the tools and equipment required for glazing.
- Remove broken glass and existing putty safely from various types of windows.
- Prepare the frame or window for new glass.
- Select suitable glass of the correct weight and type for the purpose required.
- Handle and store glass safely.
- Mark out and cut glass accurately and safely.
- Select and prepare suitable bedding putty.
- Position and fit new glass to a frame or window.

You will also learn to:

- Protect adjacent areas from damage during reglazing.
- Clean the glass and tidy the area so that it is left in a pleasing and satisfactory state.

2 INTRODUCTION

Although formerly an integral part of painting and decorating, glazing is now considered a separate skill area.

A great deal of care and skill is required to successfully master glazing.

Care is needed because you are working with a very fragile material. Skill is required because very accurate measurements must be taken and allowances made for the variable expansion of the different materials being used.

Expensive tools and equipment are not required. However it is important that quality tools be used.

The correct use of the tools will ensure that a successful job is carried out with a maximum of safety.

Take care when handling and storing glass. Incorrect handling and storing can result in:

- Personal injury
- Costly breakages

3 EQUIPMENT AND MATERIALS

3.1 TOOLS

The following tools and equipment are used for glazing:

- Glass cutters
- Glazier's T square
- Hacking knife
- Putty knives

In addition, you will also need a:

- Wood chisel
- Hammer
- Nail punch
- Pliers

Glass cutters

There are three types of glass cutters used:

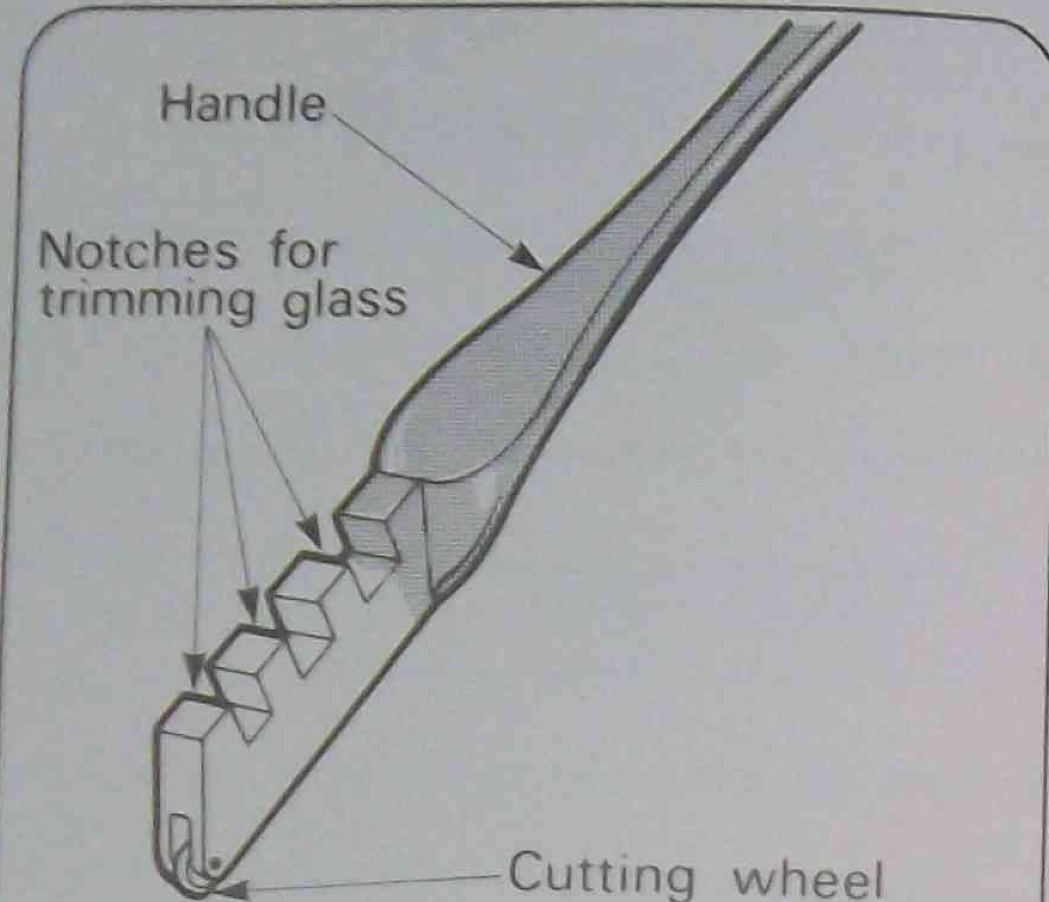
- Single-wheel type
- Multi-wheel type
- Diamond cutter

Single-wheel cutter

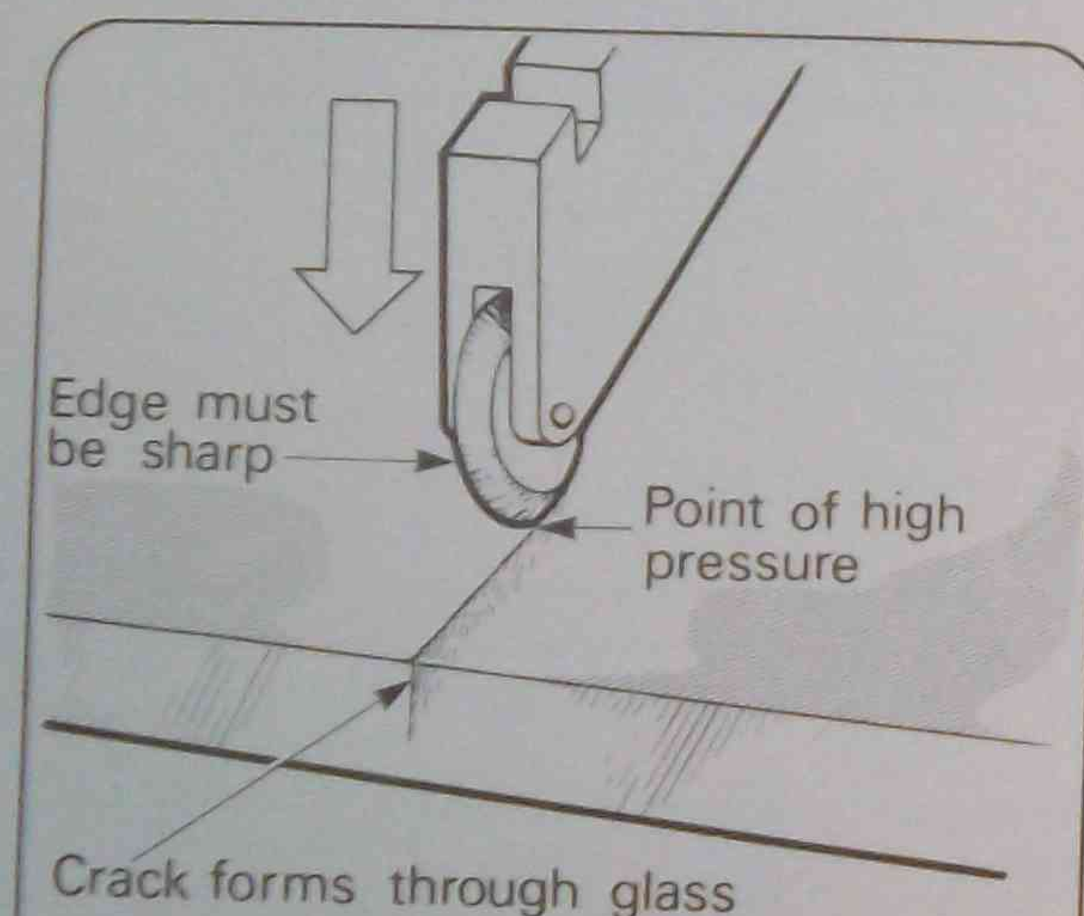
Consists of a rigid handle about 14 cms long fitted at one end with a small bevelled, hardened cutting wheel. Notches are provided along the back of the handle to trim edges off the glass.

Firm even pressure is applied by the handle to the cutting wheel edge. This creates a point of high pressure on the surface of the glass causing it to score and crack through its thickness. A plane of weakness is formed, along which the glass will break.

To successfully cut glass with a wheel type cutter, the edge must be sharp and the wheel rotate freely.



SINGLE WHEEL GLASS CUTTER



APPLY FIRM EVEN PRESSURE

If repeated passes across the glass are necessary, this usually indicates that the glass has scored but has not cracked successfully.

This could result from:

- The cutting wheel being worn or blunt.
- The wheel not rotating freely.
- Incorrect pressure (excessive) being applied to the cutter.


SINGLE WHEEL CUTTER

Multi-wheel cutter

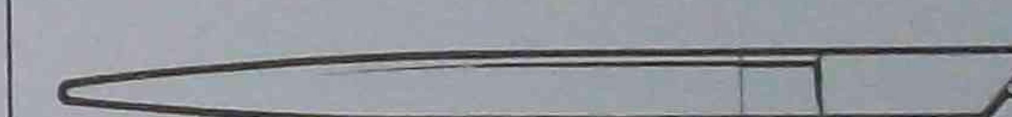
With this type of cutter a small turret, containing a number of cutting wheels, can be rotated to allow a new sharp wheel to be moved into position as the wheel being used becomes blunt and worn.


MULTI WHEEL CUTTER

Diamond cutter

A pointed, industrial grade diamond is fixed to a handle of similar size to the single-wheel cutter.

Light pressure is applied by the handle to the diamond, which being harder than the glass cuts a groove in the surface, forming a plane of weakness along which the glass breaks.


DIAMOND CUTTER

Glazier's T square

Made from wood or a light metal alloy. The cross-piece is notched to allow the glass cutter to start at the edge of the glass.

Hacking knife

A short solidly constructed knife, with the back of the cutting edge strengthened to allow blows from a hammer. This provides sufficient cutting pressure for the breaking up and removal of dried putty.

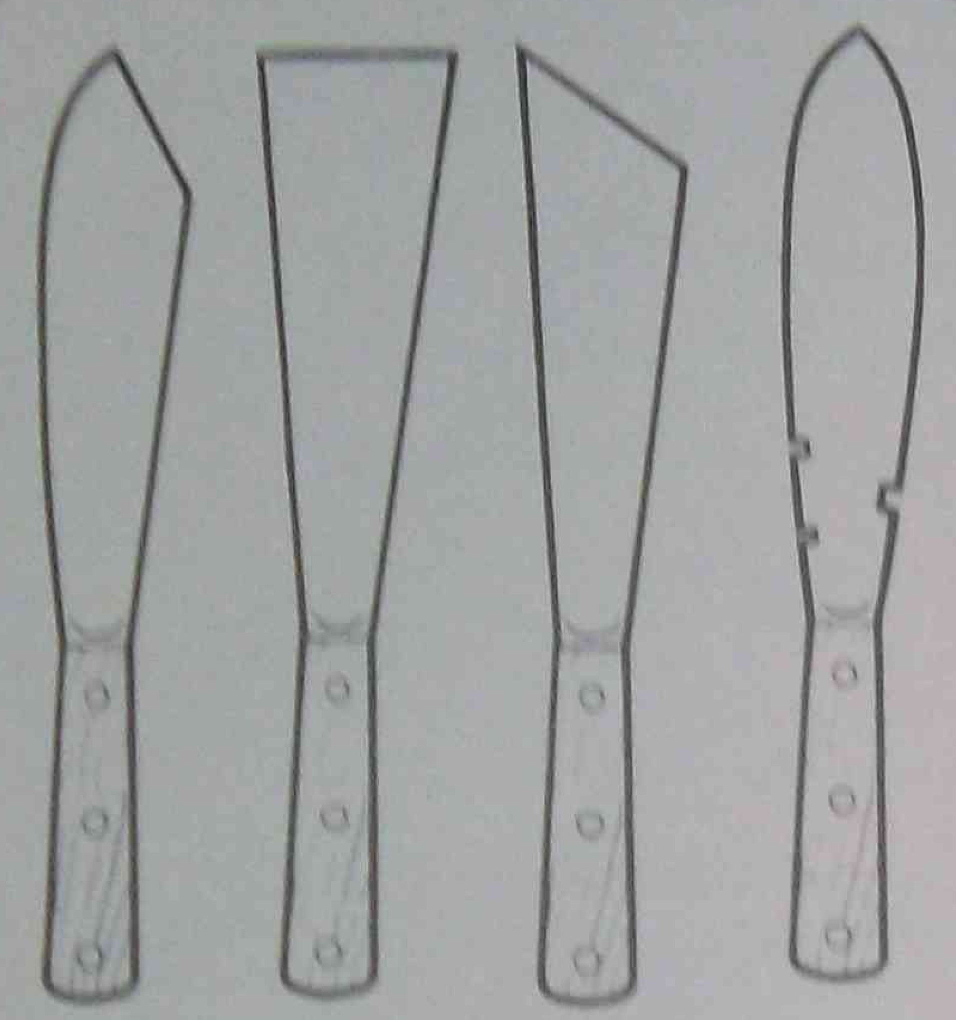

HACKING KNIFE

Putty knives

There are several shaped blades available. To give flexibility and strength, the blade and handle are formed by one continuous piece of steel. Wood or leather is riveted to the blade to provide an effective and comfortable grip.

Wood chisel

Approximately 12 mm wide. Used for removing some putty and generally cleaning up the rebates in timber windows prior to fixing the glass.



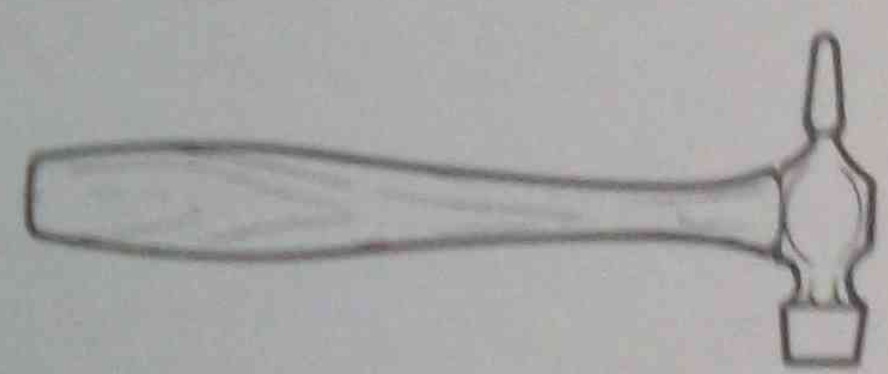
PUTTY KNIVES

Hammer

A special light weight hammer with one bevelled face. Used mainly for hammering brads and sprigs to hold the glass in place.

Nail punch

For driving brads below the surface when fixing the glazing beads.

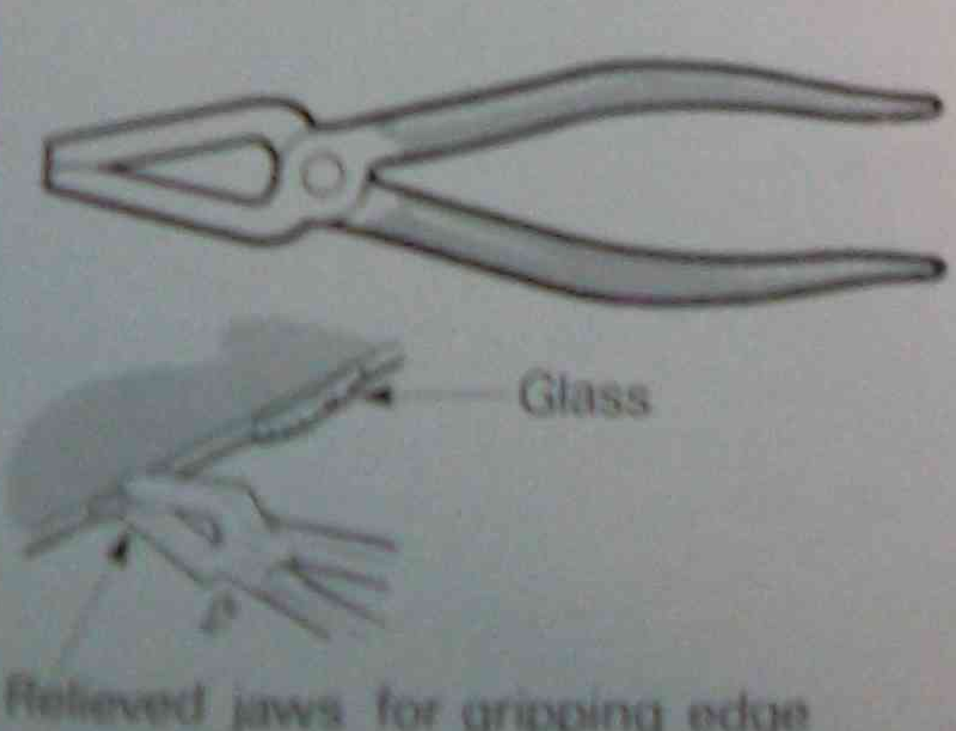


BRAD HAMMER

Pliers

Used for removing old sprigs and brads.

Special glass pliers with relieved jaws for gripping the edge of glass are available.



SPECIAL PLIERS FOR GLASS

3.2 FIXING MATERIALS

Sprigs

Wedge shaped nails approximately 15 mm long, or triangular shaped metal. Used for securing glass to timber frames.

Spring clips

Metal clips for securing glass in metal frames.

Beads

Simple timber mouldings used instead of putty on some doors and windows.

Brads or pins

Non-rusting small headed nails for fixing beads.

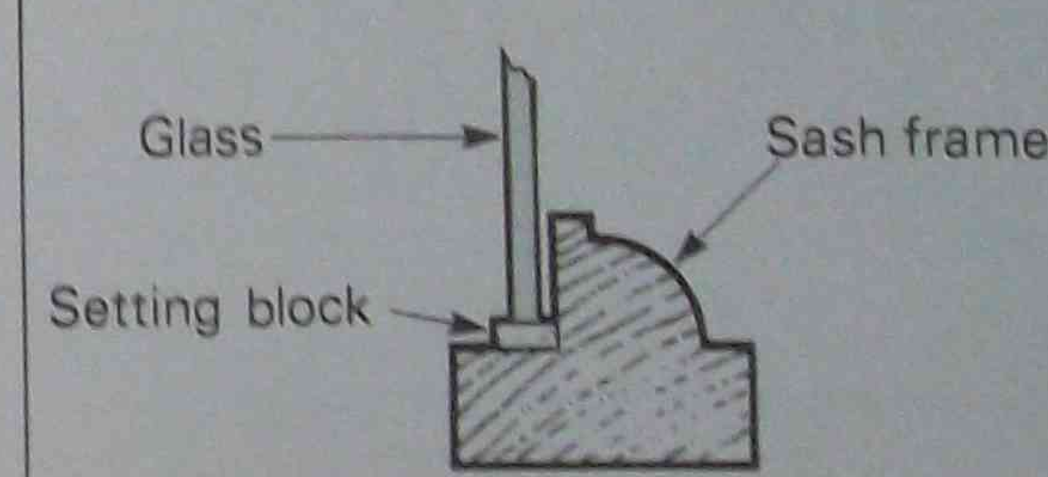
Screws

Non-rusting for securing beads if pins are not acceptable.

FIXING MATERIALS

Setting blocks

Pieces of PVC, hard rubber or similar material from 5 mm to 25 mm wide and 1 or 2 mm thick. The blocks are placed under the bottom edge of the glass to raise it sufficiently in order to centralise the glass in the frame.



USE OF SETTING BLOCKS

Putty

There are several types available:

- Linseed oil
  - — For domestic and industrial timber frames. Softens with linseed oil.
- Metal casement
  - — For industrial and domestic metal frames. Also for concrete and cement frames. Requires a special softener.
- Universal
  - — For either timber or metal frames. Soften with linseed oil.
  - — Special formulation.
- Glazing Compound
  - — For bedding glass in timber frames using face beads. Requires a special softener.

1 kilogram of putty is normally sufficient for approximately 3.5 to 4m run of glazing.

After use, scrape down the sides of the container to prevent wastage. Cover with waxed paper to keep the putty from drying out.

Handling putty

Apply water soluble barrier cream to your hands before handling putty, this makes it easier to remove when work is completed.

Wipe excess putty from your hands before handling glass to ensure a firm grip of the glass.

USE CORRECT PUTTY

USE PROTECTIVE CREAM

4 SAFETY

The following safety precautions must be observed at all times when glazing.

4.1 HANDLING GLASS

Use rubber pads, or wear leather gloves at all times when handling glass to protect your palms and hands from being cut by sharp edges of the glass.

4.2 CARRYING GLASS

Small panes of glass should be balanced centrally under one arm and steadied with the other hand on the front edge.

For larger panes, place one hand under the bottom edge and one at the front edge. Hold the glass firmly against the body.

It is safer to carry more than one pane at a time because this takes the whip out of the glass. The number to be carried depends on the size of the glass. Never attempt to carry more panes than can be comfortably held of lifted.

When glass is to be carried any distance, choose a clear path. If possible, one that has no scaffolding crossing it, low doors or uneven ground.

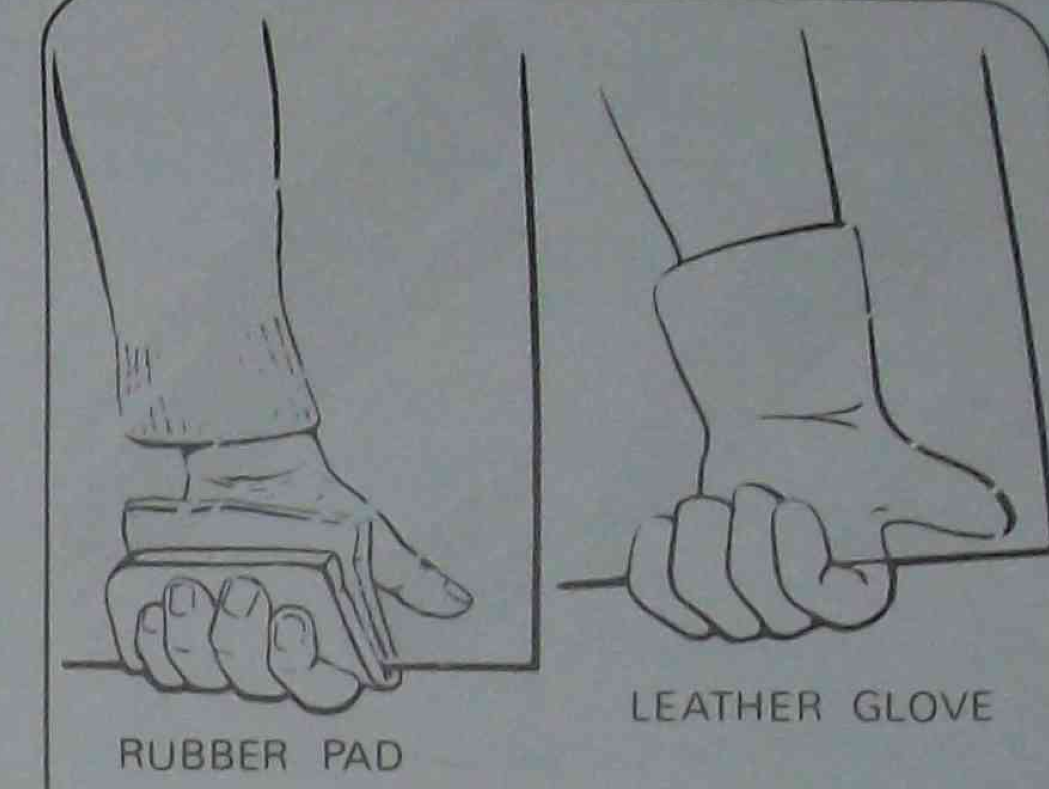
Never step back or stop suddenly; this could cause an accident.

4.3 STACKING GLASS

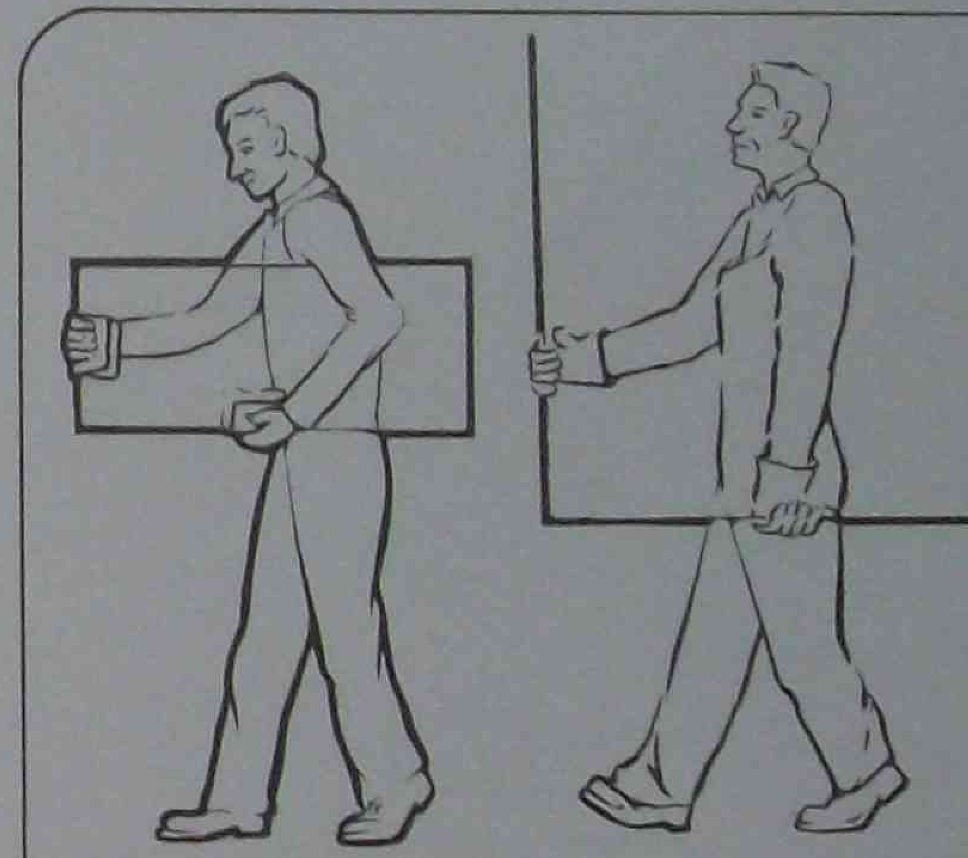
Never lay glass flat.

To prevent glass being accidentally stepped on, stand it on wooden or felt blocks almost upright (approximately 80 degrees) against a wall.

- Use felt pads to prevent the top edge of the glass coming into contact with the wall surface.
- Do not leave spaces between panes of glass; this could lead to warping and eventual breakage of the glass.



PROTECT HANDS WHEN CARRYING GLASS



CARRYING GLASS

- Always stack glass inside, out of the weather. If this is not possible, glass must be protected from the wind.
- Use wooden struts to support the back of large stacks of glass.
- Always handle glass carefully. Carry it vertically, with a pad between your hands and the sheet.

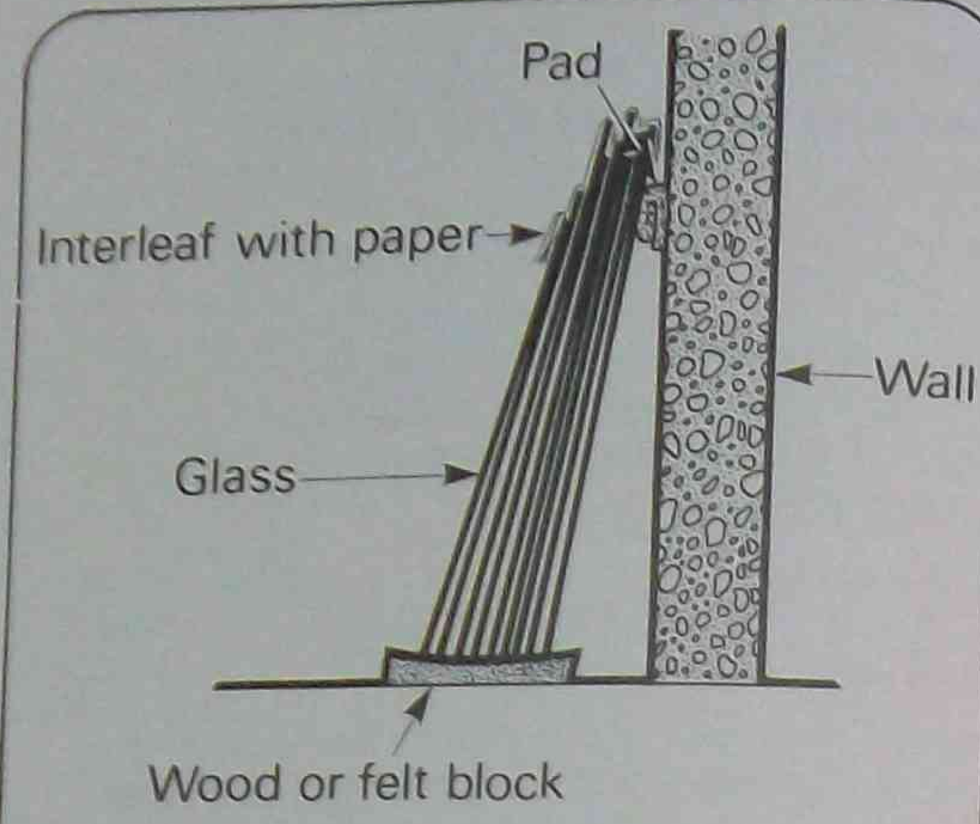
4.3.1 Storing glass

Glass must be clearly marked and stored away from any main passage way.

Use a spirit felt tip pen to mark the glass.

Indicate the size, weight or thickness.

Interleaf cloth or paper between panes when storing.



STACKING GLASS

5 MEASURING AND ORDERING GLASS

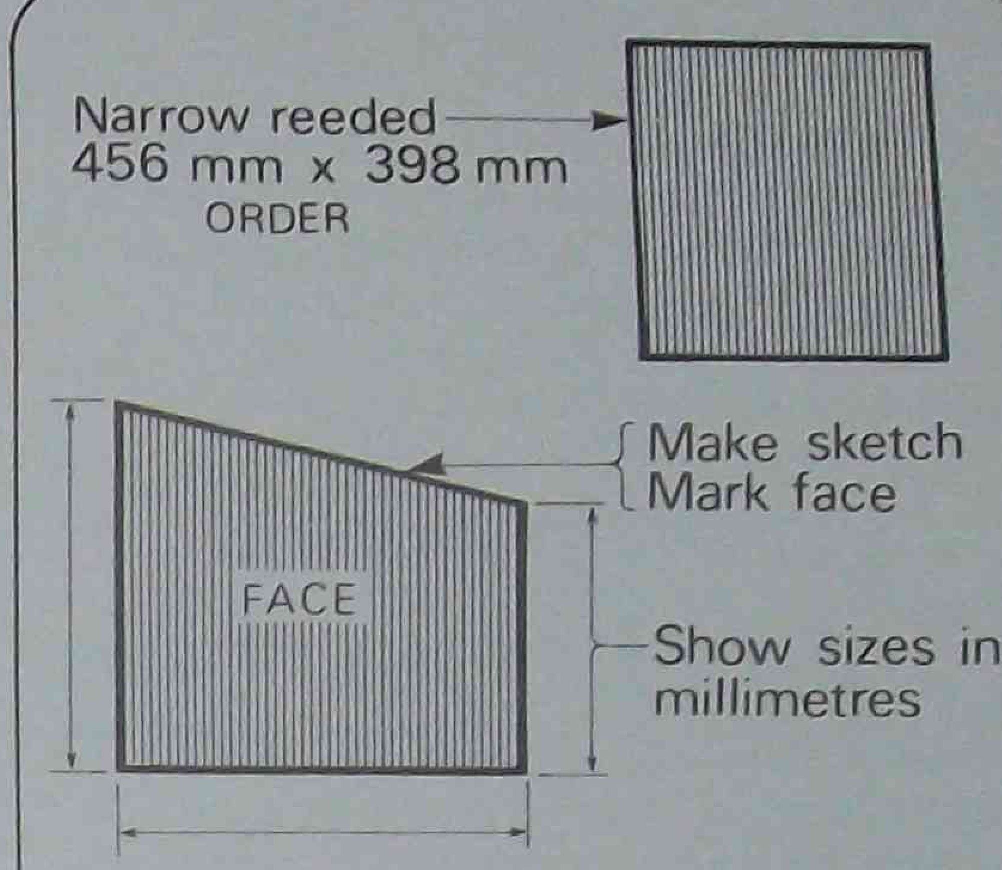
5.1 ORDERING

When ordering glass, always state the height first. This is to ensure that the pattern of some figured glass, such as reeded glass, is glazed the right way.

If figured glass is required to match existing glass, it is useful to supply a sample. Many textures are similar but not exact matches.

If the piece of glass is shaped other than rectangular, make a small sketch and mark the face. (Pattern side)

Sizes should be given in millimetres.



ORDERING GLASS

5.2 MEASURING

Daylight or sight size. D/S or S/S.

The measurement of space between the glazing bars.

Tight size. T/S.

The full measurement between each glazing rebate.

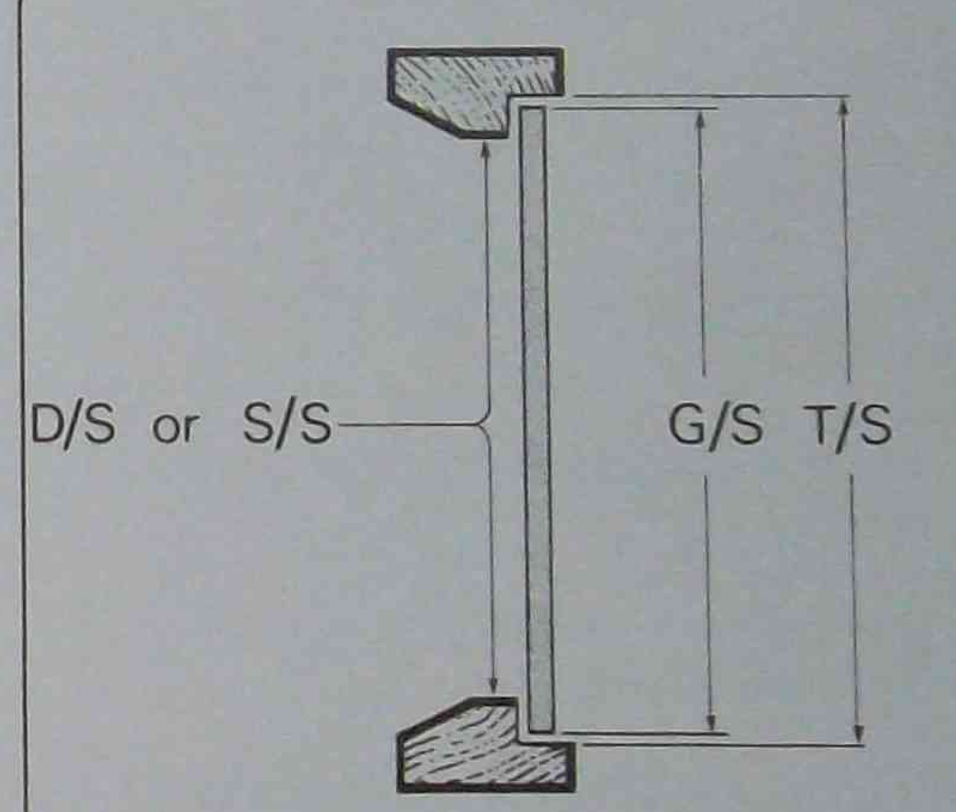
Glazing size. G/S.

The actual size of the glass.

When measuring daylight size ADD for glazing size.

When measuring tight size SUBTRACT for glazing size.

Allow 2 to 3 mm difference between Tight size and Glazing size to allow for expansion and contraction and slight variations in trueness of glazing rebates.



MEASURING GLASS

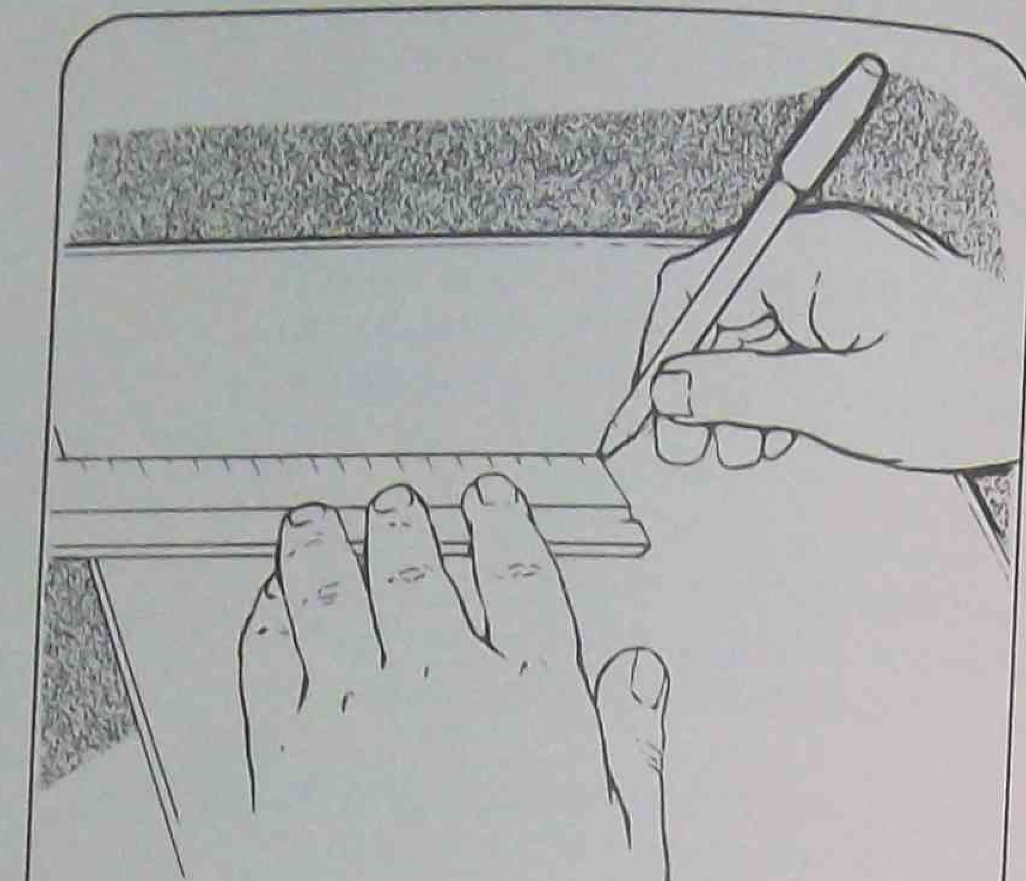
6 CUTTING GLASS

Glass should be cut on a firm flat surface. A bench or table covered with a thin felt pad or an old blanket is satisfactory. Newspaper can be used. This enables all slivers of glass to be collected and disposed off safely.

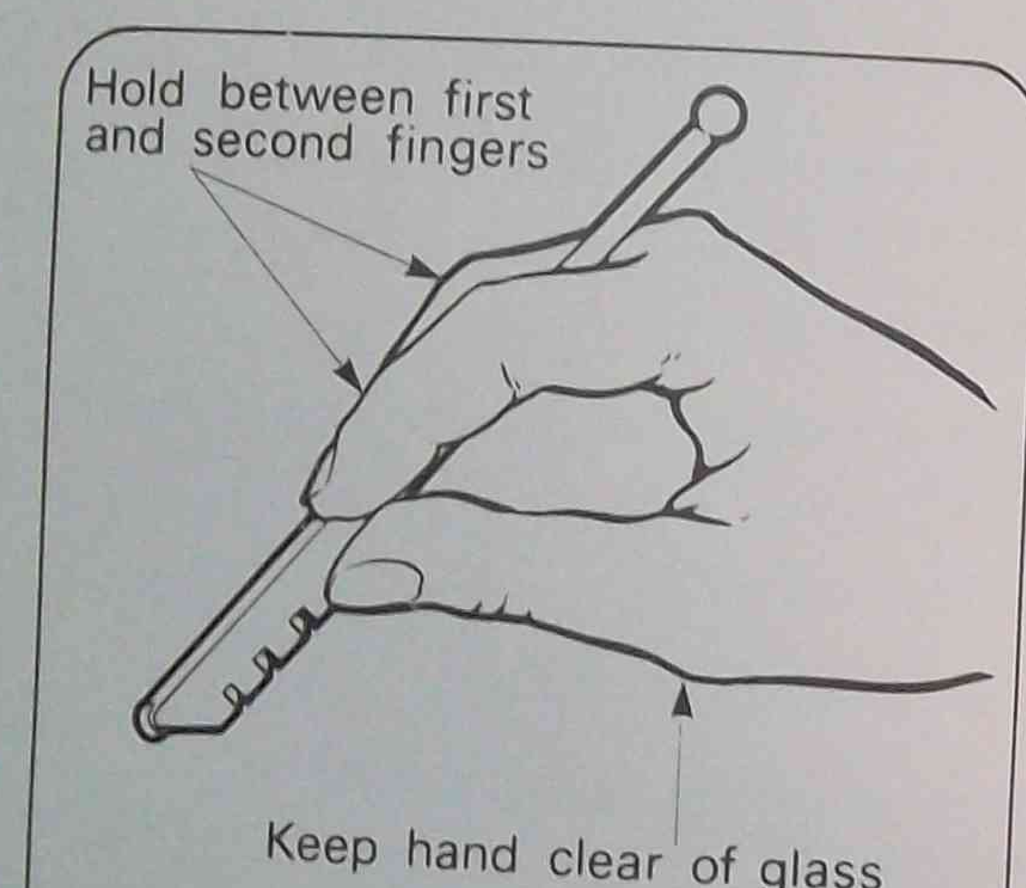
6.1 SCORING THE GLASS

To cut glass, use the following procedure:

- Wipe the area to be cut with a cloth dampened with turpentine to remove grease and dust.
- Lay the glass on the flat surface.
- Mark off the size to be cut with a marking pen and ruler.
- Hold a straight-edge, or T square firmly on the surface of the glass.
  - — Locate the edge close to the marked line to allow the wheel of the cutter to cover the line.
- Select a good quality single wheel cutter.
  - — The wheel must be sharp and rotate freely.
- Dip the cutter in kerosene or light oil to lubricate the wheel.
- Hold the cutter between the first and second finger, gripping the lower end firmly with your thumb and fingers.

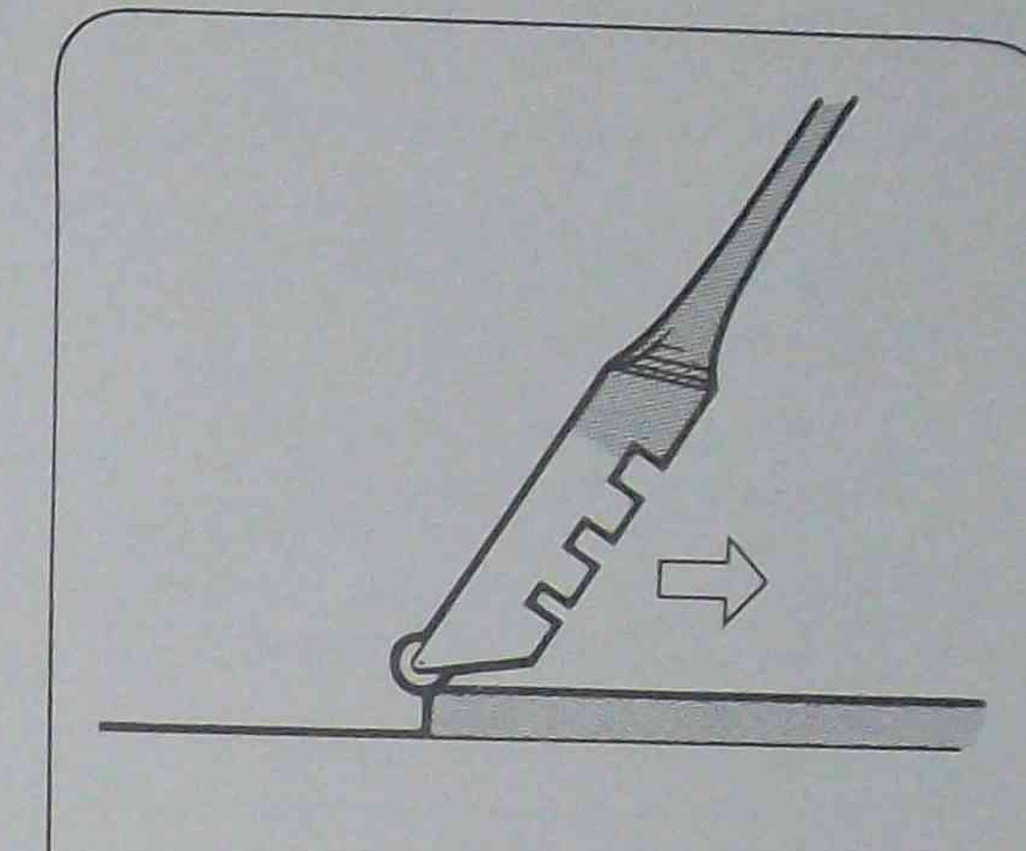


MARK OFF THE SIZE



HOLDING THE CUTTER

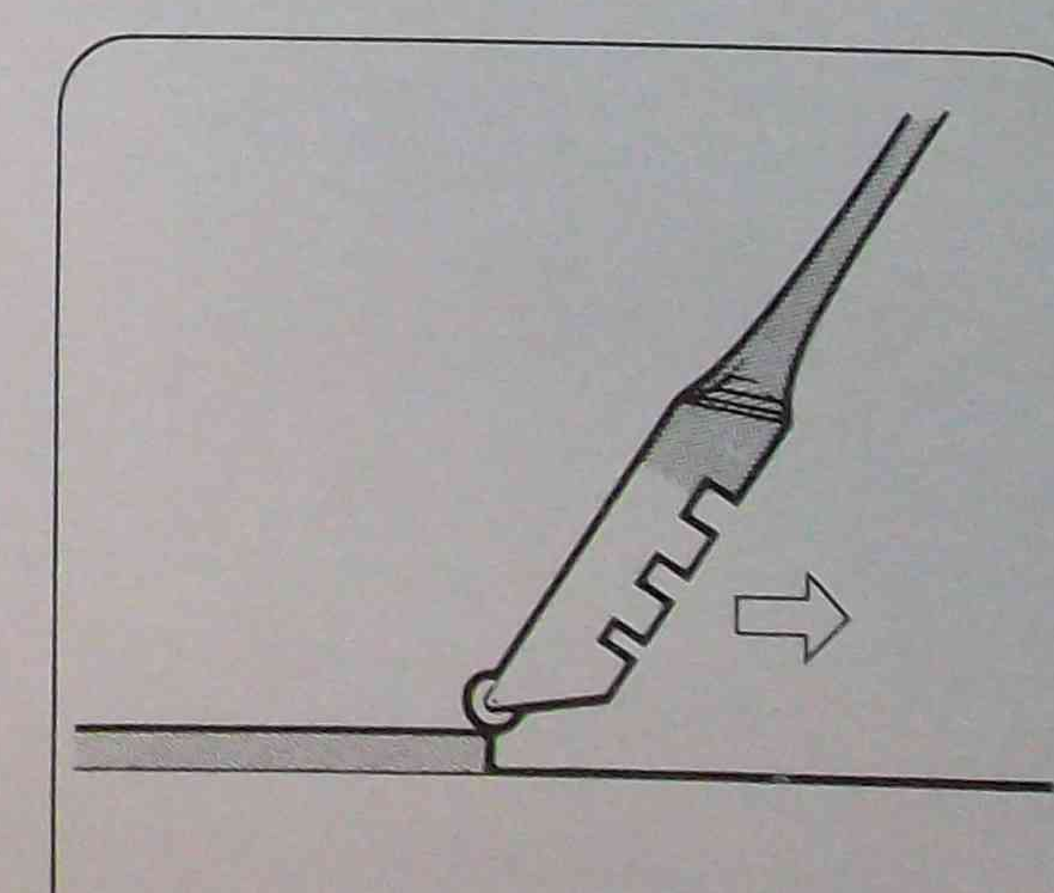
- Locate the edge of the cutter against the straight-edge, with the wheel directly on the line.
- Start scoring at the edge of the glass.



START SCORING AT THE EDGE OF THE GLASS

- Apply firm, even pressure and draw the cutter across the glass in a single stroke until it runs off the other edge.
  - — Make the movement with your arm, keeping your body still.

DRAW ACROSS IN A SINGLE STROKE



RUN OFF THE OTHER EDGE

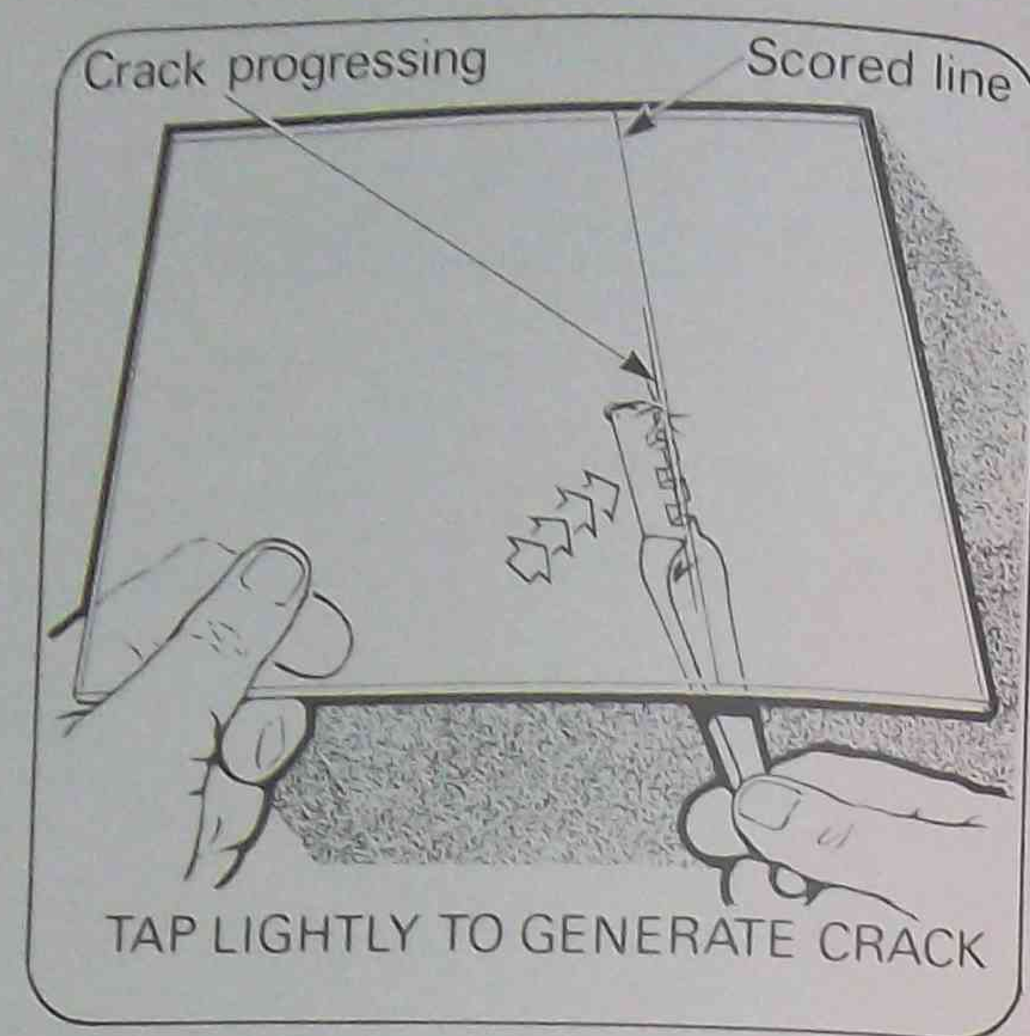
6.2 SNAPPING THE GLASS

When the glass has been scored:

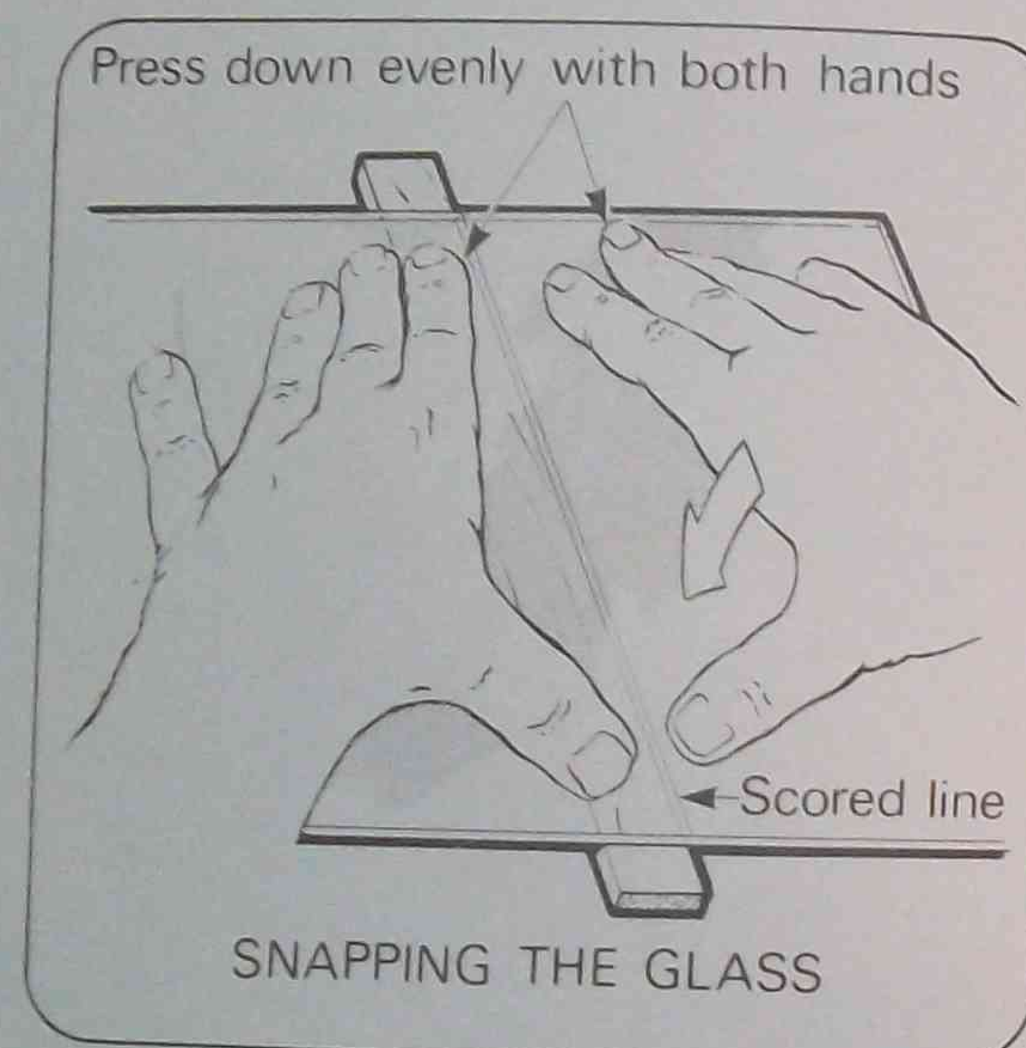
- Lift one end and gently tap the underside along the score mark, with the back edge of the cutter.
  - — This causes a split or crack to progress along the score mark.
- Hold the glass firmly with your thumbs and fingers on each side of the crack.
- Pull outwards and downwards to snap off the piece.

An alternative method of snapping the glass is as follows:

- After scoring, lay the glass on top of the straight-edge.
- Line the score mark up level with the edge of the straight-edge.
- Apply gentle but firm even pressure downwards with your fingers and thumbs to both sides of the score mark.
  - — The glass will snap cleanly along the mark.

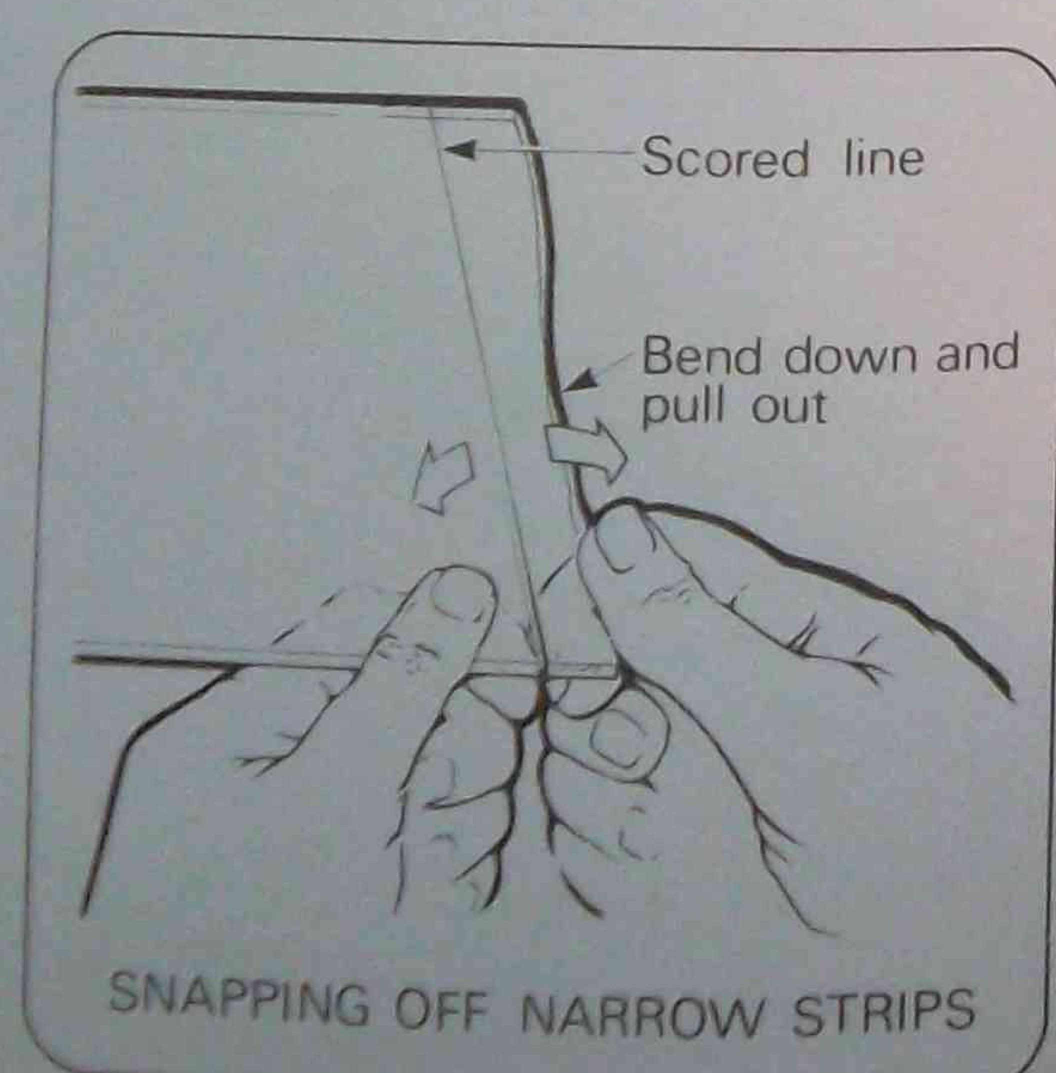


TAP LIGHTLY TO GENERATE CRACK



SNAPPING THE GLASS

If only a small strip has to be trimmed, snap off the piece along the score mark between the thumb and fore-finger.

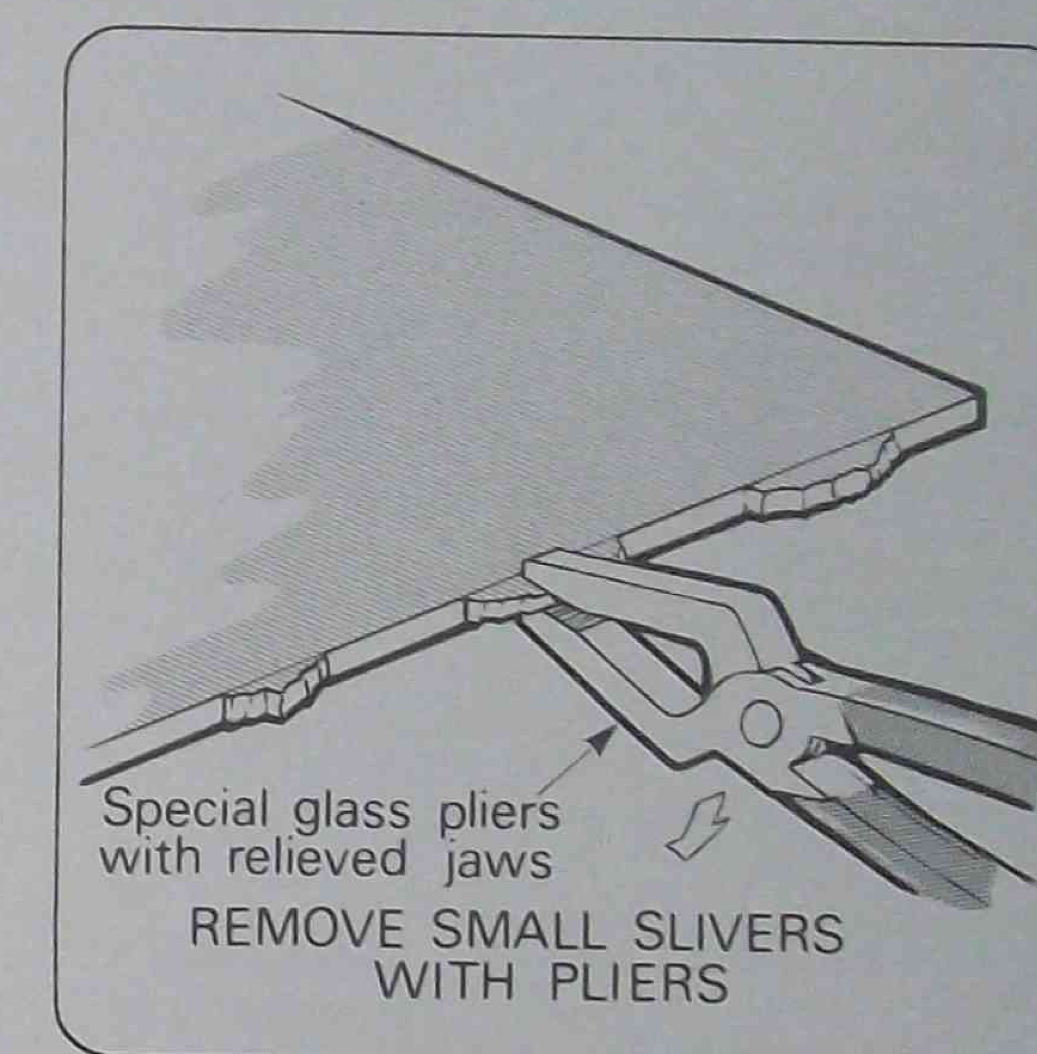


SNAPPING OFF NARROW STRIPS

On very narrow edges, trim the glass along the score line with the notches on the back of the glass cutter.

REMOVING NARROW STRIPS

Remove any remaining slivers of glass by nibbling them off with pliers.

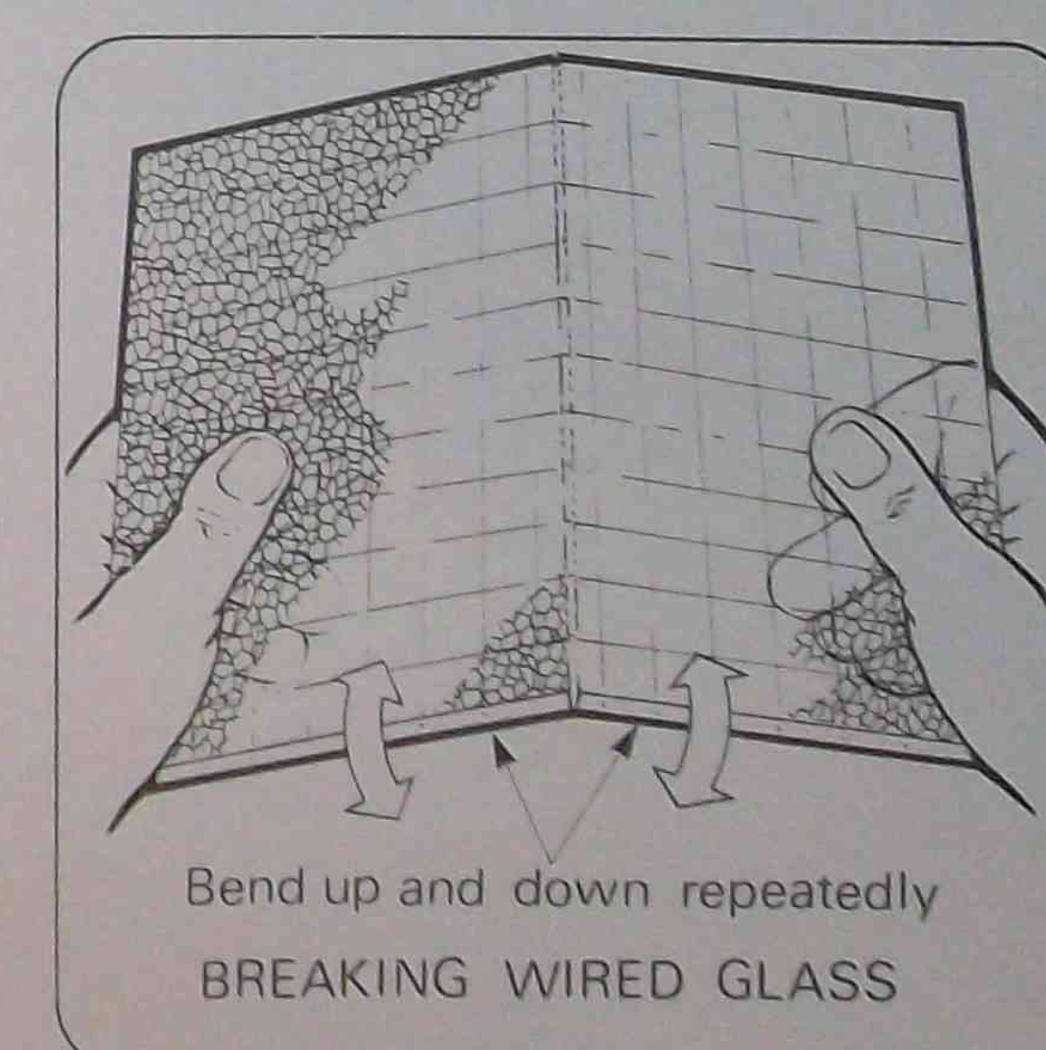


REMOVE SMALL SLIVERS WITH PLIERS

6.2.1 Wired glass

To cut wired (reinforced) glass

- Score and snap the glass as before.
- Work both pieces backwards and forwards to break the wire.
  - — If this is not successful, cut each wire with metal snips.



BREAKING WIRED GLASS

After glass has been cut:

- Smooth off the sharp and rough edges with a fine abrasive stone.
  - — Wet the stone.
- Rub from end to end, not across.
- Hold the stone about 45 degrees to the top of the glass.

REMOVE SHARP EDGES

7 REGLAZING

7.1 REMOVING GLASS

To remove a cracked or damaged pane of glass from a window, the following method can be used:

- Remove all furniture, curtains and fittings from the area.
- Cover immoveable fittings and floor covering.
- Make a cut with a glass cutter around the perimeter of the glass about 25 mm in from the putty.
- Tap the back of the glass to progress the crack.
- Carefully remove the centre.
- Cut the remainder into sections about 150 mm wide.
- Tap the cuts and ease out the pieces until all the glass has been removed.

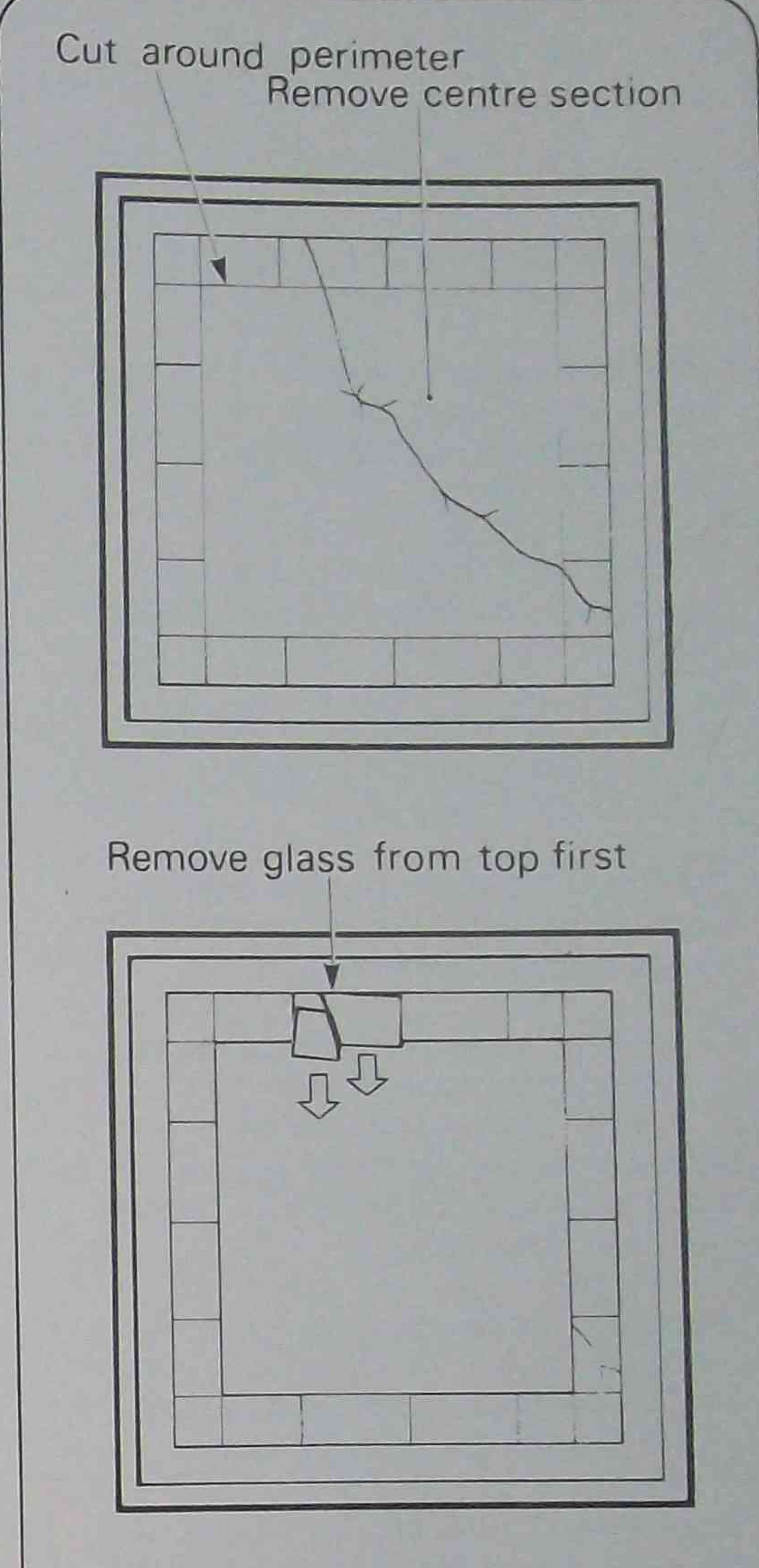
WARNING:

Never knock out old glass if the pieces are able to fall free. The pieces can be dangerous to people below or near the window, or they could cause damage to surrounding areas.

Paste paper or adhesive tape onto the glass before knocking it out.

This will hold the pieces together and prevent slivers from flying.

- Remove the glass from the top of the frame first and then work downwards.
- Wrap the pieces in newspaper and place them in a bin for safe disposal.
- Immediately sweep up and dispose of any fallen glass slivers.

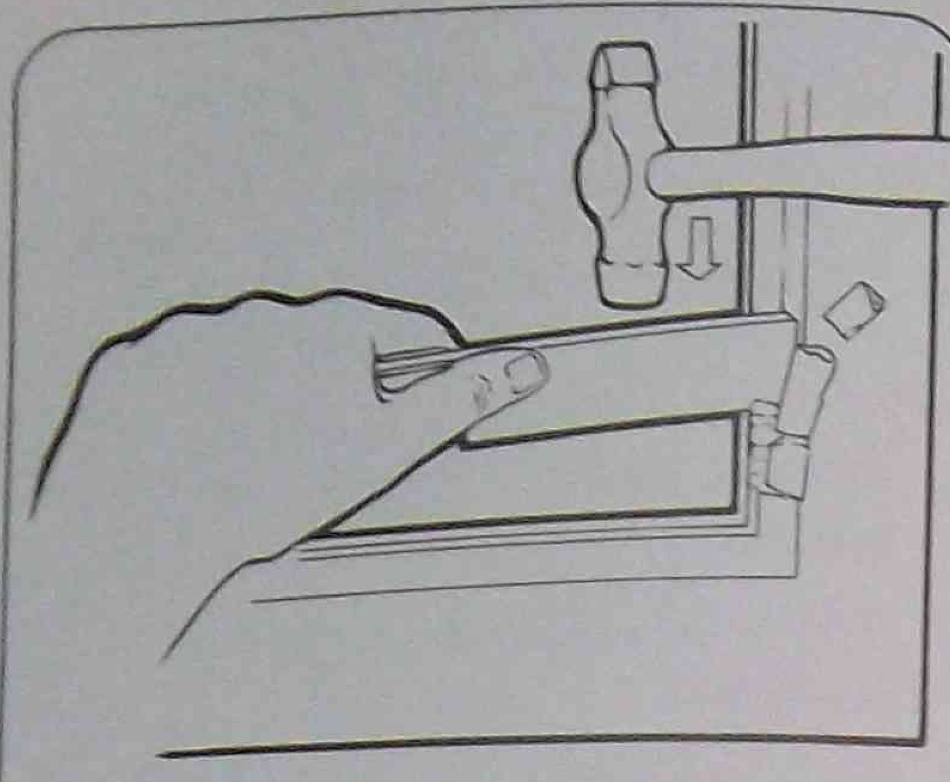


REMOVING BROKEN GLASS

7.2 REMOVING PUTTY

All glass must be removed before hacking out putty.

- Select a hacking knife or a wood chisel.
  - — Make sure the cutting edge is sharp to prevent damaging the frame.
- Hold the blade of the knife, or the back of the chisel, level with the rebate of the frame to prevent the edge cutting into the wood.
- Using a suitable hammer, drive the blade down the frame to break out the putty.
  - — Work in the direction of the grain whenever possible to avoid damaging the wood.
- Take care not to damage the cutting edge of the knife when approaching old sprigs and spring clips.
  - — Remove sprigs and clips with pliers before continuing.
- Be careful along the bottom rail of metal window frames where corrosion may have occurred.
- Remove all traces of putty.
  - — Clear putty from the location holes for spring clips in metal frames.
- Brush down the rebates and frame. Clean the area and dispose of the old putty.
- Paint the rebates with a suitable primer and allow to dry.



REMOVING PUTTY WITH A HACKING KNIFE

REMOVING PUTTY WITH A CHISEL

7.3 PREPARING THE FRAME FOR GLAZING

New metal frames

These are almost invariably treated with a bonding agent or primer or sometimes coated with an anti-corrosive paint and are ready for immediate glazing.

Old metal frames

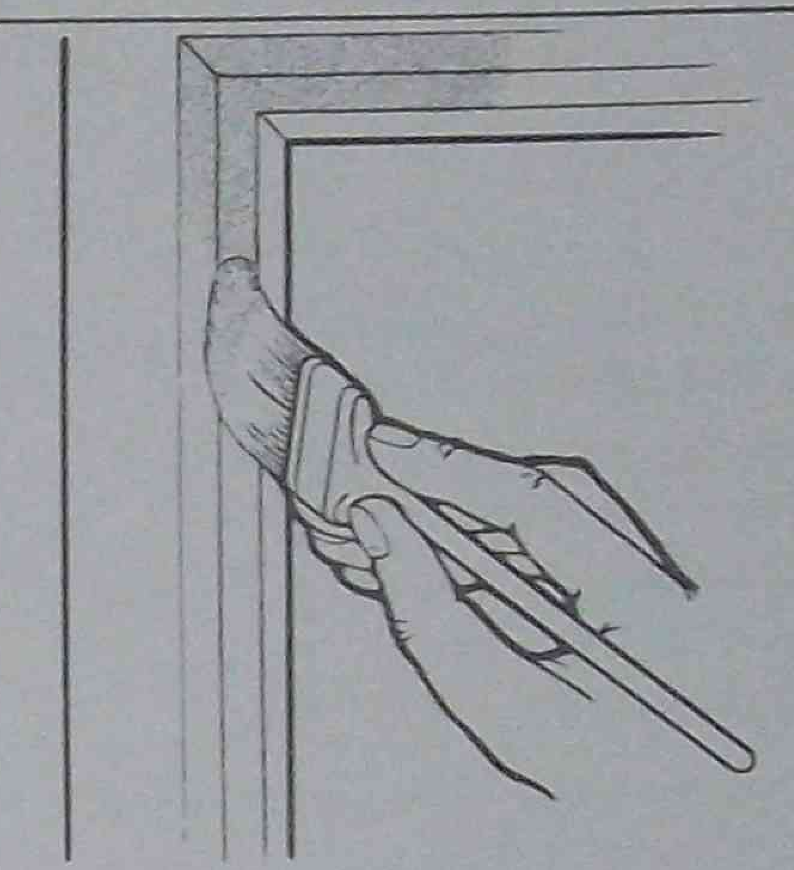
Any broken glass, old putty and pins and beads must be removed. Rusted screws, if difficult to remove, can often be eased by soaking with either kerosene or penetrating oil. Retaining pins or inner sashes will have to be knocked through and any damage to adjoining putty must be repaired at a later stage. Old putty can be knocked out with a hacking knife. Clean up and prime any rust spots before reglazing.

New wooden frames

If not already painted, new wooden frames require a coat of primer before glazing. Unpainted or absorbent wood surfaces will absorb the oil from the putty which will soon lose its grip and drop out.

Old wooden frames

After the glass and old putty have been knocked out, scrape the rebate clean and prime the surface.



PRIME THE REBATE

7.4 PREPARING THE PUTTY

Putty has to be at the right consistency for use.

To obtain the correct consistency:

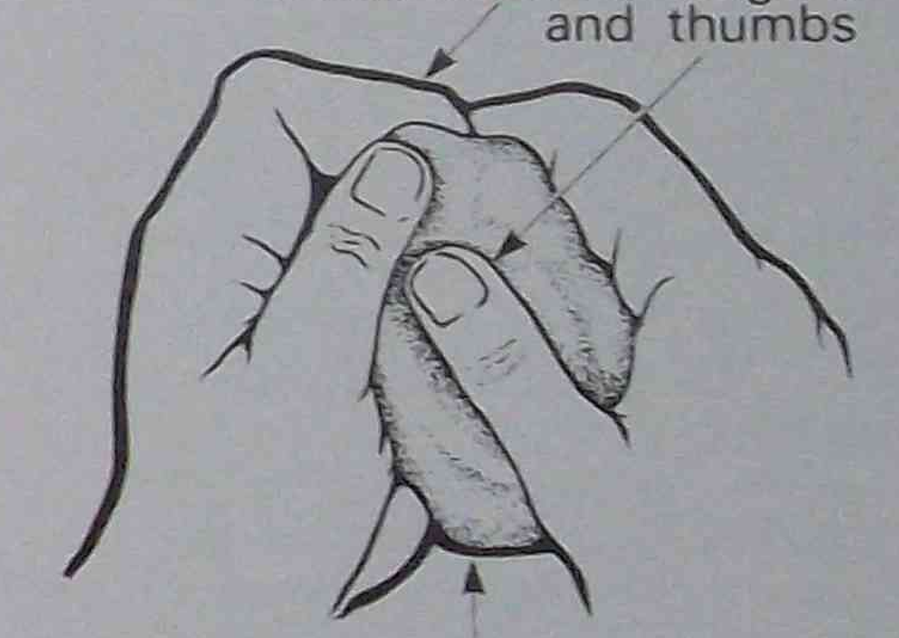
- Work the putty between your hands for about five minutes.
  - — Body heat will tend to soften the putty.

If after this time the putty is too dry and crumbles:

- Add a small amount of linseed oil.
  - — Use the special thinners if metal casement putty is being used.
- Continue kneading until soft.

If the putty is too sticky and does not leave your hands clean:

- Add a small amount of whiting.
- Continue kneading until the putty is soft, but firm.



WORK THE PUTTY UNTIL SOFT

8 PROCEDURE FOR GLAZING

Glass may be held securely by putty alone or putty with a bead.

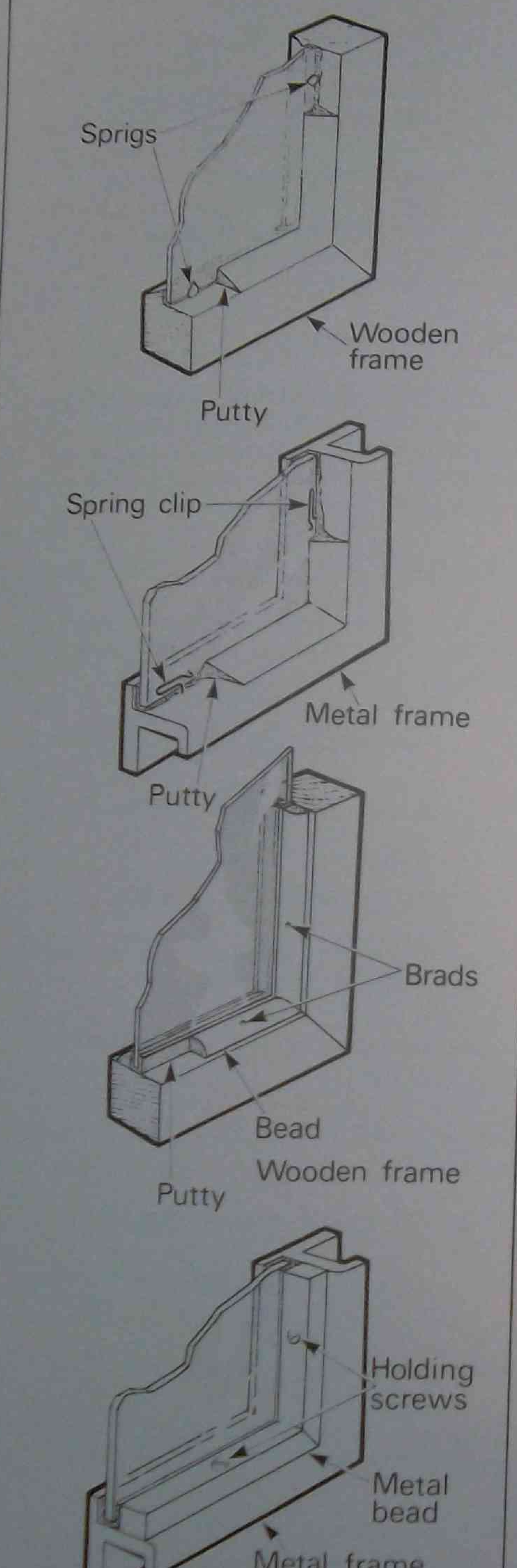
8.1 USING PUTTY ALONE

Glazing a window using putty alone.

- Place several setting blocks in position in the rebate.
- Press a thin cushion of soft putty on to the entire frame surround.
- Press the glass evenly and firmly against the putty.
- Insert brads.
- Tap the brads in carefully using a light weight hammer.
- Keep the hammer head against the surface of the glass when tapping the brads.
  - — Leave about 1/3 of the length of the brad out of the rebate.
- Press a retaining layer of putty against the glass.
- Smooth off the putty at an angle level with the edge of the rebate.

8.2 USING PUTTY WITH A BEAD

- Prepare and set the glass as before.
- Instead of retaining putty, place a further thin cushion of soft putty against the glass.
  - — If the bead is on the inside of the window it can be fitted tightly against the glass without any further putty.
  - — A bead on the outside of the window requires a bed of putty to seal the gap between the bead and the glass.
- Fit the bottom bead first and secure it with brads or clips.
  - — Do not drive the brads down fully at this stage.
- Fit both vertical beads.
- Slide, or spring in the top bead.
- Make sure the beads are in contact with the glass or the putty. Tap down the brads and punch them below the surface.
- Clean away any excess putty.

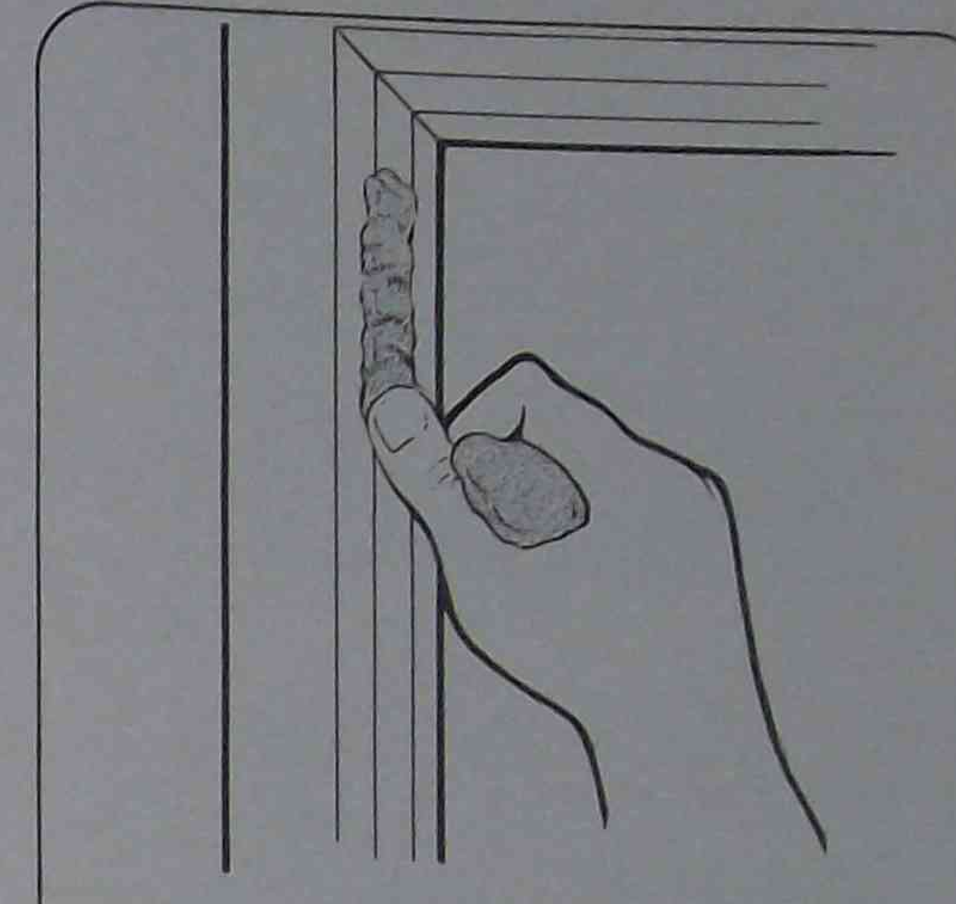


METHOD OF GLAZING WOODEN AND METAL FRAMES

8.3 GLAZING A TIMBER FRAME

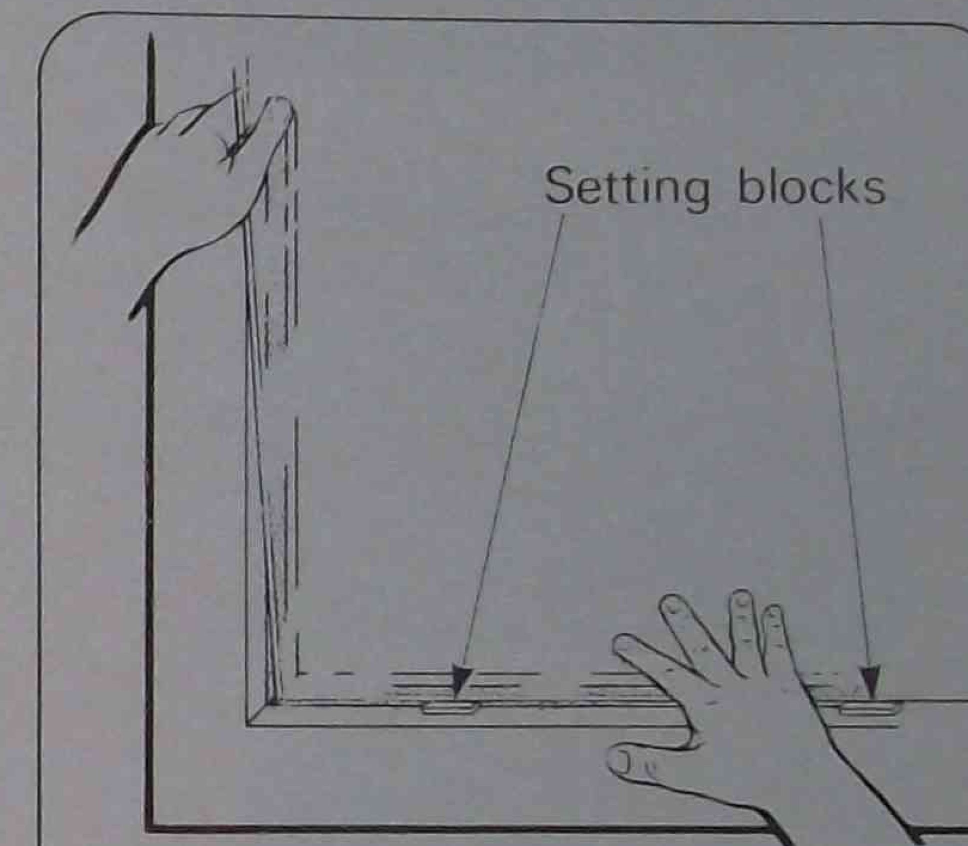
- Push bedding putty into the rebate with your thumb.

  If the pane is larger than 0.2sq.m (450x450mm) place two setting blocks on the bottom rebate between 75 and 150mm from each end.



PUSH BEDDING PUTTY INTO REBATE

- Place the bottom of the glass on the blocks and push into place.
  - — When using textured glass, keep smooth face on putty side.
- Apply pressure around the edge of the glass to obtain good contact with the bedding putty.
  - — Thickness of bedding putty on completion should be between 2 and 4 mm.

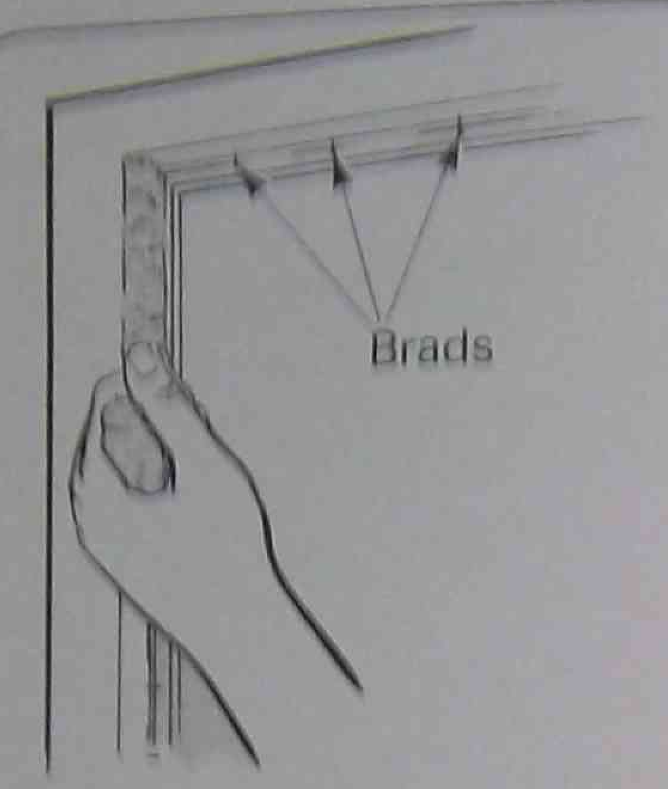


PRESS THE GLASS EVENLY AND FIRMLY

- Tap sprigs or brads into the rebate to hold glass firmly while the putty sets.
  - — Space them between 225 mm and 450 mm apart. Sprigs must be flush with glass.

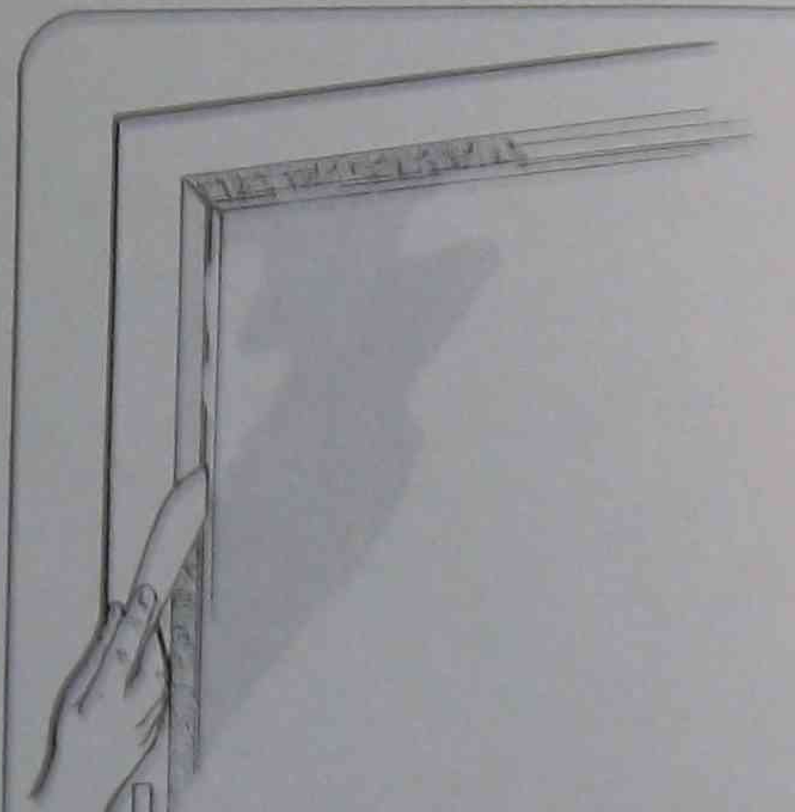
TAP IN BRADS TO HOLD GLASS

- Apply face putty with your thumb to fill the remainder of rebate.
- Smooth the putty using a putty knife. Run the flat edge of the blade along glass.
  - Top of the putty should be about 2 mm below sight line, so that when it is painted, the paint will encroach on the glass to seal the gap.



PRESS RETAINING PUTTY AGAINST GLASS

- Smooth off the bedding putty.
- Paint the putty as soon as it is hard enough to stand the pressure of the brush and no longer than two weeks after completion.
  - Some metal casement putty require a different length of time.


SMOOTH PUTTY LEVEL WITH EDGE OF REBATE

8.4 GLAZING A METAL FRAME

The method is basically the same as for glazing a timber frame, except that instead of using sprigs to hold the glass in position, metal clips are used.

These clips vary in design therefore, when removing old glass note how the clips are fitted.

Usually one end of the clip fits into a hole drilled in the vertical rebates, the other end is clamped over the glass, and maintains sufficient tension to hold the glass in place.

9 TYPES OF GLASS

9.1 CLEAR GLASS

Available in sheet form and manufactured by a newly developed process. The product is completely transparent, both surfaces being flat, parallel and completely distortion free. It can be made up to any thickness from 10 oz to 32 oz (1.2 mm to 4 mm thick).

Horticultural glass

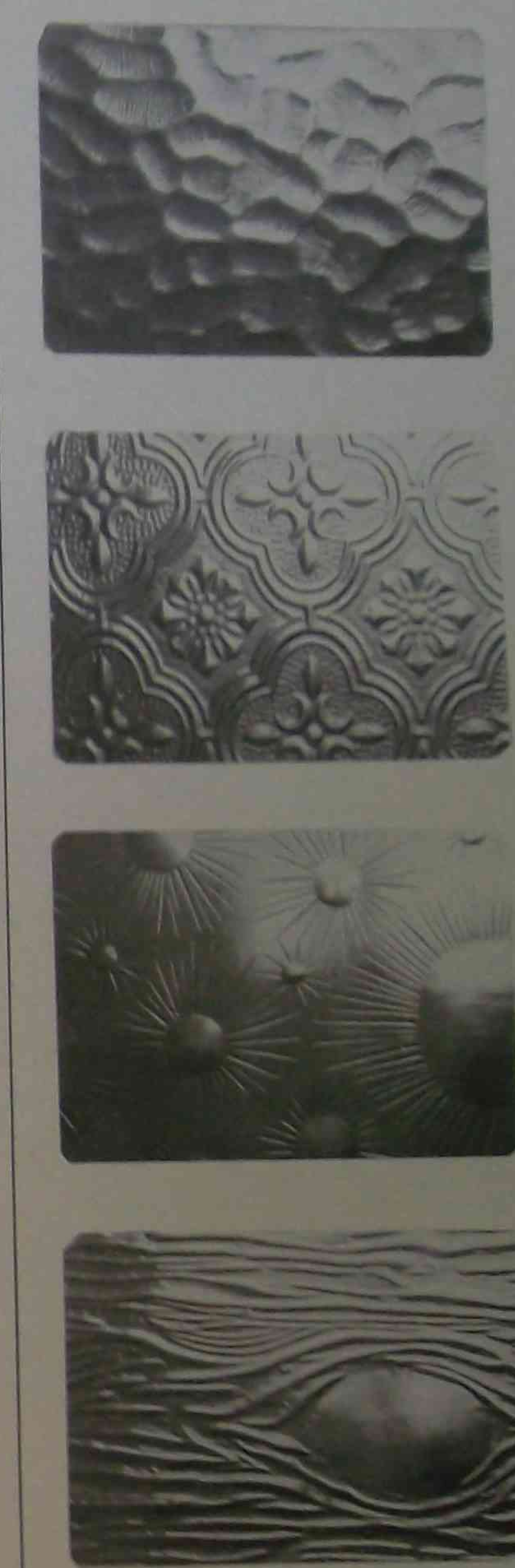
A lower grade of sheet glass suitable for greenhouses.

Plate glass

A higher grade of glass which is ground and polished to provide flat and parallel surfaces. Used for mirrors, as shelving, glass table-tops and shop windows.

9.2 PATTERNED GLASS

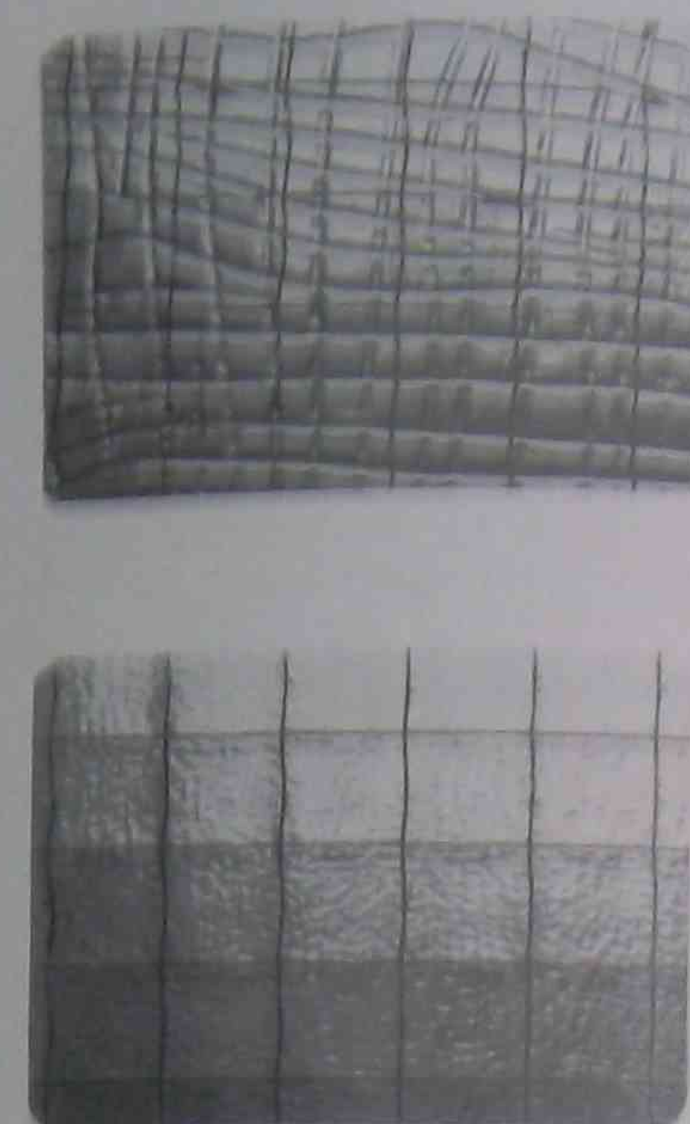
Various designs are either cast or sand-blasted during manufacture. Allows 70-85 per cent of the light to pass through and is vision-obscured. Used for decoration in door panels and in areas where privacy is required.


PATTERNED GLASS

9.3 WIRED GLASS

Wire mesh is inserted during manufacture to provide maximum protection against shock.

This glass is ideal for areas where safety is of paramount importance. Wired glass is safe, as it holds any smashed fragments together. It is also fire-retardent and comes in clear and semi-obscure patterns.



WIRED GLASS

10 PRACTICAL EXERCISE

Reglazing A Window Sash

Objective:

To remove a broken pane and replace it with Arctic (obscure) glass. Window opening size 400 x 800 mm.

Procedure:

- Protect adjacent surfaces from damage. Spread a drop sheet or other protective covering to collect all splinters and broken glass.
- Carefully remove all broken glass.
  - Wrap in sheets of old newspapers and place it in a refuse bin.
- Hack out existing putty.
- Tidy up the surrounding area by sweeping and dispose of all putty and broken glass.
- Prime the exposed rebate with a suitable alkyd-based wood primer.
- Select Arctic glass of suitable pattern.
- Measure glass, and using a single-wheel glass cutter and glaziers straight-edge, cut the glass to fit loosely in the frame. (Approximately 396 x 796 mm).
  - Cut glass on smooth side.
- Divide approximately 400 gms of putty into three parts. Knead 1/3 into a soft state, for use as bedding putty. Soften remaining putty and use as glazing putty.
- Apply the bedding putty.
- Press the glass evenly but firmly into frame and onto bed putty. Apply even pressure along sides close to rebate.
- Position and knock in metal pins (brads) to hold glass in place. Keep brads just below line of inside rebate.
- Apply weathering putty onto the exterior of glass and press firmly into position.
- Trim and smooth up the putty with a suitable glazing putty knife.
- Trim all surplus putty from inside of the sash.

NOTES FOR THE INSTRUCTOR

In these Training Manuals the term 'instructor' refers to any person who may train or be directly responsible for training individuals.

For example, the task of instructing may be the sole or shared responsibility of:

—skilled tradesmen

—leading hands

—foremen

—instructors

—apprentice masters

—managers

INITIAL PLANNING

A Analyse:

- The training requirements of a newcomer, considering that the person:

  —may have no previous experience in the subject;

  —will need to do productive work as soon as possible.

- What the trainee must learn about:

  —the tools he is to use for the subject;

  —the terminology involved in the subject;

  —basic working methods.

- What will be the first productive work you will be able to give the trainee.

B Decide:

- Whether your trainees need information to supplement that given in this manual.
- Whether or when additional training material or exercises will be required to improve on the skill gained.
- Which other Basic Training Manuals the trainee should use during training.

C Plan:

The explanations, demonstrations and the practice required by the trainee, preferably on an individual basis, if numbers allow.

USING THE MANUAL

It may be of assistance to the trainee to arrange for short periods of learning followed by short periods of practice in applying the knowledge gained.

To maintain interest, it will be useful to relate, as much as possible, the material treated in this manual with actual practical applications in the field.

PRACTICAL EXERCISES AND PROJECTS

There may be areas and tasks in actual situations where the developing skills of the trainee can be put to effective productive use at any stage during the period he is learning the subject. Such possibility should be carefully considered and used to the full for the trainee's benefit as well as that of the firm.

Give the trainee as many opportunities as possible to use the whole range of hand tools on suitable small jobs to enable him to acquire quickly the manual dexterity required.

Small projects and exercises to suit particular work situations may be devised, but they must take into consideration the limits of skill and knowledge of the trainee.

Whatever form of exercise is used to develop practical skill, it must be carefully planned. A suggested course of instruction is:

- Prepare the working area, the materials and the hand tools to be used.
- Make the aim of the project clear to the trainee.
- State how you intend to assess the proficiency of the trainee.
- Stress key points in the project, paying particular attention to safety precautions.
- Explain clearly and thoroughly any new steps in the project.
- Check that the trainee can use the hand tools correctly.
- Assess the finished project, record the results and discuss with the trainee your appraisal of his performance.
- If you are satisfied with his performance, direct the trainee to the next exercise or project.

TRAINING RECORDS

Simple training records will help in planning systematic training.

Record:

- the parts of the manual learnt by the trainee;
- your assessment of the general skills developed;
- the practical exercises undertaken and completed.

Use your record to measure the trainee's performance and to assess his readiness for undertaking actual operations.

Draw up a simple record card to suit your needs.

Using records helps to pinpoint the trainee's strengths and weaknesses. They ensure that training in essential skills is not missed. Training records can be used to help co-ordinate on-the-job training and technical school learning. Where trainees have to serve a probationary period, records assist when the trainee's progress is being assessed.

AUSTRALIAN STANDARDS FOR CIVIL ENGINEERING STUDENTS

PART 2: STRUCTURAL ENGINEERING

STANDARDS AUSTRALIA

Australian Standards for civil engineering students

SAA HB2.2—1995

Part 2
Structural engineering

Originated as part of SAA HB2—1982.
Previous edition 1991.
Fifth edition 1995.

PUBLISHED BY STANDARDS AUSTRALIA
1 The Crescent Homebush NSW 2140

INTRODUCTION

This is the fifth edition (1995) of Part 2 of the handbook, which was first published by Standards Australia in 1982 as a text book of abridged Standards suited to civil engineering subjects taught at tertiary level. The continuing intention is to make Standards more readily accessible to students and educational institutions.

Because of tightened copyright laws and the increased surveillance of copyright breaches, by 1981 the organization had become aware of a real need for a publication of this type. Lecturers from schools of civil engineering were asking for rights to copy and reproduce Standards, because purchase of Standards in their complete form was financially beyond most students. The handbook was therefore designed to fill the requirements of both students and lecturers for a copy of commonly used parts of relevant Standards at a reasonable cost.

This handbook was prepared by Standards Australia in consultation with Schools and Departments of Civil Engineering and Building in Universities, Institutes of Technology and Colleges of Technical and Further Education in all states. It is not an Australian Standard but comprises extracts from selected Australian Standards considered relevant to undergraduate courses in civil engineering and advanced courses in building and building sciences. It is hoped that by this means, students will be better able to understand and use Standards when they enter the workforce.

Extracts in this part of the handbook were selected to familiarize students with the nature and extent of structural engineering Standards and the type of constraints they impose on persons working in the building industry. While extracts include portions of Standards which refer to frequently encountered situations they do not contain all requirements that may be of critical importance to their assessment. In addition, while the Standards from which these extracts were taken were current editions at the time of publication of this handbook, at any subsequent time the relevant Standards may have been amended or superseded.

For the foregoing reasons, this book should only be used for educational purposes. Standards Australia does not accept any liability for any consequences that may result from the use of the book for any purpose other than student instruction.

Views of teachers and students on this book will be welcomed by Standards Australia particularly on inclusions of additional material or the deletion of other material in future revisions. Because these are extracts, it will be noted that in some cases Standards are referred to which are not included in the book.

Listed on the back cover are the addresses of Standards Australia offices and sales outlets where the publication may be purchased directly.

CONTENTS

LIST OF REFERENCED DOCUMENTS

This handbook contains edited extracts from the following documents:

AS 1170	SAA Loading Code Part 1—Dead and live loads and load combinations Part 2—Wind loads
AS 1720	SAA Timber Structures Code Part 1—Design methods
AS 2870	Residential slabs and footings Part 1—Construction
AS 3600	Concrete structures
AS 4100	Steel structures
AS 3700	Masonry in buildings

Originated as part of SAA HB2—1982.
Previous edition SAA HB2.2—1991.
Fifth edition 1995.

STANDARDS AUSTRALIA

Australian Standard

Concrete structures

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE AND APPLICATION

1.1.1 Scope This Standard sets out minimum requirements for the design and construction of concrete structures and members which contain reinforcing steel, or tendons, or both. It also sets out minimum requirements for plain concrete members.

NOTE: This Standard will be referenced in the Building Code of Australia by way of BCA Amendment 7 intended for publication in November 1994, thereby superseding the previous edition, AS 3600—1988, which will be withdrawn 12 months from the date of publication of this edition.

Users are advised that when BCA Amendment 7 is issued, it will not necessarily be gazetted in each State/Territory at the time of printing.

1.1.2 Application This Standard is intended to apply to structures made of concrete—

(a) with a characteristic compressive strength at 28 days, f'_c, in the range of 20 MPa to 50 MPa; and

(b) of saturated, surface-dry density in the range of 1800 kg/m^3 to 2800 kg/m^3.

This Standard may be applied to concrete bridges. However, the design Standards of the relevant bridge authority, namely the Austroads Bridge Design Code for road bridges and the ANZRC Railway Bridge Design Manual for railway bridges, shall be used where applicable.

The general principles of concrete design and construction embodied in this Standard may be applied to concrete other than that specified above, or to concrete structures or members not specifically mentioned herein.

This Standard is not intended to apply to the design of mass concrete structures. It is also not intended that the requirements of this Standard should take precedence over those of other Australian Standards.

NOTES:

1 It is intended that the design of a structure or member to which this Standard applies, be carried out by, or under the supervision of, an engineer as defined in Clause 1.6.2.

2 Consideration is being given to extending the application of the Standard to structures in which the characteristic compressive strength of concrete (f'_c) is greater than 50 MPa. However, before such an extension could be incorporated, current research data indicates that some requirements of the Standard would need to be more stringent than those presently given and others appropriately modified.

1.2 REFERENCED DOCUMENTS The Standards and other documents referred to in this Standard are listed in Appendix B.

1.3 INTERPRETATIONS AND USE OF ALTERNATIVE MATERIALS OR METHODS

1.3.1 General Provided that the requirements of Section 2 are met, this Standard shall not be interpreted so as to prevent the use of materials or methods of design or construction not specifically referred to herein.

1.3.2 Interpretations Where doubt arises concerning the meaning or effect of any part of this Standard, the matter may be referred to the SAA Committee for Concrete Structures for an interpretation of the intent of that part.

1.3.3 Use of other materials or methods If it is desired to seek the opinion of the SAA Committee on Concrete Structures as to whether materials other than those specified, or methods of design or construction not covered herein, are deemed to comply with the intention of this Standard, details of these materials or methods, including relevant test results, shall be submitted to the Committee.

NOTE: Where the intended use is subject to the control of an Authority, approval for the use of alternative materials or methods will need to be obtained from the Authority.

1.3.4 Existing structures Where the strength or serviceability of an existing structure is to be evaluated, the general principles of this Standard may be applied. (See also Clauses 21.1 and 21.4.)

1.4 DESIGN

1.4.1 Design data The following design data shall be shown in the drawings:

(a) Reference number and date of issue of applicable design Standards.

(b) Live loads used in design.

(c) Exposure classification for durability.

(d) Fire-resistance rating, if applicable.

(e) Class and where appropriate, grade designation of concrete.

(f) Grade and type of reinforcement and tendons.

(g) The appropriate earthquake design category, acceleration coefficient and site factor determined from AS 1170.4.

1.4.2 Design details The drawings or specification for concrete members and structures should include, as appropriate, the following:

(a) The shape and size of each member.

(b) The finish and method of control for unformed surfaces.

(c) Class of formwork in accordance with AS 3610 for the surface finish specified.

(d) The size, quantity and location of all reinforcement, tendons and structural fixings and the cover to each.

(e) Any required properties of the concrete (see Clause 19.1.2).

(f) The curing procedure.

(g) The force required in each tendon, the maximum jacking force to be applied and the order in which tendons are to be stressed.

(h) The location and details of planned construction or movement joints, connections and splices, and the method to be used for their protection.

(j) The minimum period of time before stripping of forms and removal of shores.

(k) Any constraint on construction assumed in the design.

(l) Any other requirements.

1.5 CONSTRUCTION All concrete structures, designed in accordance with this Standard, shall be constructed to ensure that all the requirements of the design as contained in the drawings and specifications are achieved.

1.6 DEFINITIONS

1.6.1 General The definitions below apply to this Standard. Definitions peculiar to a particular clause or section are given in that clause or section and referred to below.

1.6.2 Administrative definitions

Approved—except as may be otherwise stated, approved by the Authority.

Authority—a body having statutory powers to control the design and erection of the structure in the area in which the structure is to be erected.

Drawings—the drawings forming part of the documents setting out the work to be executed.

Engineer—a person qualified for Corporate Membership of the Institution of Engineers, Australia, or with equivalent qualifications and competent to practise in the design and construction of concrete structures.

Specification—the specification forming part of the documents setting out the work to be executed.

1.6.3 Technical definitions

Action—any agent, such as imposed load, foundation movement or temperature gradient, which may act on a structure.

Action effects—the forces and moments, deformations, cracks and other effects which are produced in a structure or in its component members by an action.

Average ambient temperature—the mean value of the daily maximum and minimum ambient temperatures at a site, averaged over the relevant period (i.e. $(\Sigma T_{max} + \Sigma T_{min})/(2 \times \text{number of days})$).

Cement—portland or blended cement complying with AS 3972, or a mixture of either of these with fly ash complying with AS 3582.1, or slag complying with AS 3582.2.

Characteristic strength—that value of the material strength, as assessed by standard test, which is exceeded by 95 percent of the material.

Composite concrete member—a member consisting of concrete components constructed separately but structurally connected so that the member responds as a unit to applied actions.

Concrete—a mixture of cement, aggregates, and water, with or without the addition of chemical admixtures.

Construction joint—a joint, including a joint between precast segments, that is located in a part of a structure for convenience of construction and made so that the load-carrying capacity and serviceability of the structure will be unimpaired by the inclusion of the joint.

Cover—the distance between the outside of the reinforcing steel or tendons and the nearest permanent surface of the member excluding any surface finish. Unless otherwise noted, the tolerances on position of reinforcement and tendons given in Clause 19.5.3 apply.

Creep factor—the ratio of creep strain to elastic strain under conditions of constant stress.

Effective depth—the distance from the extreme compressive fibre of the concrete to the resultant tensile force in the reinforcing steel and tendons in that zone which will be tensile at the ultimate strength condition in pure bending.

Effective span—the lesser of $(L_n + D)$ and L.

Exposure classification—see Clause 4.3.

Fire-resistance level—see Clause 5.2.

Fire-resistance period—see Clause 5.2

Fire-separating function—see Clause 5.2.

Fitment—a unit of reinforcement commonly known as a tie, stirrup, ligature or helix.

Flat slab—a continuous two-way solid or ribbed slab, with or without drop-panels, having at least two spans in each direction, supported internally by columns without beams and supported externally by walls, or columns with or without spandrel beams, or both.

Footing—a part of a structure in direct contact with and transmitting load to the supporting foundation.

Foundation—the soil, subsoil or rock, whether built-up or natural, upon which a structure is supported.

Grout—a mixture of cement and water, with or without the addition of sand, or chemical admixtures, proportioned to produce a pourable liquid without segregation of the constituents.

Hollow-core slab or wall—see Clause 5.2.

Initial force—the force immediately after transfer, at a stated position in a tendon.

Insulation—see Clause 5.2.

Integrity—see Clause 5.2.

Jacking force—the force in a tendon measured at the jack.

Lightweight concrete—concrete made with light-weight coarse and normal-weight fine aggregates and having a saturated surface-dry density in the range of 1800 kg/m^3 to 2100 kg/m^3.

Limit state—any limiting condition for which the structure ceases to fulfil its intended function.

(Deletion)

Loadbearing member—see Clause 5.2.

Movement joint—a joint which is made in or between portions of a structure for the specific purpose of permitting relative movement between the parts of the structure on either side of the joint.

Normal-class concrete—concrete which is specified primarily by a Standard strength grade and which complies with AS 1379.

One-way slab—a slab characterised by flexural action mainly in one direction.

Plain concrete member—a member either unreinforced or containing reinforcement but assumed to be unreinforced.

Post-tensioning—the tensioning of tendons after the concrete has hardened.

Prestressed concrete—concrete into which internal stresses are induced deliberately by tendons and includes concrete commonly referred to as partially prestressed.

Prestressing steel—see tendon.

Pretensioning—the tensioning of tendons before the concrete is placed.

Reinforcement, reinforcing steel—steel bar, wire, or fabric but not tendons.

Ribbed slab—see Clause 5.2.

Shear wall—a wall which is intended to resist lateral forces acting in or parallel to the plane of the wall.

‖ *Slag*—ground granulated iron blast furnace slag complying with AS 3582.2.

Special-class concrete—concrete which is specified to have certain properties or characteristics different from or additional to those of normal-class concrete and which ‖ complies with AS 1379.

Strength grade—the numerical value of the characteristic compressive strength of concrete at 28 days, f'_c. (See Clauses 6.1.1.1 and 19.1.6.)

Structural adequacy—see Clause 5.2.

Tendon—a wire, strand or bar or any discrete group of such wires, strands or bars, which is intended to be pretensioned or post-tensioned.

Transfer—the time of initial transfer of prestressing forces from the tendons to the concrete.

Transmission length—the length, at transfer, over which the stress in a pretensioned tendon builds up from zero at one end to its full value.

Two-way slab—a slab characterized by significant flexural action in two directions, usually at right angles to one another.

1.7 NOTATION Every symbol used in this Standard is listed below. Symbols which occur in more than one clause are defined below and used in the various clauses without further reference. Symbols which occur only in one clause are defined in that clause as well as being listed below.

Unless a contrary intention appears, the following applies:

(a) The symbols used in this Standard shall have the meanings ascribed to them below, with respect to the structure, or member, or condition to which a clause is applied.

(b) Where non-dimensional ratios are involved, both the numerator and denominator are expressed in identical units.

(c) The dimensional units for length, force and stress in all expressions or equations are to be taken as millimetres (mm), newtons (N) and megapascals (MPa) respectively.

(d) An asterisk (*) placed after a symbol as a superscript (e.g. M*) denotes a design action effect due to the design load for strength given in Clause 3.3.

A_b = the cross-sectional area of a reinforcing bar

A_c = the cross-sectional area of the core of a column used in Appendix A

A_g = the gross cross-sectional area of a member

| A_m = an area (see Clause 8.3.3)

A_p = the cross-sectional area of prestressing steel

A_{pt} = the cross-sectional area of the tendons in that zone which will be tensile under ultimate load conditions

A_s = the cross-sectional area of reinforcement

A_{st} = the cross-sectional area of tension reinforcement

A_{sc} = the cross-sectional area of compression reinforcement

A_{sv} = the cross-sectional area of shear reinforcement

$A_{sv.min}$ = the cross-sectional area of minimum shear reinforcement

A_{sw} = the cross-sectional area of the bar forming a closed tie

A_t = the area of a polygon (see Clause 8.3.5)

A_1 = a bearing area (see Clause 12.3)

A_2 = a supplementary area (see Clause 12.3)

A_1/A_2 = a ratio of areas (see Clause 8.4.2)

a = a distance

a_s = the length of a span support (see Clause 7.1.2)

a_v = the distance from the section at which shear is being considered to the face of the nearest support (see Clause 8.2.7.1)

b = the width of a cross-section

b_c = the width of the compression strut (see Clause 12.1.2.2)

b_{ef} = the effective width of a compression face or flange of a member

b_f = the width of the shear interface (see Clause 8.4.3)

b_l = a member size (see Clause A9.2.3.2)

b_o = the width of a critical opening (see Clause 9.2.1)

b_t = a member size (see Clause A9.2.3.2)

b_v = the effective width of a web for shear (see Clause 8.2.6)

| b_w = a width of the web; or

= the minimum thickness of the wall of a hollow section (see Clause 8.3.3)

c = the cover to reinforcing steel or tendons

D = the overall depth of a cross-section in the plane of bending

D_b = the overall depth of a spandrel beam

D_c = the smaller column dimension (see Clause 10.7.3.3)

D_s = the overall depth of a slab or drop panel

d = the effective depth of a cross-section (see Clause 1.6.3)

d_b = the nominal diameter of a bar, wire, or tendon

d_c = the depth of a compression strut (see Clause 12.1.2.2)

d_d = the diameter of a prestressing duct (see Clause 8.2.6)

d_o = the distance from the extreme compression fibre of the concrete to the centroid of the outermost layer of tensile reinforcement or tendons but not less than $0.8D$

d_p = the distance from the extreme compressive fibre of the concrete to the centroid of the tendons in that zone which will be tensile under ultimate strength conditions

d_{sc} = the distance from the extreme compressive fibre of the concrete to the centroid of compressive reinforcement (see Clause 8.1.5)

E_c = the mean value of the modulus of elasticity of concrete at 28 days

E_{cj} = the mean value of the modulus of elasticity of concrete at the appropriate age, determined in accordance with Clause 6.1.2

M^*_v = the design bending moment to be transferred from a slab to a support

M^*_x, M^*_y = the design bending moment in a column about the major and minor ax respectively; or

= the positive design bending moment, at midspan in a slab, in the x and direction respectively

M^*_1, M^*_2 = the smaller and larger design bending moment respectively at the ends of column

M_{cr} = the bending moment causing cracking of the section with due considerati to prestress, restrained shrinkage and temperature stresses

M_o = the total static moment in a span (see Clause 7.4.2); or

= the decompression moment (see Clause 8.2.7.2)

M_s = a service load bending moment (see Clause 8.5.3.1)

M_u = the ultimate strength in bending at a cross-section of an eccentrically loade compression member

M_{ub} = the particular ultimate strength in bending when k_{uo} = 0.6

M_{ud} = the reduced ultimate strength in bending without axial force, at cross-section (see Clause 8.1.3 (c))

M_{uo} = the ultimate strength in bending without axial force, at a cross-section

M_{ux}, M_{uy} = the ultimate strength in bending about the major and minor axe respectively of a column under the design axial force N^*

N^* = the axial compressive or tensile force on a cross-section calculated using the design load for strength specified in Clause 3.3, i.e. the design axial force

N_c = the buckling load used in column design

N_u = the ultimate strength in compression, or tension, at a cross-section of a eccentrically loaded compression or tension member respectively

N_{ub} = the particular ultimate strength in compression of a cross-section whe k_{uo} = 0.6

N_{uo} = the ultimate strength in compression without bending, of an axially loade cross-section

N_{uot} = the ultimate strength in tension without bending, of an axially loade cross-section

P = the force in the tendons; or

= the maximum force in the anchorage (see Clause 12.2.4)

P_v = the vertical component of the prestressing force

p = a reinforcement ratio

p_w = a reinforcement ratio in a wall

Q = the live load (including impact, if any)

q = the live load per unit length or area

R = the design relaxation of a tendon, determined in accordance wi Clause 6.3.4.3

R_b = the basic relaxation of a tendon, determined in accordance wi Clause 6.3.4.2

R_u = the ultimate strength (see Clause 2.3)

r = the radius of gyration of a cross-section

S^* = the design action effect (see Clause 2.3)

s = the centre-to-centre spacing of shear or torsional reinforcement, measured parallel to the longitudinal axis of a member; or

= the standard deviation

T = temperature; or

= the force resultant of tensile stresses (see Clause 12.2.4)

T^* = the torsional moment at a cross-section calculated using the design load for strength specified in Clause 3.3, i.e. the design torsional moment

T_u = the ultimate torsional strength

T_{uc} = the ultimate torsional strength of a beam without torsional reinforcement and in the presence of shear

T_{us} = the ultimate torsional strength of a beam with torsional reinforcement, (see Clause 8.3.5)

$T_{u.max}$ = ultimate torsional strength of a beam limited by web crushing failure

t_{nom} = the nominal thickness of topping (see Clause 5.10.2)

t_d = a difference in thicknesses (see Clause 5.10.2)

t_h = the hypothetical thickness of a member used in determining creep and shrinkage, taken as $2A_g/u_e$

t_w = the thickness of a wall

u = the length of the critical shear perimeter for two-way action (see Clause 9.2.1)

u_e = the exposed perimeter of a member cross-section plus half the perimeter of any closed voids contained therein, used to calculate t_h

u_t = the perimeter of the polygon defined for A_t (see Clause 8.3.6)

V^* = the shear force at a section, calculated using the design load for strength specified in Clause 3.3, i.e. the design shear force

V_o = the shear force which would occur at a section when the bending moment at that section was equal to the decompression moment M_o

V_t = the shear force producing a principal tensile stress (see Clause 8.2.7.2)

V_u = the ultimate shear strength

$V_{u.max}$ = the ultimate shear strength limited by web crushing failure

$V_{u.min}$ = the ultimate shear strength of a beam provided with minimum shear reinforcement (see Clause 8.2.9)

V_{uc} = the ultimate shear strength excluding shear reinforcement (see Clause 8.2.7)

V_{uf} = the ultimate longitudinal shear strength at an interface

V_{uo} = the ultimate shear strength of a slab with no moment transfer

V_{us} = the contribution by shear reinforcement to the ultimate shear strength of a beam or wall (see Clauses 8.2.10, 11.5.5)

(Deletion)

W_u = the wind load for strength design

W_s	= the wind load for serviceability design
X	= a dimension (see Figure 9.2.1)
x	= the shorter overall dimension of a rectangular part of a cross-section; or
	= the smaller dimension of a component rectangle of a T-, L-, or I-section
Y	= a dimension (see Figure 9.2.1)
y	= the longer overall dimension of a rectangular part of a cross-section; or
	= the larger dimension of a component rectangle of a T-, L-, or I-section
y_1	= the larger dimension of a closed rectangular tie
Z	= the section modulus of an uncracked cross-section (see Clause 8.1.4.1)
α	= a coefficient
α_n	= a coefficient (see Clause 10.6.5)
α_{tot}	= an angular value in radians (see Clause 6.4.2.3)
α_v	= the angle between the inclined shear reinforcement and the longitudinal tensile reinforcement
β	= a coefficient with or without numerical subscripts; or
	= a fixity factor
β_d	= a factor (see Clause 10.4.3)
β_h	= a ratio (see Clause 9.2.1)
β_p	= an estimated angular deviation in radians per metre (see Clause 6.4.2.3)
β_x, β_y	= the short and long span bending moment coefficients respectively, for slabs supported on four sides
γ	= the ratio, under design bending or combined bending and compression, of the depth of the assumed rectangular compressive stress block to $k_u d$
γ_1, γ_2	= the column end restraint coefficients determined in accordance with Clause 10.5.3
Δ	= a deflection
δ, δ_b, δ_s	= moment magnifiers for slenderness effects, (see Clause 10.4)
ε	= a strain
ε_{cc}	= the strain due to concrete creep (see Clause 6.4.3.3)
ε_{cs}	= the design shrinkage strain determined in accordance with Clause 6.1.7.2
$\varepsilon_{cs.b}$ =	the basic shrinkage strain determined in accordance with Clause 6.1.7.1
θ_v, θ_t	= the angle between the concrete compression strut and the longitudinal axis of the member (see Clauses 8.2.10, 8.3.5)
λ_{sc}	= a ratio of loads (see Clause 10.4.3)
μ	= the friction curvature coefficient (see Clause 6.4.2.3)
ν	= Poisson's ratio for concrete, determined in accordance with Clause 6.1.5
ρ	= the density of concrete in kilograms per cubic metre (kg/m^3), determined in accordance with Clause 6.1.3
σ_{cs}	= a sustained concrete stress (see Clause 6.4.3.3)
σ_{cp}	= the average intensity of effective prestress in concrete

$\sigma_{cp.f}$	= a compressive stress at the extreme fibre (see Clause 8.2.7.2)
σ_{pa}	= the stress at a point in the tendon (see Clause 6.4.2.3)
$\sigma_{p.ef}$	= the effective stress in the tendon (see Clause 8.1.6)
σ_{pi}	= the stress in the tendon immediately after transfer
σ_{pj}	= the stress in the tendon at the jacking end (see Clause 6.4.2.3)
σ_{pu}	= the maximum stress which would be reached in a tendon at ultimate strength of a flexural member
σ_{st}	= a calculated tensile stress in reinforcement (see Clause 13.1.2.3)
ϕ	= the strength reduction factor (see Clause 2.3)
ϕ_{cc}	= the design creep factor determined in accordance with Clause 6.1.8.2
$\phi_{cc.b}$	= the basic creep factor determined in accordance with Clause 6.1.8.1
ψ_c	= the combination live load factor used in assessing the design load for strength
ψ_s	= the short-term live load factor used in assessing the design load for serviceability
ψ_l	= the long-term live load factor used in assessing the design load for serviceability

SECTION 2 DESIGN REQUIREMENTS AND PROCEDURES

2.1 DESIGN REQUIREMENTS

2.1.1 Aim The aim of structural design is to provide a structure which is durable, serviceable and has adequate strength while serving its intended function and which also satisfies other relevant requirements such as robustness, ease of construction and economy.

A structure is durable if it withstands expected wear and deterioration throughout its intended life without the need for undue maintenance.

A structure is serviceable and has adequate strength if the probability of loss of serviceability and the probability of structural failure, are both acceptably low throughout its intended life.

2.1.2 Requirements The design of a structure and its component members shall take into account, as appropriate, stability, strength, serviceability, durability, fire resistance and any other relevant design requirements, in accordance with the procedures given in this section.

2.2 DESIGN FOR STABILITY

The structure as a whole and its parts shall be designed to prevent instability due to overturning, uplift and sliding as follows:

(a) The design action effect and the design resistance effect shall be determined from Clause 3.2.

(b) The whole or part of the structure shall be proportioned so that its design resistance effect is not less than the design action effect.

2.3 DESIGN FOR STRENGTH

The structure and its component members shall be designed for strength as follows:

(a) The loads and other actions shall be determined from Clause 3.1 and the design load for strength determined from Clause 3.3.

(b) The design action effect, S^*, due to the design load for strength shall be determined by an appropriate analysis in accordance with the requirements of Section 7.

(c) The design strength, ϕR_u, shall be determined in accordance with the requirements of Sections 8 to 15, as appropriate, where ϕ is a strength reduction factor which shall not exceed the appropriate value given in Table 2.3.

(d) The member shall be proportioned so that its design strength is not less than the design action effect, i.e. $\phi R_u \geq S^*$.

2.4 DESIGN FOR SERVICEABILITY

2.4.1 General The structure and its component members shall be designed for serviceability by controlling or limiting deflection, lateral drift, cracking and vibration, as appropriate, in accordance with the relevant requirements of Clauses 2.4.2 to 2.4.5.

2.4.2 Deflection limits for beams and slabs The deflection of beams and slabs under service conditions shall be controlled as follows:

(a) A limit for the calculated deflection of the member shall be chosen appropriate to the structure and its intended use. The values chosen shall not exceed the relevant value given in Table 2.4.2.

(b) The member shall be designed so that, under the design load for serviceability given in Clause 3.4, the deflections calculated in accordance with Section 8 or 9, as appropriate, do not exceed the value chosen.

TABLE 2.3
STRENGTH REDUCTION FACTORS

Type of action effect	Strength reduction factor (ϕ)
(a) Axial force without bending—	
(i) tension	0.8
(ii) compression	0.6
(b) Bending without axial tension or compression where:	
(i) $k_u \leq 0.4$	0.8
(ii) $k_u > 0.4$	$0.8\, M_{ud}/M_{uo} \geq 0.6$
(c) Bending with axial tension	$\phi + [(0.8 - \phi)(N_u/N_{uot})]$ and ϕ is obtained from (b)
(d) Bending with axial compression where:	
(i) $N_u \geq N_{ub}$	0.6
(ii) $N_u \leq N_{ub}$	$0.6 + [(\phi - 0.6)(1 - N_u/N_{uot})]$ and ϕ is obtained from (b)
(e) Shear	0.7
(f) Torsion	0.7
(g) Bearing	0.6
(h) Compression and tension in strut and tie action	0.7
(i) Bending shear and compression in plain concrete	0.6
(j) Bending shear and tension in fixings	0.6

TABLE 2.4.2
LIMITS FOR CALCULATED DEFLECTION OF BEAMS AND SLABS

Type of member	Deflection to be considered	Deflection limitation (Δ/L_{ef}) for spans (Notes 1 and 2)	Deflection limitation (Δ/L_{ef}) for cantilevers (Note 3)
All members	The total deflection	1/250	1/125
Members supporting masonry partitions	The deflection which occurs after the addition or attachment of the partitions	1/500 where provision is made to minimize the effect of movement, otherwise 1/1000	1/250 where provision is made to minimize the effect of movement, otherwise 1/ 500
Bridge members	The live load (and impact) deflection	1/800	1/400

NOTES:

1 In flat slabs, the deflection to which the above limits apply is the theoretical deflection of the line diagram representing the idealized frame defined in Clause 7.5.2.

2 Deflection limits given may not safeguard against ponding.

3 For cantilevers, the values of Δ/L_{ef} given in this Table apply only if the rotation at the support is included in the calculation of Δ.

2.4.3 Lateral drift Unbraced frames and multistorey buildings subject to lateral loading, shall be designed to limit calculated inter-storey lateral drift to 1/500 of the storey height.

2.4.4 Cracking The cracking of beams or slabs under service conditions shall be controlled in accordance with the requirements of Clause 8.6 or 9.4 as appropriate.

2.4.5 Vibration The vibration of beams or slabs under service conditions shall be controlled in accordance with the requirements of Clause 8.7 or 9.5 as appropriate.

2.5 DESIGN FOR STRENGTH AND SERVICEABILITY BY LOAD TESTING OF A PROTOTYPE Notwithstanding the requirements of Clauses 2.3 and 2.4, a structure or a component member may be designed for strength or serviceability, or both, by load testing a prototype in accordance with Clause 21.2 using appropriate design loads determined from Clauses 3.3 or 3.4. If this alternative procedure is adopted, the requirements of Clause 2.2 and of Clauses 2.6 to 2.8 as appropriate, shall also apply.

2.6 DESIGN FOR DURABILITY The structure and its component members shall be designed for durability in accordance with the requirements of Section 4.

2.7 DESIGN FOR FIRE RESISTANCE The structure and its component members shall be designed for the appropriate fire resistance in accordance with Section 5.

2.8 OTHER DESIGN REQUIREMENTS Requirements such as fatigue, progressive collapse and any special performance requirements, shall be considered where relevant and if significant, shall be taken into account in the design of the structure in accordance with the principles of this Standard and appropriate engineering principles.

The design of bridges for loads resulting from floods or collision shall be carried out in accordance with the Austroads Bridge Design Code, or the ANZRC Railway Bridge Design Manual, as appropriate.

Where seismic actions are a consideration, the additional requirements of Appendix A shall apply.

SECTION 3 LOADS AND LOAD COMBINATIONS FOR STABILITY, STRENGTH AND SERVICEABILITY

3.1 LOADS AND OTHER ACTIONS

3.1.1 Loads The design of a structure for stability, strength and serviceability shall take account of the action effects directly arising from the following loads:

(a) For structures generally, the dead and live, wind, snow and earthquake loads specified in AS 1170.1, AS 1170.2, AS 1170.3 and AS 1170.4 respectively.

(b) For housing, the wind loads specified in AS 4055 may be used, if applicable.

(c) For bridges, if applicable, loads specified in the Austroads Bridge Design Code, or the ANZRC Railway Bridge Design Manual.

(d) For retaining structures, earth pressure and liquid pressure, as applicable.

(e) Accidental loading, if applicable.

(f) Any additional load that may be required.

3.1.2 Construction loads Loading conditions which may arise from construction activities and which adversely affect the requirements for stability, strength or serviceability, shall be taken into account. If appropriate, the values assumed for design purposes shall be specified (see also Clause 19.6.2).

3.1.3 Other actions Any action which may significantly affect the stability, strength or serviceability of the structure, including but not limited to the following, shall be taken into account:

(a) Foundation movements.

(b) Temperature changes and gradients.

(c) Axial shortening.

(d) Dynamic effects.

(e) Shrinkage or expansion of concrete during setting or subsequently.

(f) Creep of concrete.

The value of any of the above actions shall be appropriate to the design state being considered.

3.2 LOAD COMBINATIONS FOR STABILITY DESIGN The design action effects and the design resistance effects for stability design shall be determined as follows:

(a) The loads and other actions determined from Clause 3.1 shall be subdivided into components tending to cause instability and components tending to resist instability.

(b) The design action effect shall be calculated from the components of the loads and other actions tending to cause instability, factored and combined in accordance with Clause 3.3.

(c) The design resistance effect shall be calculated from 0.8 times the components of the unfactored loads and other actions tending to resist instability.

3.3 LOAD COMBINATIONS FOR STRENGTH DESIGN

3.3.1 Structures other than bridges The design load for strength design of structures other than bridges, shall be determined from the load combinations for the strength limit states given in AS 1170.1, except that the combination

$$1.25G + W_u + \psi_c Q$$

may be replaced by the more severe of—

$1.4G$; and

$1.1G + W_u + \psi_c Q$

Where applicable, the prestressing force, P, shall be included with a load factor of unity in each load combination, except for the case of dead load plus prestress at transfer, when the more severe of—

$1.15G + 1.15P$; and

$0.8G + 1.15P$

shall apply (see also Clause 7.6.7).

3.3.2 Bridges Where applicable, the design loads for the strength design of bridges shall be determined from the load combinations given in the Austroads Bridge Design Code, or the ANZRC Railway Bridge Design Manual, as appropriate.

3.4 LOAD COMBINATIONS FOR SERVICEABILITY DESIGN

The design load for serviceability design for deflection shall be taken from the appropriate combinations of factored loads for short-term and long-term effects given in AS 1170.1. Where applicable, the prestressing force, P, shall be included with a load factor of unity in all load combinations (see also Clause 7.6.7).

3.5 LOAD COMBINATIONS FOR FIRE-RESISTANCE DESIGN

The combinations of factored loads to be used for fire resistance in conjunction with Clause 5.8 and 5.9 shall be as given in AS 1170.1 for the fire limit state.

SECTION 4 DESIGN FOR DURABILITY

4.1 APPLICATION OF SECTION

The requirements of this Section apply to plain, reinforced, and prestressed, concrete structures and members with a design life of 40 to 60 years.

NOTES:

1. More stringent requirements would be appropriate for structures with a design life in excess of 60 years (e.g. monumental structures), while some relaxation of the requirements may be acceptable for structures with a design life less than 40 years (e.g. temporary structures).
2. Durability is a complex topic and compliance with these requirements may not be sufficient to ensure a durable structure. The Commentary (AS 3600 Supplement 1) contains background to, and further guidance on, the provisions of this Section.

4.2 DESIGN FOR DURABILITY

4.2.1 General Durability shall be allowed for in design by determining the exposure classification in accordance with Clause 4.3 and, for that exposure classification, complying with the appropriate requirements for—

(a) concrete quality and curing, in accordance with Clauses 4.4 to 4.6;

(b) chemical content restrictions, in accordance with Clause 4.9; and

(c) cover, in accordance with Clause 4.10.

4.2.2 Additional requirements In addition to the requirements specified in Clause 4.2.1—

(a) members subject to abrasion from traffic (e.g. pavements and floors) shall satisfy the requirements of Clause 4.7; and

(b) members subject to cycles of freezing and thawing shall satisfy the requirements of Clause 4.8.

4.3 EXPOSURE CLASSIFICATION

4.3.1 General

(a) The exposure classification for a surface of a member shall be determined from Table 4.3 and Figure 4.3.

(b) For determining concrete quality requirements in accordance with Clauses 4.4 to 4.6 and Clause 4.9, as appropriate, the exposure classification for the member shall be taken as the most severe exposure of any of its surfaces.

(c) For determining cover requirements for corrosion protection in accordance with Clause 4.10.3, the exposure classification shall be taken as the classification for the surface from which the cover is measured.

NOTE: In Table 4.3, classifications A1, A2, B1, B2 and C represent increasing degrees of severity of exposure, while classification U represents an exposure environment not specified in the table but for which a degree of severity of exposure should be appropriately assessed. Protective surface coatings may be taken into account in the assessment of the exposure classification.

4.3.2 Concession for exterior exposure of a single surface Where the exterior exposure is essentially only one surface of a member, concrete of the next lower grade than would otherwise be required by Clause 4.4 or 4.5 may be used, provided that the cover from that surface is increased by—

(a) 20 mm from the value required by Clause 4.10.3.2; or

(b) 15 mm from the value required by Clause 4.10.3.4.

TABLE 4.3
EXPOSURE CLASSIFICATIONS

Surface and exposure environment	Exposure classification: Reinforced or prestressed concrete members (Note 1)	Exposure classification: Plain concrete members (Note 1)
1. *Surface of members in contact with the ground*		
(a) Members protected by a damp-proof membrane	A1	A1
(b) Residential footings in non-aggressive soils	A1	A1
(c) Other members in non-aggressive soils	A2	A1
(d) Members in aggressive soils (Note 2)	U	U
2. *Surfaces of members in interior environments*		
(a) Fully enclosed within a building except for a brief period of weather exposure during construction;	A1	A1
(b) In industrial buildings, the member being subject to repeated wetting and drying	B1	A1
3. *Surfaces of members in above-ground exterior environments*		
In areas that are:		
(a) Inland (> 50 km from coastline) environment being—		
(i) non-industrial and arid climatic zone (Notes 3 & 4)	A1	A1
(ii) non-industrial and temperate climatic zone	A2	A1
(iii) non-industrial and tropical climatic zone	B1	A1
(iv) Industrial and any climatic zone	B1	A1
(b) Near-coastal (1 km to 50 km from coastline), any climatic zone	B1	A1
(c) Coastal (Up to 1 km from coastline but excluding tidal and splash zones) (Note 5), any climatic zone	B2	A1
4. *Surfaces of members in water*		
(a) In fresh water	B1	A1
(b) In sea water—		
(i) permanently submerged	B2	U
(ii) in tidal or splash zones	C	U
(c) In soft or running water	U	U
5. *Surfaces of members in other environments* Any exposure environment not otherwise described in Items 1 to 4	U	U

NOTES:

1. In this context, reinforced concrete includes any concrete containing metals which rely on the concrete for protection against environmental degradation. Plain concrete members containing reinforcement or other metallic embedments, should therefore be treated as reinforced members when considering durability.
2. Permeable soils with a pH < 4.0, or with ground water containing more than 1 g per litre of sulphate ions would be considered aggressive. Salt-rich soils in arid areas should be considered as exposure classification C.
3. The climatic zones referred to are those given in Figure 4.3, which is a simplified version of Plate 8 of the Bureau of Meteorology publication 'Climate of Australia', 1982 Edition.
4. Industrial refers to areas that are within 3 km of industries that discharge atmospheric pollutants.
5. For the purpose of this Table, the coastal zone includes locations within 1 km of the shoreline of large expanses of salt water (e.g. Port Phillip Bay, Sydney Harbour east of the Spit and Harbour Bridges, Swan River west of the Narrows Bridge). Where there are strong prevailing winds or vigorous surf, the distance should be increased beyond 1 km and higher levels of protection should be considered. Proximity to small salt water bays, estuaries and rivers may be disregarded.

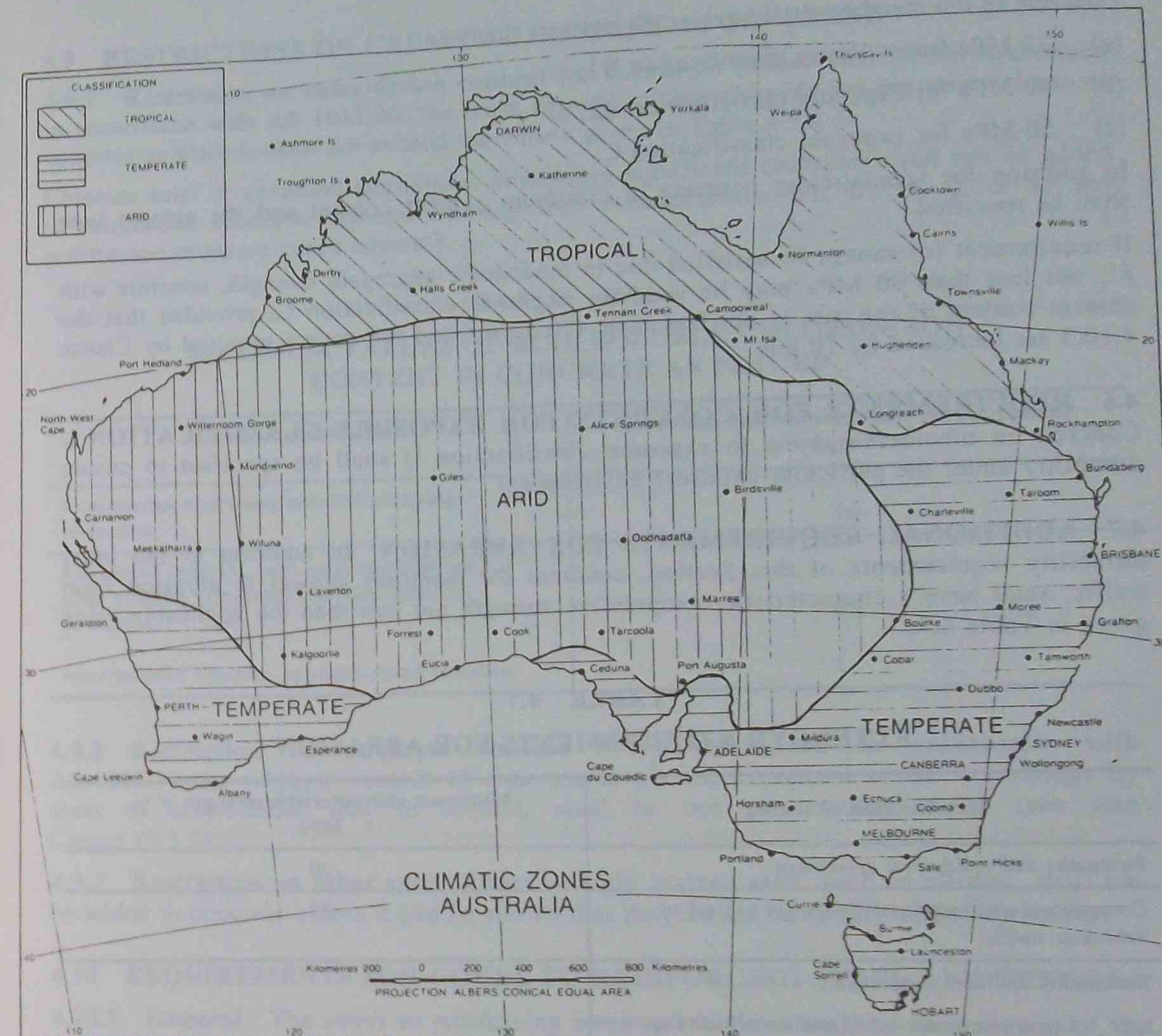


FIGURE 4.3 CLIMATIC ZONES REFERRED TO IN TABLE 4.3

4.4 REQUIREMENTS FOR CONCRETE FOR EXPOSURE CLASSIFICATIONS A1 AND A2 Members subject to exposure classifications A1 or A2 shall be initially cured continuously for at least three days under ambient conditions, or cured by accelerated methods, so that the average compressive strength of the concrete at the completion of curing is not less than 15 MPa.

Concrete in the member shall have an f'_c not less than—

(a) 20 MPa for exposure classification A1; or

(b) 25 MPa for exposure classification A2.

4.5 REQUIREMENTS FOR CONCRETE FOR EXPOSURE CLASSIFICATIONS B1, B2 AND C Members subject to exposure classifications B1, B2 or C shall be initially cured continuously for at least seven days under ambient conditions, or cured by accelerated methods so that the average compressive strength of the concrete at the completion of curing is not less than 20 MPa for exposure classification B1, 25 MPa for exposure classifications B2 and 32 MPa for exposure classification C.

Concrete in the member shall have an f'_c not less than—

(a) 32 MPa for exposure classification B1;

(b) 40 MPa for exposure classification B2; or

(c) 50 MPa for exposure classification C.

In addition for special-class concrete, a minimum cement content and the cement type shall be specified.

If requirement (c) cannot be satisfied due to inadequate aggregate strength, concrete with f'_c not less than 40 MPa may be used for exposure classification C, provided that the cement content of the mix is not less than 470 kg/m^3 and the covers required by Clause 4.10.3 are increased by 10 mm.

4.6 REQUIREMENTS FOR CONCRETE FOR EXPOSURE CLASSIFICATION U Concrete in members subject to exposure classification U shall be specified to ensure durability under the particular exposure environment.

4.7 ADDITIONAL REQUIREMENTS FOR ABRASION In addition to the other durability requirements of this Section, concrete for members subject to abrasion from traffic, shall have a characteristic compressive strength not less than the applicable value given in Table 4.7.

TABLE 4.7

STRENGTH REQUIREMENTS FOR ABRASION

Member and/or traffic	Minimum characteristic strength (f'_c) MPa
Footpaths and residential driveways	20
Commerical and industrial floors not subject to vehicular traffic	25
Pavements or floors subject to:	
(a) Light pneumatic-tyred traffic (vehicles up to 3t gross mass)	25
(b) Medium or heavy pneumatic-tyred traffic (vehicles heavier than 3t gross mass)	32
(c) Non-pneumatic-tyred traffic	40
(d) Steel-wheeled traffic	To be assessed but not less than 40

NOTE: f'_c refers to the strength of the wearing course.

4.8 ADDITIONAL REQUIREMENTS FOR FREEZING AND THAWING In addition to the other durability requirements of this Section, where the surface exposure includes exposure to cycles of freezing and thawing, concrete in the member shall—

(a) have an f'_c not less than—

(i) 32 MPa for occasional exposure (< 25 cycles p.a.); or

(ii) 40 MPa for frequent exposure (≥ 25 cycles p.a.); and

(b) contain a percentage of entrained air not outside the following ranges—

(i) for 10 mm to 20 mm nominal size aggregate . . . . 8% to 4%; or

(ii) for 40 mm nominal size aggregate . . . . 6% to 3%,

where the percentage of entrained air is determined in accordance with AS 1012.4.

4.9 RESTRICTIONS ON CHEMICAL CONTENT IN CONCRETE

4.9.1 Restriction on chloride-ion content for corrosion protection When determined in accordance with AS 1012.20, the mass of acid-soluble chloride-ion per unit volume of concrete as placed, shall not exceed the values given in Table 4.9.1.

Chloride salts or chemical admixtures containing significant chlorides shall not be added to reinforced concrete required for exposure classifications B1, B2 or C, or to any prestressed or steam-cured concrete.

TABLE 4.9.1

MAXIMUM VALUES OF ACID-SOLUBLE CHLORIDE-ION CONTENT IN CONCRETE AS PLACED

Form of construction	Maximum acid-soluble chloride-ion content kg/m^3
Concrete not containing material requiring protection	3.0
Reinforced concrete, post-tensioned concrete, or plain concrete containing material requiring protection.	0.8
Pre-tensioned concrete, or steam-cured concrete.	

4.9.2 Restriction on sulphate content When determined in accordance with AS 1012.20 the sulphate content of concrete as placed, expressed as the percentage by mass of acid-soluble SO_3 to cement, shall be not greater than 5.0% (see also Clause 19.1.2).

4.9.3 Restriction on other salts Other strongly ionized salts, such as nitrates, shall not be added to concrete unless it can be shown that they do not adversely affect durability.

4.10 REQUIREMENTS FOR COVER TO REINFORCING STEEL AND TENDONS

4.10.1 General The cover to reinforcing steel and tendons shall be the greatest of the values determined from Clauses 4.10.2 and 4.10.3, as appropriate, unless exceeded by the covers required by Section 5 for fire resistance.

4.10.2 Cover for concrete placement For concrete placement:

(a) The cover and arrangement of the steel shall be such that concrete can be properly placed and compacted to comply with Clause 19.1.3.

(b) The cover shall be not less than either the maximum nominal aggregate size, or the nominal size of the bar or tendon to which the cover is measured.

4.10.3 Cover for corrosion protection

4.10.3.1 *General* For corrosion protection, the cover shall be not less than the appropriate value given in Clauses 4.10.3.2 to 4.10.3.5.

4.10.3.2 *Standard formwork and compaction* Where concrete is cast in formwork complying with AS 3610 and compacted in accordance with Clause 19.1.3 of this Standard, the cover shall be not less than the value given in Table 4.10.3.2 appropriate to the exposure classification and f'_c.

4.10.3.3 *Cast against ground* Where concrete is cast on or against ground and compacted in accordance with Clause 19.1.3, the cover to a surface in contact with the ground shall be as given in Table 4.10.3.2 but increased by—

(a) 10 mm if the concrete surface is protected by a damp-proof membrane; or

(b) 20 mm otherwise.

4.10.3.4 *Rigid formwork and intense compaction* Where concrete is precast in rigid steel forms and subjected to intense compaction, such as obtained with vibrating tables or form vibrators, the cover shall be not less than the value given in Table 4.10.3.4 appropriate to the exposure classification and f'_c.

4.10.3.5 *Structural members manufactured by spinning or rolling* Where structural members are manufactured by spinning or rolling concrete having a water/cement ratio less than 0.35, and provided that no negative tolerance is allowed on the fixing of reinforcement, the cover for corrosion protection shall be not less than the value given in Table 4.10.3.5 for the appropriate exposure classification.

TABLE 4.10.3.2

REQUIRED COVER WHERE STANDARD FORMWORK AND COMPACTION ARE USED

Exposure classification	Required cover, mm				
	Characteristic strength (f'_c)				
	20 MPa	25 MPa	32 MPa	40 MPa	50 Mpa
A1	20	20	20	20	20
A2	(50)	30	25	20	20
B1	—	(60)	40	30	25
B2	—	—	(65)	45	35
C	—	—	—	(70)	50

NOTES:

1 Bracketed figures are the appropriate covers when the concession given in Clause 4.3.2, relating to the strength grade permitted for a particular exposure classification, is applied.

2 Increased values are required if Clause 4.10.3.3 applies.

TABLE 4.10.3.4

REQUIRED COVER WHERE RIGID FORMWORK AND INTENSE COMPACTION ARE USED

Exposure classification	Required cover, mm				
	Characteristic strength (f'_c)				
	20 MPa	25 MPa	32 MPa	40 MPa	50 Mpa
A1	15	15	15	15	15
A2	(35)	20	15	15	15
B1	—	(45)	30	25	20
B2	—	—	(50)	35	25
C	—	—	—	(55)	40

NOTE: Bracketed figures are the appropriate covers when the concession given in Clause 4.3.2, relating to the strength grade permitted for a particular exposure classification, is applied.

TABLE 4.10.3.5

REQUIRED COVER FOR SPUN OR ROLLED MEMBERS

Exposure classification	Cover mm
A1 & A2	10
B1	15
B2	20
C	25

SECTION 5 DESIGN FOR FIRE RESISTANCE

5.1 SCOPE OF SECTION This Section sets out the requirements for the design of reinforced and prestressed concrete structures and members to resist the effects of fire and gives methods for determining the fire-resistance levels required by the Authority.

5.2 DEFINITIONS For the purpose of this Section, the following definitions apply:

Fire-resistance level—the fire-resistance periods for structural adequacy, integrity and insulation expressed in that order, as required by the Authority.

Fire-resistance period—the time, in minutes, for a member to reach the appropriate failure criterion, specified in AS 1530.4, if tested for fire in accordance with that Standard.

Fire-separating function—the function served by the boundary elements of a fire compartment, which are required to have a fire-resistant level, of preventing a fire in that compartment from spreading to adjoining compartments.

NOTES:

1 When tested in accordance with AS 1530.4, prototypes of such members are exposed to fire from only one direction at a time and are assumed to be similarly exposed for the purpose of interpreting this Section.

2 Roofs, walls and floors may serve this function.

Hollow-core slab or wall—a slab or wall having mainly a uniform thickness and containing essentially continuous voids, where the thickness of concrete between adjacent voids and the thickness of concrete between any part of a void and the nearest surface is not less than the greater of one fifth the required effective thickness of the slab or wall and 25 mm.

Insulation—the ability of a fire-separating member, such as a wall or floor, to limit the surface temperature on one side of the member when exposed to fire on the other side.

Integrity—the ability of a fire-separating member to resist the passage of flames or hot gases through the member when exposed to fire on one side.

Loadbearing member—a member intended to support or transmit vertical loads additional to its own weight and where the design axial force at mid-height of the member is greater than $0.03 f'_c A_g$.

Ribbed slab—a slab incorporating parallel ribs spaced at not greater than 1500 mm centre-to-centre in one or two directions.

Structural adequacy—the ability of a member to maintain its structural function when exposed to fire.

5.3 DESIGN REQUIREMENTS

5.3.1 General A member shall be designed to have a fire-resistance period for each of structural adequacy, integrity and insulation not less than the required fire-resistance level.

5.3.2 Joints Joints between members or between adjoining parts shall be constructed so that the fire-resistance level of the whole assembly is not less than that required for the member.

SECTION 6 DESIGN PROPERTIES OF MATERIALS

6.1 PROPERTIES OF CONCRETE

6.1.1 Strength

6.1.1.1 *Characteristic compressive strength* The characteristic compressive strength of concrete at 28 days, f'_c, may be either—

(a) taken as equal to the specified strength grade, provided that the appropriate curing is ensured and that the concrete complies with Section 20; or

(b) determined statistically from compressive strength tests carried out in accordance with AS 1012.9.

The characteristic compressive strengths of the standard strength grades are 20 MPa, 25 MPa, 32 MPa, 40 MPa and 50 MPa.

6.1.1.2 *Characteristic flexural tensile strength* The characteristic flexural tensile strength of concrete, f'_{cf}, may be either—

(a) taken as equal to $0.6\sqrt{f'_c}$ at 28 days and standard curing; or

(b) determined statistically from flexural strength tests carried out in accordance with AS 1012.11.

6.1.1.3 *Characteristic principal tensile strength* The characteristic principal tensile strength of concrete, f'_{ct}, may be either—

(a) taken as equal to $0.4\sqrt{f'_c}$ at 28 days and standard curing; or

(b) determined statistically from indirect tensile strength tests carried out in accordance with AS 1012.10.

6.1.2 Modulus of elasticity The modulus of elasticity of concrete at the appropriate age, E_{cj}, may be either—

(a) taken as equal to $(\rho)^{1.5} \times (0.043\sqrt{f_{cm}})$, in megapascals, consideration being given to the fact that this value has a range of ±20%; or

(b) determined by test in accordance with AS 1012.17.

6.1.3 Density The density of concrete, ρ, may be either—

(a) for normal-weight concrete, taken as not less than 2400 kg/m^3; or

(b) determined by test in accordance with AS 1012.12.

6.1.4 Stress-strain curves A stress-strain curve for concrete may be either—

(a) assumed to be of curvilinear form defined by recognized simplified equations; or

(b) determined from suitable test data.

For design purposes, the shape of the curve shall be modified so that the maximum stress is $0.85f'_c$.

6.1.5 Poisson's ratio Poisson's ratio for concrete, ν, may be either—

(a) taken as equal to 0.2; or

(b) determined by test in accordance with AS 1012.17.

6.1.6 Coefficient of thermal expansion The coefficient of thermal expansion of concrete may be either—

(a) taken as equal to 10×10^{-6}/°C, consideration being given to the fact that this value has a range of ±20%; or

(b) determined from suitable test data.

6.1.7 Shrinkage

6.1.7.1 *Basic shrinkage strain* The basic shrinkage strain of concrete, $\varepsilon_{cs.b}$, may be—

(a) taken as equal to a median value of 700×10^{-6}; or

(b) determined from measurements on similar local concrete; or

(c) determined by tests in accordance with AS 1012.13, after eight weeks drying.

6.1.7.2 *Design shrinkage strain* The design shrinkage strain, ε_{cs}, shall be determined from the basic shrinkage strain, $\varepsilon_{cs.b}$, by any accepted mathematical model for shrinkage behaviour, calibrated such that $\varepsilon_{cs.b}$ is also predicted by the chosen model.

In the absence of more accurate methods, the design shrinkage strain at any time after commencement of drying shrinkage may be taken as—

$$k_1 \varepsilon_{cs.b}$$

where

k_1 is obtained from Figure 6.1.7.2.

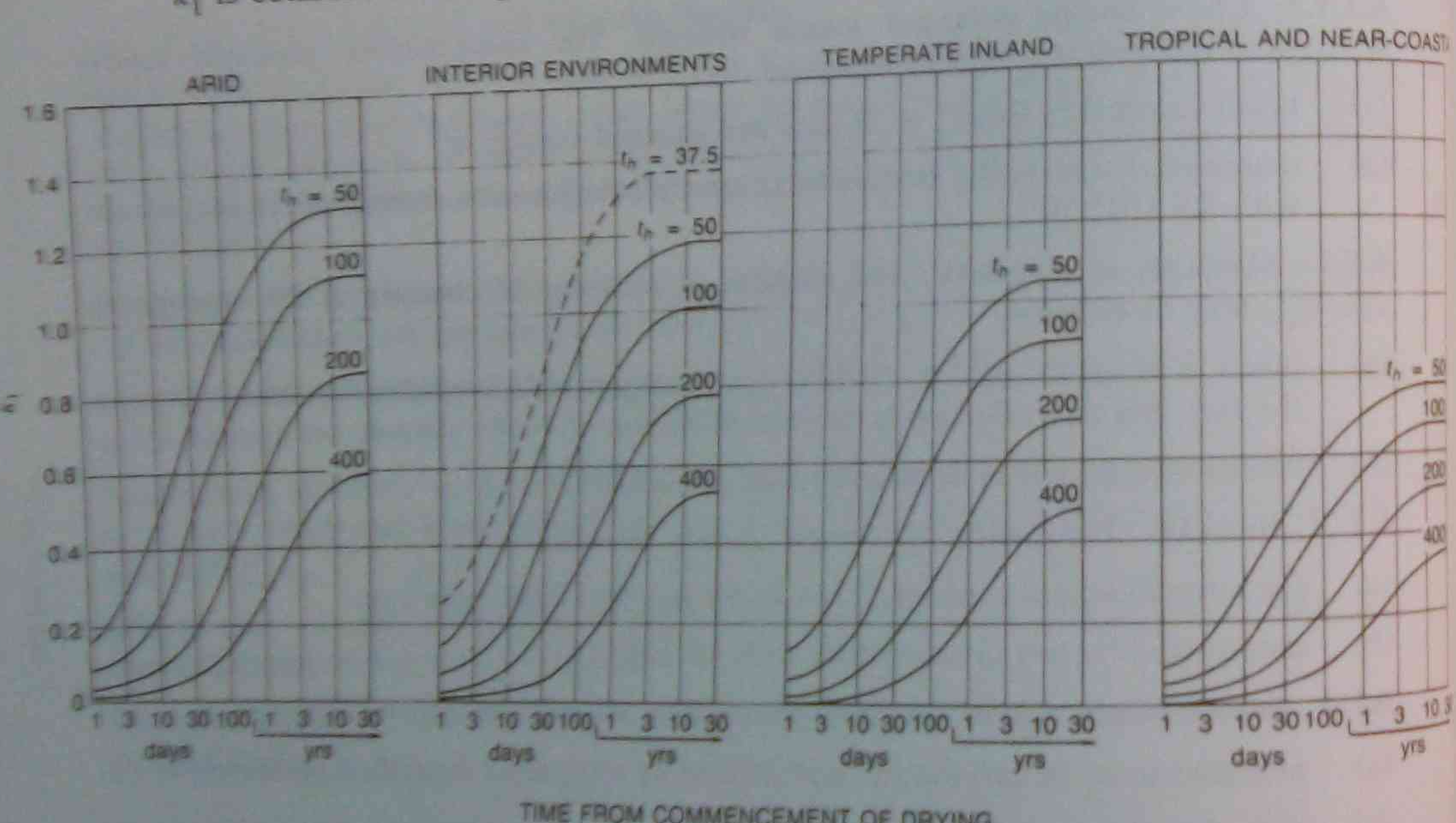


FIGURE 6.1.7.2 SHRINKAGE STRAIN COEFFICIENT (k_1) FOR VARIOUS ENVIRONMENTS

Based on a value of $\varepsilon_{cs.b}$ of 700×10^{-6}, this method gives the typical design shrinkage strains given in Table 6.1.7.2.

Consideration shall be given to the fact that ε_{cs} has a range of ±30%.

TABLE 6.1.7.2

TYPICAL DESIGN SHRINKAGE STRAINS AFTER 30 YEARS IN VARIOUS ENVIRONMENTS

Exposure environment	Final design shrinkage strain (ε_{cs}), 10^{-6} — Hypothetical thickness (t_h), mm: 50	100	200	400
Arid	910	780	600	410
Interior environments	830	710	550	370
Temperate inland	740	630	490	340
Tropical and near-coastal	540	470	360	250

NOTE: For descriptions of exposure environments, see Table 4.3 and Figure 4.3.

6.1.8 Creep

6.1.8.1 *Basic creep factor* The basic creep factor of concrete, $\phi_{cc.b}$, is the ratio of ultimate creep strain to elastic strain for a specimen loaded at 28 days under a constant stress of $0.4f'_c$ and may be —

(a) taken as the values given in Table 6.1.8.1; or

(b) determined from measurements on similar local concrete; or

(c) determined by tests in accordance with AS 1012.16.

TABLE 6.1.8.1

BASIC CREEP FACTOR

Characteristic strength, f'_c, MPa	20	25	32	40	50
Creep factor $\phi_{cc.b}$	5.2	4.2	3.4	2.5	2.0

6.1.8.2 *Design creep factor* The design creep factor, ϕ_{cc}, for concrete shall be determined from the basic creep factor, $\phi_{cc.b}$ by any accepted mathematical model for creep behaviour, calibrated such that $\phi_{cc.b}$ is also predicted by the chosen model.

In the absence of more accurate methods, ϕ_{cc} at any time may be taken as—

$$k_2 k_3 \phi_{cc.b}$$

where k_2 and k_3 are obtained from Figure 6.1.8.2(A) and Figure 6.1.8.2(B) respectively.

Consideration shall be given to the fact that ϕ_{cc} has a range of approximately ±30%. This range is likely to be exceeded if—

(a) the cement used in the concrete has a sulphate content, expressed as SO_3 by mass of cement in accordance with AS 2350, outside the range 2% to 3.5%; or

(b) the concrete member is subjected to prolonged periods of temperature in excess of 25°C; or

(c) the member is subject to sustained stress levels in excess of $0.5f'_c$.

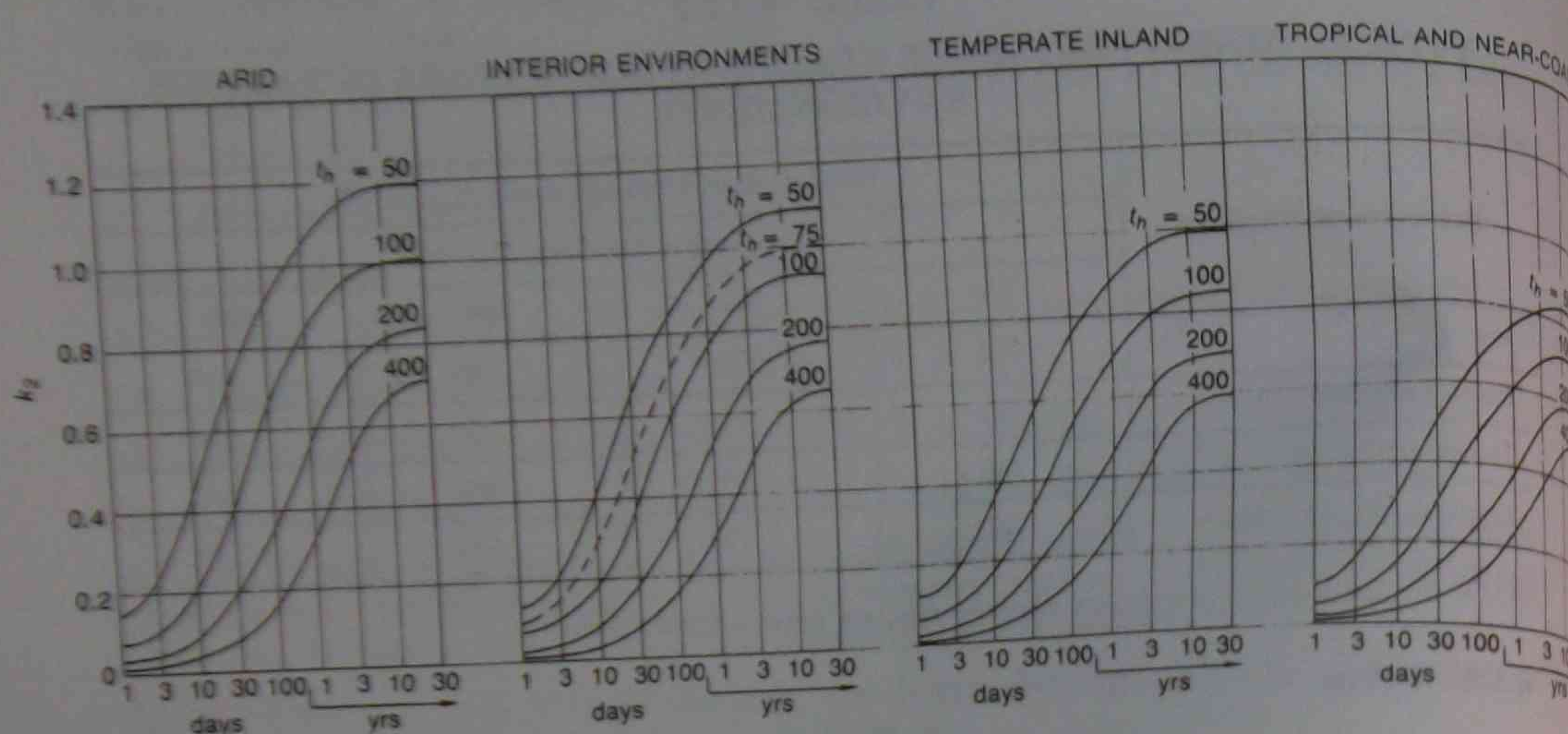


FIGURE 6.1.8.2(A) CREEP FACTOR COEFFICIENT (k_2) FOR VARIOUS ENVIRONMENTS

FIGURE 6.1.8.2(B) MATURITY COEFFICIENT (k_3)

Based on a value of 2.5 for $\phi_{cc.b}$, this method gives the typical design creep factors given in Table 6.1.8.2.

TABLE 6.1.8.2

TYPICAL DESIGN CREEP FACTOR AFTER 30 YEARS IN VARIOUS ENVIRONMENTS FOR $\phi_{cc.b}$ = 2.5

Exposure environment	Concrete age at loading (days)	Design creep factor (ϕ_{cc}) — Hypothetical thickness (t_h), mm: 50	100	200	400
Arid	0 to 7	3.9	3.3	2.7	2.3
	8 to 28	3.0	2.5	2.1	1.8
	> 28	2.7	2.3	1.9	1.6
Interior environment	0 to 7	3.5	3.1	2.5	2.1
	8 to 28	2.7	2.3	1.9	1.6
	> 28	2.5	2.1	1.7	1.5
Temperate inland	0 to 7	3.2	2.8	2.3	1.9
	8 to 28	2.5	2.1	1.8	1.5
	> 28	2.2	1.9	1.6	1.3
Tropical and near-coastal	0 to 7	2.7	2.3	1.9	1.6
	8 to 28	2.1	1.8	1.5	1.3
	> 28	1.9	1.6	1.4	1.1

NOTE: For descriptions of exposure environments, see Table 4.3, and Figure 4.3.

6.2 PROPERTIES OF REINFORCEMENT

6.2.1 Strength The yield strength of reinforcement, f_{sy}, shall be taken as not greater than the minimum yield strength specified in Table 6.2.1.

NOTE: Clause 19.2.1.1 requires all reinforcing steel to be deformed bars or fabric, except that plain bars or wire may be used for fitments.

TABLE 6.2.1

STRENGTH OF REINFORCEMENT

Reinforcement — Type	Reinforcement — Grade	Minimum yield strength (f_{sy}) MPa
(a) Plain bars	250 R	250
(b) Deformed bars to AS 1302	400 Y	400
Steel wire, plain and deformed to AS 1303	450 W	450
Welded wire fabric, to AS 1304	450 F	450

6.2.2 Modulus of elasticity The modulus of elasticity of reinforcement, E_s, for all stress values not greater than the yield strength f_{sy}, may be either—

(a) taken as equal to 200×10^3 MPa; or

(b) determined by test.

6.2.3 Stress-strain curves A stress-strain curve for reinforcement may be either—

(a) assumed to be of a form defined by recognized simplified equations; or

(b) determined from suitable test data.

6.2.4 Coefficient of thermal expansion The coefficient of thermal expansion of reinforcement may be either—

(a) taken as equal to 12×10^{-6}/°C; or

(b) determined from suitable test data.

6.3 PROPERTIES OF TENDONS

6.3.1 Strength

(a) The tensile strength of tendons, f_p, shall be taken as the minimum tensile strength specified in Table 6.3.1.

(b) The yield strength of tendons, f_{py}, may either be taken as—

(i) for wire used in the as-drawn condition $0.75 f_p$;

(ii) for stress-relieved wire .... $0.85 f_p$;

(iii) for all grades of strand and bar tendons $0.85 f_p$;

or be determined by test.

TABLE 6.3.1

TENSILE STRENGTH OF COMMONLY USED WIRE STRAND AND BAR

Material type and Standard	Nominal diameter mm	Area mm^2	Minimum breaking load kN	Minimum tensile strength (f_p) MPa
Wire—AS 1310	5 5 7	19.6 19.6 38.5	30.4 33.3 65.5	1 550 1 700 1 700
7-wire super strand—AS 1311	9.3 12.7 15.2	54.7 100 143	102 184 250	1 860 1 840 1 750
7-wire regular strand—AS 1311	12.7	94.3	165	1 750
Bars—AS 1313 (Super grade only)	23 29 32 38	415 660 804 1 140	450 710 870 1 230	1 080 1 080 1 080 1 080

6.3.2 Modulus of elasticity The modulus of elasticity of tendons, E_p, may be either—

(a) taken as equal to—

(i) for stress-relieved wire to AS 1310 .... 200×10^3 MPa;

(ii) for stress-relieved steel strand to AS 1311 .... 195×10^3 MPa;

(iii) for cold worked high tensile alloy steel bars to AS 1313 .. 170×10^3 MPa; or

(b) determined by test.

Consideration should be given to the fact that the modulus of elasticity of tendons may vary by ±5% and will vary more when a number of tendons are combined into a single cable.

6.3.3 Stress-strain curves A stress-strain curve for tendons may be determined from appropriate test data.

6.3.4 Relaxation of tendons

6.3.4.1 *General* This Clause applies to the relaxation, at any age and stress level, of low-relaxation wire, low-relaxation strand, and alloy-steel bars.

NOTE: Relevant information for normal-relaxation wire and strand will be given in the Commentary when published.

6.3.4.2 *Basic relaxation* The basic relaxation, R_b, of a tendon after one thousand hours at 20°C and $0.7 f_p$, may be either—

(a) taken as equal to, for Australian manufactured materials—

(i) low-relaxation wire 1%;

(ii) low relaxation strand 2%;

(iii) alloy-steel bars .... 3%; or

(b) determined in accordance with AS 1310, AS 1311, or AS 1313 as appropriate.

6.3.4.3 *Design relaxation* Subject to Clause 6.3.4.4, the design relaxation of a tendon, R, shall be determined from—

$$R = k_4 k_5 k_6 R_b$$

where

k_4 = a coefficient dependent on the duration of the prestressing force

= $\log [5.4 (j)^{1/6}]$

j = the time after prestressing, in days

k_5 = a coefficient, dependent on the stress in the tendon as a proportion of f_p, determined from Figure 6.3.4.3;

k_6 = a function, dependent on the average annual temperature, T, in degrees Celsius, taken as T/20 but not less than 1.0.

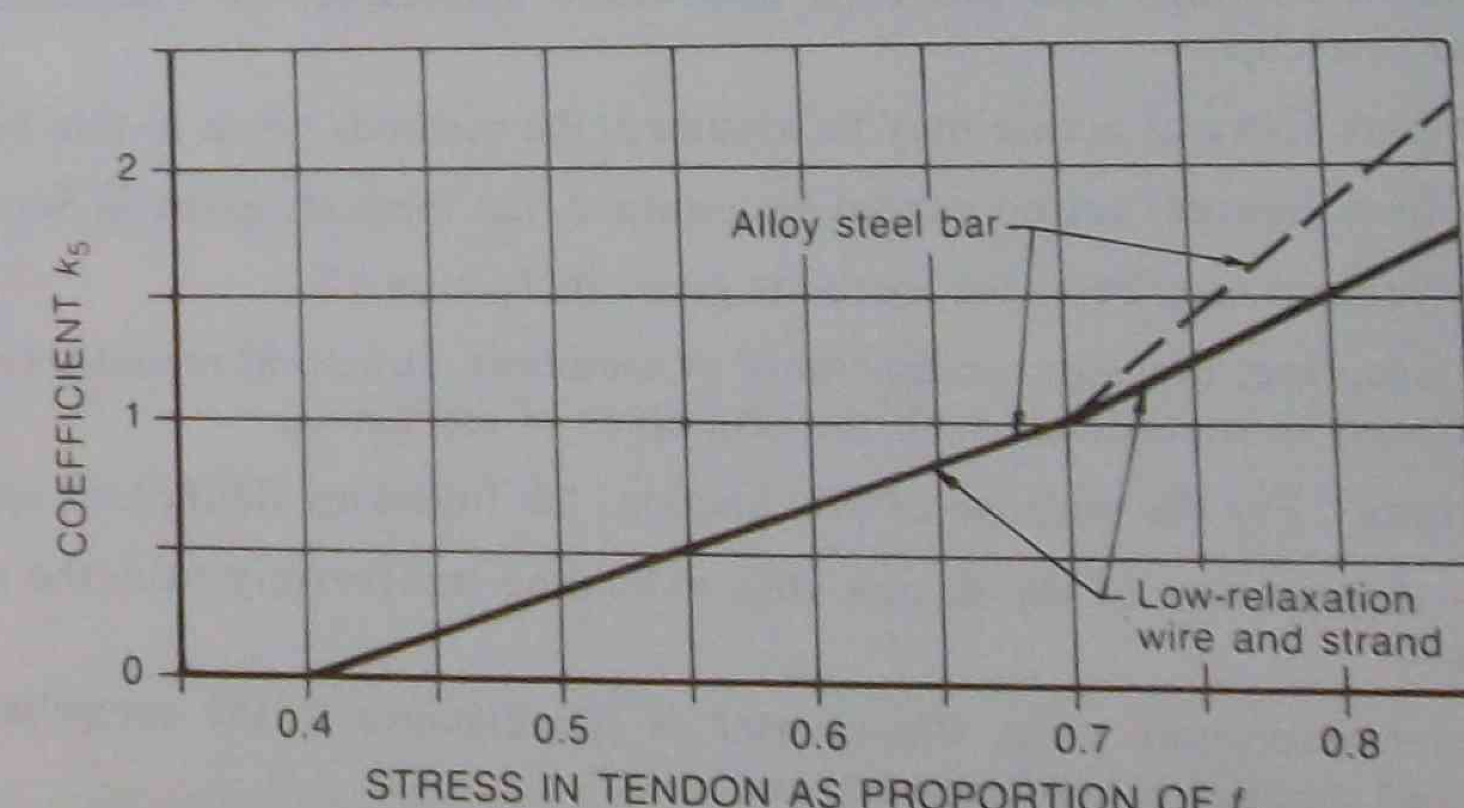


FIGURE 6.3.4.3 COEFFICIENT k_5

6.3.4.4 *Design relaxation for elevated temperature curing* Where curing of a prestressed member is carried out at elevated temperatures, ultimate relaxation shall be deemed to have occurred by the end of the curing cycle. In such cases the design relaxation shall be taken as either—

(a) the value determined from suitable test data; or

(b) 10% for low-relaxation strand stressed to $0.8 f_p$.

SECTION 7 METHODS OF STRUCTURAL ANALYSIS

7.1 GENERAL

7.1.1 Methods of analysis For the purpose of complying with the requirements for stability, strength and serviceability specified in Section 2, the action effects in a structure and its component members shall be determined by one of the following methods:

(a) For reinforced continuous beams or one-way slabs, the simplified method given in Clause 7.2.

(b) For reinforced two-way slabs supported by walls or beams on all four sides, the simplified method given in Clause 7.3.

(c) For reinforced two-way slab systems having multiple spans, the simplified method given in Clause 7.4.

(d) For reinforced or prestressed framed structures incorporating two-way slab systems, the idealized frame method given in Clause 7.5.

(e) For reinforced or prestressed structures—

(i) static analysis for determinate structures;

(ii) linear elastic analysis, in accordance with Clause 7.6;

(iii) an elastic analysis incorporating secondary bending moments due to lateral joint displacement, in accordance with Clause 7.7; or

(iv) rigorous structural analysis, in accordance with Clause 7.8.

(f) For slabs and frames, plastic methods of analysis, in accordance with Clause 7.9 or 7.10.

(g) For isolated footings and pile-caps and where applicable, for combined footings, mats and pile-caps—

(i) where flexural action may be assumed, the methods given in this Section; or

(ii) where flexural action cannot be assumed, the methods given in Section 12.

(h) For non-flexural members, the methods given in Section 12.

(j) For any structure, member, or assembly of members, structural model tests designed and evaluated in accordance with the principles of mechanics.

7.1.2 Definitions For the purpose of this Section, the following definitions apply:

Column strip—that portion of the design strip extending transversely from the centre line of the supports—

(a) for an interior column strip, one-quarter of the distance to the centreline of each adjacent and parallel row of supports; or

(b) for an edge column strip, to the edge of the slab and one-quarter of the distance to the centre line of the next interior and parallel row of supports,

but of total width not greater than $L/2$, as shown in Figure 7.1.2(A).

Design strip—that part of a two-way slab system which is supported, in the direction of bending being considered, by a single row of supports and which in each span extends transversely from the centre line of the supports—

(a) for an interior design strip, halfway to the centre line of each adjacent and parallel row of supports; or

(b) for an edge design strip, to the edge of the slab and halfway to the centre line of the next interior and parallel row of supports. (See Figure 7.1.2(A).)

Middle strip—the portion of the slab between two column strips or between a column strip and a parallel supporting wall (See Figure 7.1.2(A)).

Span support—the length of a support in the direction of the span, a_s, taken as—

(a) for beams or for flat slabs without either drop panels or column capitals, the distance from the centre line of the support to the face of the support; or

(b) for flat slabs with drop panels or column capitals or both, the distance from the centre line of the support to the intersection with the plane of the slab soffit of the longest line, inclined at an angle of 45 degrees to the centre line of the support, which lies entirely within the surfaces of the slab and the support,

as shown in Figure 7.1.2(B). For the purpose of Item (b), circular or polygonal columns may be treated as square columns with the same cross-sectional area.

Transverse width—the width of the design strip, L_t, measured perpendicular to the direction of bending being considered. (See Figure 7.1.2(A)).

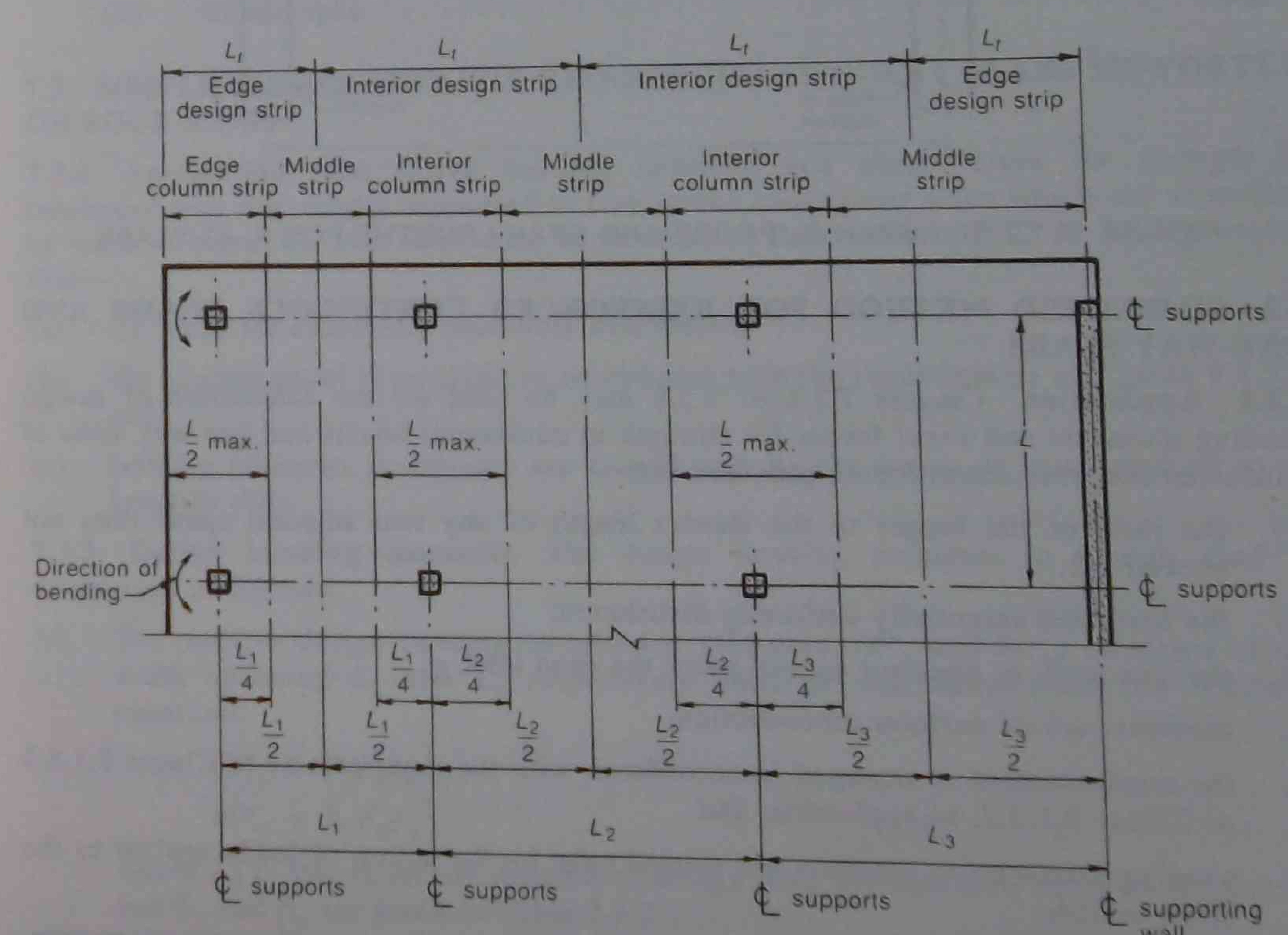


FIGURE 7.1.2.(A) WIDTHS OF STRIPS FOR TWO-WAY SLAB SYSTEMS

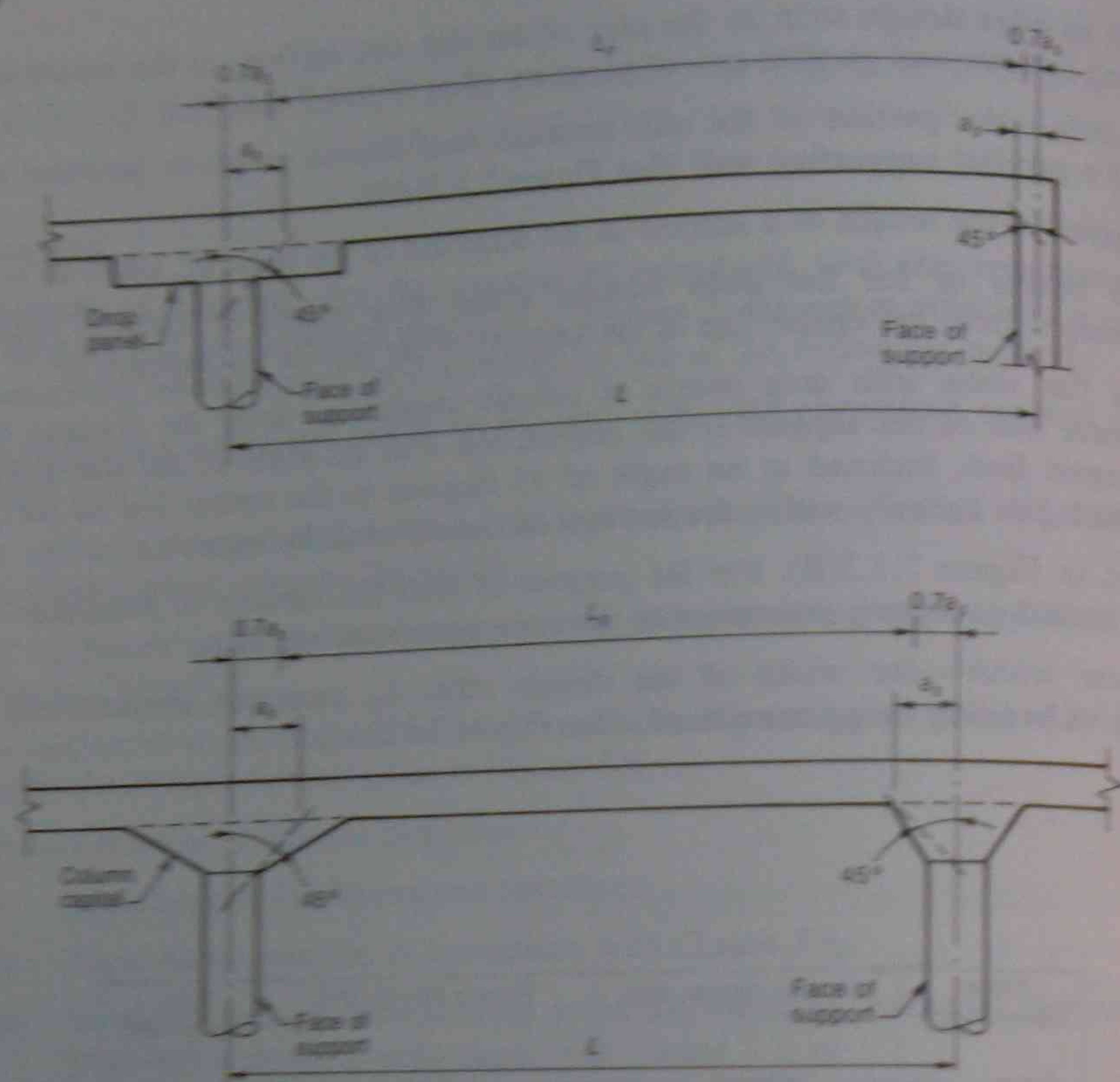


FIGURE 7.1.2(B) SPAN SUPPORT AND SPAN LENGTHS FOR FLAT SLABS

7.2 SIMPLIFIED METHOD FOR REINFORCED CONTINUOUS BEAMS AND ONE-WAY SLABS

7.2.1 Application Clauses 7.2.2 to 7.2.4 may be used for the calculation of design bending moments and shear forces for strength in continuous beams and one-way slabs of reinforced concrete construction, provided that—

(a) the ratio of the longer to the shorter length of any two adjacent spans does not exceed 1.2;

(b) the loads are essentially uniformly distributed;

(c) the live load, q, does not exceed twice the dead load, g;

(d) members are of uniform cross-section;

(e) the reinforcement is arranged in accordance with the requirements of Clause 8.1.8.5 or Clause 9.1.3.2, as applicable; and

(f) bending moments at supports are caused only by the action of loads applied to the beam or slab.

7.2.2 Negative design moment The negative design moment at the critical section taken for the purpose of this Clause at the face of the support, shall be as follows:

(a) At the first interior support:

(i) Two spans only .... $F_d L_n^2/8$

(ii) More than two spans .... $F_d L_n^2/10$

(b) At other interior supports .... $F_d L_n^2/11$

(c) At interior faces of exterior supports for members built integrally with their supports:

(i) For beams where the support is a column .... $F_d L_n^2/16$.

(ii) For slabs and beams where the support is a beam .... $F_d L_n^2/24$.

7.2.3 Positive design moment The positive design moment shall be taken as follows:

(a) In an end span .... $F_d L_n^2/11$.

(b) In interior spans .... $F_d L_n^2/16$.

7.2.4 Transverse design shear force The transverse design shear force in a member shall be taken as follows:

(a) In an end span:

(i) At the face of the interior support .... $1.15 F_d L_n/2$.

(ii) At mid-span .... $F_d L_n/7$.

(iii) At the face of the end support .... $F_d L_n/2$.

(b) In interior spans:

(i) At the face of supports .... $F_d L_n/2$.

(ii) At mid-span .... $F_d L_n/8$.

7.3 SIMPLIFIED METHOD FOR REINFORCED TWO-WAY SLABS SUPPORTED ON FOUR SIDES

7.3.1 Application The design bending moments and shear forces for strength in reinforced two-way simply supported or continuous rectangular slabs which are supported by walls or beams on four sides, may be determined from Clauses 7.3.2 to 7.3.4 provided that—

(a) the loads are essentially uniformly distributed;

(b) the reinforcement is arranged in accordance with the requirements of Clause 9.1.3.3; and

(c) bending moments at supports are caused only by the action of loads applied to the beam or slab.

7.3.2 Design bending moments The design bending moments in a slab shall be determined as follows:

(a) The positive design bending moments at mid-span, M^*_x and M^*_y, on strips of unit width spanning L_x and L_y respectively shall be calculated from the following equations:

$$M^*_x = \beta_x F_d L_x^2$$

$$M^*_y = \beta_y F_d L_x^2$$

where F_d is the uniformly distributed design load per unit area factored for strength and β_x and β_y are given in Table 7.3.2.

The moments so calculated, shall apply over a central region of the slab equal to three-quarters of L_x and L_y respectively. Outside of this region the requirement for strength shall be deemed to be complied with by the minimum strength requirement of Clause 9.1.1.

(b) The negative design bending moments at a continuous slab edge shall be taken as 1.33 times the mid-span values in the direction considered.

[illegible]

(b) The negative design bending moment at a discontinuous edge [illegible] may be taken as half the mid-span value in the direction considered.

TABLE 7.3.3

BENDING MOMENT COEFFICIENTS FOR RECTANGULAR SLABS SUPPORTED ON FOUR SIDES

Edge condition	Short span coefficients								Long span coefficients
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

7.3.3 Torsional moment at exterior corners [illegible]

7.3.4 Load allocation [illegible]

7.4 SIMPLIFIED METHOD FOR REINFORCED TWO-WAY SLAB SYSTEMS [illegible]

7.4.1 Application [illegible]

(a) [illegible]

(b) [illegible]

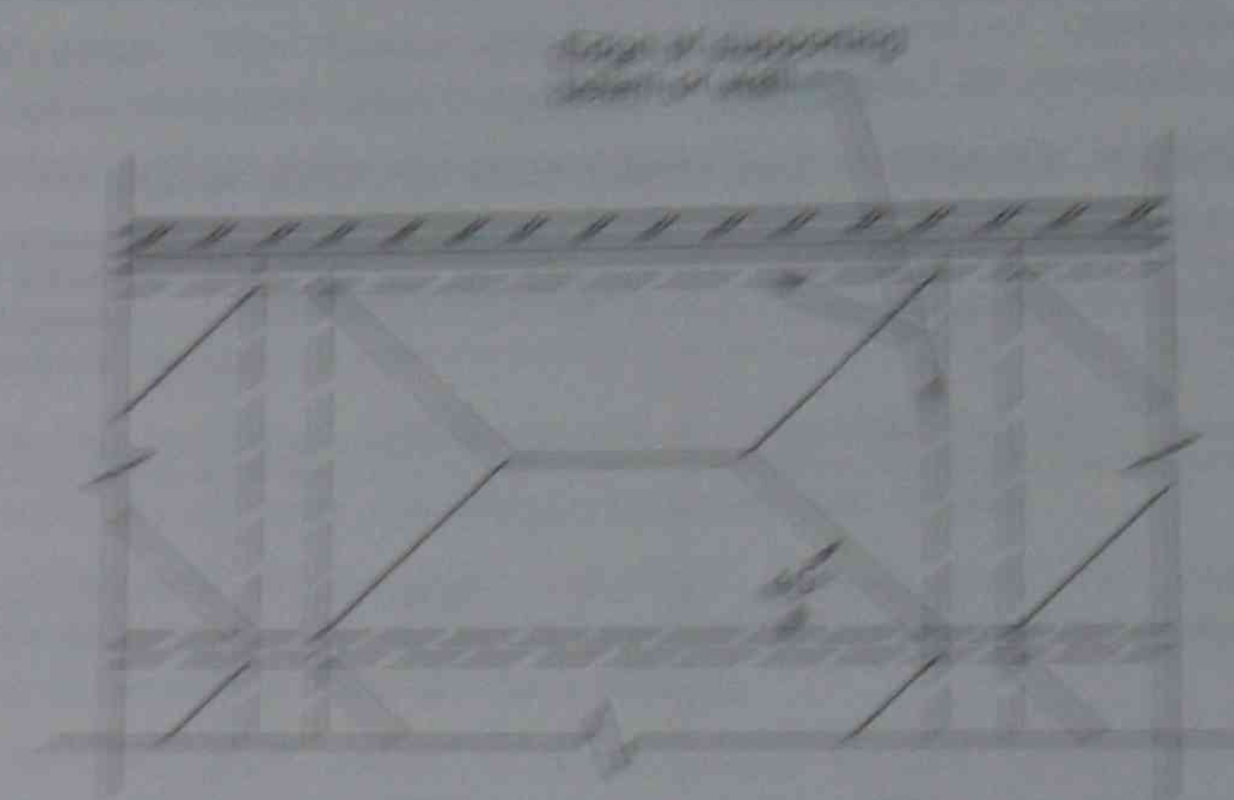


FIGURE 7.3.4 ALLOCATION OF LOAD

(c) In any portion of the slab enclosed by the centre lines of its supporting members, the ratio of the longer span to the shorter span is not greater than 2.0.

(d) In the design strips in each direction, successive span lengths do not differ by more than one third of the longer span and in no case is an end-span longer than the adjacent interior span.

(e) Lateral forces on the structure are resisted by shear walls or braced frames.

(f) Vertical loads are essentially uniformly distributed.

(g) The live load, q does not exceed twice the dead load, g.

(h) The reinforcement is arranged in accordance with Clause [illegible] or Clause [illegible], as applicable.

7.4.2 Total static moment for a span The total static moment, M_o for a span of the design strip shall be taken as not less than—

$$M_o = \frac{F_d L_t L_o^2}{8}$$

where

F_d = the design load per unit area on the slab

L_t = the width of the design strip

L_o = L minus 0.7 times the sum of the values of a_s at each end of the span. (See Figure [illegible].)

7.4.3 Design moments The design moments in a span shall be determined by multiplying the total static moment, M_o by the relevant factor given in Tables [illegible] and [illegible].

These design moments may be modified by up to 10% provided that the total static moment M_o for the span in the direction considered is not reduced.

The section under negative moment shall be designed to resist the larger of the two interior negative design moments determined for the spans framing into a common [illegible] support unless an analysis is made to distribute the unbalanced moment in accordance with the stiffness of the adjoining members.

TABLE 7.4.3(A)

DESIGN MOMENT FACTORS FOR AN END SPAN

Type of slab system and edge rotation restraint	Exterior negative moment factor	Positive moment factor	Interior negative moment factor
Flat slabs with exterior edge unrestrained	0.0	0.60	0.80
Flat slabs with exterior edge restrained by columns only	0.25	0.50	0.75
Flat slabs with exterior edge restrained by spandrel beams and columns	0.30	0.50	0.70
Flat slabs with exterior edge fully restrained	0.65	0.35	0.65
Beam-and-slab construction	0.15	0.55	0.75

TABLE 7.4.3(B)

DESIGN MOMENT FACTORS FOR AN INTERIOR SPAN

Type of slab system	Negative moment factor	Positive moment factor
All types	0.65	0.35

7.4.4 Transverse distribution of the design bending moment The design negative and positive bending moments shall be distributed to the column strip and middle strip in accordance with Clause 7.5.5.

7.4.5 Moment transfer for shear in flat slabs For the purpose of shear design, the bending moment, transferred from the slab to the support, M^*_v, shall be taken as the unbalanced bending moment at that support.

At an interior support, M^*_v shall be taken as not less than—

$$0.06[(1.25g + 0.75q)L_t(L_o)^2 - 1.25g\ L_t(L'_o)^2]$$

where

L'_o is the smaller value of L_o for the adjoining spans.

At an exterior support, the actual moment shall be taken.

7.4.6 Shear forces in beam-and-slab construction In beam- and-slab construction, the shear forces in the supporting beams may be determined by using the allocation of load given in Clause 7.3.4.

7.4.7 Openings in slabs Only openings which comply with the requirements of Clause 7.5.7(a) and (b) shall be permitted in slabs.

7.5 IDEALIZED FRAME METHOD FOR STRUCTURES INCORPORATING TWO-WAY SLAB SYSTEMS

7.5.1 Application This Clause applies to the analysis of reinforced and prestressed framed structures incorporating two-way slab systems having multiple spans including—

(a) solid slabs with or without drop panels;

(b) slabs incorporating ribs in two directions, including waffle-slabs;

(c) slabs having recessed soffits, if the portion of reduced thickness lies entirely within both middle strips;

(d) slabs having openings complying with the requirements of Clause 7.5.7; and

(e) beam-and-slab systems, including thickened slab bands.

7.5.2 The idealized frame The idealized frame shall be one of a series of approximately parallel frames running longitudinally through the building, and a second series running transversely through the building.

Each idealized frame shall consist of the structure formed by the full height of a row of vertical supports, including footings and the design strips at each floor level supported by them.

7.5.3 Arrangement of vertical load for buildings For building structures, the arrangement of vertical loads considered in the analysis shall consist of at least the following:

(a) Where the live loading pattern is fixed; the factored live load.

(b) Where the live load, Q, is variable but is not greater than three-quarters of the dead load, G; factored live load on all spans.

(c) Where the live load, Q, is variable and exceeds three-quarters of the dead load, G; for the floor under consideration—

(i) three-quarters of the factored live load on alternate spans;

(ii) three-quarters of the factored live load on two adjacent spans; and

(iii) factored live load on all spans.

(d) The factored dead load, but patterned variations of factored dead loads need not be considered.

7.5.4 Calculation of action effects in the idealized frame Each idealized frame shall be analysed in its entirety except that, for vertical loads on the frame it shall be permissible to analyse one floor at a time in accordance with Clause 7.6.2.

The bending moments, shear forces and axial forces in the idealized frame shall be calculated in accordance with the requirements for the linear elastic analysis of frames as specified in Clause 7.6 except that Clause 7.6.4 shall not apply.

Any change in length of columns and slabs due to axial force and any deflection due to shear force may be neglected.

The effective width of the idealized frame to be used in the determination of bending moments, varies depending on span length and column size and may be different for vertical and lateral forces. In the absence of more accurate calculations, the stiffness of horizontal flexural members at each floor level for a vertical load analysis may be based on a width—

(a) for flat slabs, equal to the width of the design strip, L_t; or

(b) for T-beams and L-beams, calculated in accordance with Clause 8.8.2.

7.5.5 Distribution of bending moments between column and middle strips In the idealized frame method each design strip shall be divided into column strips and middle strips.

The column strip shall be designed to resist the total negative or positive bending moment at the critical cross-sections multiplied by an appropriate factor within the ranges given in Table 7.5.5.

TABLE 7.5.5
DISTRIBUTION OF BENDING MOMENTS TO THE COLUMN STRIP

Bending moment under consideration	Column strip moment factor
Negative moment at an interior support	0.60 to 1.00
Negative moment at an exterior support	0.75 to 1.00
Positive moment at all spans	0.50 to 0.70

That part of the design strip bending moment not resisted by the column strip shall be proportionally assigned to the half-middle strips on either side of it.

Each middle strip shall be designed to resist the sum of the moments assigned to its two adjoining halves, except that a middle strip adjacent to and parallel with an edge supported by a wall shall be designed to resist twice the bending moment assigned to the adjoining half middle strip from the next interior design strip parallel to the wall.

7.5.6 Torsional moments Where moment is transferred to the column by torsional moment in the slab or spandrel beams, the slab or spandrel beams shall be designed in accordance with Clause 8.3 or Clause 9.2, as applicable.

In beam-and-slab construction, the spandrel beams shall be reinforced with at least the minimum torsional reinforcement required by Clause 8.3.7.

7.5.7 Openings in slabs Slabs containing openings may be analysed in accordance with all of Clause 7.5 without the need for further calculation provided that the amount of reinforcement interrupted by the opening is distributed to each side of the opening and the plan dimensions of the opening are no larger than the following:

(a) The width of each middle strip, in the area common to two middle strips.

(b) One-quarter of the width of each strip, in the area common to a column strip and a middle strip.

(c) One-eighth of the width of each column strip, in the area common to two column strips, provided that the reduced section is capable of transferring the moment and shear forces to the support. The slab shall also comply with the shear requirements of Clause 9.2.

7.6 LINEAR ELASTIC ANALYSIS

7.6.1 Application Linear elastic analysis may be used for the purpose of determining the action effects in a structure for strength and serviceability design.

For a structure which can be represented as a framework of line members, the analysis shall comply with Clauses 7.6.2 to 7.6.11. For other structures, the analysis shall comply with the general principles of these clauses as appropriate.

7.6.2 General In the analysis of multistorey buildings, in-situ concrete floor slabs may be assumed to act as horizontal diaphragms which distribute lateral forces to the framework.

The framework shall be analysed in its entirety except that the following simplifications may be used:

(a) Regular building structures may be analysed as a series of parallel frames, the analysis being carried out in each of two directions at right angles.

(b) For beam and slab moments due to vertical loading in a building structure, each level thereof together with the columns as they occur above and below may be analysed separately, the columns being assumed fixed at the ends remote from the level under consideration. The bending moment at a given support may be determined on the assumption that the floor is fixed at the support one span away provided that the floor continues beyond that point.

(c) For column forces and moments due to vertical loading in a building structure, each level of columns together with the floors above and below, if any, may be analysed separately, the columns being assumed fixed against rotation and translation at their remote ends and the floors being assumed fixed at the adjacent supports.

7.6.3 Span length The span length of flexural members shall be taken as the distance centre-to-centre of supports.

7.6.4 Arrangement of vertical loads for buildings For building structures, the arrangement of vertical loads considered in the analysis shall consist of at least the following:

(a) Where the live loading pattern is fixed; the factored live load.

(b) Where the live load, Q, is variable and is not greater than three-quarters of dead load, G; factored live load on all spans.

(c) Where the live load, Q, is variable and exceeds three-quarters of the dead load, G; arrangements for the floor under consideration consisting of—

(i) factored live load on alternate spans;

(ii) factored live load on two adjacent spans; and

(iii) factored live load on all spans.

(d) The factored dead load, but patterned variations of factored dead loads need not be considered.

7.6.5 Stiffness

7.6.5.1 *Relative stiffness* In the calculation of the relative stiffness of members for analysis, any reasonable assumption may be made. All such assumptions shall be applied consistently throughout the analysis.

The effect of haunching and variation of the cross-section along the axis of a member shall be considered and where significant, taken into account in the determination of relative stiffness.

7.6.5.2 *Member stiffness* The assumed stiffness of members shall be chosen to represent conditions at the limit state being analysed.

7.6.6 Deflections Calculated deflections shall be modified to allow for cracking, tension-stiffening and creep and shrinkage unless these effects have already been taken into account in the analysis.

7.6.7 Secondary bending moments and shear resulting from prestress The secondary bending moments and shears, and associated deformations which are produced in an indeterminate structure by prestressing, shall be taken into account in the design calculations for serviceability.

The secondary bending moments and shears may be determined by elastic analysis of the unloaded, uncracked structure for the effects of prestress.

In design calculations for strength, the secondary bending moments and shears shall be included with a load factor of 1.0 when the design moments and shears for the load combinations given in Clause 3.3.1 are calculated. For the special case of dead load plus prestress at transfer, the load factors given by Clause 3.3.1 shall apply.

7.6.8 Moment redistribution in reinforced concrete members for strength design In the design of statically indeterminate reinforced concrete members for strength, the elastically determined negative bending moment at any interior support may be reduced or increased provided the following requirements for adjoining spans are met:

(a) The positive bending moments shall be adjusted to maintain equilibrium.

(b) Where the neutral axis parameter, k_u, is less than or equal to 0.2 in all peak-moment regions, the redistribution shall not exceed 30%.

(c) Where k_u exceeds 0.2 in one or more peak-moment regions, but does not exceed 0.4, the redistribution shall not exceed $75(0.4 - k_u)$%.

(d) Where k_u exceeds 0.4 in any peak-moment region, no redistribution shall be made.

7.6.9 Moment redistribution in prestressed concrete members for strength design In the design of continuous prestressed concrete members for strength, the resultant elastically determined negative moment at any intermediate support, including the secondary moment, may be reduced or increased in accordance with the requirements of Clause 7.6.8.

7.6.10 Critical section for negative moments The critical section for maximum negative bending moment shall be taken at 0.7 times the span support, a_s, from the centre line of the support.

7.6.11 Minimum transverse shear Where the design is based on uniformly distributed live loads, in order to provide for live load on part of the span, the minimum live load shear force to be resisted by any section of the member shall be taken as not less than one quarter of the maximum live load shear force in the member.

SECTION 8 DESIGN OF BEAMS FOR STRENGTH AND SERVICEABILITY

8.1 STRENGTH OF BEAMS IN BENDING

8.1.1 General The strength of a beam cross-section under bending shall be determined using Clauses 8.1.2 to 8.1.8, the material properties given in Section 6 and the beam properties given in Clause 8.8.

This Clause does not apply to non-flexural members covered by Section 12.

8.1.2 Basic principles

8.1.2.1 *Combined bending and axial force* Calculations for strength of cross-sections in bending, or in bending combined with axial force, shall incorporate equilibrium and strain-compatibility considerations and be consistent with the following assumptions:

(a) Plane sections normal to the axis remain plane after bending.

(b) The concrete has no tensile strength.

(c) The distribution of compressive stress is determined from a stress-strain relationship for the concrete in accordance with Clause 6.1.4. (see Note).

(d) The strain in compressive reinforcement does not exceed 0.003.

NOTE: If a curvilinear stress-strain relationship is used, Clause 6.1.4 places a limit on the value of the maximum concrete stress.

8.1.2.2 *Rectangular stress block* Where the neutral axis lies within the cross-section and provided that the maximum strain in the extreme compression fibre of the concrete is taken as 0.003, Clause 8.1.2.1(c) shall be deemed to be satisfied by assuming that a uniform compressive stress of $0.85f'_c$ acts on an area bounded by—

(a) the edges of the cross-section; and

(b) a line parallel to the neutral axis at the strength limit state under the loading concerned, and located at a distance $\gamma k_u d$ from the extreme compressive fibre where—

$$\gamma = [0.85 - 0.007(f'_c - 28)] \text{ within the limits 0.65 to 0.85.}$$

NOTE: The modification given in Clause 6.1.4 is included in the rectangular stress block assumptions.

8.1.2.3 *Dispersion angle of prestress* In the absence of a more exact calculation, the dispersion angle of the prestressing force from the anchorage shall be assumed to be 60 degrees, i.e. 30 degrees either side of the centre-line.

8.1.3 Design strength in bending The design strength in bending of a section with the neutral axis parameter, k_u, not greater than 0.4, shall be taken as ϕM_{uo}.

In peak moment regions, sections with k_u greater than 0.4 should be avoided and shall not be used unless all the following requirements are met:

(a) The structural analysis shall be carried out in accordance with Clauses 7.6 to 7.8.

(b) Compression reinforcement of at least 0.01 times the area of concrete in compression shall be provided.

(c) The design strength in bending shall be taken as ϕM_{uo}, where ϕ is determined from (b) (ii) of Table 2.3.

In the determination of ϕ, M_{ud} is the reduced ultimate strength of the cross-section in bending where $k_u = 0.4$ and the tensile force has been reduced to balance the reduced compressive force.

M_{ud} may be calculated by assuming that—

(i) there are no axial forces acting on the cross-section;

(ii) the concrete strain at the extreme compression fibre is 0.003;

(iii) the effective depth, d is calculated for M_{uo};

(iv) k_u is reduced to 0.4; and

(v) the resultant of the tensile forces in the reinforcement and tendon is equal to the reduced compressive force calculated on the above assumptions.

8.1.4 Minimum strength requirements

8.1.4.1 *General* The ultimate strength in bending, M_{uo}, at critical sections shall be not less than 1.2 times the cracking moment, M_{cr}, given by—

$$M_{cr} = Z(f'_{cf} + P/A_g) + P_e$$

where

Z = the section modulus of the uncracked section, referred to the extreme fibre at which cracking occurs

f'_{cf} = the characteristic flexural tensile strength of the concrete.

For the purpose of this Clause, the critical section to be considered for negative moment shall be the weakest section in the negative moment region (i.e. where $\phi M_{uo}/M^*$ is least).

For rectangular reinforced concrete cross-sections, this requirement shall be deemed to be satisfied if minimum tensile reinforcement is provided such that—

$$A_{st}/bd \geq 1.4/f_{sy}$$

For reinforced T-beams or L-beams where the web is in tension, b shall be taken as b_w.

8.1.4.2 *Prestressed beams at transfer* The strength of a prestressed beam at transfer shall be checked using the load combinations specified in Clause 3.3.1 and a strength reduction factor, ϕ, for the section of 0.6.

This requirement shall be deemed to be satisfied if the maximum compressive stress in the concrete, under the loads at transfer, does not exceed $0.5f_{cp}$.

8.1.5 Stress in reinforcement and bonded tendons at ultimate strength The stress in the reinforcement at ultimate strength shall be taken as not greater than f_{sy}.

In the absence of a more accurate calculation and provided that the minimum effective stress in the tendons is not less than $0.5f_p$, the maximum stress which would be reached in bonded tendons at ultimate strength, σ_{pu}, shall be taken as—

$$\sigma_{pu} = f_p\left(1 - \frac{k_1 k_2}{\gamma}\right)$$

where

k_1 = 0.4 generally; or

if $f_{py}/f_p \geq 0.9$,

k_1 = 0.28; and

$$k_2 = \frac{1}{b_{ef} d_p f'_c}[A_{pt} f_p + (A_{st} - A_{sc}) f_{sy}]$$

Compression reinforcement may only be taken into account if d_{sc} is not greater than $0.15d_p$, in which case k_2 shall be taken as not less than 0.17.

8.1.6 Stress in tendons not yet bonded Where the tendon is not yet bonded, the stress in the tendon at ultimate strength, σ_{pu}, shall be determined from the formula given in (a) below if the span-to-depth ratio is 35 or less, or from the formula given in (b) below if the span-to-depth ratio is greater than 35 but in no case shall σ_{pu} be taken greater than f_{py}—

(a) $$\sigma_{pu} = \sigma_{p.ef} + 70 + \frac{f'_c b_{ef} d_p}{100A_{pt}} \leq \sigma_{p.ef} + 400$$

(b) $$\sigma_{pu} = \sigma_{p.ef} + 70 + \frac{f'_c b_{ef} d_p}{300A_{pt}} \leq \sigma_{p.ef} + 200$$

where $\sigma_{p.ef}$ is the effective stress in the tendon after allowing for all losses.

8.1.7 Spacing of reinforcement and tendons The minimum clear distance between parallel bars (including bundled bars), ducts and tendons shall be such that the concrete can be properly placed and compacted in accordance with Clause 19.1.3. The maximum spacing of longitudinal reinforcement and tendons shall be determined in accordance with Clause 8.6.

8.1.8 Detailing of flexural reinforcement

8.1.8.1 *Distribution* Tensile reinforcement shall be well distributed in zones of maximum concrete tension, including those portions of flanges of T-beams, L-beams and I-beams over a support.

8.1.8.2 *General procedure for arrangement* The termination and anchorage of flexural reinforcement shall be based on a hypothetical bending-moment diagram formed by uniformly displacing the calculated positive and negative bending-moment envelopes a distance D along the beam from each side of the relevant sections of maximum moment.

Not less than one-third of the total negative moment tensile reinforcement required at a support shall be extended a distance D beyond the point of contra-flexure.

8.1.8.3 *Anchorage of positive moment reinforcement* Anchorage of positive moment reinforcement shall comply with the following requirements:

(a) At a simple support, sufficient positive moment reinforcement shall be anchored past the face of the support for a length L_{st} such that the anchored reinforcement can develop a tensile force of $1.5V^*$ at the face of the support, where V^* is the design shear force at a distance, d, from that face and L_{st} is determined from Clause 13.1.2.3.

(b) At a simple support, of the tensile reinforcement required at mid-span, not less than either—

  (i) one-half shall extend past the face of the support for a length of $12d_b$ or an equivalent anchorage; or

  (ii) one-third shall extend past the face of the support for a length of $8d_b$ plus $D/2$.

(c) At a support where the beam is continuous or flexurally restrained, not less than one quarter of the total positive moment reinforcement required at midspan shall continue past the near face of the support.

8.1.8.4 *Shear strength requirements near terminated flexural reinforcement* If tensile reinforcement is terminated, the effect on the shear strength shall be assessed in accordance with the principles of the truss analogy.

This requirement shall be deemed to be satisfied if any one of the following conditions is met:

(a) Not more than a quarter of the maximum tensile reinforcement is terminated within any distance $2D$.

(b) At the cut-off point, $\phi V_u \geq 1.5V^*$.

(c) Stirrups are provided to give an area of shear reinforcement of $A_{sv} + A_{sv.min}$ for a distance D along the terminated bar from the cut-off point, where A_{sv} and $A_{sv.min}$ are determined in accordance with Clause 8.2.

8.1.8.5 *Deemed to comply arrangement* For continuous reinforced beams where the ratio of the longer to the shorter length of any two adjacent spans does not exceed 1.2 and where the loads are uniformly distributed and the live load, q, does not exceed twice the dead load, g, compliance with the following shall be deemed to satisfy the requirements of Clauses 8.1.8.2 to 8.1.8.4.

(a) Of the negative moment tensile reinforcement provided at the support—

(i) not less than one-quarter shall extend over the whole span;

(ii) not less than one-half shall extend $0.3L_n$ or more beyond the face of the support; and

(iii) the remainder, if any, shall extend $0.2L_n$ or more beyond the face of the support.

Where adjacent spans are unequal, the extension of negative reinforcement beyond each face of the common support shall be based on the longer span.

(b) Of the positive moment tensile reinforcement provided at mid-span—

(i) not less than one-half shall extend into a simple support for a length of $12d_b$;

(ii) not less than one-quarter shall extend into a support where the beam is continuous or flexurally restrained; and

(iii) the remainder, if any, shall extend to within $0.1L_n$ from the face of the support.

(c) To comply with shear requirements, not more than a quarter of the maximum tensile reinforcement shall be terminated within any distance $2D$.

8.1.8.6 *Restraint of compression reinforcement* Compression reinforcement required for strength in beams shall be adequately restrained by fitments in accordance with Clause 10.7.3.3.

8.1.8.7 *Bundled bars* Groups of parallel longitudinal bars bundled to act as a unit shall—

(a) have not more than four bars in any one bundle;

(b) be tied together in contact; and

(c) be enclosed within stirrups or ties.

Individual bars within a bundle, terminated within the span of flexural members, shall terminate at different points staggered by at least 40 times the diameter of the larger bar. The unit of bundled bars shall be treated as an equivalent single bar of diameter derived from the total area of the bars in the bundle.

8.2 STRENGTH OF BEAMS IN SHEAR

8.2.1 Application This Clause applies to reinforced and prestressed beams—

(a) subjected to shear force, bending moment and axial force; or

(b) subjected to shear force, bending moment and axial force in combination with torsion, provided that the additional requirements given in Clause 8.3 are complied with.

This Clause does not apply to non-flexural members covered by Section 12.

8.2.2 Design shear strength of a beam The design shear strength of a beam shall be taken as ϕV_u where either—

(a) $V_u = V_{uc} + V_{us}$, taking account of Clauses 8.2.3 to 8.2.6, where V_{uc} is determined from Clause 8.2.7 and V_{us} is determined from Clauses 8.2.9 and 8.2.10; or

(b) V_u is calculated by means of a method based on the truss analogy, in which case Clauses 8.2.3 to 8.2.10 may not apply.

8.2.3 Tapered members In members which are tapered along their length, the components of inclined tension or compression forces shall be taken into account in the calculation of shear strength.

8.2.4 Maximum transverse shear near a support The maximum transverse shear near a support shall be taken as the shear at—

(a) a distance equal to d from the face of the support; or

(b) the face of the support, where diagonal cracking can take place at the support or extend into it.

8.2.5 Requirements for shear reinforcement The following requirements for shear reinforcement shall apply:

(a) Where $V^* \leq 0.5\phi V_{uc}$, no shear reinforcement is required, except that where the overall depth of the beam exceeds 750 mm, minimum shear reinforcement shall be provided in accordance with Clause 8.2.8.

(b) Where $0.5\phi V_{uc} < V^* \leq \phi V_{u\,min}$, minimum shear reinforcement, $A_{sv.min}$ shall be provided in accordance with Clause 8.2.8.

(c) The minimum shear reinforcement requirements of (a) and (b) may be waived—

(i) for beams, if $V^* \leq \phi V_{uc}$ and D does not exceed the greater of 250 mm and half the width of the web; and

(ii) for slabs to which this Clause applies, if $V^* \leq \phi V_{uc}$.

(d) Where $V^* > \phi V_{u\,min}$, shear reinforcement shall be provided in accordance with Clause 8.2.10.

8.2.6 Shear strength limited by web crushing In no case shall the ultimate shear strength, V_u, be taken as greater than—

$$V_{u.max} = 0.2 f'_c b_v d_o + P_v$$

where

b_v = $(b_w - 0.5\Sigma d_d)$

Σd_d = the sum of the diameters of the grouted ducts, if any, in a horizontal plane across the web.

P_v = the vertical component of the prestressing force at the section under consideration.

8.2.7 Shear strength of a beam excluding shear reinforcement

8.2.7.1 *Reinforced beams* The ultimate shear strength, V_{uc}, of a reinforced beam, excluding the contribution of shear reinforcement, shall be calculated from the following equation:

$$V_{uc} = \beta_1 \beta_2 \beta_3 b_v d_o \left(\frac{A_{st} f'_c}{b_v d_o} \right)^{1/3}$$

where

$\beta_1 = 1.1(1.6 - d_o/1000) \geq 1.1$

$\beta_2 = 1$; or

$= 1 - (N^*/3.5A_g) \geq 0$ for members subject to significant axial tension; or

$= 1 + (N^*/14A_g)$ for members subject to significant axial compression.

$\beta_3 = 1$; or may be taken as—

$= 2d_o/a_v$ but not greater than 2, provided that the applied loads and the support are orientated so as to create diagonal compression over the length a_v.

A_{st} = cross-sectional area of longitudinal reinforcement provided in the tension zone and fully anchored at the cross-section under consideration.

8.2.7.2 *Prestressed beams* The ultimate shear strength, V_{uc}, of a prestressed beam, excluding the contribution of shear reinforcement, shall be taken as not greater than the lesser of the values obtained from (a) and (b) below unless the cross-section under consideration is cracked in flexure, in which case only (a) applies.

(a) *Flexure-shear cracking*

$$V_{uc} = \beta_1 \beta_2 \beta_3 b_v d_o \left[\frac{(A_{st} + A_{pt}) f'_c}{b_v d_o} \right]^{1/3} + V_o + P_v$$

where

β_1, β_2, β_3 and A_{st} are as given in Clause 8.2.7.1 except that in determining β_2, N^* is taken as the value of the axial force excluding prestress

V_o = the shear force which would occur at the section when the bending moment at that section was equal to the decompression moment, M_o, given by—

$M_o = Z\sigma_{cp.f}$

where

$\sigma_{cp.f}$ = the compressive stress due to prestress, at the extreme fibre where cracking occurs.

For simply-supported conditions,

$V_o = M_o/(M^*/V^*)$

where M^* and V^* are the bending moment and shear force respectively, at the section under consideration, due to the same design loading.

For statically indeterminate structures, shear forces and bending moments due to the secondary effects of prestress, shall be taken into account when determining M_o and V_o.

(b) *Web-shear cracking*

$V_{uc} = V_t + P_v$

where

V_t = the shear force which, in combination with the prestressing force and other action effects at the section, would produce a principal tensile stress of $0.33\sqrt{f'_c}$ at either the centroidal axis or the intersection of flange and web, whichever is the more critical.

8.2.7.3 *Secondary effects on* V_{uc} Where stresses due to secondary effects such as creep, shrinkage and differential temperature are significant, they shall be taken into account in the calculation of V_{uc}.

NOTE: Where significant reversal of loads may occur, causing cracking in a zone usually in compression, the value of V_{uc} obtained from Clause 8.2.7.1 may not apply.

8.2.8 Minimum shear reinforcement The minimum area of shear reinforcement, $A_{sv.min}$, provided in a beam shall be given by:

$A_{sv.min} = 0.35 b_v s/f_{sy.f}$

8.2.9 Shear strength of a beam with minimum reinforcement The ultimate shear strength of a beam provided with minimum shear reinforcement, $A_{sv.min}$, shall be taken as—

$V_{u.min} = V_{uc} + 0.6 b_v d_o$

8.2.10 Contribution to shear strength by the shear reinforcement The contribution to the ultimate shear strength by shear reinforcement in a beam, V_{us}, shall be determined from the following equations:

(a) *For perpendicular shear reinforcement:*

$V_{us} = (A_{sv} f_{sy.f} d_o/s) \cot \theta_v$

(b) *For inclined shear reinforcement:*

$V_{us} = (A_{sv} f_{sy.f} d_o/s)(\sin \alpha_v \cot \theta_v + \cos \alpha_v)$

where, for both (a) and (b)—

s = the centre-to-centre spacing of shear reinforcement, measured parallel to the longitudinal axis of the member

θ_v = the angle between the axis of the concrete compression strut and the longitudinal axis of the member, taken conservatively as 45 degrees or, more accurately, to vary linearly from 30 degrees when $V^* = \phi V_{u\,min}$ to 45 degrees when $V^* = \phi V_{u\,max}$

α_v = angle between the inclined shear reinforcement and the longitudinal tensile reinforcement.

8.2.11 Suspension reinforcement If forces are applied to a beam in such a way that hanging action is required, reinforcement or tendons shall be provided to carry all the forces concerned.

8.2.12 Detailing of shear reinforcement

8.2.12.1 *Types* Shear reinforcement shall comprise one or more of—

(a) stirrups or ties making an angle of between 45 degrees and 90 degrees with the longitudinal bars; and

(b) welded wire fabric placed to have wires perpendicular to the axis of the beam.

8.2.12.2 *Spacing* Shear reinforcement shall be spaced longitudinally not further apart than $0.5D$ or 300 mm, whichever is less, except that where $V^* \leq \phi V_{u\,min}$, the spacing may be increased to $0.75D$ or 500 mm whichever is less.

The maximum transverse spacing across the width of the member shall not exceed the lesser of 600 mm and D.

8.2.12.3 *Extent* Shear reinforcement, of area not less than that calculated as being necessary at any cross-section, shall be provided for a distance D from that cross-section in the direction of decreasing shear.

Shear reinforcement shall extend as close to the compression face and the tension face of the member as cover requirements and the proximity of other reinforcement and tendons will permit.

8.2.12.4 *End anchorage of bars* Bars used as shear reinforcement shall be anchored to develop the yield strength of the bar at mid-depth of the member.

A fitment hook shall be deemed to develop $0.5f_{sy.f}$ in accordance with Clause 13.1.2.5.

A fitment hook which encloses a longitudinal bar shall be deemed to develop $0.67f_{sy.f}$.

Notwithstanding the above, fitment cogs shall not be used when the anchorage of the fitment is solely in the cover concrete of the beam. Fitment hooks shall be used in this case.

8.2.12.5 *End anchorage of fabric* Where fabric is used as shear reinforcement, the ends shall be anchored—

(a) in accordance with Clause 8.2.12.4, if the wires are bent at least to the dimensions of a standard fitment hook; or

(b) by embedding two or more transverse wires at least 25 mm within the compression zone.

8.3 STRENGTH OF BEAMS IN TORSION

8.3.1 Application This Clause applies to beams subjected to torsion combined with flexure and shear. It does not apply to non-flexural members covered by Section 12.

8.3.2 Torsion redistribution Where torsional strength is not required for the equilibrium of the structure and the torsion in a member is induced solely by the angular rotation of adjoining members, it shall be permissible to disregard the torsional stiffness in the analysis and torsion in the member, if the torsion reinforcement requirements of Clauses 8.3.7 and the detailing requirements of Clause 8.3.8 are satisfied.

8.3.3 Torsional strength limited by web crushing To prevent web crushing under the combined action of torsion and flexural shear, beams shall be proportioned so that the following inequality is satisfied:

$$\frac{T^*}{\phi T_{u.max}} + \frac{V^*}{\phi V_{u.max}} \leq 1$$

where $V_{u.max}$ is calculated from Clause 8.2.6 and—

$$T_{u.max} = 0.2 f'_c J_t$$

The torsional modulus, J_t, may be taken as—

= $0.4x^2y$ for solid rectangular sections;

= $0.4\Sigma x^2y$ for solid T-, L-, or I-shaped sections, and

= $2A_m b_w$ for thin walled hollow sections, A_m being the area enclosed by the median lines of the walls of a single cell

8.3.4 Requirements for torsional reinforcement Requirements for torsional reinforcement shall be determined from the following:

(a) Torsional reinforcement is not required if—

(i) $T^* < 0.25\phi T_{uc}$; or

(ii) $\frac{T^*}{\phi T_{uc}} + \frac{V^*}{\phi V_{uc}} \leq 0.5$; or

(iii) the overall depth does not exceed the greater of 250 mm and half the width of the web, and

$$\frac{T^*}{\phi T_{uc}} + \frac{V^*}{\phi V_{uc}} \leq 1$$

where T_{uc} and V_{uc} are calculated in accordance with Clauses 8.3.5 and 8.2.7 respectively.

(b) If (a) above is not satisfied, torsional reinforcement, consisting of transverse closed ties and longitudinal reinforcement shall be provided so that the following inequality is satisfied:

$$\frac{T^*}{\phi T_{us}} + \frac{V^*}{\phi V_{us}} \leq 1$$

where T_{us} is calculated in accordance with Clause 8.3.5, considering all the closed ties provided and V_{us} is calculated in accordance with Clause 8.2.10, considering all the closed and open ties provided.

Longitudinal torsional reinforcement shall comply with Clause 8.3.6 and both transverse and longitudinal torsional reinforcement shall comply with Clause 8.3.7.

8.3.5 Torsional strength of a beam For the purpose of Clause 8.3.4, the ultimate strength of a beam in pure torsion, T_{uc} or T_{us}, shall be determined from the following:

(a) For a beam without closed ties, the ultimate strength in pure torsion, T_{uc}, shall be calculated from—

$$T_{uc} = J_t\left(0.3\sqrt{f'_c}\right)\sqrt{(1 + 10\sigma_{cp}/f'_c)}$$

(b) For a beam with closed ties, the ultimate strength in pure torsion, T_{us}, shall be calculated from—

$$T_{us} = f_{sy.f}(A_{sw}/s)2A_t \cot\theta_t$$

where

A_t = the area of a polygon with vertices at the centre of longitudinal bars at the corners of the cross-section;

θ_t = the angle between the axis of the concrete compression strut and the longitudinal axis of the member, taken conservatively as 45 degrees or, more accurately, to vary linearly from 30 degrees when $T^* = \phi T_{uc}$ to 45 degrees when $T^* = \phi T_{u.max}$.

8.3.6 Longitudinal torsional reinforcement Longitudinal torsional reinforcement shall be provided to resist the following design tensile forces, taken as additional to any design tensile forces due to flexure:

(a) In the flexural tensile zone, a force of—

$$0.5 f_{sy.f} (A_{sw}/s) u_t \cot^2\theta_t; \text{ and}$$

(b) In the flexural compressive zone, a force of—

$$0.5 f_{sy.f} (A_{sw/s}) u_t \cot^2\theta_t - F^*_c; \text{ but not less than zero,}$$

where

u_t = the perimeter of the polygon defined for A_t.

F^*_c = the absolute value of the design force in the compression zone due to flexure.

8.3.7 Minimum torsional reinforcement Where torsional reinforcement is required by Clause 8.3.4—

(a) all of the minimum shear reinforcement required by Clause 8.2.8 shall be provided in the form of closed ties; and

(b) longitudinal torsional reinforcement shall be provided in accordance with Clause 8.3.6.

8.3.8 Detailing of torsional reinforcement Torsional reinforcement shall be detailed in accordance with the following:

(a) Torsional reinforcement shall consist of both closed ties and longitudinal reinforcement.

(b) The closed ties shall be continuous around all sides of the cross-section and anchored so as to develop full strength at any point, unless a more refined analysis shows that over part of the tie full anchorage is not required. The spacing, *s*, of the closed ties shall not exceed the lesser of $0.12u_t$ and 300 mm.

(c) The longitudinal reinforcement shall be placed as close as practicable to the corners of the cross-section, and in all cases at least one longitudinal bar shall be provided at each corner of the closed ties.

8.4 LONGITUDINAL SHEAR IN BEAMS

8.4.1 Application This Clause applies to the transfer of longitudinal shear forces across interface shear planes through webs and flanges of composite beams, and across shear planes through flanges cast monolithically.

8.4.2 Design shear force For the purpose of this Clause, the design longitudinal shear force acting on a shear plane shall be taken as—

(a) For a shear plane through a flange, equal to V^*A_1/A_2

where

(i) for a flange in compression—

A_1/A_2 = the ratio of the area of flange outstanding beyond the shear plane to the total area of flange;

(ii) for a flange in tension—

A_1/A_2 = the ratio of the area of longitudinal reinforcement in the flange outstanding beyond the shear plane to the total area of longitudinal tensile reinforcement.

(b) For a shear plane through the web, equal to ...

8.4.3 Design shear strength The design longitudinal shear strength shall be taken as ϕV_{uf} where -

$$V_{uf} = \beta_4 A_s f_{sy} d/s + \beta_5 b_f d f'_{ct} \le 0.2 f'_c b_f d$$

where

β_4, β_5 = the shear plane surface coefficients given in Clause 8.4.4

A_s = cross-sectional area of reinforcement anchored each side of the shear plane

f_{sy} = the yield strength of the reinforcement crossing the shear plane

d = effective depth of the composite beam

s = spacing of reinforcement crossing the shear plane

b_f = the width of the shear interface

f'_{ct} = the characteristic principal tensile strength of the concrete.

8.4.4 Shear plane surface coefficients The shear plane surface coefficients, β_4 and β_5, for the surface condition of the shear plane, shall be determined from Table 8.4.4, except that where the beam is subject to high levels of differential shrinkage, temperature effects, tensile stress, or fatigue effects across the shear plane, the value of β_5 should be reduced.

TABLE 8.4.4

SHEAR PLANE SURFACE COEFFICIENTS

Surface condition of the shear plane	Coefficients	
	β_4	β_5
A smooth surface, as obtained by casting against a form, or finished to a similar standard	0.6	0.1
A surface trowelled or tamped, so that the fines have been brought to the top, but where some small ridges, indentations or undulations have been left; slip-formed and vibro-beam screeded; or produced by some form of extrusion technique.	0.6	0.2
A surface deliberately roughened— (a) by texturing the concrete to give a pronounced profile; (b) by compacting but leaving a rough surface with coarse aggregate protruding but firmly fixed in the matrix; (c) by spraying when wet, to expose the coarse aggregate without disturbing it; or (d) by providing mechanical shear keys.	0.9	0.4
Monolithic construction	0.9	0.5

8.4.5 Shear plane reinforcement Where reinforcement is required to increase the longitudinal shear strength, the reinforcement shall consist of shear reinforcement anchored to develop its full strength at the shear plane. Shear and torsional reinforcement already provided and which crosses the shear plane, may be taken into account for this purpose.

An area of shear reinforcement not less than $0.35 b_f s / f_{sy.f}$ shall be provided.

8.4.6 Minimum thickness of structural components The average thickness of structural components subject to interface shear shall be not less than 50 mm with a minimum local thickness not less than 30 mm.

8.5 DEFLECTION OF BEAMS

8.5.1 General The deflection of a beam shall be determined in accordance with Clause 8.5.2 or Clause 8.5.3.

Alternatively, for reinforced beams, the span-to-effective depth ratio shall comply with Clause 8.5.4.

8.5.2 Beam deflection by refined calculation The calculation of the deflection of a beam by refined calculation shall make allowance for the following:

(a) Shrinkage and creep properties of the concrete.

(b) Expected load history.

(c) Cracking and tension stiffening.

8.5.3 Beam deflection by simplified calculation

8.5.3.1 *Immediate deflection* The immediate deflections due to external loads and prestressing, which occur immediately on their application, shall be calculated using the value of E_{cj} determined in accordance with Clause 6.1.2 and the value of the effective second moment of area of the member, I_{ef}. This value of I_{ef} may be determined from the values of I_{ef} at nominated cross-sections as follows:

(a) For a simply-supported span, the value at midspan.

(b) In a continuous beam:

(i) for an interior span, half the midspan value plus one quarter of each support value; or

(ii) for an end span, half the midspan value plus half the value at the continuous support.

(c) For a cantilever, the value at the support.

For the purpose of the above determinations, the value of I_{ef} at each of the cross-sections nominated in (a) to (c) above is given by—

$$I_{ef} = I_{cr} + (I - I_{cr})(M_{cr}/M_s)^3 \le I$$

where

M_{cr} = the cracking moment at the section (see Clause 8.1.4.1); and

M_s = the maximum bending moment at the section, based on the short-term serviceability load or the construction load.

Alternatively, as a further simplification but only for reinforced members, I_{ef} at each nominated cross-section may be taken as equal to—

(i) for rectangular sections .... $0.045bd^3$; or

(ii) for T and L-sections .... $0.045b_{ef}d^3\,(0.7 + 0.3b_w/b_{ef})^3$.

8.5.3.2 *Long-term deflection* For reinforced or prestressed beams, that part of the deflection which occurs after the short-term deflection shall be calculated as the sum of—

(a) the shrinkage component of the long-term deflection, determined from the estimated shrinkage properties of the concrete and the principles of mechanics; and

(b) the additional long-term creep deflections, determined by multiplying the short-term concrete deformations due to loads and prestress by appropriate creep coefficients.

8.5.3.3 *Multiplier method for long-term deflection of reinforced beams* In the absence of more accurate calculations, the additional long-term deflection of a reinforced beam due to creep and shrinkage may be calculated by multiplying the immediate deflection caused by the sustained load considered, by a multiplier, k_{cs}, given by—

$$k_{cs} = [2 - 1.2(A_{sc}/A_{st})] \ge 0.8$$

where A_{sc}/A_{st} is taken at—

(a) midspan, for a simply-supported or continuous beam; or

(b) the support, for a cantilever beam.

8.5.4 Deemed to comply span-to-depth ratios for reinforced beams For reinforced beams of uniform cross-section subject to uniformly distributed loads only and where the live load, q, does not exceed the dead load, g, beam deflections shall be deemed to comply with the requirements of Clause 2.4.2 if the ratio of effective span to effective depth is not greater than the value given by—

$$L_{ef}/d = \left[\frac{k_1(\Delta/L_{ef})b_{ef}E_c}{k_2F_{d.ef}}\right]^{1/3}$$

where

Δ/L_{ef} = the deflection limit selected in accordance with Clause 2.4.2

$F_{d.ef}$ = the effective design load per unit length, taken as—

(a) $(1.0 + k_{cs})g + (\psi_s + k_{cs}\psi_l)q$ for total deflection; or

(b) $k_{cs}g + (\psi_s + k_{cs}\psi_l)q$ for the deflection which occurs after the addition or attachment of the partitions.

where

k_{cs} is determined in accordance with Clause 8.5.3.3 and ψ_s and ψ_l are given in AS 1170.1.

k_1 = I_{ef}/bd^3, which may be taken as

= 0.045 for rectangular sections, or

= $0.045(0.7 + 0.3b_w/b_{ef})^3$ for T- and L-sections

k_2 = the deflection constant, taken as—

(a) for simply-supported beams, 5/384; or

(b) for continuous beams, where in adjacent spans the ratio of the longer span to the shorter span does not exceed 1.2 and where no end span is longer than an interior span—

(i) 1/185 in an end span; or

(ii) 1/384 in interior spans.

8.6 CRACK CONTROL OF BEAMS

8.6.1 Crack control for flexure in reinforced beams Flexural cracking in reinforced beams shall be deemed to be controlled if the following requirements are satisfied:

(a) The centre-to-centre spacing of bars near the tension face of the beam shall not exceed 200 mm.

(b) The distance from the side or soffit of a beam to the centre of the nearest longitudinal bar shall be not greater than 100 mm.

For the purpose of (a) and (b) above, a bar having a diameter less than half the diameter of the largest bar in the cross-section shall be ignored.

8.6.2 Crack control for flexure in prestressed beams Flexural cracking, in a prestressed beam, shall be deemed to be controlled if, under the short-term service loads, the resulting maximum tensile stress in the concrete does not exceed $0.25\sqrt{f'_c}$ or, if this stress is exceeded, by providing reinforcement or bonded tendons, or both, near the tensile face and limiting either—

(a) the calculated maximum flexural tensile stress under short term service loads to $0.6\sqrt{f'_c}$; or

(b) both—

(i) the increment in steel stress near the tension face to 200 MPa, as the load increases from its value when the extreme concrete tensile fibre is at zero stress to the short-term service load value; and

(ii) the centre-to-centre spacing of reinforcement, including bonded tendons, to 200 mm.

8.6.3 Crack control in the side face of beams For crack control in side faces of beams where the overall depth exceeds 750 mm, longitudinal reinforcement, consisting of Y12 bars at 200 mm centres, or Y16 bars at 300 mm centres, shall be placed in each side face.

8.6.4 Crack control at openings and discontinuities Reinforcement shall be provided for crack control at openings and discontinuities in a beam.

8.7 VIBRATION OF BEAMS Vibration of beams shall be considered and appropriate action taken where necessary to ensure that the vibrations induced by machinery, or vehicular or pedestrian traffic, will not adversely affect the serviceability of the structure.

8.8 T-BEAMS AND L-BEAMS

8.8.1 General Where a slab is assumed to provide the flange of a T-beam or L-beam, the longitudinal shear capacity of the flange-web connection shall be checked in accordance with Clause 8.4.

For isolated T-beams or L-beams, the shear strength of the slab flange on vertical sections parallel to the beam shall also be checked in accordance with Clause 8.2.

8.8.2 Effective width of flange for strength and serviceability In the absence of a more accurate determination, the effective width of the flange of a T-beam or L-beam for strength and serviceability shall be taken as—

(a) T-beams . . . . $b_{ef} = b_w + 0.2a$; and

(b) L-beams . . . . $b_{ef} = b_w + 0.1a$; and

where a is the distance between points of zero bending moment, which for continuous beams, may be taken as $0.7L$.

In both (a) and (b) above, the overhanging part of the flange considered effective shall not exceed half the clear distance to the next member. The effective width so determined may be taken as constant over the entire span.

8.9 SLENDERNESS LIMITS FOR BEAMS

8.9.1 General Unless a stability analysis is carried out, beams shall comply with the limit specified in Clauses 8.9.2 to 8.9.4, as appropriate.

8.9.2 Simply-supported and continuous beams For a simply-supported or continuous beam, the distance L_l between points at which lateral restraint is provided shall be such that L_l/b_{ef} does not exceed the lesser of $180b_{ef}/D$ and 60.

8.9.3 Cantilever beams For a cantilever beam having lateral restraint only at the support, the ratio of the clear projection L_n to the width, b_{ef}, at the support shall be such that L_n/b_{ef} does not exceed the lesser of $100b_{ef}/D$ and 25.

8.9.4 Reinforcement for slender prestressed beams For a prestressed beam in which L_l/b_{ef} exceeds 30, or for a prestressed cantilever beam in which L_n/b_{ef} exceeds 12, the following reinforcement shall be provided—

(a) stirrups providing a steel area, A_{sv}, in accordance with Clause 8.2.8; and

(b) additional longitudinal reinforcement, consisting of at least one bar in each corner of the compression face, such that—

$$A_{sc} \geq 0.35A_{pt}f_p/f_{sy}$$

SECTION 9 DESIGN OF SLABS FOR STRENGTH AND SERVICEABILITY

9.1 STRENGTH OF SLABS IN BENDING

9.1.1 General The strength of a slab in bending shall be determined in accordance with Clauses 8.1.1 to 8.1.6 except that for two-way reinforced slabs, the minimum strength requirements of Clause 8.1.4.1 shall be deemed to be satisfied by providing minimum tensile reinforcement such that A_{st}/bd is not less than one of the following:

(a) Slabs supported by columns .... $1.0/f_{sy}$

(b) Slabs supported by beams or walls .... $0.8/f_{sy}$

(c) Slab footings .... $0.8/f_{sy}$

9.1.2 Reinforcement and tendon distribution in two-way flat slabs In two-way flat slabs, at least 25 percent of the total of the design negative moment in a column-strip and adjacent half middle-strips shall be resisted by reinforcement or tendons or both, located in a cross-section of slab centred on the column and of a width equal to twice the overall depth of the slab or drop panel plus the width of the column.

9.1.3 Detailing of tensile reinforcement in slabs

9.1.3.1 *General procedure for arrangement* Tensile reinforcement shall be arranged in accordance with the following as appropriate:

(a) Where the bending moment envelope has been calculated, the termination and anchorage of flexural reinforcement shall be based on a hypothetical bending-moment diagram formed by displacing the calculated positive and negative bending-moment envelopes a distance D along the slab from each side of the relevant sections of maximum moment. Nevertheless, the following shall apply:

(i) Not less than one-third of the total negative moment reinforcement required at a support shall be extended a distance $12d_b$ or D, whichever is greater, beyond the point of contraflexure.

(ii) At a simply-supported discontinuous end of a slab, not less than one-half of the total positive moment reinforcement required at midspan shall be anchored by extension past the face of the support for a distance of $12d_b$ or D, whichever is greater, or by an equivalent anchorage.

Where no shear reinforcement is required in accordance with Clause 8.2.5 or Clause 9.2, the extension of the mid-span positive moment reinforcement past the face of the support may be reduced to $8d_b$ if at least one-half of the reinforcement is so extended, or to $4d_b$ if all the reinforcement is so extended.

(iii) At a support where the slab is continuous or flexurally restrained, not less than one-quarter of the total positive moment reinforcement required at midspan shall continue past the near face of the support.

(iv) Where frames incorporating slabs are intended to resist lateral loading, the effects of such loading on the arrangement of the slab reinforcement shall be taken into account but in no case shall the lengths of reinforcement be made less than those shown in Figures 9.1.3.2 and 9.1.3.4, as appropriate.

(b) Where the bending moment envelope has not been calculated, the requirements of Clauses 9.1.3.2 to 9.1.3.4, as appropriate to the type of slab, shall be satisfied.

9.1.3.2 *Deemed-to-comply arrangement for one-way slabs* For one-way slabs continuous over two or more spans where—

(a) the ratio of the longer to the shorter of any two adjacent spans does not exceed 1.2; and

(b) the live loads may be assumed to be uniformly distributed and the live load, q, is not greater than twice the dead load, g,

the arrangement of tensile reinforcement shown in Figure 9.1.3.2 shall be deemed to comply with Clause 9.1.3.1(a).

Where adjacent spans are unequal, the extension of negative moment reinforcement beyond each face of the common support shall be based on the longer span.

For one-way slabs of single span the arrangement of tensile reinforcement shown in Figure 9.1.3.2, for the appropriate end support conditions, shall be deemed to comply with Clause 9.1.3.1(a).

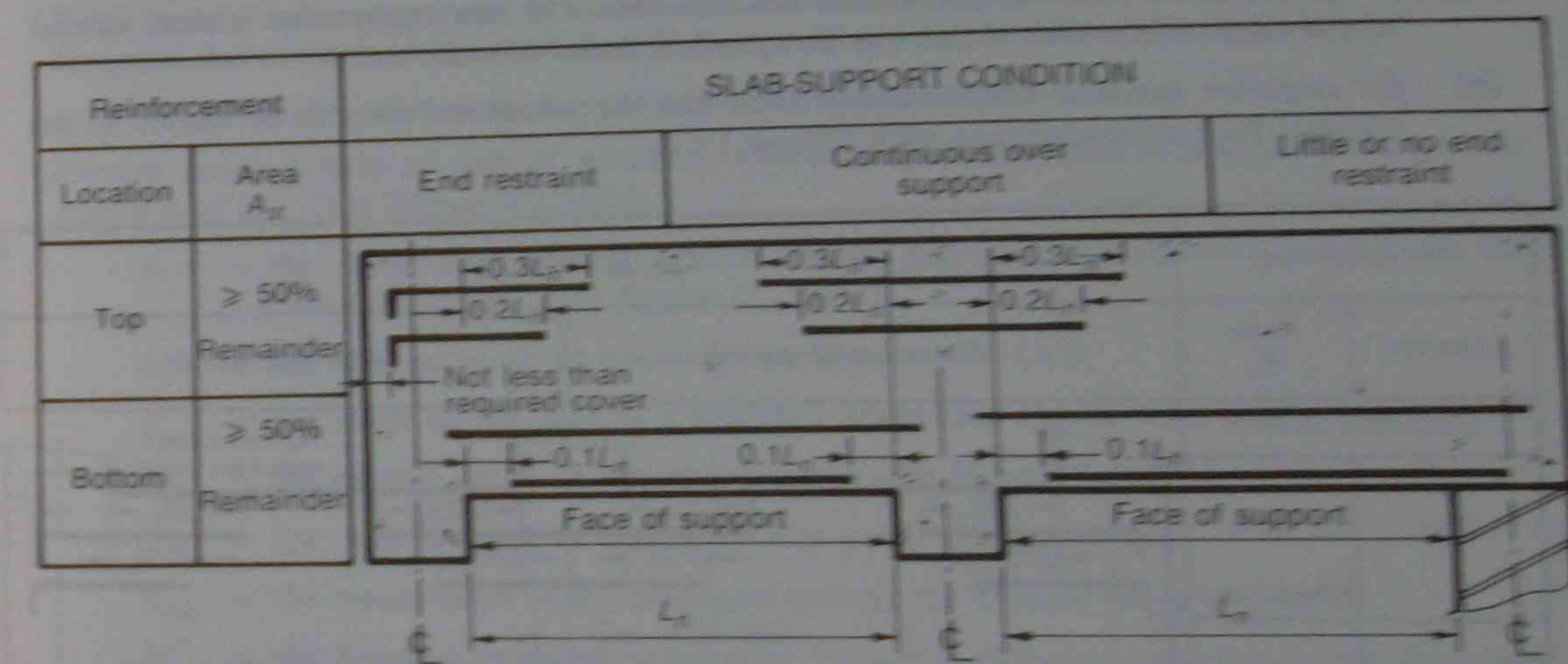


FIGURE 9.1.3.2 ARRANGEMENT OF REINFORCEMENT

9.1.3.3 *Deemed-to-comply arrangement for two-way slabs supported on beams or walls* For two-way simply-supported or continuous rectangular slabs supported by walls or beams on four sides, the arrangement of tensile reinforcement, shown in Figure 9.1.3.2 and further prescribed herein, shall be deemed to comply with Clause 9.1.3.1(a).

The arrangement shall apply to each direction.

Where a simply-supported or continuous slab is not square, the arrangement shall be based on the span, L_n, taken as the shorter span.

Where adjacent continuous rectangular slabs have unequal shorter spans, the extension of negative moment reinforcement beyond each face of a common support shall be based on the span, L_n, taken as the longer of the shorter spans.

Negative moment reinforcement provided at a discontinuous edge shall extend from the face of the support into the span for a distance of 0.15 times the shorter span.

At an exterior corner of a two-way rectangular slab supported on four sides and restrained against uplift, reinforcement shall be provided in both the top and the bottom of the slab. This reinforcement shall consist of two layers perpendicular to the edges of the slab and extend from each edge for a distance not less than 0.2 times the shorter span. The area of the reinforcement in each of the four layers shall be not less than—

(a) for corners where neither edge is continuous .... $0.75\ A_{st}$; and

(b) for corners where one edge is continuous .... $0.5\ A_{st}$;

where A_{st} is the area of the maximum positive moment reinforcement required at mid-span.

Any reinforcement provided may be considered as part of this reinforcement.

9.1.3.4 *Deemed-to-comply arrangement for two-way flat slabs* For multispan reinforced, two-way flat slabs, the arrangement of tensile reinforcement, shown in Figure 9.1.3.4 and further prescribed herein, shall be deemed to comply with Clause 9.1.3.1(a).

Where adjacent spans are unequal the extension of negative moment reinforcement beyond each face of the common support shall be based on the longer span.

All slab reinforcement perpendicular to a discontinuous edge shall be extended (straight, bent or otherwise) past the internal face of the spandrel, wall or column for a length —

(a) *for positive moment reinforcement* not less than 150 mm except that it shall extend to the edge of the slab if there is no spandrel beam or wall; and

(b) *for negative moment reinforcement* such that the calculated force is developed at the internal face in accordance with Clause 13.1.

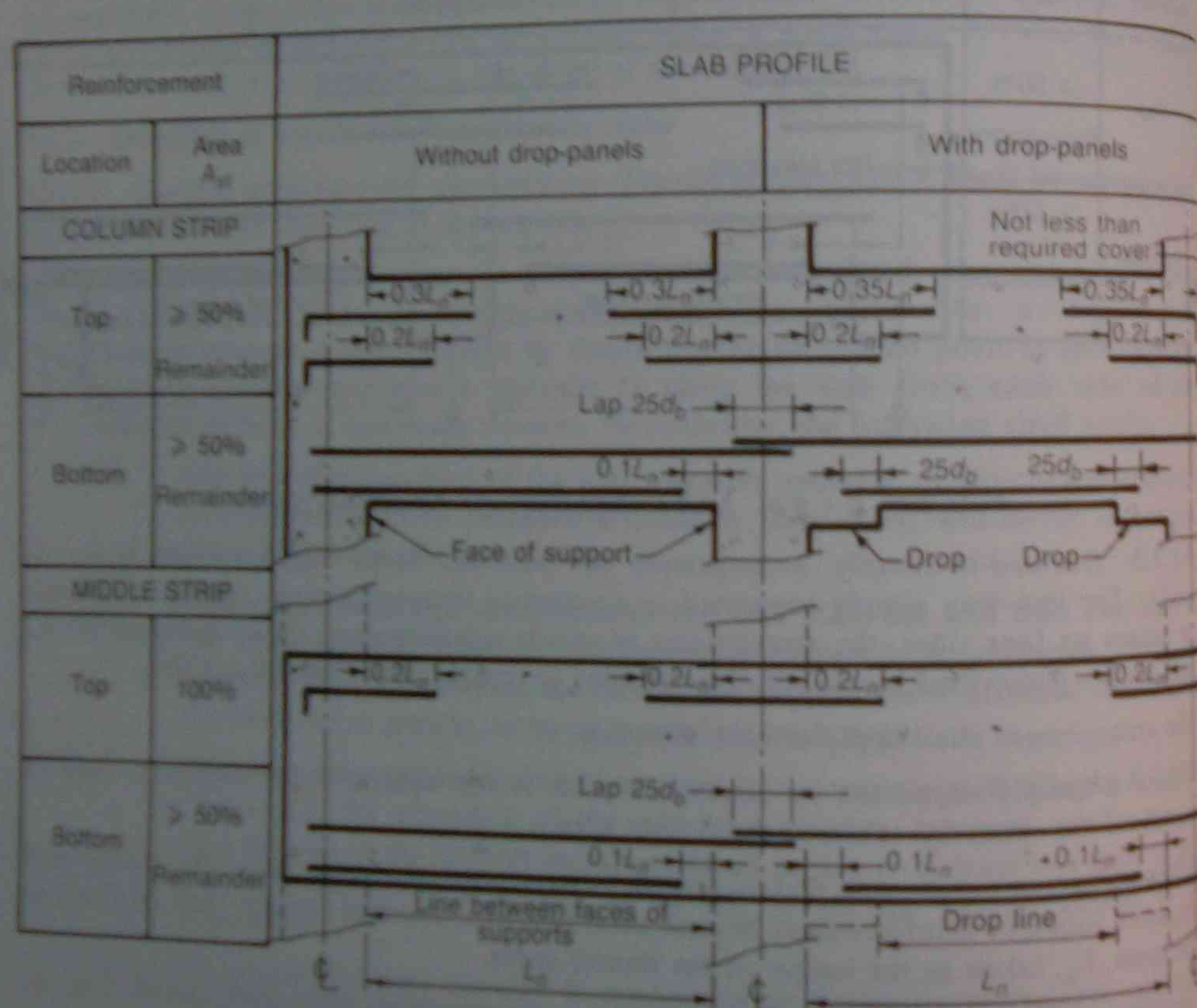


FIGURE 9.1.3.4 ARRANGEMENT OF REINFORCEMENT

9.1.4 Spacing of reinforcement and tendons The minimum clear distance between parallel bars (including bundled bars), ducts and tendons shall be such that the concrete can be properly placed and compacted in accordance with Clause 19.1.3. The maximum spacing of reinforcement and tendons shall be determined in accordance with Clause 9.4.

9.2 STRENGTH OF SLABS IN SHEAR

9.2.1 General For the purpose of this Clause, the following definitions and symbols apply to flat slabs:

Critical shear perimeter—the perimeter defined by a line geometrically similar to the boundary of the effective area of a support or concentrated load and located at a distance of $d_{om}/2$ therefrom (see Figure 9.2.1(A)).

Critical opening—any opening through the thickness of a slab where an edge, or part of the edge, of the opening is located at a clear distance of less than $2.5b_o$ from the critical shear perimeter (see Figure 9.2.1(A)).

Effective area of a support or concentrated load—the area totally enclosing the actual support or load and for which the perimeter is a minimum (see Figure 9.2.1(A)).

Shear head—an arrangement of reinforcement or fabricated steel sections at a support, designed and constructed so that shear failure will not occur within the shear head.

NOTE: The design of shear heads is not covered in this Standard.

Torsion strip—a strip of slab of width a, whose longitudinal axis is perpendicular to the direction of M^*_v (see Figure 9.2.1(B)).

a = the dimension of the critical shear perimeter measured parallel to the direction of M^*_v (see Figure 9.2.1(B))

b_o = the dimension of an opening (see Figure 9.2.1(A))

b_w = the width of the web of a spandrel beam (see Figure 9.2.1(B))

D_b = the overall depth of a spandrel beam (see Figure 9.2.6)

D_s = the overall depth of a slab or drop panel as appropriate

d_{om} = the mean value of d_o, averaged around the critical shear perimeter

M^*_v = the bending moment transferred from the slab to a support in the direction being considered (see Figure 9.2.1(B))

u = the effective length of the critical shear perimeter (see Figure 9.2.1(A))

y_1 = the larger overall dimension of a closed tie (see Figure 9.2.6)

β_h = the ratio of the longest overall dimension of the effective loaded area, Y, to the overall dimension, X, measured perpendicular to Y (see Figure 9.2.1(A)).

9.2.2 Application The strength of a slab in shear shall be determined in accordance with the following:

(a) Where shear failure can occur across the width of the slab, the design shear strength of the slab shall be calculated in accordance with Clause 8.2.

(b) Where shear failure can occur locally around a support or concentrated load, the design shear strength of the slab shall be taken as ϕV_u where V_u is calculated in accordance with one of the following as appropriate:

(i) Where M^*_v is zero, V_u is taken as equal to V_{uo} calculated in accordance with Clause 9.2.3.

(ii) Where M^*_v is not zero, V_u is calculated in accordance with Clause 9.2.4.

9.2.3 Ultimate shear strength where M^*_v is zero The ultimate shear strength of a slab where M^*_v is zero, V_{uo}, is given by either—

(a) where there is no shear head—

$$V_{uo} = ud_{om}(f_{cv} + 0.3\sigma_{cp})$$

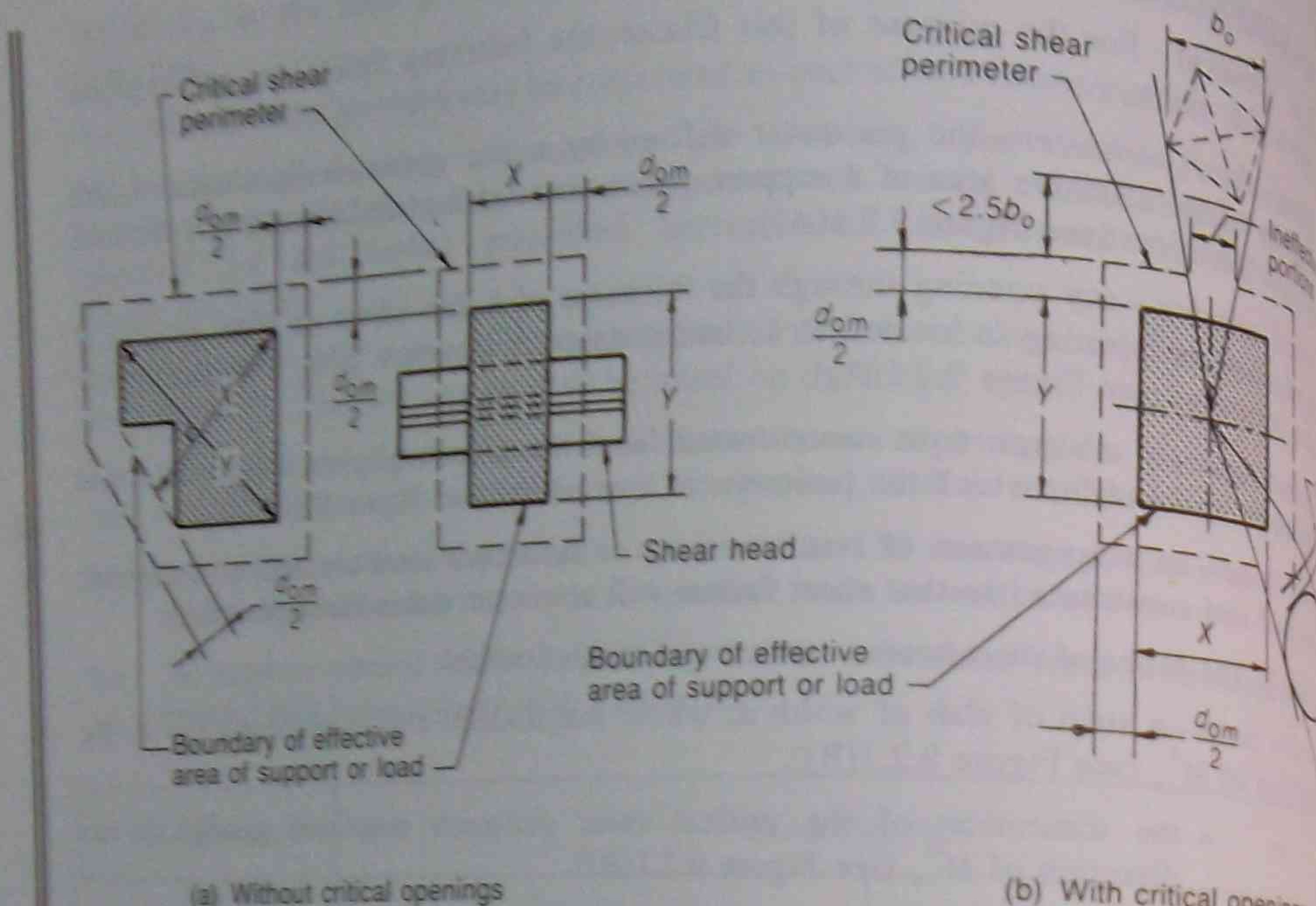


FIGURE 9.2.1(A) CRITICAL SHEAR PERIMETER

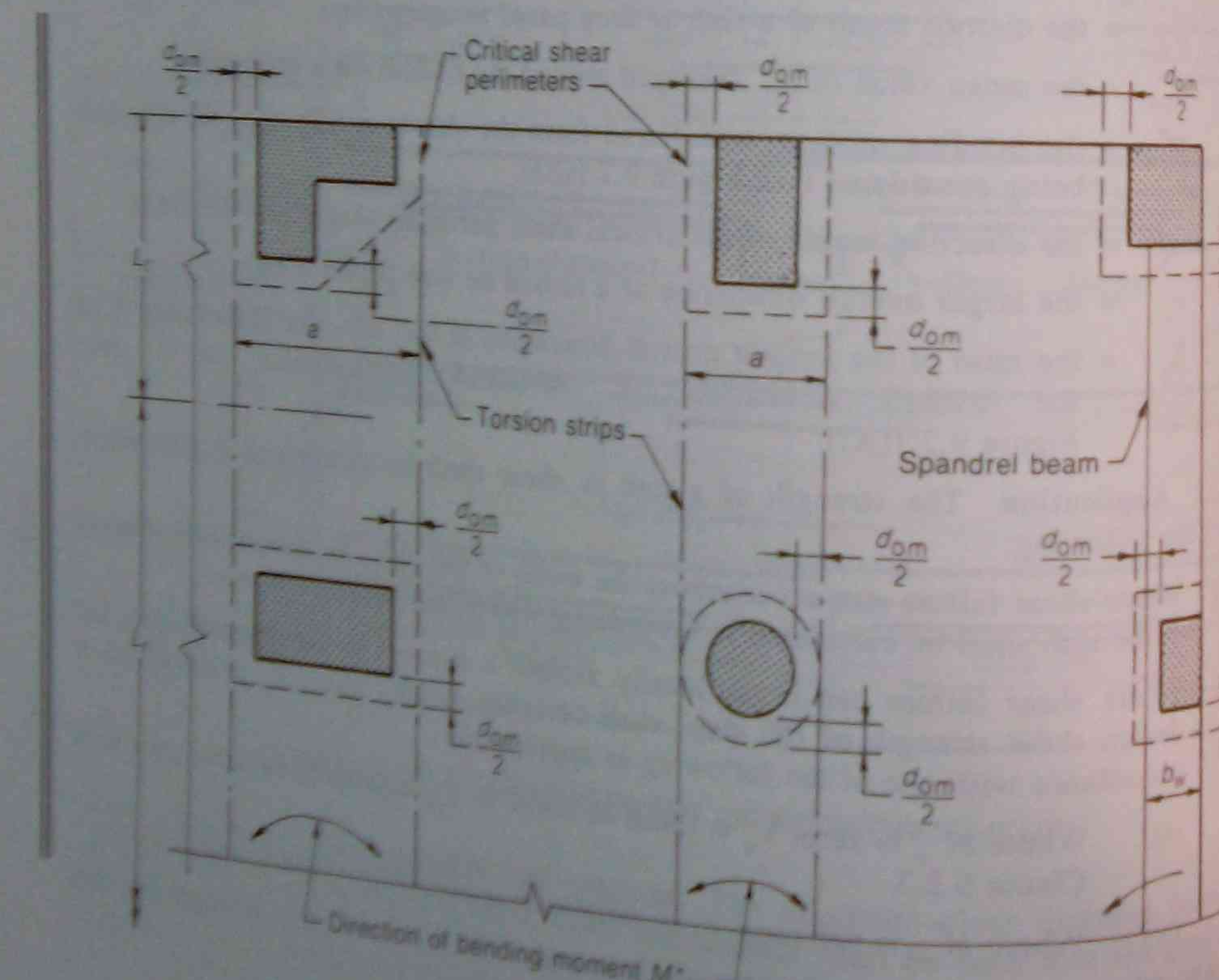


FIGURE 9.2.1(B) TORSION STRIPS AND SPANDREL BEAMS

where

$$F_{cv} = 0.17\left(1 + \frac{2}{\beta_h}\right)\sqrt{f'_c} \le 0.34\sqrt{f'_c}\text{; or}$$

(b) where there is a shear head—

$$V_{uo} = ud_{om}(0.5\sqrt{f'_c} + 0.3\sigma_{cp}) \le 0.2\ ud_{om}f'_c$$

9.2.4 Ultimate shear strength where M^*_v is not zero Where M^*_v is not zero and shear reinforcement, if provided, complies with Clauses 9.2.5 and 9.2.6, then V_u shall be determined from one of the following:

(a) If there are no closed ties in the torsion strip or spandrel beams, V_u is given by—

$$V_u = V_{uo}/[1.0 + (uM^*_v/8V^*ad)].$$

(b) If the torsion strip contains the minimum quantity of closed ties, V_u shall be taken as $V_{u\ min}$ given by—

$$V_{u\ min} = 1.2\ V_{uo}/[1.0 + (uM^*_v/2V^*a^2)].$$

(c) If there are spandrel beams perpendicular to the direction of M^*_v which contain the minimum quantity of closed ties, V_u shall be taken as $V_{u\ min}$ given by—

$$V_{u\ min} = 1.2\ V_{uo}(D_b/D_s)/[1.0 + (uM^*_v/2V^*ab_w)].$$

(d) If the torsion strip or spandrel beam, contains more than the minimum quantity of closed ties, V_u is given by—

$$V_u = V_{u.min}\sqrt{[(A_{sw}/s)/(0.2y_1/f_{sy.f})]}$$

where $V_{u\ min}$ is calculated in accordance with (b) or (c), as appropriate.

In no case shall V_u be taken greater than $V_{u\ max}$ given by—

$$V_{u.max} = 3V_{u.min}\sqrt{(x/y)}$$

where x and y are the shorter and longer dimensions respectively of the cross-section of the torsion strip or spandrel beam.

9.2.5 Minimum area of closed ties The minimum cross-sectional area of the reinforcement forming the closed ties shall satisfy the following inequality:

$$A_{sw}/s \ge 0.2y_1/f_{sy.f}$$

9.2.6 Detailing of shear reinforcement Reinforcement for slab shear in torsion strips and spandrel beams shall be in the form of closed ties arranged and detailed in accordance with the following:

(a) The ties shall extend along the torsion strip or spandrel beam for a distance not less than $L_t/4$ from the face of the support or concentrated load, on one or both sides of the centroidal axis, as applicable. The first tie shall be located at not more than $0.5s$ from the face of the support.

(b) The spacing, s, of the ties shall not exceed the greater of 300 mm and, D_b or D_s, as applicable.

(c) At least one longitudinal bar shall be provided at each corner of the tie.

(d) The dimensions of the ties are as shown in Figure 9.2.6.

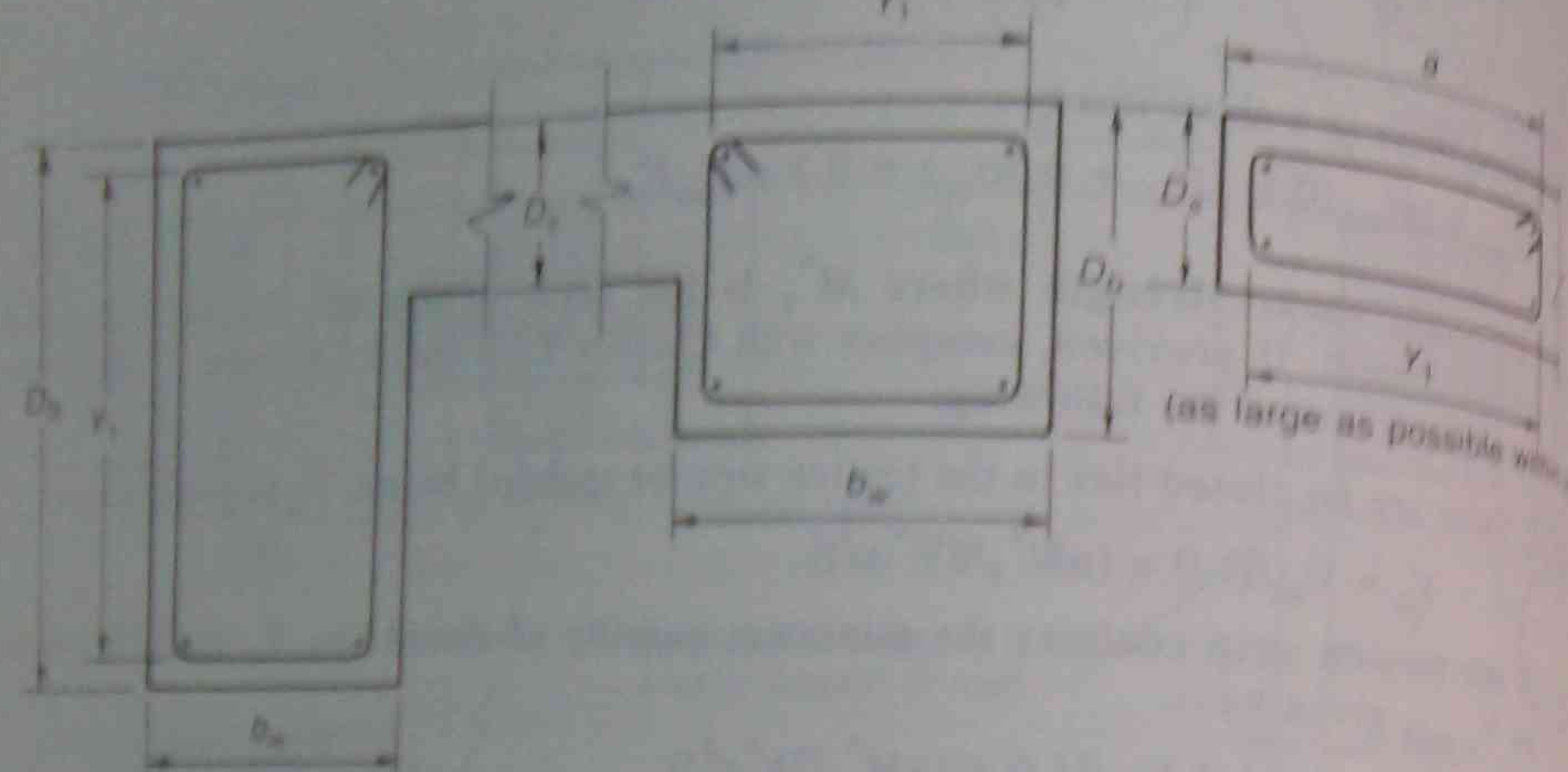


FIGURE 9.2.6 PARAMETERS AND DETAILS OF SHEAR REINFORCEMENT FOR SLABS

9.3 DEFLECTION OF SLABS

9.3.1 General The deflection of a slab shall be determined in accordance wi[th] Clause 9.3.2 or Clause 9.3.3.

Alternatively, for reinforced slabs, the span-to-depth ratio of the slab shall comply wi[th] Clause 9.3.4.

9.3.2 Slab deflection by refined calculation The calculation of the deflection of a sla[b] by refined calculation shall make allowance for the following:

(a) Two-way action.

(b) Shrinkage and creep properties of the concrete.

(c) Expected load history.

(d) Cracking and tension stiffening.

9.3.3 Slab deflection by simplified calculation The deflection of a slab subject [to] uniformly distributed loads shall be calculated in accordance with Clause 8.5.3 on the basis of an equivalent beam taken as follows:

(a) For a one-way slab, a prismatic beam of unit width.

(b) For a rectangular slab supported on four sides, a prismatic beam of unit wid[th] through the centre of the slab, spanning in the short direction L_x, with the same conditions of continuity as the slab in that direction and with the load distributed s[o] that the proportion of load carried by the beam is given by:

$$L_y^4/(\alpha L_x^4 + L_y^4)$$

where α is given in Table 9.3.3 for the appropriate slab-edge condition.

(c) For a two-way flat slab having multiple spans (for deflections along the centreline of the supports), the design strips of the idealized frame described in Clause 7.5.2

TABLE 9.3.3

COEFFICIENT OF PROPORTIONALITY (α)

	Edge Condition	Coefficient (α)
1	Four edges continuous	1.0
2	One short edge discontinuous	0.5
3	One long edge discontinuous	2.0
4	Two short edges discontinuous	0.2
5	Two long edges discontinuous	5.0
6	Two adjacent edges discontinuous	1.0
7	Three edges discontinuous (one long edge continuous)	0.4
8	Three edges discontinuous (one short edge continuous)	2.5
9	Four edges discontinuous	1.0

9.3.4 Deemed to comply span-to-depth ratio for reinforced slabs

9.3.4.1 *One-way slabs and two-way flat slabs* For a reinforced one-way slab, or a multiple-span reinforced two-way flat-slab of essentially uniform depth, subject to uniformly distributed loads and where the live load, q, does not exceed the dead load, g; slab deflections shall be deemed to comply with the requirements of Clause 2.4.2 if the ratio of the effective span to the effective depth is not greater than the value given by—

$$L_{ef}/d = k_3 k_4 \left[\frac{(\Delta/L_{ef})E_c}{F_{d.ef}}\right]^{1/3}$$

where

Δ/L_{ef} = the deflection limit selected in accordance with Clause 2.4.2 and the deflection, Δ, is taken on the centreline between the supports used to calculate L_{ef}

L_{ef} = the effective span

$F_{d.ef}$ = the effective design load, per unit area, taken as—

(a) $(1.0 + k_{cs})g + (\psi_s + k_{cs}\psi_l)q$, for total deflection; or

(b) $k_{cs}g + (\psi_s + k_{cs}\psi_l)q$, for the deflection which occurs after the addition or attachment of the partitions

where

k_{cs} is determined in accordance with Clause 8.5.3.3 and ψ_s and ψ_l are given in AS 1170.1.

k_3 = 1.0 for a one-way slab

= 0.95 for a two-way flat slab without drop panels

= 1.05 for a two-way flat slab with drop panels, which extend at least $L/6$ in each direction on each side of a support centreline and have an overall depth not less than 1.3 D where D is the slab thickness beyond the drops.

k_4 = the deflection constant which may be taken as—

(a) for simply supported slabs, 1.6; or

(b) for continuous slabs, where in adjoining spans the ratio of the long span to the shorter span does not exceed 1.2 and where no end span longer than an interior span—

(i) 2.0 in an end span; or

(ii) 2.4 in interior spans.

9.3.4.2 *Rectangular slabs supported on four sides* For a reinforced concrete slab supported on four sides by walls or beams, subject to uniformly distributed loads where the live load, q, does not exceed the dead load, g, the slab deflection shall be deemed to comply with the requirements of Clause 2.4.2 if the ratio of the short effective span to the effective depth satisfies the requirements given in Clause 9.3.4 except that—

(a) k_3 shall be taken as 1.0; and

(b) the appropriate value of k_4 shall be taken from Table 9.3.4.2.

TABLE 9.3.4.2

SLAB-SYSTEM MULTIPLIER (k_4) FOR RECTANGULAR SLABS SUPPORTED ON FOUR SIDES

	Edge condition	Deflection constant (k_4)			
		Ratio of long to short side (L_y/L_x)			
		1.0	1.25	1.5	2.0
1	Four edges continuous	4.00	3.40	3.10	2.75
2	One short edge discontinuous	3.75	3.25	3.00	2.70
3	One long edge discontinuous	3.75	2.95	2.65	2.30
4	Two short edges discontinuous	3.55	3.15	2.90	2.65
5	Two long edges discontinuous	3.55	2.75	2.25	1.80
6	Two adjacent edges discontinuous	3.25	2.75	2.50	2.20
7	Three edges discontinuous (one long edge continuous)	3.00	2.55	2.40	2.15
8	Three edges discontinuous (one short edge continuous)	3.00	2.35	2.10	1.75
9	Four edges discontinuous	2.50	2.10	1.90	1.70

9.4 CRACK CONTROL OF SLABS

9.4.1 Crack control for flexure in reinforced slabs Flexural cracking in reinforced slabs, shall be deemed to be controlled if the centre-to-centre spacing of bars in each direction does not exceed the lesser of 2.5D or 500 mm. For the purpose of this Clause bars with a diameter less than half the diameter of the largest bar in the cross-section shall be ignored.

9.4.2 Crack control for flexure in prestressed slabs Flexural cracking in a prestressed slab shall be deemed to be controlled if under the short-term service loads, the resulting maximum tensile stress in the concrete does not exceed $0.25\sqrt{f'_c}$ or, if this stress is exceeded, by providing reinforcement or bonded tendons near the tensile face and limiting—

(a) either the calculated maximum flexural tensile stress in the concrete under short-term service load to $0.5\sqrt{f'_c}$; or

(b) both—

(i) the increment in steel stress near the tension face to 150 MPa as the load increases from its value when the extreme concrete tensile fibre is at zero stress to the short-term service load value; and

(ii) the centre-to-centre spacing of reinforcement, including bonded tendons, to 500 mm.

9.4.3 Crack control for shrinkage and temperature effects

9.4.3.1 *General* The area of reinforcement required to control cracking due to shrinkage and temperature effects shall take into account the influence of flexural action, the degree of restraint against in-plane movements and the exposure classification, in accordance with Clauses 9.4.3.2 to 9.4.3.5.

For members greater than 500 mm thick, the reinforcement required near each surface may be calculated using 250 mm for D.

9.4.3.2 *Reinforcement in the primary direction* No additional reinforcement is required to control expansion or contraction cracking if the area of reinforcement in the direction of the span of a one-way slab, or in each direction of a two-way slab, is not less than—

(a) the area required by Clause 9.1.1; and

(b) 75% of the area required by one of Clauses 9.4.3.3 to 9.4.3.5, as appropriate.

9.4.3.3 *Reinforcement in the secondary direction in unrestrained slabs* Where the slab is free to expand or contract in the secondary direction, the minimum area of reinforcement in that direction shall be $(0.7 - \sigma_{cp})bD/f_{sy}$, except that this requirement may be waived if the width of the slab in the secondary direction is less than 2.5 m.

9.4.3.4 *Reinforcement in the secondary direction in restrained slabs* Where a slab is restrained from expanding or contracting in the secondary direction, the area of reinforcement in that direction shall be not less than the following, as appropriate:

(a) For exposure classifications A1 and A2—

(i) where a minor degree of control over cracking is required $(0.7 - \sigma_{cp})bD/f_{sy}$;

(ii) where a moderate degree of control over cracking is required . . . . $(1.4 - \sigma_{cp})bD/f_{sy}$; and

(iii) where a strong degree of control over cracking is required $(2.5 - \sigma_{cp})bD/f_{sy}$.

(b) For exposure classifications B1, B2 and C . . . . $(2.5 - \sigma_{cp})bD/f_{sy}$.

9.4.3.5 *Reinforcement in the secondary direction in partially restrained slabs* Where a slab is partially restrained from expanding or contracting in the secondary direction, the minimum area of reinforcement in that direction shall be assessed taking into account the requirements of Clauses 9.4.3.3 and 9.4.3.4.

9.4.4 Crack control in the vicinity of restraints In the vicinity of restraints, special attention shall be paid to the internal forces and cracks which may be induced by prestressing, shrinkage or temperature.

9.4.5 Crack control at openings and discontinuities For crack control at openings and discontinuities in a slab, additional properly-anchored reinforcement shall be provided if necessary.

9.5 VIBRATION OF SLABS Vibration in slabs shall be considered and appropriate action taken where necessary to ensure that vibrations induced by machinery or vehicular and pedestrian traffic, will not adversely affect the serviceability of the structure.

9.6 MOMENT RESISTING WIDTH FOR ONE-WAY SLABS SUPPORT CONCENTRATED LOADS The width of a solid one-way simply-supported continuous slab deemed to resist the moments caused by a concentrated load, ma taken as follows:

(a) Where the load is not near an unsupported edge:

b_{ef} = the load width + $2.4a(1.0—(a/L_n))$

where

a = the perpendicular distance from the nearer support to the section u consideration.

(b) Where the load is near an unsupported edge, not greater than the lesser of—

(i) the value given in Item (a) above; and

(ii) half the value given in Item (a) above plus the distance from the cent the load to the unsupported edge.

9.7 LONGITUDINAL SHEAR IN COMPOSITE SLABS Composite slab sys shall be checked for longitudinal shear at the interfaces between componen accordance with Clause 8.4.

SECTION 10 DESIGN OF COLUMNS FOR STRENGTH AND SERVICEABILITY

10.1 GENERAL

10.1.1 Design strength The design strength of a column shall be determined by its ability to resist the axial forces and bending moments caused by the design loading for strength and any additional bending moments produced by slenderness effects.

10.1.2 Minimum bending moment At any cross-section of a column, the design bending moment about each principal axis shall be taken to be not less than N^* times $0.05D$, where D is the overall depth of the column in the plane of the bending moment.

10.1.3 Definitions For the purpose of this Section the following definitions apply:

Braced columns—members for which the lateral load on the structure in the direction under consideration is resisted by masonry infill panels, shear walls or lateral bracing.

Short columns—columns in which the additional bending moments due to slenderness can be taken as zero.

Slender columns—columns that do not satisfy the requirements for short columns.

10.2 DESIGN PROCEDURES

10.2.1 Design procedure using linear elastic analysis Where the axial forces and bending moments are determined by a linear elastic analysis as provided in Clause 7.6, a column shall be designed as follows:

(a) For a short column, in accordance with Clauses 10.3, 10.6 and 10.7.

(b) For a slender column, in accordance with Clauses 10.4 to 10.7.

10.2.2 Design procedure, incorporating secondary bending moments Where the axial forces and bending moments are determined by an elastic analysis incorporating secondary bending moments due to lateral joint displacements, as provided in Clause 7.7, a column shall be designed in accordance with Clauses 10.6 and 10.7. The bending moments in slender columns shall be further increased by applying the moment magnifier for a braced column, δ_b, calculated in accordance with Clause 10.4.2 with L_e taken as L_u in the determination of N_c.

10.2.3 Design procedure, using rigorous analysis Where the axial forces and bending moments are determined by a rigorous analysis, as provided in Clause 7.8, a column shall be designed in accordance with Clauses 10.6 and 10.7 without further consideration of additional moments due to slenderness.

10.3 DESIGN OF SHORT COLUMNS

10.3.1 General Short columns shall be designed in accordance with Clauses 10.6 and 10.7, with additional bending moments due to slenderness taken to be zero. Alternatively, for short columns with small axial forces or small bending moments, the design may be in accordance with Clauses 10.3.2 and 10.3.3 respectively.

A column shall be deemed to be short where—

(a) for a braced column—

$L_e/r \leq 25$; or

$\leq 60(1 + M^*_1/M^*_2)(1.0 - N^*/0.6N_{uo})$

whichever is the greater; or

(b) for an unbraced column—

$L_e/r \leq 22$.

In both (a) and (b) above —

r = the radius of gyration of the cross-sections determined in accordance with Clause 10.5.2

M^*_1/M^*_2 = the ratio of the smaller to the larger of the design bending moments at the ends of the column. The ratio is taken to be negative when the column is bent in single curvature and positive when the column is bent in double curvature. When the absolute value of M^*_2 is equal to $0.05DN^*$, the ratio shall be taken as −1.0.

L_e = the effective length determined in accordance with Clause 10.5, or alternatively may be taken as—

(i) for a braced column restrained by a flat slab floor, L_u;

(ii) for a braced column restrained by beams, $0.9L_u$; and

(iii) for a column designed in accordance with Clause 10.2.2, L_u.

10.3.2 Short column with small compressive axial force Where the design compressive axial force, N^*, in a short column is less than $0.1f'_cA_g$, the cross-section may be designed for bending only.

10.3.3 Short braced column with small bending moments The bending moments in a short interior column of a braced rectangular framed building structure may be disregarded if—

(a) the ratio of the longer to the shorter length of any two adjacent spans does not exceed 1.2;

(b) the loads are essentially uniformly distributed;

(c) the live load, q, does not exceed twice the dead load, g;

(d) members are of uniform cross-section; and

(e) the cross-section of the column is symmetrically reinforced,

in which case the design axial strength, ϕN_u, is taken as not greater than $0.75\phi N_{uo}$, where N_{uo} is determined in accordance with Clause 10.6.3.

10.4 DESIGN OF SLENDER COLUMNS

10.4.1 General Slender columns shall be designed in accordance with Clauses 10.6 and 10.7, with additional bending moments due to slenderness effects taken into account by multiplying the largest design bending moment by the moment magnifier, δ.

The moment magnifier, δ, shall be calculated in accordance with Clause 10.4.2 for a braced column and Clause 10.4.3 for an unbraced column.

For columns subject to bending about both principal axes, the bending moment about each axis shall be magnified by δ, using the restraint conditions applicable to each plane of bending.

The additional end moments calculated from moment magnification may be distributed to the members of the joint in proportion to their stiffness.

10.4.2 Moment magnifier for a braced column The moment magnifier, δ, for a braced column, shall be taken to be equal to δ_b given by—

$$\delta_b = k_m/(1 - N^*/N_c) \geq 1.0$$

where

N_c = the buckling load given in Clause 10.4.4.

k_m = $(0.6 - 0.4\,M^*_1/M^*_2)$ but shall be taken as not less than 0.4, except that if the column is subjected to significant transverse loading between its ends and in the absence of more exact calculations, k_m shall be taken as 1.0.

10.4.3 Moment magnifier for an unbraced column The moment magnifier, δ, for an unbraced column shall be taken as the larger value of δ_b or δ_s where—

(a) δ_b for an individual column is calculated in accordance with Clause 10.4.2 assuming the column is braced; and

(b) δ_s for each column in the storey is calculated as

$$1/(1 - \Sigma N^*/\Sigma N_c)$$

where the summations include all columns within the storey and N_c is calculated for each column in accordance with Clause 10.4.4.

As an alternative to (b), δ_s may be calculated from a linear elastic critical buckling load analysis of the entire frame, where δ_s is taken as a constant value for all columns given by—

$$\delta_s = 1/[1 - (1 + \beta_d)/(\phi_s\lambda_{uc})]$$

where

β_d = $G/(G + Q)$ taken as zero when $L_e/r \leq 40$ and $N^* \leq M^*/2D$, and G and Q are the design axial load components due to dead load and live load respectively.

ϕ_s = a correlation factor taken as 0.6.

λ_{uc} = the ratio of the elastic critical buckling load of the entire frame to the design load for strength, calculated by taking the cross-sectional stiffness of the flexural members and columns as $0.4E_cI_f$ and $0.8E_cI_c$ respectively.

The frame shall be proportioned so that δ_s for any column is not greater than 1.5.

10.4.4 Buckling load The buckling load, N_c, shall be taken as—

$$N_c = (\pi^2/L_e^2)[200d_o(\phi M_{ub})/(1 + \beta_d)]$$

where

ϕM_{ub} = the design strength in bending of the cross-section when $k_{uo} = 0.60$ and $\phi = 0.6$.

10.5 SLENDERNESS

10.5.1 General The slenderness ratio, L_e/r, of a column shall not exceed 120, unless a rigorous analysis has been carried out in accordance with Clause 7.8 and the column is designed in accordance with Clause 10.2.3.

Where the forces and moments acting on a column have been obtained from a linear elastic analysis, as specified in Clause 7.6, the influence of slenderness shall be taken into account using a radius of gyration, r, specified in Clause 10.5.2 and an effective length, L_e, in accordance with Clause 10.5.3.

10.5.2 Radius of gyration The radius of gyration, r, shall be calculated for the gross concrete cross-section. For a rectangular cross-section, r may be taken as $0.3D$, where D is the overall dimension in the direction in which stability is being considered and for a circular cross-section, r may be taken as $0.25D$.

10.5.3 Effective length of a column The effective length of a column, L_e, shall be taken as kL_u where the effective length factor, k, is determined from Figure 10.5.3(A) for columns with simple end restraints, or more generally from Figure 10.5.3(B) or 10.5.3(C), as appropriate.

The end restraint coefficients, γ_1 and γ_2, shall be determined—

(a) for regular rectangular framed structures where the axial forces in the beams are generally small, in accordance with Clause 10.5.4;

(b) for all structures, including non-rectangular framed structures or structures where the axial forces in the restraining members are large, in accordance with Clause 10.5.5; and

(c) where the column ends at a footing, in accordance with Clause 10.5.6.

Alternatively, the effective length of a column may be determined from the elastic critical buckling load of the frame as calculated by analysis.

10.5.4 End restraint coefficients for regular rectangular framed structures For regular rectangular framed structures, the end restraint coefficient, γ_1, at one end of a column and the end restraint coefficient, γ_2, at the other end, may each be calculated as—

$$\frac{\Sigma(I/L)_c}{\Sigma(\beta I/L)_b}$$

where

$\Sigma(I/L)_c$ = the sum of the stiffnesses in the plane of bending of all the columns meeting at and rigidly connected to the end of the column under consideration,

$\Sigma(\beta I/L)_b$ = the sum of the stiffnesses in the plane of bending of all the beams or slabs, or both, meeting at and rigidly connected to the same end of the column under consideration,

β = a fixity factor, given in Table 10.5.4, for fixity conditions at the end of each beam or slab, or both, opposite to the end connected to the column under consideration.

TABLE 10.5.4
FIXITY FACTOR, β

Fixity conditions at far end of a beam or slab, or both	Fixity factor (β)	
	Beam or slab or both, in a braced frame	Beam or slab or both in an unbraced frame
Pinned	1.5	0.5
Rigidly connected to a column	1.0	1.0
Fixed	2.0	0.67

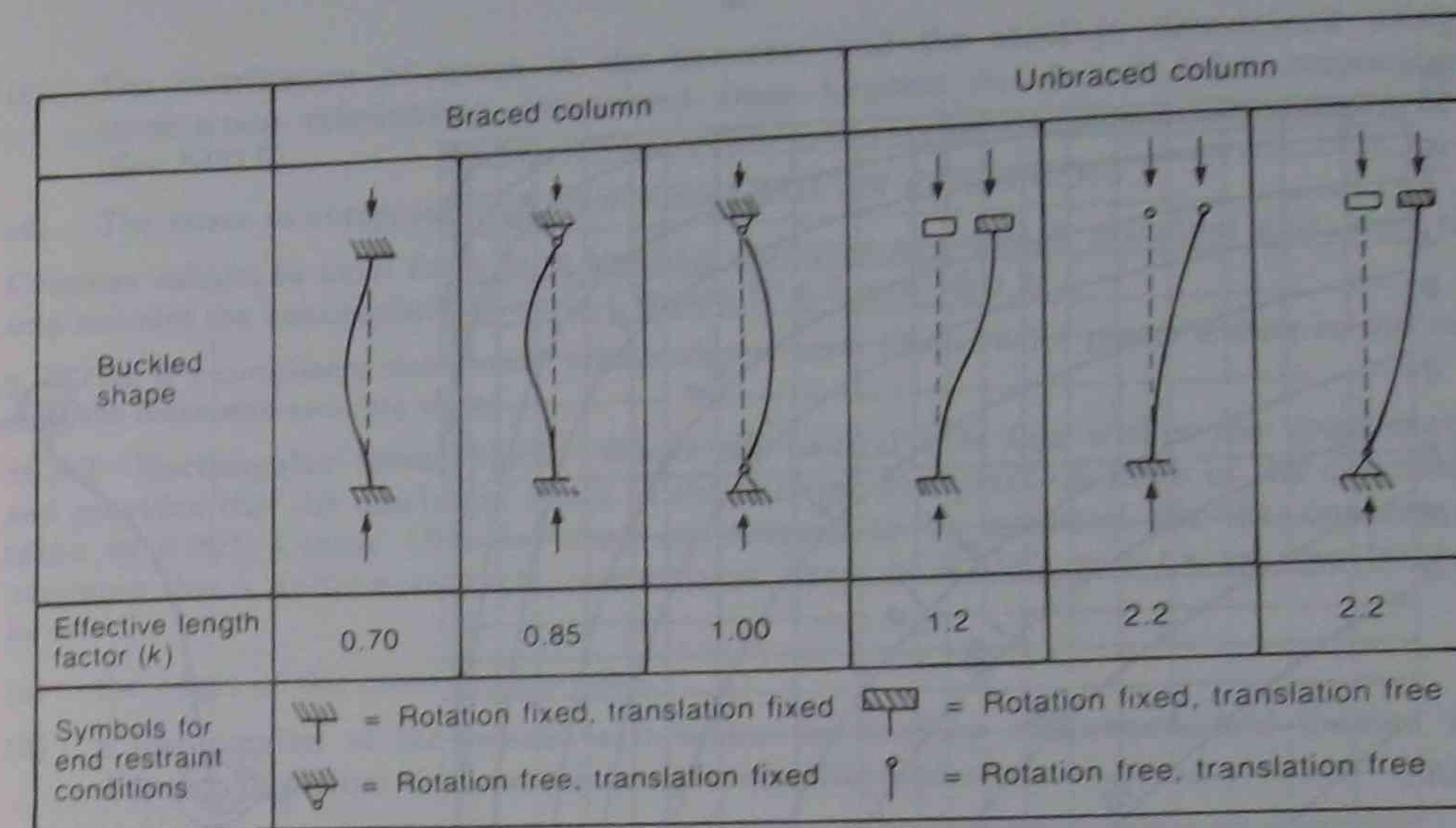


FIGURE 10.5.3(A) EFFECTIVE LENGTH FACTORS (*k*) FOR COLUMNS WITH SIMPLE END RESTRAINTS

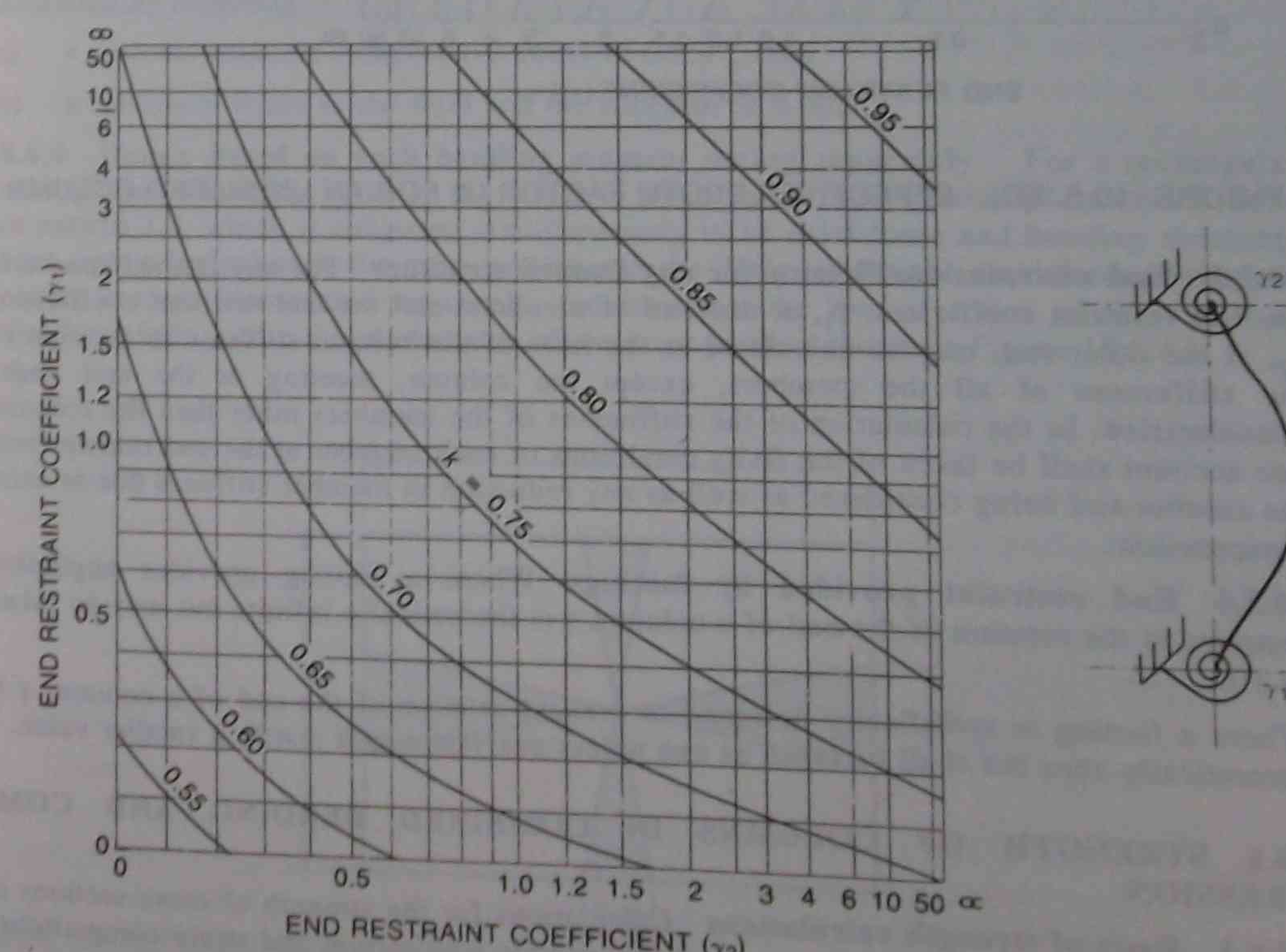


FIGURE 10.5.3(B) EFFECTIVE LENGTH FACTOR (*k*) FOR A BRACED COLUMN

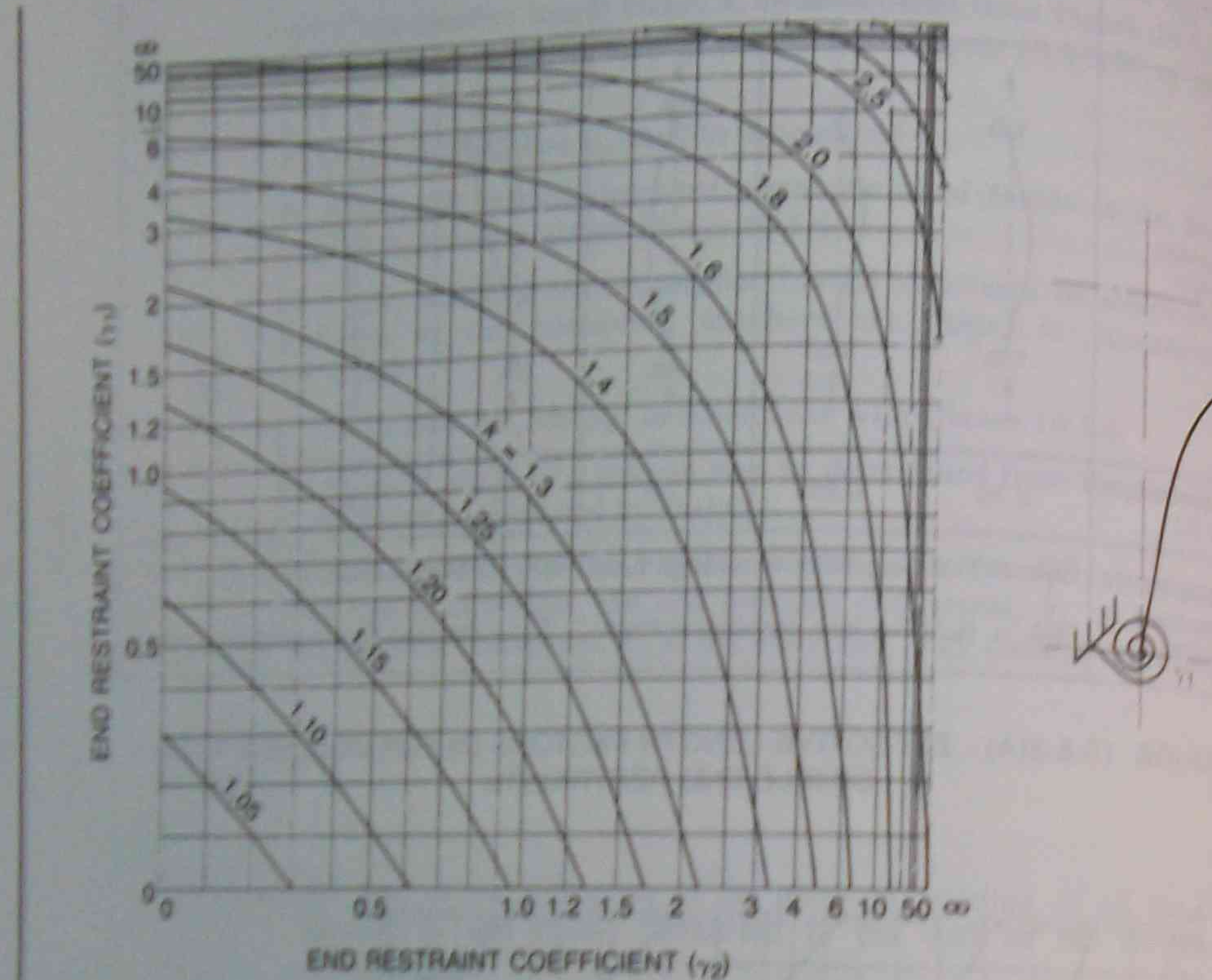


FIGURE 10.5.3(C) EFFECTIVE LENGTH FACTOR (k) FOR AN UNBRACED COLUMN

10.5.5 End restraint coefficients for any framed structure For any framed structure the end restraint coefficient, γ_1, at one end of a column and the end restraint coefficient γ_2, at the other end, may be calculated as the ratio of the column stiffness to the sum of the stiffnesses of all the members, except the column, meeting at the end under consideration. In the calculation of the stiffnesses of the members other than the column due account shall be taken of the fixity conditions of each member at the end remote from the column-end being considered as well as any reduction in member stiffness due to axial compression.

10.5.6 End restraint provided by footings Where a footing provides negligible restraint to the rotation of the end of a column, γ is theoretically infinite but may be taken as 10.

Where a footing is specifically designed to prevent rotation of the end of a column, γ is theoretically zero but shall be taken as one unless analysis would justify a smaller value.

10.6 STRENGTH OF COLUMNS IN COMBINED BENDING AND COMPRESSION

10.6.1 Basis of strength calculations Calculations for the strength of cross-sections in bending combined with axial forces, shall incorporate equilibrium and strain-compatibility considerations and be consistent with the following assumptions:

(a) Plane sections normal to the axis remain plane after bending.

(b) The concrete has no tensile strength.

(c) The distribution of stress in the concrete and the steel is determined using a stress-strain relationship determined from Clauses 6.1.4 and 6.2.3 respectively. (See NOTE).

(d) The strain in compressive reinforcement does not exceed 0.003.

Columns subject to axial force with bending moments about each principal axis, may take into account the concessions given in Clauses 10.6.4 and 10.6.5.

NOTE: If a curvilinear stress-strain relationship is used, Clause 6.1.4 places a limit on the value of the maximum concrete stress.

10.6.2 Rectangular stress block Where the neutral axis lies within the cross-section and provided that the maximum strain in the extreme compression fibre of the concrete is taken as 0.003, Clause 10.6.1(c) shall be deemed to be satisfied for the concrete by assuming that a uniform concrete compressive stress of $0.85f'_c$ acts on an area bounded by—

(a) the edges of the cross-section; and

(b) a line parallel to the neutral axis under the loading concerned, and located at a distance $\gamma k_u d$ from the extreme compressive fibre where—

$\gamma = [0.85 - 0.007\,(f'_c - 28)]$ within the limits 0.65 to 0.85.

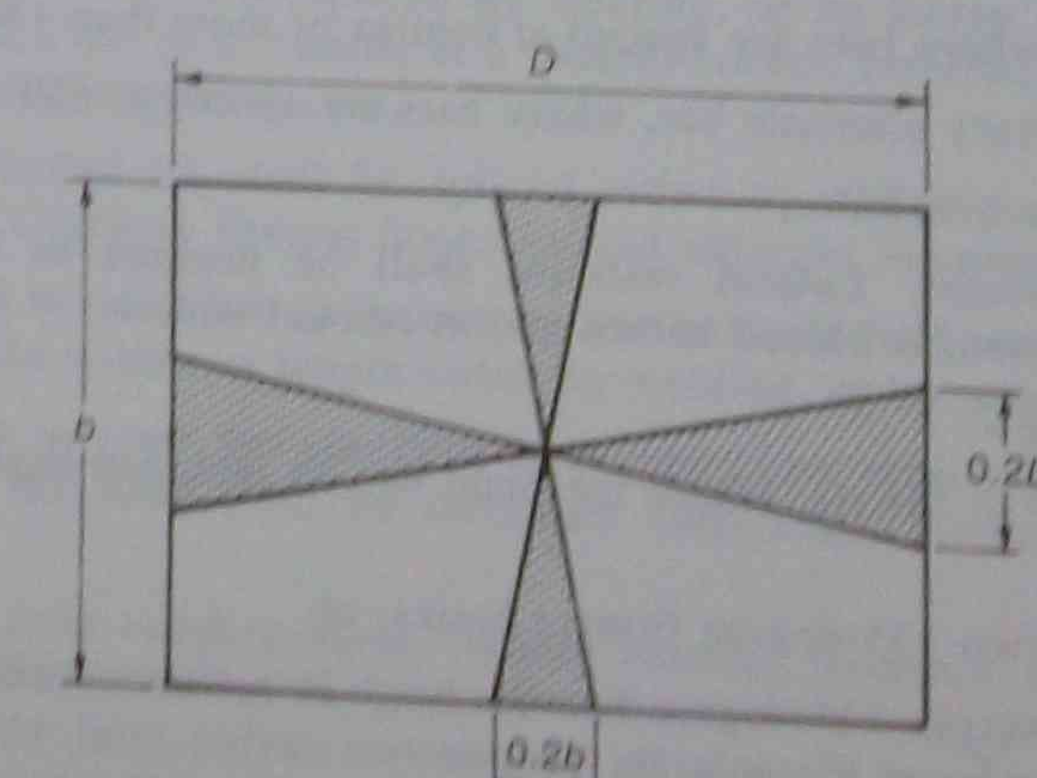
NOTE: The modification given in Clause 6.1.4 is included in the rectangular stress block assumptions.

10.6.3 Calculation of N_{uo} The ultimate strength in compression, N_{uo}, shall be calculated by assuming—

(a) a uniform concrete compressive stress of $0.85f'_c$; and

(b) a maximum strain in the steel and the concrete of 0.002.

10.6.4 Design based on each bending moment acting separately For a rectangular cross-section, where the ratio of the larger to the smaller cross-sectional dimension does not exceed 3.0, which is subjected simultaneously to an axial force and bending moments about each principal axis, the cross-section may be designed for the axial force with each bending moment considered separately, provided that the line of action of the resultant axial force falls within the shaded area of the cross-section shown in Figure 10.6.4.



Shaded areas symmetrical about column centrelines

FIGURE 10.6.4 LIMITATION FOR LINE OF ACTION OF THE RESULTANT AXIAL FORCE

10.6.5 Design for biaxial bending and compression A rectangular cross-section subject to axial force and bending moment acting simultaneously about each principal axis, may be designed such that—

$$\left(\frac{M^*_x}{\phi M_{ux}}\right)^{\alpha_n} + \left(\frac{M^*_y}{\phi M_{uy}}\right)^{\alpha_n} \leq 1.0$$

where

ϕM_{ux}, ϕM_{uy} = the design strength in bending, calculated separately, about the major and minor axis respectively under the design axial force, N^*

M^*_x, M^*_y = the design bending moment about the major and minor axis respectively, magnified if applicable

α_n = $0.7 + 1.7\,N^*/0.6N_{uo}$, within the limits $1 \leq \alpha_n \leq 2$.

10.7 REINFORCEMENT REQUIREMENTS FOR COLUMNS

10.7.1 Limitations on longitudinal steel The cross-sectional area of the longitudinal reinforcement in a column shall—

(a) be not less than $0.01A_g$ except that, in a column which has a larger area than that required for strength, a reduced value of A_{sc} may be used if $A_{sc}f_{sy} > 0.15N^*$; and

(b) not exceed $0.04A_g$ unless the amount and disposition of the reinforcement will not prevent the proper placing and compaction of the concrete at splices and at junctions of the members.

10.7.2 Bundled bars Groups of parallel longitudinal bars bundled to act as a unit, shall have not more than 4 bars in any one bundle and be tied together in contact.

10.7.3 Restraint of longitudinal reinforcement

10.7.3.1 *General requirements* The following longitudinal bars in columns shall be laterally restrained in accordance with Clause 10.7.3.2:

(a) Single bars—

(i) each corner bar;

(ii) all bars, where bars are spaced at centres of more than 150 mm; and

(iii) at least every alternate bar, where bars are spaced at 150 mm or less.

(b) Bundled bars, each bundle.

10.7.3.2 *Lateral restraint* Lateral restraint shall be deemed to be provided if the longitudinal reinforcement is placed within and in contact with—

(a) a non-circular tie—

(i) at a bend in the tie, where the bend has an included angle of 135 degrees or less;

(ii) between two 135-degree fitment hooks; or

(iii) inside a single 135-degree fitment hook of a fitment which is approximately perpendicular to the column face; or

(b) a circular tie or helix and the longitudinal reinforcement is equally spaced around the circumference.

10.7.3.3 *Size and spacing of ties and helices* The size and spacing of ties and helices shall comply with the following:

(a) The bar size of the tie or helix shall be not less than that given in Table 10.7.3.3.

TABLE 10.7.3.3

BAR SIZES FOR TIES AND HELICES

Longitudinal bar size	Minimum bar size of tie or helix millimetres
Up to Y20 single bars	6
Y24 to Y36 single bars	10
Bundled bars	12

(b) The spacing of ties, or the pitch of a helix shall not exceed the smaller of:

(i) D_c and $15d_b$ for single bars; or

(ii) $0.5D_c$ and $7.5d_b$ for bundled bars,

where

D_c = the smaller column dimension if rectangular or the column diameter if circular.

d_b = the diameter of the smallest bar in the column

(c) One tie, or the first turn of a helix, shall be located not more than 50 mm vertically above the top of a footing, or the top of a slab in any storey. Another tie, or the final turn of a helix, shall be located not more than 50 mm vertically below the soffit of the slab except that in a column with a capital, the tie or turn of the helix shall be located at a level at which the area of the cross-section of the capital is not less than twice that of the column.

Where beams or brackets frame from four directions into a column and adequately restrain the column in all directions, the ties or helix may be terminated 50 mm below the highest soffit of such beams or brackets.

(d) Welded wire fabric, having strength and anchorage equivalent to that required for bars, may be used.

10.7.3.4 *Detailing of ties and helices* Detailing of ties and helices shall be as follows:

(a) A rectangular tie shall be spliced by welding, or by fixing two 135-degree fitment hooks around a bar or a bundle at a fitment corner. Internal ties may be spliced by lapping within the column core.

(b) A circular shaped tie shall be spliced either by welding, or by overlapping and fixing two 135-degree fitment hooks around adjacent longitudinal bars or bundles.

(c) A helix shall be anchored at its end by one-and-one-half extra turns of the helix. It may be spliced within its length either by welding, or by mechanical means.

(d) Where hooks or cogs are specified in combination with bundled bars, the internal diameter of the bend shall be increased sufficiently to readily accommodate the bundle.

10.7.3.5 *Column joint reinforcement* Where bending moments from a floor system are transferred to a column, lateral shear reinforcement, of area $A_{sv} \geq 0.35\,bs/f_{sy.f}$, shall be provided through the joint unless restraint on all sides is provided by a floor system of approximately equal depth.

10.7.4 Splicing of longitudinal reinforcement

10.7.4.1 *General* Longitudinal reinforcement in columns shall be spliced in accordance with Clauses 10.7.4.2 to 10.7.4.5 and the splices shall comply with Clause 13.2.

10.7.4.2 *Minimum tensile strength* At any splice in a column a tensile strength in each face of the column of not less than $0.25f_{sy}A_s$ shall be provided; where A_s is the cross-sectional area of longitudinal reinforcement in that face.

10.7.4.3 *Where tensile force exceeds the minimum tensile strength* At any splice in a column where tensile stress exists and the tensile force in the longitudinal bars at any face of the column, due to strength design load effects, exceeds the minimum strength requirements given in Clause 10.7.4.2, the force in the bars shall be transmitted by—

(a) a welded or mechanical splice in accordance with Clause 13.2.2; or

(b) a lap-splice in tension in accordance with Clause 13.2.3 or 13.2.6.

10.7.4.4 *End-bearing splice in compression* Where the splice is always in compression the force in the longitudinal bar may be transmitted by the bearing of square-cut mating ends held in concentric contact by a sleeve, provided that an additional tie which complies with Clause 10.7.3 is placed above and below each sleeve. The bars shall be rotated to achieve the maximum possible area of contact between the ends of the bars and the requirements of Clause 10.7.4.2 shall be met.

10.7.4.5 *Offset bars* Where a longitudinal bar is offset to form a lap splice—

(a) the slope of the inclined part of the bar in relation to the axis shall not exceed 1 in 6;

(b) the portions of the bar on either side of the offset shall be parallel; and

(c) adequate lateral support shall be provided at the offset.

Where a column face is offset 75 mm or greater, longitudinal bars shall not be offset by bending but shall be lap-spliced with the longitudinal bars with separate splicing bars placed adjacent to the offset column faces.

10.8 TRANSMISSION OF AXIAL FORCE THROUGH FLOOR SYSTEMS The transmission of axial force through floor systems shall be designed for in accordance with the following:

(a) Where the strength specified for the column concrete is greater than 1.4 times that specified for the floor system, proper transmission of force through the floor concrete shall be provided by adding vertical reinforcement, in accordance with calculations made on the basis of the lower concrete strength.

(b) Notwithstanding the requirements of (a) above, where the ratio of specified strength for the columns to specified strength for the floor system does not exceed 2.0 proper transmission of force through the floor concrete shall be deemed to exist if—

  (i) the column is restrained on four sides by beams of approximately equal depth, or by a slab;

  (ii) the column is restrained on three sides by beams of approximately equal depth, or by a slab, and the unrestrained face is the shorter side of the column and the column has a ratio of long to short sides of not less than 3.0

  (iii) the column is restrained on three sides by beams of approximately equal depth, or by a slab, and the dimension of the column perpendicular to the unrestrained face is not less than twice the depth of the floor system; or

  (iv) the column is restrained on two sides by beams of approximately equal depth, or by a slab, and the height of the column cast with concrete of the floor system is not greater than 0.25 times the least dimension of the column

SECTION 12 DESIGN OF NON-FLEXURAL MEMBERS, END ZONES AND BEARING SURFACES

12.3 BEARING SURFACES Unless special confinement reinforcemnt is provided, the design bearing stress at a concrete surface shall not exceed $\phi 0.85f'_c\sqrt{(A_2/A_1)}$, or $\phi 2f'_c$, whichever is less,

where

A_2 = the largest area of the supporting surface that is geometrically similar to and concentric with A_1.

A_1 = the bearing area.

In the case of a bearing surface where the supporting structure is sloped or stepped, it shall be permissible to take A_2 as the area of the base of the largest frustrum of a right pyramid or cone—

(a) having for its opposite end the bearing area A_1;

(b) having side slopes of 1 longitudinally to 2 transversely, with respect to the direction of the load; and

(c) contained wholly within the supporting structure.

SECTION 13 STRESS DEVELOPMENT AND SPLICING OF REINFORCEMENT AND TENDONS

13.1 STRESS DEVELOPMENT IN REINFORCEMENT

13.1.1 General The calculated force in reinforcing steel at any cross-section shall be developed on each side of that cross-section in accordance with Clauses 13.1.2 to 13.1.5.

13.1.2 Development length for bar in tension

13.1.2.1 *Development length to develop yield strength* The development length, $L_{sy.t}$, to develop the yield strength, f_{sy}, of a bar in tension shall be calculated as follows:

(a) For all deformed bars:

$$L_{sy.t} = \frac{k_1 k_2 f_{sy} A_b}{(2a + d_b)\sqrt{f'_c}} \geq 25 k_1 d_b$$

where

k_1 = 1.25 for a horizontal bar with more than 300 mm of concrete cast below the bar; or

= 1.0 for all other bars.

k_2 = 1.7 for bars in slabs and walls if the clear distance between adjacent parallel bars developing stress is not less than 150 mm;

= 2.2 for longitudinal bars in beams and columns with fitments;

= 2.4 for any other longitudinal bar.

A_b = the cross-sectional area of the reinforcing bar.

$2a$ = twice the cover to the deformed bar or the clear distance between adjacent parallel bars developing stress, whichever is less.

(b) For plain bars used as fitments, where d_b < 13 mm,

$L_{sy.t}$ = $40d_b$ but not less than 300 mm.

(c) For hard-drawn wire:

$L_{sy.t}$ = $50d_b$.

13.1.2.2 *Deemed-to-comply development lengths* The development length, $L_{sy.t}$, for deformed bars given in Table 13.1.2.2(A) and Table 13.1.2.2(B) for the various bar sizes shall be deemed to comply with the requirements of Clause 13.1.2.1(a) provided that—

(a) the characteristic compressive strength of the concrete, f'_c, and the cover, c, are not less than the corresponding values given in the table;

(b) for horizontal bars with more than 300 mm of concrete cast below the bar, the lengths given are multiplied by 1.25;

(c) for slabs and walls, the clear distance between adjacent parallel bars developing stress is not less than 150 mm; and

(d) for beams and columns, fitments are provided and the clear distance between bars is not less than twice the cover.

13.1.2.3 *Development length to develop less than yield strength* The development length, L_{st}, to develop a tensile stress, σ_{st}, less than the yield strength, f_{sy}, shall be calculated from—

TABLE 13.1.2.2(A)

TENSILE DEVELOPMENT LENGTH ($L_{sy.t}$) FOR A DEFORMED BAR WITH COVERS APPROPRIATE TO STANDARD FORMWORK AND COMPACTION

Combination of minimum values		Tensile development length ($L_{sy.t}$) mm						
		Bar size						
Characteristic strength (f'_c)	Cover to nearest bar or fitment	Y12	Y16	Y20	Y24	Y28	Y32	Y36
20 MPa	20 mm	350	600	800	1150	—	—	—
20 MPa 25 MPa 32 MPa	50 mm 30 mm 25 mm	300	400	600	850	1100	—	—
25 MPa 32 MPa 40 MPa	60 mm 40 mm 30 mm	300	400	500	600	800	1000	1200
32 MPa 40 MPa 50 MPa	65 mm 45 mm 35 mm	300	400	500	600	700	800	1000
40 MPa 50 MPa	70 mm 50 mm	300	400	500	600	700	800	900

NOTE: Intermediate values of $L_{sy.t}$ are not to be interpolated.

TABLE 13.1.2.2(B)

TENSILE DEVELOPMENT LENGTH ($L_{sy.t}$) FOR A DEFORMED BAR WITH COVERS APPROPRIATE TO PRECAST MEMBERS IN RIGID STEEL FORMWORK AND INTENSE COMPACTION

Combination of minimum values		Tensile development length ($L_{sy.t}$) mm						
		Bar size						
Characteristic strength (f'_c)	Cover to nearest bar or fitment	Y12	Y16	Y20	Y24	Y28	Y32	Y36
20 MPa	15 mm	400	700	—	—	—	—	—
20 MPa 25 MPa 32 MPa	35 mm 20 mm 15 mm	300	500	700	950	—	—	—
25 MPa 32 MPa 40 MPa	45 MM 30 MM 25 MM	300	400	550	750	1000	1250	1500
32 MPa 40 MPa 50 MPa	50 mm 35 mm 25 mm	300	400	500	600	800	1000	1200
40 MPa 50 MPa	55 mm 40 mm	300	400	500	600	700	800	900

NOTE: Intermediate values of $L_{sy.t}$ are not to be interpolated.

L_{st} = $L_{sy.t}\sigma_{st}/f_{sy}$

but shall be not less than—

(a) 12 d_b; or

(b) for slabs, as permitted by Clause 9.1.3.1(a)(ii).

13.1.2.4 *Development length around a curve* Tensile stress may be considered to be developed around a curve if the internal diameter of the curve is $10d_b$ or greater.

13.1.2.5 *Development length of a bar with a standard hook* Where a bar ends in a standard hook complying with Clause 13.1.2.6, the tensile development length of that end of the bar, measured from the outside of the hook, shall be taken as $0.5L_{sy.t}$ or $0.5L_{st}$ as applicable.

13.1.2.6 *Standard hooks* The standard hook referred to in Clause 13.1.2.5, shall be one of the following—

(a) a hook consisting of a 135-degree or 180-degree bend with a nominal internal diameter complying with Clause 19.2.3.2 plus a straight extension of $4d_b$ or 70 mm whichever is greater; or

(b) a cog, consisting of a 90-degree bend with a nominal internal diameter complying with Clause 19.2.3.2 but not greater than $8d_b$ and having the same total length as required for a 180° hook of the same diameter bar.

13.1.3 Development length for a bar in compression The development length, $L_{sy.c}$, to develop the yield strength, f_{sy}, in compression in a deformed bar shall be taken as $20d_b$.

A bend or a standard hook shall not be considered effective in developing stress in reinforcement in compression.

13.1.4 Development length of bundled bars The development length of a unit of bundled bars shall be based on the development length required for the largest bar within the bundle increased by—

(a) for a 3-bar bundle .... 20%; and

(b) for a 4-bar bundle 33%

13.1.5 Development length of fabric in tension The development length in tension for longitudinal wires of welded wire fabric shall be deemed to be provided by an embedment of at least two transverse wires so that the closer one is not less than 25 mm from the critical section concerned.

13.1.6 Strength development in reinforcement by an anchorage A welded or mechanical anchorage shall be designed, or shown by testing, to be capable of developing in the reinforcement a tensile strength of $1.1f_{sy}$, as appropriate to the size and grade of the reinforcement.

13.2 SPLICING OF REINFORCEMENT

13.2.1 General The following general requirements shall apply to the splicing of reinforcement:

(a) The splice shall be made by welding, by mechanical means, by end-bearing, or by lapping.

(b) Where lapped splices are used, the lapped portions of bars shall be in contact unless shown otherwise on the drawings.

(c) Where cold-worked bars are to be spliced by welding, by mechanical means, or by end-bearing, any untwisted end shall be cut off before splicing.

(d) Splices required in bars in tension tie members shall be made only by welding or mechanical means.

(e) Splicing of reinforcement shall take into account the requirements of Clause 19.1.3 regarding the placement of concrete.

13.2.2 Welded or mechanical splices

13.2.2.1 *General* A welded or mechanical splice shall be designed, or shown by testing, to be capable of developing a stress, in tension or compression, not less than $1.1f_{sy}$, as appropriate to the weaker bar at the splice.

13.2.2.2 *Allowable stresses in welds* Where components are joined by welding, the maximum stress allowed in the weld shall be as follows:

(a) *Butt welds* The relevant value of f_{sy} for complete-penetration butt welds shall be the minimum value pertaining to the components joined. For incomplete-penetration butt welds, f_{sy} shall be taken as 0.50 times the nominal tensile strength of the electrode used.

(b) *Fillet welds* In a fillet weld, f_{sy} shall be taken as 0.35 times the nominal tensile strength of the electrode used. The stress in the weld shall be calculated on the basis of the design throat thickness, specified in AS 1554.3.

13.2.3 Lapped splices for bars in tension The lap length for splices for bars in tension shall be not less than the development length, $L_{sy.t}$, given in Clause 13.1.2.1 or Clause 13.1.2.2.

13.2.4 Lapped splices for fabric in tension A lapped splice for welded wire fabric in tension shall be made so that the two outermost transverse wires of one sheet of fabric overlap the two outermost transverse wires of the sheet being lapped as shown in Figure 13.2.4.

FIGURE 13.2.4 LAPPED SPLICES FOR FABRIC

13.2.5 Lapped splices for bars in compression A lap splice for deformed bars in compression shall be not less than $30d_b$, where d_b is the diameter of the smaller size bar at the splice.

13.2.6 Lapped splices for bundled bars Lapped splices for a unit of bundled bars shall be based on the lap splice length required for the largest bar within the bundle increased by —

(a) for a 3-bar bundle .... 20%; and

(b) for a 4-bar bundle .... 33%.

Individual bar splices within a bundle shall not overlap.

13.3 STRESS DEVELOPMENT IN TENDONS

13.3.1 General The calculated force in tendons at any cross-section shall be developed on each side of that cross-section in accordance with Clause 13.3.2 or Clause 13.3.3.

13.3.2 Development length of pretensioned tendons In the absence of substantiating test data, the development length, L_p, of pretensioned tendons for gradual release shall be taken as the transmission length given in Table 13.3.2, as appropriate to type of tendon and the strength of the concrete at transfer f_{cp}.

Where strand or wire is untensioned, the development length shall be taken as not less than 1.5 times the value given in Table 13.3.2, as appropriate.

It shall be assumed that no change in the position of the inner end of the transmission length occurs with time but that a completely unstressed zone of length $0.1L_p$ develops at the end of the tendon.

TABLE 13.3.2

MINIMUM TRANSMISSION LENGTH FOR PRETENSIONED TENDONS

Type of tendon	L_p for gradual release	
	$f_{cp} \geq 32$ MPa	$f_{cp} < 32$ MPa
Indented wire	100 d_b	175 d_b
Crimped wire	70 d_b	100 d_b
Regular, super and compact strand	60 d_b	60 d_b

NOTES:

1 Sudden release of a tendon at transfer may cause large increases above the values tabulated.

2 The transmission lengths towards the top of a member may be as much as twice the values tabulated.

13.3.3 Stress development in post-tensioned tendons by anchorages Anchorages for tendons shall be capable of developing in the tendon the minimum tensile strength, f_p.

In addition anchorages for unbonded tendons shall be capable of sustaining cyclic loading conditions.

13.4 COUPLING OF TENDONS

13.4.1 Coupling of tendons Coupling of tendons shall comply with the following:

(a) Couplers shall be capable of developing the minimum tensile strength, f_p.

(b) Couplers shall be enclosed in housings of sufficient length to permit the necessary movements and to facilitate grouting of the duct.

SECTION 15 PLAIN CONCRETE MEMBERS

15.1 APPLICATION Plain concrete shall be used only for members in which a crack will not induce collapse. The requirements of this Section may be applied to plain concrete floors and pavements resting on the ground, footings and bored piers.

15.2 DESIGN

15.2.1 Basic principles of strength design Members shall be designed in accordance with the following basic principles:

(a) Design of members for flexure shall be based on a linear stress-strain relationship in both tension and compression.

(b) The tensile strength of concrete may be considered in the design.

(c) No strength shall be assigned to reinforcement that may be present.

15.2.2 Section properties In the calculation of strength, the entire cross-section of a member shall be considered except that for a member cast against soil, the overall relevant dimension shall be taken as 50 mm less than the actual dimension.

15.3 STRENGTH IN BENDING The design strength of a member in bending shall be taken as ϕM_{uo}, where M_{uo} is calculated using the characteristic flexural tensile strength, f'_{cf}.

15.4 STRENGTH IN SHEAR

15.4.1 One-way action Where the member acts essentially as a one-way member, and a shear failure can occur across the width, b, of the member, the design strength in shear shall be taken as ϕV_u where:

$$V_u = 0.15bD(f'_c)^{1/3}$$

The maximum shear shall be taken to occur at a distance $0.5D$ from the face of a support.

15.4.2 Two-way action Where a shear failure can occur locally around a support or loaded area, the design strength in shear shall be taken as—

$$\phi V_u/[1 + (uM^*/8V^*aD)]$$

where

$$V_u = 0.1uD(1 + 2/\beta_h)\sqrt{f'_c} \leq 0.2uD\sqrt{f'_c}$$

and

u = the effective length of the critical shear perimeter (see Figure 9.2.1(A))

a = the dimension of the critical shear perimeter which is parallel to the direction of bending being considered (see Figure 9.2.1(B)).

β_h = the ratio given in Clause 9.2.1

15.5 STRENGTH IN AXIAL COMPRESSION The design strength under axial compression of a member other than a wall, shall be taken as ϕN_{uo},

where—

$$N_{uo} = 0.45f'_c A_g$$

provided that the unsupported length of the member is not greater than three times least lateral dimension, except that this restriction does not apply to bored piers in-situ.

15.6 STRENGTH IN COMBINED BENDING AND COMPRESSION In the abs of more exact calculations, members subject to combined bending and axial load shall designed so that—

$$\frac{M^*_x}{\phi M_{ux}} + \frac{M^*_y}{\phi M_{uy}} + \frac{N^*}{\phi N_u} \le 1$$

SECTION 19 MATERIAL AND CONSTRUCTION REQUIREMENTS

19.1 MATERIAL AND CONSTRUCTION REQUIREMENTS FOR CONCRETE AND GROUT

19.1.1 Materials and limitations on constituents Materials for concrete and grout and limitations on their chemical content shall comply with the relevant requirements of AS 1379, and this Clause.

Where control of shrinkage or creep, or both, is a design requirement for concretes manufactured with type GP or HE cements, the acid-soluble sulphate content of the concrete from all mix sources, expressed as the proportion of SO_3 by mass, shall be not less than 20 g/kg of cement.

19.1.2 Specification and manufacture of concrete Concrete to which this Standard applies shall be—

(a) specified as either normal-class or special-class in accordance with AS 1379, together with the strength grade, slump, nominal aggregate size, method of placement and other relevant parameters; and

(b) manufactured in accordance with AS 1379.

Project assessment shall be specified for special-class concrete specified by strength grade and may be specified for normal-class concrete.

The constituent materials shall be proportioned so that when manufactured and delivered in accordance with AS 1379 and handled, placed, compacted, finished and cured in accordance with this Standard, the hardened concrete will satisfy the design requirements for strength, serviceability and durability.

19.1.3 Handling, placing and compacting of concrete Concrete shall be handled, placed and compacted so as to—

(a) limit segregation or loss of materials;

(b) limit premature stiffening;

(c) produce a monolithic mass between planned joints or the extremities of members, or both;

(d) completely fill the formwork to the intended level, expel entrapped air, and closely surround all reinforcement, tendons, ducts, anchorages and embedments; and

(e) provide the specified finish to the formed surfaces of the member.

19.1.4 Finishing of unformed concrete surfaces Unformed concrete surfaces shall be finished by appropriate methods, to achieve the specified—

(a) dimensions, falls, tolerances, or similar details relating to the shape and uniformity of the surfaces;

(b) cover from the surfaces to reinforcement, tendons, ducts and embedments; and

(c) texture of the surface.

19.1.5 Curing and protection of concrete

19.1.5.1 *Curing* Concrete shall be cured continuously for a period of time that ensures that the design requirements for strength, serviceability and stripping are satisfied. To satisfy durability requirements, the initial curing periods shall be not less than those given in Clauses 4.4 to 4.6 inclusive.

Curing shall be achieved by the application of water or steam to, or the retention of wa in, the freshly cast concrete and shall commence as soon as practicable after finishing any unformed surfaces has been completed. Where retention of water in the fresh concre relies on the application to exposed surfaces of sprayed membrane-forming cur compounds, the compounds used shall comply with AS 3799.

Curing requirements for the various elements of the structure shall be detailed in the project specification.

19.1.5.2 *Protection* Freshly cast concrete shall be protected from the effects of the running water and freezing or drying prior to hardening. During the initial curing perio the concrete shall be protected from freezing or drying.

19.1.6 Sampling and testing for compliance

19.1.6.1 *General* Concrete for structures designed in accordance with this Standar shall be sampled in accordance with AS 1012.1 and tested for compliance with the parameters specified in Clauses 19.1.6.2 and 19.1.6.3 and the relevant requirements of AS 1379.

19.1.6.2 *Concrete specified by grade or compressive strength* Concrete specifie principally by either compressive strength grade, or characteristic compressive strength at 28 days, shall be tested and assessed, in accordance with Section 20, for compliance with the following requirements:

(a) For all concrete, the average compressive strength shall be maintained within the appropriate limits during production.

(b) For concrete subject to project assessment, the compressive strength of batches of concrete being delivered to the project shall be consistent with their stated compressive strength.

NOTE: If project assessment is required, the project specification should nomina responsibility for carrying out the relevant sampling, testing and assessment, and should gi the details of how the assessment is to be made, if this is to be different from that specified AS 1379.

19.1.6.3 *Concrete specified by parameters other than compressive strength* Whe concrete is specified principally by a parameter other than 28-day compressive strength, i shall be classified as special-class. The method of production control and project contr if required, together with the relevant compliance criteria shall be specified.

19.1.7 Rejection of concrete

19.1.7.1 *Plastic concrete* Plastic concrete may be rejected if, after completion of mixing but prior to site handling—

(a) the slump, determined in accordance with AS 1012.3, differs from the specified slump by more than the tolerances permitted in AS 1379;

(b) the time since completion of mixing is outside the time interval allowed in AS 1379; or

(c) the appearance and cohesiveness of a particular quantity is significantly different from previously supplied quantities of the same specification.

19.1.7.2 *Hardened concrete* Hardened concrete shall be liable to rejection if—

(a) it does not satisfy the requirements of Clause 19.1.6;

(b) it is porous, segregated, or honeycombed, or contains surface defects; or

(c) it fails to comply with the other requirements of this Standard.

19.1.7.3 *Action on hardened concrete liable to rejection* Where hardened concrete is liable to rejection in terms of Clause 19.1.7.2, the concrete may be accepted if it can be demonstrated, either by calculation or by testing in accordance with the appropriate clauses of Section 21, that the structural adequacy and intended use of the affected members are not significantly impaired. Otherwise, the concrete shall be rejected.

19.1.8 Requirements for grout and grouting

19.1.8.1 *Grout properties* Grout shall be proportioned to give the desired properties for its intended use. Grout to be used in grouting prestressing ducts shall have sufficient fluidity to enable it to be pumped through the duct, have low sedimentation and shrinkage, and contain no more than 750 mg of chloride ions per litre of grout.

19.1.8.2 *Mixing and agitation* Grout shall be mixed in a mixer capable of producing a uniform grout of the specified fluidity and free from lumps of undispersed cement.

After mixing, grout shall be held in an agitation tank and kept in motion, to prevent settlement or segregation occurring, before it is pumped into its final position.

19.2 MATERIAL AND CONSTRUCTION REQUIREMENTS FOR REINFORCING STEEL

19.2.1 Materials

19.2.1.1 *Reinforcement* Reinforcement shall be deformed bars or welded wire fabric except that plain bars or wire may be used for fitments. All reinforcement shall comply with AS 1302, AS 1303 and AS 1304, as applicable.

19.2.1.2 *Protective coatings* A protective coating may be applied to reinforcement provided that such coating does not reduce the properties of the reinforcement below those assumed in the design.

19.2.2 Fabrication

(a) Reinforcement shall be fabricated to the shape and dimensions shown in the drawings and within the following tolerances:

  (i) On any overall dimension for bars and fabric except where used as a fitment:

    A. For lengths up to 600 mm .... -25, +0 mm.

    B. For lengths over 600 mm .... -40, +0 mm.

  (ii) On any overall dimension of bars or fabric used as a fitment:

    A. For deformed bars and fabric .... -15, +0 mm.

    B. For plain round bars and wire .... -10, +0 mm.

  (iii) On the overall offset dimension of a cranked column bar .... -0, +10 mm.

  (iv) For the sawn or machined end of a straight bar intended for use as an end-bearing splice, the angular deviation from square, measured in relation to the end 300 mm, shall be within .... 2 degrees.

(b) Bending of reinforcement shall comply with Clause 19.2.3.

(c) Welding if required shall comply with AS 1554.3. Tack welding not complying with that Standard shall not be used.

19.2.3 Bending

19.2.3.1 *General* Reinforcement may be bent either —

(a) cold, by the application of a force, around a pin of diameter complying with Clause 19.2.3.2, so as to avoid impact loading of the bar and mechanical damage to the bar surface; or

(b) hot, provided that—

(i) the steel is heated uniformly through and beyond the portion to be bent;

(ii) the temperature of the steel does not exceed 600°C;

(iii) the bar is not cooled by quenching; and

(iv) if during heating the temperature of the bar exceeds 450°C, the design yield strength of the steel after bending shall be taken as 250 MPa.

Reinforcement which has been bent and subsequently straightened or bent in the reverse direction, shall not be bent again within 20 bar diameters of the previous bend.

Reinforcement partially embedded in concrete may be field bent provided that the bending complies with Items (a) or (b) above and the bond of the embedded portion is not impaired thereby.

19.2.3.2 *Internal diameter of bends or hooks* The nominal internal diameter of a reinforcement bend or hook shall be taken as the external diameter of the pin around which the reinforcement is bent. The diameter of the pin shall be not less than the value determined from the following as appropriate:

(a) For fitments of:

(i) Wire .... $3d_b$

(ii) Grade 250 bars .... $3d_b$

(iii) Grade 400 bars .... $4d_b$

(b) For reinforcement, other than that specified in Items (c) and (d) below, of any grade .... $5d_b$

(c) For reinforcement, in which the bend is intended to be subsequently straightened or rebent, of:

(i) Size 16 mm or less .... $4d_b$

(ii) Size 20 mm or 24 mm .... $5d_b$

(iii) Size 28 mm or greater .... $6d_b$

Any such straightening or rebending shall be clearly specified or shown in the drawings.

(d) For reinforcement which is epoxy-coated or galvanized, either before or after bending of:

(i) Size 16 mm or less .... $5d_b$

(ii) Size 20 mm or greater .... $8d_b$

19.2.4 **Surface condition** At the time concrete is placed, the surface condition of reinforcement shall be such as not to impair its bond to the concrete or its performance in the member. The presence of millscale or surface rust shall not be cause for rejection of reinforcement under this Clause.

19.2.5 **Fixing** All reinforcement, including secondary reinforcement provided for the purpose of maintaining main reinforcement and tendons in position, shall be supported and maintained in position within the tolerances given in Clause 19.5.3 until the concrete has hardened. Bar chairs, spacers and ties used for this purpose shall be made of concrete, steel or plastics, as appropriate.

19.2.6 **Lightning protection by reinforcement** Where lightning protection is to be provided by the reinforcement, the reinforcement shall comply with the relevant requirements of AS 1768.

19.4 CONSTRUCTION REQUIREMENTS FOR JOINTS AND EMBEDDED ITEMS

19.4.1 Location of construction joints

(a) Construction joints shall be located to facilitate the placement of concrete in accordance with Clause 19.1.3.

(b) Unless otherwise specified, a construction joint shall be made between the soffits of slabs or beams and their supporting columns or walls.

(c) Where an interruption to the placing of concrete occurs such that the requirements of Clause 19.1.3(c) or (d) cannot be fulfilled, a construction joint complying with Clause 14.1.1 shall be made at an appropriate location.

19.4.2 **Embedded and other items not shown in the drawings** Where an embedded item, driven fixing device, or hole is required but is not specifically shown in the drawings, or included in the specification, it shall be located so that the behaviour of the members is not impaired.

19.5 TOLERANCES FOR STRUCTURES AND MEMBERS

19.5.1 **General** For the purposes of the strength requirements of this Standard, the position of any point on the surface of a concrete member shall comply with Clause 19.5.2. More stringent tolerances may be required for reasons of serviceability, fit of components, or aesthetics of the structure.

For formed surfaces the tolerances given in AS 3610 take precedence, unless those in Clause 19.5.2 are more stringent. For unformed plane surfaces, the flatness tolerances and the methods for measuring them, shall be detailed in the project specification but in any case, they shall be not greater than the relevant values given in Clause 19.5.2.

19.5.2 Tolerances for position and size of structures and members

19.5.2.1 *Absolute position* The deviation from the specified position shall not exceed the following:

(a) In plan, for a point on the surface of a column or wall at any floor level—

(i) in the first 20 storeys of any building .... 40 mm horizontally; and

(ii) for subsequent storeys, an increase of 15 mm horizontally for each additional 10 storeys or part thereof.

(b) In elevation, for a point on the top surface of a floor or the soffit of a beam or slab adjacent to a column or wall .... 40 mm vertically.

19.5.2.2 *Floor-to-floor plumb* In any column or wall the deviation from plumb, measured floor-to-floor, shall not exceed 1/200 times the dimension between the floors or 10 mm, whichever is the greater.

19.5.2.3 *Deviation from specified dimensions* The deviation from any specified height, plan, or cross-sectional dimension, shall not exceed 1/200 times, the specified dimension or 5 mm, whichever is the greater.

19.5.2.4 *Deviation from surface alignment* The deviation of any point on a surface of a member from a straight line joining any two points on the surface, shall not exceed 1/250 times the length of the line or 10 mm, whichever is the greater.

19.5.3 **Tolerance on position of reinforcement and tendons** The deviation from the specified position of reinforcement and tendons shall not exceed the following:

(a) For positions controlled by cover—

(i) in beams, slabs, columns and walls .... -5, +10 mm;

(ii) in slabs-on-ground .... -10, + 20 mm;

(iii) in footings cast in the ground .... -20, + 40 mm;

where a positive value indicates the amount the cover may increase and a negative value indicates the amount the cover may decrease.

(b) For positions *not* controlled by cover, namely—

(i) the location of tendons on a profile .... 5 mm

(ii) the position of the ends of reinforcement .... 50 mm

(iii) the spacing of bars in walls and slabs and of fitments in beams and columns ..... 10% of the specified spacing or 15 mm, whichever is greater.

19.6 FORMWORK

19.6.1 General The materials, design and construction of formwork shall comply with AS 3610. Stripping of forms and removal of formwork supports from members cast in-situ shall comply with the requirements of Clause 19.6.2 where these are more stringent than the relevant requirements of AS 3610.

19.6.2 Stripping of forms and removal of formwork supports

19.6.2.1 *General* The stripping of forms and the removal of formwork supports shall comply with the following:

(a) Forms shall not be stripped or any formwork supports removed until the part of the member which will be left unsupported has attained sufficient strength to support with safety and without detriment to its intended use, its own weight and any superimposed loads due to concurrent or subsequent construction works.

(b) Removal of formwork supports shall be carried out in a planned sequence so that the concrete structure will not be subject to any unnecessary deformation, impact or eccentric loading during the process.

(c) Removal of formwork from vertical surfaces shall be carried out in accordance with Clause 19.6.2.2.

(d) Stripping of forms, from the soffits of reinforced slabs and beams between formwork supports, shall be carried out in accordance with Clause 19.6.2.3 or Clause 19.6.2.4 as appropriate. Where backpropping is used, the procedure shall comply with the appropriate requirements of AS 3610.

(e) Removal of formwork supports from the soffits of reinforced slabs or beams shall be carried out in accordance with—

(i) Clause 19.6.2.5 for members not supporting structures above; or

(ii) Clause 19.6.2.6 for multi-storey structures.

(f) Stripping of forms and removal of formwork supports from prestressed beams and slabs shall be carried out in accordance with Clause 19.6.2.7.

19.6.2.2 *Removal of formwork from vertical surfaces* Formwork shall not be removed from vertical surfaces unless the concrete in the member has achieved sufficient strength to withstand potential damage to its surfaces.

When formwork is stripped at less than 18 hours after casting, extra care shall be exercised to avoid surface damage during stripping.

19.6.2.3 *Stripping of soffit forms from reinforced beams and slabs where control samples are available* Where control samples have been taken, cured and tested in accordance with Clause 19.6.2.8, soffit forms may be stripped from between the formwork supports of reinforced beams and slabs if—

(a) the elapsed time between casting of the concrete and the commencement of stripping is greater than 3 days; and

(b) the spans between the remaining formwork supports are such that the member will remain uncracked under the action effects of bending and shear due to the maximum concurrent or subsequent construction loads.

In determining whether sufficient curing time has elapsed, the design resistance of the member shall be taken as ϕR_u, where R_u is determined in accordance with the relevant clauses of Section 15 and the appropriate characteristic strength of the concrete is determined from the average strength of the control samples.

19.6.2.4 *Stripping of soffit forms from reinforced slabs of normal-class concrete* For reinforced slabs of normal-class concrete, for which an early-age strength has been specified and which are continuous over formwork supports, the period of time between casting of the concrete and the commencement of stripping of the forms between formwork supports shall be not less than that given in Table 19.6.2.4 for the appropriate average ambient temperature over the period. The periods given in the table shall be increased if—

(a) $L_s/D > 280/\sqrt{(D + 100)}$

(b) the superimposed construction load is greater than 2.0 kN/m^2; or

(c) the average ambient temperature over the period is less than 5°C, in which case the periods shall be increased by half a day for each day the daily average temperature was between 2°C and 5°C, or by a whole day for each day the daily average temperature was below 2°C.

TABLE 19.6.2.4

STRIPPING OF FORMWORK FROM REINFORCED SLABS CONTINUOUS OVER FORMWORK SUPPORTS

Average ambient temperature over the period (T)	Period of time before stripping *normal-class* concrete with specified early-age strength
°C	days
$T > 20$	4
$20 \geq T > 12$	6
$12 \geq T > 5$	8

19.6.2.5 *Removal of formwork supports from reinforced members not supporting structures above* For the purpose of determining the minimum period before any undisturbed supports or backprops can be removed from the soffits of reinforced members not supporting structures above, it may be assumed that the requirements of Clause 19.6.2.1(a) will be satisfied if either—

(a) it can be demonstrated by calculations, based on known or specified early-age strengths that, at the time of removal, the concrete has gained sufficient strength so that the degree of cracking or deformation, that will occur then or subsequently, is not greater than that which would occur if the design serviceability load were applied to the member when the concrete has attained its required design strength; or

(b) in the absence of any early-age strength data, the period of time is not less than that given in Table 19.6.2.5 for the appropriate average ambient temperature over the period. The periods given in Table 19.6.2.5 shall be increased if—

(i) the superimposed construction load is greater than 2.0 kN/m^2; or

(ii) the average ambient temperature is less than 5°C, in which case the periods shall be increased by half a day for each day the daily average temperature was between 2°C and 5°C, or by a whole day for each day the daily average temperature was below 2°C.

TABLE 19.6.2.5

REMOVAL OF FORMWORK SUPPORTS FROM SLABS AND BEAMS NOT SUPPORTING STRUCTURES ABOVE

Average ambient temperature over the period (T) °C	Period of time before removal of all formwork supports from reinforced members days
$T > 20$	12
$20 \geq T > 12$	18
$12 \geq T > 5$	24

19.6.2.6 *Removal of formwork supports from reinforced members in multistorey structures* In multistorey structures, the number of storeys, including the lowest storey, which are to remain supported by formwork at any one time and the maximum spacing ot the formwork supports in any storey, shall be calculated on the basis of the relevant properties of the concrete in each floor at that time and the interaction between the formwork supports and the concrete structure.

Where removal of formwork supports from a storey will result in the floors above being supported mainly by formwork and suspended concrete construction, all supported and supporting floors and beams shall be checked by calculation for cracking and deflection under the resulting loads. Removal of formwork supports from that storey may then be permitted only if the magnitude of the cracks and deflections so calculated will not impair the strength or serviceability of the completed structure.

No undisturbed supports or backprops shall be removed within 2 days of the placing of any slab directly or indirectly supported by such supports.

19.6.2.7 *Stripping of forms and removal of supports from soffits of prestressed concrete slabs and beams* Formwork shall not be stripped and formwork supports not removed from the soffits of prestressed concrete slabs or beams until the strength of the concrete in the member and the number of tendons stressed are such as to provide the necessary strength to carry the dead and construction loads.

19.6.2.8 *Control tests* If specified, control test-samples of the concrete shall be taken where it is intended that removal of formwork or the stressing of tendons will occur before the concrete has attained the strength assumed in the design of the member.

Control test-samples shall be taken at a minimum frequency of one sample for each 50 m^3, or part thereof, of a concrete grade placed on any one day and the sample specimens stored and cured under conditions similar to those of the concrete in the work.

At least two specimens from each grade shall be tested for strength at the desired time of stripping or stressing and the strength of the concrete at that age assessed on the basis of the average strength of the specimens.

CHAPTER 2

STEEL STRUCTURES

This Chapter consists of edited extracts from AS 4100, *Steel structures*. The Standard applies to the design, fabrication and erection of steel work in buildings and in principle to other structures such as lattice towers, bridges and cranes. The Standard incorporates AS 1511—SAA *Code for High Strength Bolting* and the design requirements of AS 1154.1—*Welding of steel structures*.

The extracts incorporate Amendment No. 1 of August 1992 and Amendment No. 2 of June 1993, indicated by a single bar and a double bar respectively in the left-hand margin, Amendment No. 3 of December 1995, indicated by treble bar and includes Appendix B which gives suggested deflection limits for serviceability.

STANDARDS AUSTRALIA

Australian Standard
Steel Structures

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE This Standard sets out minimum requirements for the design, fabrication, erection, and modification of steelwork in structures in accordance with the limit state design method.

This Standard applies to buildings, structures and cranes constructed of steel.

This Standard is intended to apply also to roadway, railway, and pedestrian bridges. However, the requirements given in this Standard may not always be sufficient for bridge applications. In these circumstances, the specifications of the relevant Authority shall be used.

This Standard does not apply to the following structures and materials:

(a) Steel elements less than 3 mm thick, with the exception of sections complying with AS 1163 and packers.

(b) Steel members for which the value of the yield stress used in design (f_y) exceeds 450 MPa.

(c) Cold-formed members, other than those complying with AS 1163, which shall be designed in accordance with AS 1538.

(d) Composite steel-concrete members, which shall be designed in accordance with AS 2327.

NOTE: The general principles of design, fabrication, erection, and modification embodied in this Standard may be applied to steel-framed structures or members not specifically mentioned herein.

1.2 REFERENCED DOCUMENTS The documents referred to in this Standard are listed in Appendix A.

1.3 DEFINITIONS For the purpose of this Standard, the definitions below apply. Definitions peculiar to a particular Clause or Section are also given in that Clause or Section.

Action—the cause of stress or deformations in a structure.

Action effect or load effect—the internal force or bending moment due to actions or loads.

Authority—a body having statutory powers to control the design and erection of a structure.

Bearing-type connection—connection effected using either snug-tight bolts, or high-strength bolts tightened to induce a specified minimum bolt tension, in which the design action is transferred by shear in the bolts and bearing on the connected parts at the strength limit state.

Bearing wall system—see AS 1170.4

Braced member—one for which the transverse displacement of one end of the member relative to the other is effectively prevented.

Braced frame—see AS1170.4.

Building frame system—see AS 1170.4

Capacity factor—a factor used to multiply the nominal capacity to obtain the design capacity.

Complete penetration butt weld—a butt weld in which fusion exists between the weld and parent metal throughout the complete depth of the joint.

Concentric braced frame—see AS 1170.4

Constant stress range fatigue limit—highest constant stress range for each detail category at which fatigue cracks are not expected to propagate (see Figure 11.6.1).

Cut-off limit—for each detail category, the highest variable stress range which does not require consideration when carrying out cumulative damage calculations (see Figures 11.6.1 and 11.6.2).

Design action effect or design load effect—the action or load effect computed from the design actions or design loads.

Design action or design load—the combination of the nominal actions or loads and the load factors, as specified in AS 1170.1, AS 1170.2, AS 1170.3 or AS 1170.4.

Design capacity—the product of the nominal capacity and the capacity factor.

Design life—period over which a structure or structural element is required to perform its function without repair.

Design resistance effect—the resistance effect computed from the loads and design capacities contributing towards the stability limit state resistance.

Design spectrum—sum of the stress spectra from all of the nominal loading events expected during the design life.

Detail category—designation given to a particular detail to indicate which of the S-N curves is to be used in the fatigue assessment.

Discontinuity—an absence of material, causing a stress concentration.

Drift—see AS 1170.4.

Dual system—see AS 1147.4

Ductility—see AS 1170.4.

Earthquake design category—see AS 1170.4.

Earthquake resisting system—see AS 1170.4.

Eccentric braced frame—see AS 1170.4.

Exposed surface area to mass ratio—the ratio of the surface area exposed to the fire to the mass of steel.

Fatigue—damage caused by repeated fluctuations of stress leading to gradual cracking of a structural element.

Fatigue loading—set of nominal loading events described by the distribution of the loads, their magnitudes and the numbers of applications of each nominal loading event.

Fatigue strength—the stress range defined in Clause 11.6 for each detail category (see Figures 11.6.1 and 11.6.2) varying with the number of stress cycles.

Fire exposure condition—

(a) *three-sided fire exposure condition*—steel member incorporated in or in contact with a concrete or masonry floor or wall.

(b) *four-sided fire exposure condition*—a steel member exposed to fire on all sides.

Fire protection system—the fire protection material and its method of attachment to the steel member.

Fire-resistance level (FRL)—the fire-resistance grading period for structural adequacy only, in minutes, which is required to be attained in the standard fire test.

Friction-type connection—connection effected using high-strength bolts tightened to induce a specified minimum bolt tension such that the resultant clamping action transfers the design shear forces at the serviceability limit state acting in the plane of the common contact surfaces by the friction developed between the contact surfaces.

Full tensioning—a method of installing and tensioning a bolt in accordance with Clauses 15.2.4 and 15.2.5.

Geometrical slenderness ratio—the geometrical slenderness ratio (L_e/r), taken as the effective length (L_e), specified in Clause 6.3.2, divided by the radius of gyration (r) computed for the gross section about the relevant axis.

Incomplete penetration butt weld—a butt weld in which the depth of penetration is less than the complete depth of the joint.

In-plane loading—loading for which the design forces and bending moments are in the plane of the connection, so that the design action effects induced in the connection components are shear forces only.

Intermediate moment resisting frame—see AS 1170.4.

Length (of a compression member)—the actual length (L) of an axially loaded compression member, taken as the length centre-to-centre of intersections with supporting members, or the cantilevered length in the case of a free-standing member.

Limit state—any limiting condition beyond which the structure ceases to fulfil its intended function.

Load—an externally applied force.

Moment resisting frame system—see AS 1170.4.

Miner's summation—cumulative damage calculation based on the Palmgren-Miner summation or equivalent.

Nominal action or load—an action or load, as specified in Clause 3.2.1 or 3.2.2.

Nominal capacity—the capacity of a member or connection computed using the parameters specified in this Standard.

Nominal loading event—the loading sequence for the structure or structural element.

Non-slip fasteners—fasteners which do not allow slip to occur between connected plates or members at the serviceability limit state so that the original alignment and relative positions are maintained.

Ordinary moment resisting frame—see AS 1170.4.

Out-of-plane loading—loading for which the design forces or bending moments result in design action effects normal to the plane of the connection.

Period of structural adequacy (PSA) (fire)—the time (t), in minutes, for the member to reach the limit state of structural adequacy in the standard fire test.

Pin—an unthreaded fastener manufactured out of round bar.

Plastic hinge—a yielding zone with significant inelastic rotation which forms in a member when the plastic moment is reached.

Prequalified weld preparation—a joint preparation prequalified in terms of AS 1554.1.

Proof testing—the application of test loads to a structure, sub-structure, member or connection to ascertain the structural characteristics of only that one unit under test.

Prototype (fire)—a test specimen representing a steel member and its fire protection system which is subjected to the standard fire test.

Prototype testing—the application of test loads to one or more structures, sub-structures, members or connections to ascertain the structural characteristics of that class of structures, sub-structures, members or connections which are nominally identical to the units tested.

Prying force—additional tensile force developed as a result of the flexing of a connection component in a connection subjected to tensile force. External tension force reduces the contact pressure between the component and the base, and bending in part of the component develops a prying force near the edge of the connection component.

Segment (in a member subjected to bending)—the length between adjacent cross-sections which are fully or partially restrained, or the length between an unrestrained end and the adjacent cross-section which is fully or partially restrained.

Serviceability limit state—a limit state of acceptable in-service condition.

Shear wall—a wall designed to resist lateral forces parallel to the plane of the wall.

S-N curve—curve defining the limiting relationship between the number of stress cycles and stress range for a detail category.

Snug tight—the tightness of a bolt achieved by a few impacts of an impact wrench or by the full effort of a person using a standard podger spanner.

Space frame—see AS 1170.4.

Special moment resisting frame—see AS 1170.4.

Stability limit state—a limit state corresponding to the loss of static equilibrium of a structure considered as a rigid body.

Standard fire test—the fire-resistance test specified in AS 1530.4.

Stickability—the ability of the fire protection system to remain in place as the member deflects under load during a fire test.

Strength limit state—a limit state of collapse or loss of structural integrity.

Stress cycle—one cycle of stress defined by stress cycle counting.

Stress cycle counting method—any rational method used to identify individual stress cycles from the stress history.

Stress range—algebraic difference between two extremes of stress.

Stress spectrum—histogram of the stress cycles produced by a nominal loading event.

Structural adequacy (fire)—the ability of the member exposed to the standard fire test to carry the test load specified in AS 1530.4.

Sway member—one for which the transverse displacement of one end of the member relative to the other is not effectively prevented.

Tensile strength—the minimum ultimate strength in tension specified for the grade of steel in the appropriate Australian Standard.

Yield stress—the minimum yield stress in tension specified for the grade of steel in the appropriate Australian Standard.

1.4 NOTATION Symbols used in this Standard are listed below.

Where non-dimensional ratios are involved, both the numerator and denominator are expressed in identical units.

The dimensional units for length and stress in all expressions or equations are to be taken as millimetres (mm) and megapascals (MPa) respectively, unless specifically noted otherwise.

A superscripted '*' placed after a symbol denotes a design action effect due to the design load for the strength limit state.

A	=	area of cross-section
A_c	=	minor diameter area of a bolt, as defined in AS 1275
A_e	=	effective area of a cross-section; or
	=	area enclosed by a hollow section
A_{ep}	=	area of an end plate
A_{fc}	=	flange area at critical cross-section
A_{fg}	=	gross area of a flange
A_{fm}	=	flange area at minimum cross-section; or
	=	lesser of the flange effective areas
A_{fn}	=	net area of a flange
A_g	=	gross area of a cross-section
A_n	=	net area of a cross-section; or
	=	sum of the net areas of the flanges and the gross area of the web
A_o	=	plain shank area of a bolt
A_p	=	cross-sectional area of a pin
A_s	=	tensile stress area of a bolt as defined in AS 1275; or
	=	area of a stiffener or stiffeners in contact with a flange; or
	=	area of an intermediate web stiffener
A_w	=	gross sectional area of a web; or
	=	effective shear area of a plug or slot weld
a_e	=	minimum distance from the edge of a hole to the edge of a ply measured in the direction of the component of a force plus half the bolt diameter
a_o	=	length of unthreaded portion of the bolt shank contained within the grip
a_t	=	length of threaded portion of the bolt contained within the grip
a_0, a_1	=	out-of-square dimensions of flanges
a_2, a_3	=	diagonal dimensions of a box section
b	=	width; or
	=	lesser dimension of a web panel; or
	=	clear width of an element outstand from the face of a supporting plate element; or
	=	clear width of a supported element between faces of supporting plate elements
b_b, b_{bf}, b_{bw}, b_o	=	bearing widths defined in Clause 5.13
b_d	=	distance from the stiff bearing to the end of the member
b_e	=	effective width of a plate element
b_{es}	=	stiffener outstand from the face of a web
b_f	=	width of a flange
b_{fo}	=	distance from mid-plane of the web to the nearer edge of the flange; or
	=	half the clear distance between the webs
b_s	=	stiff bearing length

b_w	=	web depth
b_1, b_2	=	greater and lesser leg lengths of an angle section
C_3, C_4, C_{4r}	=	factors defined by Table H3 and Paragraph H5
c_h	=	perpendicular distance to centroid of an angle section from the face of the loaded leg of the angle
c_m	=	factor for unequal moments
d	=	depth of a section; or
	=	depth of preparation for incomplete penetration butt weld; or
	=	maximum cross-sectional dimension of a member
d_b	=	lateral distance between centroids of the welds or fasteners on battens
d_c	=	depth of a section at a critical cross-section
d_e	=	effective outside diameter of a circular hollow section; or
	=	factor defined in Appendix I
d_f	=	diameter of a fastener (bolt or pin); or
	=	distance between flange centroids
d_m	=	depth of a section at minimum cross-section
d_o	=	overall section depth including out-of-square dimensions; or
	=	overall section depth of a segment; or
	=	outside diameter of a circular hollow section
d_p	=	clear transverse dimension of a web panel; or
	=	depth of deepest web panel in a length
d_x, d_y	=	distances of the extreme fibres from the neutral axes
d_1	=	clear depth between flanges ignoring fillets or welds
d_2	=	twice the clear distance from the neutral axis to the compression flange
d_3, d_4	=	depths of preparation for incomplete penetration butt welds
d_5	=	flat width of web.
E	=	Young's modulus of elasticity, 200 x 10^3 MPa
$E(T)$, $E(20)$	=	E at T, 20 degrees Celsius respectively
e	=	eccentricity; or
	=	web off-centre dimension; or
	=	distance between an end plate and a load-bearing stiffener
e_c, e_t	=	eccentricities of compression and tension angles (Clause 8.4.6)
F	=	action in general, force or load
F^*	=	total design load on a member between supports
F_n^*	=	design force normal to a web panel
F_p^*	=	design force parallel to a web panel
f_c	=	fatigue strength corrected for thickness of material
f_f	=	uncorrected fatigue strength
f_{rn}	=	detail category reference fatigue strength at n_r cycles—normal stress
f_{rnc}	=	corrected detail category reference fatigue strength—normal stress
f_{rsc}	=	corrected detail category reference fatigue strength—shear stress

f_{rs} = detail category reference fatigue strength at n_r cycles—shear stress

f_u = tensile strength used in design

f_{uf} = minimum tensile strength of a bolt

f_{up} = tensile strength of a ply

f_{uw} = nominal tensile strength of weld metal

f_y = yield stress used in design

$f_y(T), f_y(20)$ = yield stresses of steel at T, 20 degrees Celsius respectively

f_{yp} = yield stress of a pin used in design

f_{ys} = yield stress of a stiffener used in design

f_3 = detail category fatigue strength at constant amplitude fatigue limit

f_{3c} = corrected detail category fatigue strength at constant amplitude fatigue limit

f_5 = detail category fatigue strength at cut-off limit

f_{5c} = corrected detail category fatigue strength at cut-off limit

f^* = design stress range

f_i^* = design stress range for loading event i

f_{va}^* = average design shear stress in a web

f_{vm}^* = maximum design shear stress in a web

f_w^* = equivalent design stress on a web panel (Appendix I)

G = shear modulus of elasticity, 80 x 10^3 MPa; or
= nominal dead load

h = rectangular centroidal axis for angle parallel to the loaded leg

h_b = vertical distance between tops of beams

h_e = effective thickness of fire protection material

h_i = thickness of fire protection material

h_s = storey height

I = second moment of area of a cross-section

I_{cy} = second moment of area of compression flange about the section minor principal y-axis

I_m = I of the member under consideration

I_r = I of a restraining member

I_s = I of a pair of stiffeners or a single stiffener

I_w = warping constant for a cross-section

I_x = I about the cross-section major principal x-axis

I_y = I about the cross-section minor principal y-axis

i = number of loading event

J = torsion constant for a cross-section

K = $\sqrt{[\pi^2 EI_w/(GJL^2)]}$

K_s = deflection amplification factor.

k = coefficient used in Appendix J

k_b = elastic buckling coefficient for a plate element

k_{bo} = basic value of k_b

k_e = member effective length factor

k_f = form factor for members subject to axial compression

k_h = factor for different hole types

k_l = load height effective length factor

k_p = factor for pin rotation

k_r = effective length factor for restraint against lateral rotation; or
= effective length factor for a restraining member; or
= reduction factor to account for the length of a bolted or welded lap splice connection

k_s = ratio used to determine α_p and α_{pm}.

k_{sm} = exposed surface area to mass ratio

k_t = twist restraint effective length factor; or
= correction factor for distribution of forces in a tension member

k_v = ratio of flat width of web (d_5)to thickness (t) of section.

k_0-k_6 = regression coefficients (Section 12)

L = span; or
= member length; or
= segment or sub-segment length

L_b = length between points of effective bracing or restraint

L_c = distance between adjacent column centres

L_e = effective length of a compression member; or
= effective length of a laterally unrestrained member

$\frac{L_e}{r}$ = geometrical slenderness ratio

$\left(\frac{L_e}{r}\right)_{bn}$ = slenderness ratio of a battened compression member about the axis normal to the plane of the battens

$\left(\frac{L_e}{r}\right)_{bp}$ = slenderness ratio of a battened compression member about the axis parallel to the plane of the battens

$\left(\frac{L_e}{r}\right)_c$ = slenderness ratio of the main component in a laced or battened compression member

$\left(\frac{L_e}{r}\right)_m$ = slenderness ratio of the whole battened compression member

L_j = length of a bolted lap splice connection

L_m = length of the member under consideration

L_r = length of a restraining member; or
= length of a segment over which the cross-section is reduced

L_s = distance between points of effective lateral support

L_w = greatest internal dimension of an opening in a web; or
= length of a fillet weld in a welded lap splice connection

L_z = distance between partial or full torsional restraints

M_b = nominal member moment capacity

M_{bx} = M_b about major principal x-axis

M_{bxo} = M_{bx} for a uniform distribution of moment

M_{cx} = lesser of M_{ix} and M_{ox}

M_f = nominal moment capacity of flanges alone

M_i = nominal in-plane member moment capacity

M_{ix} = M_i about major principal x-axis

M_{iy} = M_i about minor principal y-axis

M_o = nominal out-of-plane member moment capacity; or
= reference elastic buckling moment for a member subject to bending

M_{oa} = amended elastic buckling moment for a member subject to bending

M_{ob} = elastic buckling moment determined using an elastic buckling analysis

M_{obr} = M_{ob} decreased for elastic torsional end restraint

M_{oo} = reference elastic buckling moment obtained using $L_e = L$

M_{os} = M_{ob} for a segment, fully restrained at both ends, unrestrained against lateral rotation and loaded at shear centre

M_{ox} = nominal out-of-plane member moment capacity about major principal x-axis

M_p = nominal moment capacity of a pin

M_{pr} = nominal plastic moment capacity reduced for axial force

M_{prx} = M_{pr} about major principal x-axis

M_{pry} = M_{pr} about minor principal y-axis

M_{rx} = M_s about major principal x-axis reduced by axial force

M_{ry} = M_s about minor principal y-axis reduced by axial force

M_s = nominal section moment capacity

M_{sx} = M_s about major principal x-axis

M_{sy} = M_s about minor principal y-axis

M_{tx} = lesser of M_{rx} and M_{ox}

M_w = nominal section moment capacity of a web panel

M^* = design bending moment

M^*_c = second-order or amplified end bending moment

M^*_f = design end bending moment

M^*_{fb} = braced component of M^*_f obtained from a first-order elastic analysis of a frame with sway prevented

M^*_{fs} = sway component of M^*_f obtained from ($M^*_f - M^*_{fb}$)

M^*_h = design bending moment on an angle, acting about the rectangular h-axis parallel to the loaded leg

M^*_m = maximum calculated design bending moment along the length of a member or in a segment

M^*_w = design bending moment acting on a web panel

M^*_x = design bending moment about major principal x-axis

M^*_y = design bending moment about minor principal y-axis

M^*_2, M^*_3, M^*_4 = design bending moments at quarter and mid points of a segment

N_c = nominal member capacity in compression

N_{ch} = N_c for angle buckling about h-axis, parallel to the loaded leg

N_{cy} = N_c for member buckling about minor principal y-axis

N_{oL} = $\dfrac{\pi^2 EI}{L^2}$

N_{oLr} = $\dfrac{\pi^2 EI_r}{L_r^2}$

N_{om} = elastic flexural buckling load of a member

N_{omb} = N_{om} for a braced member

N_{oms} = N_{om} for a sway member

N_{oz} = nominal elastic torsional buckling capacity of a member

N_s = nominal section capacity of a compression member; or
= nominal section capacity for axial load

N_t = nominal section capacity in tension

N_{tf} = nominal tension capacity of a bolt

N_{ti} = minimum bolt tension at installation; or
= tension induced in a bolt during installation

N_{wo} = nominal axial load capacity of a web panel

N^* = design axial force, tensile or compressive

N^*_r = design axial force in a restraining member

N^*_{tf} = design tensile force on a bolt

N^*_w = design axial force acting on a web panel

n = number of specimens tested

n_b = number of parallel planes of battens

n_{ei} = number of effective interfaces

n_i = number of cycles of nominal loading event i

n_n = number of shear planes with threads intercepting the shear plane-bolted connections

n_r = reference number of stress cycles

n_s = number of shear planes

n_{sc} = number of stress cycles

n_w = number of webs

n_x = number of shear planes without threads intercepting the shear plane—bolted connections

Q = nominal live load

Q^* = design transverse force; or
= design live load

R_b = nominal bearing capacity of a web

R_{bb} = nominal bearing buckling capacity

R_{by} = nominal bearing yield capacity

R_f = structural response factor.

R_{sb} = nominal buckling capacity of a stiffened web

R_{sy} = nominal yield capacity of a stiffened web

R_u = nominal capacity

R^* = design bearing force; or
= design reaction

R_w^* = design bearing force or reaction on a web panel

r = radius of gyration; or
= transition radius

r_{ext} = outside radius of section.

r_f = ratio of design action on the member under design load for fire to the design capacity of the member at room temperature

r_r = ratio defined in Clause 5.6.1.1

r_s = ratio defined in Clause 5.6.1.1

r_y = radius of gyration about minor principal y-axis

S = plastic section modulus

S^* = design action effect

s = spacing of stiffeners; or
= width of a web panel

s_b = longitudinal centre-to-centre distance between battens

s_g = gauge of bolts

s_p = staggered pitch of bolts

T = steel temperature in degrees Celsius

T_l = limiting steel temperature in degrees Celsius

t = thickness; or
= thickness of thinner part joined; or
= wall thickness of a circular hollow section; or
= thickness of an angle section; or
= time

t_f = thickness of a flange; or
= thickness of the critical flange

t_n = thickness of a nut

t_p = thickness of a ply; or
= thickness of thinner ply connected; or
= thickness of a plate

t_s = thickness of a stiffener

t_t, t_{t1}, t_{t2} = design throat thickness of a weld

t_w = thickness of a web

t_w, t_{w1}, t_{w2} = size of a fillet weld

V_b = nominal bearing capacity of a ply or a pin; or
= nominal shear buckling capacity of a web

V_f = nominal shear capacity of a bolt or pin—strength limit state

V_{sf} = nominal shear capacity of a bolt—serviceability limit state

V_{si} = measured slip-load at the ith bolt

V_u = nominal shear capacity of a web with a uniform shear stress distribution

V_v = nominal shear capacity of a web

V_{vm} = nominal web shear capacity in the presence of bending moment

V_w = nominal shear yield capacity of a web; or
= nominal shear capacity of a plug or slot weld

V^* = design shear force; or
= design horizontal storey shear force at lower column end; or
= design transverse shear force

V_b^* = design bearing force on a ply at a bolt or pin location

V_f^* = design shear force on a bolt or a pin-strength limit state

V_l^* = design longitudinal shear force

V_{sf}^* = design shear force on a bolt—serviceability limit state

V_w^* = design shear force acting on a web panel; or
= design shear force on a plug or slot weld

v_w = nominal capacity of a fillet weld per unit length

v_w^* = design force per unit length on a fillet weld

x = major principal axis coordinate

y = minor principal axis coordinate

y_L = distance of the gravity loading below the centroid

y_o = coordinate of shear centre

Z = elastic section modulus

Z_c = Z_e for a compact section

Z_e = effective section modulus

Z_{we} = elastic section modulus of a web panel

α = angle between x- and h-axes for an angle section

α_a = compression member factor, as defined in Clause 6.3.3

α_b = compression member section constant, as defined in Clause 6.3.3

α_{bc} = moment modification factor for bending and compression

α_c	= compression member slenderness reduction factor
α_d	= tension field coefficient for web shear buckling
α_f	= flange restraint factor for web shear buckling
α_L, α_{Lc}, α_{mc}	= factors for bending defined in Paragraphs H2 and H3
α_m	= moment modification factor for bending
α_p	= coefficient used to calculate the nominal bearing yield capacity (R_{by}) for square and rectangular hollow sections to AS 1163.
α_{pm}	= coefficient used to calculate α_p.
α_{ry}	= elastic stiffness of a flexural end restraint
α_{rz}	= elastic stiffness of a torsional end restraint
α_s	= slenderness reduction factor; or = inverse of the slope of the S-N curve for fatigue
α_{sc}	= stability function multiplier
α_{st}	= reduction factor for members of varying cross-section
α_T	= coefficient of thermal expansion for steel, 11.7 x 10^{-6} per degree Celsius
α_t	= factor for torsional end restraint defined in Clause 5.14.5
α_v	= shear buckling coefficient for a web
α_w	= factor, as defined in Appendix I
β_e	= modifying factor to account for conditions at the far ends of beam members
β_m	= ratio of smaller to larger bending moment at the ends of a member; or = ratio of end moment to fixed end moment
β_t	= measure of elastic stiffness of torsional end restraint used in Appendix H
β_x	= monosymmetry section constant
β_w	= factor defined in Appendix I
γ	= index used in Clause 8.3.4; or = factor for transverse stiffener arrangement
γ, γ_1, γ_2	= ratios of compression member stiffness to end restraint stiffness used in Clause 4.6.3.3
Δ	= deflection; or = deviation from nominated dimension; or = measured total extension of a bolt when tightened
Δ_{ct}	= mid-span deflection of a member resulting from transverse loading together with both end bending moments
Δ_{cw}	= mid-span deflection of a member resulting from transverse loading together with only those end bending moments which produce a mid-span deflection in the same direction as the transverse load
Δ_f	= out-of-flatness of a flange plate
Δh_b	= deviation from h_b
ΔL_c	= deviation from L_c

Δ_s	= translational displacement of the top relative to the bottom for a storey height
Δ_v	= deviation from verticality of a web at a support
Δ_w	= out-of-flatness of a web
δ	= standard deviation
δ_b	= moment amplification factor for a braced member
δ_m	= moment amplification factor, taken as the greater of δ_b and δ_s
δ_p	= moment amplification factor for plastic design
δ_s	= moment amplification factor for a sway member
ξ	= compression member factor, as defined in Clause 6.3.3
η	= compression member imperfection factor, as defined in Clause 6.3.3
θ	= angle of preparation of an incomplete penetration butt weld
π	= pi (= 3.14159)
λ	= slenderness ratio; or = elastic buckling load factor
λ_c	= elastic buckling load factor
λ_e	= plate element slenderness
λ_{ed}	= plate element deformation slenderness limit
λ_{ep}	= plate element plasticity slenderness limit
λ_{ey}	= plate element yield slenderness limit
λ_m	= elastic buckling load factor for a member
λ_{ms}	= elastic buckling load factor for the storey under consideration
λ_n	= modified compression member slenderness
λ_s	= section slenderness
λ_{sp}	= section plasticity slenderness limit
λ_{sy}	= section yield slenderness limit
μ	= slip factor
μ_m	= mean value of the slip factor
ν	= Poisson's ratio, 0.25
ρ	= the ratio of design axial force in a restraining member to the elastic buckling load for a member of length L (Appendix G); or = I_{cy}/I_y
ϕ	= capacity factor

1.5 USE OF ALTERNATIVE MATERIALS OR METHODS

1.5.1 General This Standard shall not be interpreted so as to prevent the use of materials or methods of design or construction not specifically referred to herein, provided that the requirements of Section 3 are complied with.

1.5.2 Existing structures Where the strength or serviceability of an existing structure is to be evaluated, the general principles of this Standard may be applied. The actual properties of the materials in the structure shall be used.

1.6 DESIGN

1.6.1 Design data The following design data shall be shown in the drawings:

(a) The reference number and date of issue of applicable design Standards used.

(b) The nominal loads.

(c) The corrosion protection, if applicable.

(d) The fire-resistance level, if applicable.

(e) The steel grades used.

1.6.2 Design details The drawings or specification or both for steel members and structures shall include, as appropriate, the following:

(a) The size and designation of each member.

(b) The sizes and categories of the bolts and welds used in the connections.

(c) The sizes of the connection components.

(d) The locations and details of planned joints, connections and splices.

(e) Any constraint on construction assumed in the design.

(f) The camber of any members.

(g) Any other requirements.

1.7 CONSTRUCTION All steel structures, designed in accordance with this Standard, shall be constructed to ensure that all the requirements of the design, as contained in the drawings and specification, are satisfied.

SECTION 2 MATERIALS

2.1 YIELD STRESS AND TENSILE STRENGTH USED IN DESIGN

2.1.1 Yield stress The yield stress used in design (f_y) shall not exceed that given in Table 2.1.

2.1.2 Tensile strength The tensile strength used in design (f_u) shall not exceed that given in Table 2.1.

2.2 STRUCTURAL STEEL

2.2.1 Australian Standards Except as otherwise permitted in Clause 2.2.3, all structural steel coming within the scope of this Standard shall, before fabrication, comply with the requirements of the following Australian Standards, as appropriate:

AS 1163 Structural steel hollow sections.

AS 1594 Hot-rolled steel flat products.

AS 3678 Structural steel—Hot-rolled plates, floorplates and slabs

AS 3679 Structural steel
AS 3679.1 Part 1: Hot-rolled bars and sections
AS 3679.2 Part 2: Welded sections

2.2.2 Acceptance of steels Certified mill test reports, or test certificates issued by the mill, shall constitute sufficient evidence of compliance with the Australian Standards referred to in this Standard.

2.2.3 Unidentified steel If unidentified steel is used, it shall be free from surface imperfections, and shall be used only where the particular physical properties of the steel and its weldability will not adversely affect the strength and serviceability of the structure. Unless a full test in accordance with AS 1391 is made, the yield stress of the steel used in design (f_y) shall be taken as not exceeding 170 MPa, and the tensile strength used in design (f_u) shall be taken as not exceeding 300 MPa.

2.3 FASTENERS

2.3.1 Steel bolts, nuts and washers Steel bolts, nuts and washers shall comply with the following Australian Standards, as appropriate:

AS 1110 ISO metric hexagon precision bolts and screws.

AS 1111 ISO metric hexagon commercial bolts and screws.

AS 1112 ISO metric hexagon nuts, including thin nuts, slotted nuts and castle nuts.

AS 1252 High strength steel bolts with associated nuts and washers for structural engineering.

AS 1559 Fasteners—Bolts, nuts and washers for tower construction.

2.3.2 Equivalent high strength fasteners The use of other high strength fasteners having special features in lieu of bolts to AS 1252 shall be permitted provided that evidence of their equivalence to high strength bolts complying with AS 1252 and installation in accordance with this Standard is available.

Equivalent fasteners shall meet the following requirements:

(a) The chemical composition and mechanical properties of equivalent fasteners shall comply with AS 1252 for the relevant bolt, nut and washer components.

(b) The body diameter, head or nut bearing areas, or their equivalents, of equivalent fasteners shall not be less than those provided by a bolt and nut complying with AS 1252 of the same nominal dimensions. Equivalent fasteners may differ in other dimensions from those specified in AS 1252.

(c) The method of tensioning and the inspection procedure for equivalent fasteners may differ in detail from those specified in Clauses 15.2.5 and 15.4 respectively, provided that the minimum fastener tension is not less than the minimum bolt tension specified in Table 15.2.5.1 and that the tensioning procedure is able to be checked.

2.3.3 Welds All welding consumables and deposited weld metal shall comply with AS 1554.1, except that where required by Clause 11.1.5, they shall comply with AS 1554.5.

2.3.4 Welded studs All welded studs shall comply with, and shall be installed in accordance with AS 1554.2.

2.3.5 Explosive fasteners All explosive fasteners shall comply with, and shall be installed in accordance with AS 1873.

2.3.6 Anchor bolts Anchor bolts shall comply with either the bolt Standards of Clause 2.3.1 or shall be manufactured from rods complying with the steel Standards of Clause 2.2.1 provided that the threads comply with AS 1275.

2.4 STEEL CASTINGS All steel castings shall comply with AS 2074.

TABLE 2.1

STRENGTHS OF STEELS COMPLYING WITH AS 1163, AS 1594, AS 3678 AND AS 3679

Steel Standard	Form	Steel grade	Thickness of material (t) mm	Yield stress MPa	Tensile strength MPa
AS 1163	Hollow sections	C450 C450L0	All	450	500
		C350 C350L0	All	350	430
		C250 C250L0	All	250	320
AS 1594	Plate and strip	XF500	All	480 (See Note)	570
	Plate, strip and floorplate	Hd400	All	400	460
	Plate and strip	XF400	$t \leq 3.5$	380	460
		XF400	$3.5 < t$	360	440
	Plate, strip and floorplate	Hd350	All	350	430
	Plate and strip	HW350	All	340	450
	Plate, strip and floorplate	Hd300/1	All	300	430
		Hd300	All	300	400
	Plate and strip	XF300	All	300	440
	Plate, strip and floorplate	Hd250	All	250	350
		Hd200	All	200	300
AS 3678	Plate	400 400L15	$t \leq 12$	400	480
		400 400L15	$12 < t \leq 20$	380	480
		400 400L15	$20 < t \leq 50$	360	480
		350 350L15	$t \leq 12$	360	450
		350 350L15	$12 < t \leq 20$	350	450
		350 350L15	$20 < t \leq 80$	340	450
		350 350L15	$80 < t \leq 150$	330	450
		WR350/1 WR350/1L0	$t \leq 50$	340	450
	Plate and floorplate	300 300L15	$t \leq 8$	320	430

(continued)

TABLE 2.1 *(continued)*

Steel Standard	Form	Steel grade	Thickness of material (t) mm	Yield stress MPa	Tensile strength MPa
AS 3678	Plate	300 300L15	$8 < t \leq 12$	310	430
		300 300L15	$12 < t \leq 20$	300	430
		300 300L15	$20 < t \leq 150$	280	430
	Plate and floorplate	250 250L15	$t \leq 8$	280	410
		250 250L15	$8 < t \leq 12$	260	410
	Plate	250 250L15	$12 < t \leq 50$	250	410
		250L15	$50 < t \leq 150$	240	410
		250	$50 < t \leq 80$	240	410
		250	$80 < t \leq 150$	230	410
	Plate and floorplate	200	$t \leq 12$	200	300
AS 3679	Sections and flat bars	350	$t \leq 12$	360	480
		350 350L0 350L15	$12 < t < 40$	340	480
		350 350L0 350L15	$40 \leq t$	330	480
		WR350/1 WR350/1L0	$t \leq 12$	340	480
		WR350/2	$t \leq 50$	340	480
		WR350/2L0 WR350/2L15	$t \leq 30$	340	480
		250 250L0 250L15	$t \leq 12$	260	410
		250 250L0 250L15	$12 < t < 40$	250	410
		250 250L0 250L15	$40 \leq t$	230	410

(continued)

TABLE 2.1 *(continued)*

Steel Standard	Form	Steel grade	Thickness of material (t) mm	Yield stress MPa	Tensile strength MPa
AS 3679	Round, square and hexagonal bars	350 350L0 350L15	$t \leq 50$	340	480
		350 350L0 350L15	$50 < t < 100$	330	480
		350	$100 \leq t$	320	480
		WR350/1 WR350/1L0	$t \leq 12$	340	480
		WR350/2	$t \leq 50$	340	480
		WR350/2L0 WR350/2L15	$t \leq 30$	340	480
		250 250L10 250L15	$t \leq 50$	250	410
		250	$50 < t < 100$	250	410
		250	$100 \leq t$	230	410

NOTE: Clause 1.1(b) does not permit the yield stress used in design (f_y) to exceed 450 MPa.

SECTION 3 GENERAL DESIGN REQUIREMENTS

3.1 DESIGN

3.1.1 Aim The aim of structural design is to provide a structure which is stable, has adequate strength, is serviceable and durable, and which satisfies other objectives such as economy and ease of construction.

A structure is stable if it does not overturn, tilt or slide throughout its intended life.

A structure has adequate strength and is serviceable if the probabilities of structural failure and of loss of serviceability throughout its intended life are acceptably low.

A structure is durable if it withstands the expected wear and deterioration throughout its intended life without the need for undue maintenance.

3.1.2 Requirements The structure and its component members and connections shall satisfy the design requirements for stability, strength, serviceability, brittle fracture, fatigue, fire and earthquake in accordance with the procedures given in this Standard, as appropriate.

3.2 LOADS AND OTHER ACTIONS

3.2.1 Loads The design of a structure for the stability, strength and serviceability limit states shall account for the action effects directly arising from the following loads:

(a) Dead, live, wind, snow and earthquake loads specified in AS 1170.1, AS 1170.2, AS 1170.3 and AS 1170.4.

(b) For the design of cranes, any relevant loads specified in AS 1418.

(c) For the design of fixed platforms, walkways, stairways and ladders, any relevant loads specified in AS 1657.

(d) For the design of lifts, any relevant loads specified in AS 1735.

(e) Other specific loads, as required.

NOTES:

1 For the design of bridges, loads specified in the AUSTROADS Bridge Design Code or the ANZRC Railway Bridge Design Manual, as applicable, should be used.

2 For multi-storey building structures, see also Clause 3.2.4.

3.2.2 Other actions Any action which may significantly affect the stability, strength or serviceability of the structure, including the following, shall be taken into account:

(a) Foundation movements.

(b) Temperature changes and gradients.

(c) Axial shortening.

(d) Dynamic effects.

(e) Construction loading.

3.2.3 Design load combinations The design load combinations for the stability, strength and serviceability limit states shall be those specified in AS 1170.1.

NOTE: For the design of bridges, load combinations specified in the AUSTROADS Bridge Design Code or the ANZRC Railway Bridge Design Manual, as applicable, should be used.

3.2.4 Notional horizontal forces For multi-storey building structures only, notional horizontal forces, each equal to 0.002 times the total design vertical loads applied at a floor level, shall be applied at that floor level. These notional horizontal forces shall be considered to act in conjunction with only the design dead and live loads from AS 1170.1 for the strength and serviceability limit states. These notional horizontal forces shall not be included for the stability limit state.

3.3 STABILITY LIMIT STATE

The structure as a whole (and any part of it) shall be designed to prevent instability due to overturning, uplift or sliding as follows:

(a) The loads determined in accordance with Clause 3.2 shall be subdivided into the components tending to cause instability and the components tending to resist instability.

(b) The design action effect (S^*) shall be calculated from the components of the loads tending to cause instability, combined in accordance with the load combinations for the strength limit state specified in AS 1170.1.

(c) The design resistance effect shall be calculated as 0.8 times the part of the dead load tending to resist the instability plus the design capacity (ϕR_u) of any elements contributing towards resisting the instability, where ϕ is a capacity factor which shall not exceed the appropriate value given in Table 3.4.

(d) The whole or part of the structure shall be proportioned so that the design resistance effect is not less than the design action effect.

3.4 STRENGTH LIMIT STATE

The structure and its component members and connections shall be designed for the strength limit state as follows:

(a) The loads and actions shall be determined in accordance with Clauses 3.2.1 and 3.2.2, and the strength limit state design loads shall be determined in accordance with Clauses 3.2.3 and 3.2.4.

(b) The design action effects (S^*) resulting from the strength limit state design loads shall be determined by an analysis in accordance with Section 4.

(c) The design capacity (ϕR_u) shall be determined from the nominal capacity (R_u) determined from Sections 5 to 9, as appropriate, where the capacity factor (ϕ) shall not exceed the appropriate value given in Table 3.4.

(d) All members and connections shall be proportioned so that the design capacity (ϕR_u) is not less than the design action effect (S^*), i.e.—

$$S^* \leq \phi R_u$$

3.5 SERVICEABILITY LIMIT STATE

3.5.1 General The structure and its components shall be designed for the serviceability limit state by controlling or limiting deflection, vibration, bolt slip and corrosion, as appropriate, in accordance with the relevant requirements of Clauses 3.5.2 to 3.5.6.

3.5.2 Method The structure and its components shall be designed for the serviceability limit state as follows:

(a) The loads and other actions shall be determined in accordance with Clauses 3.2.1 and 3.2.2, and the serviceability limit state design loads shall be determined from Clauses 3.2.3 and 3.2.4.

(b) Deflections due to the serviceability limit state design loads shall be determined by the first-order elastic analysis method of Clause 4.4.2.1 with all amplification factors taken as unity. Deflections shall comply with Clause 3.5.3.

(c) Vibration behaviour shall be assessed in accordance with Clause 3.5.4.

(d) Bolt slip shall be limited, where required, in accordance with Clause 3.5.5.

(e) Corrosion protection shall be provided in accordance with Clause 3.5.6.

TABLE 3.4

CAPACITY FACTORS (φ) FOR STRENGTH LIMIT STATES

Design capacity for	Clauses	Capacity factor (φ)	
Member subject to bending			
—full lateral support	5.1, 5.2 & 5.3	0.90	
—segment without full lateral support	5.1 & 5.6	0.90	
—web in shear	5.11 & 5.12	0.90	
—web in bearing	5.13	0.90	
—stiffener	5.14, 5.15 & 5.16	0.90	
Member subject to axial compression			
—section capacity	6.1 & 6.2	0.90	
—member capacity	6.1 & 6.3	0.90	
Member subject to axial tension	7.1 & 7.2	0.90	
Member subject to combined actions			
—section capacity	8.3	0.90	
—member capacity	8.4	0.90	
Connection component other than a bolt, pin or weld	9.1.9	0.90	
Bolted connection			
—bolt in shear	9.3.2.1	0.80	
—bolt in tension	9.3.2.2	0.80	
—bolt subject to combined shear and tension	9.3.2.3	0.80	
—ply in bearing	9.3.2.4	0.90	
—bolt group	9.4	0.80	
Pin connection			
—pin in shear	9.5.1	0.80	
—pin in bearing	9.5.2	0.80	
—pin in bending	9.5.3	0.80	
—ply in bearing	9.5.4	0.90	
Welded connection		SP Category	GP Catego
—complete penetration butt weld	9.7.2.7	0.90	0.60
—Longitudinal fillet weld in RHS ($t < 3$ mm)	9.7.3.10	0.70	—
—other fillet weld and incomplete penetration butt weld	9.7.3.10	0.80	0.60
—plug or slot weld	9.7.4	0.80	0.60
—weld group	9.8	0.80	0.60

3.5.3 Deflection limits The deflection limits for the serviceability limit state shall be appropriate to the structure and its intended use, the nature of the loading, and the elements supported by it.

NOTE: Suggested deflection limits may be found in Appendix B.

3.5.4 Vibration of beams Beams which support floors or machinery shall be checked to ensure that the vibrations induced by machinery, or vehicular or pedestrian traffic do not adversely affect the serviceability of the structure.

Where there is a likelihood of a structure being subjected to vibration from causes such as wind forces or machinery, measures shall be taken to prevent discomfort or alarm, damage to the structure, or interference with its proper function.

NOTE: AS 2670 gives guidance for the evaluation of human exposure to whole-body vibrations of the type likely to be transmitted by structures.

3.5.5 Bolt serviceability limit state In a connection, where slip under the serviceability design loads must be avoided, the fasteners shall be selected in accordance with Clause 9.1.6.

For a friction-type connection which is subject to shear force in the plane of the interfaces, and for which slip under serviceability loads must be avoided, the capacity factor (φ) shall be taken as 0.7 and the bolts shall be designed in accordance with Clause 9.3.3.

3.5.6 Corrosion protection Where steelwork in a structure is to be exposed to a corrosive environment, the steelwork shall be given protection against corrosion. The degree of protection to be employed shall be determined after consideration has been given to the use of the structure, its maintenance, and the climatic or other local conditions.

NOTE: Recommendations on corrosion protection may be found in Appendix C.

SECTION 4 METHODS OF STRUCTURAL ANALYSIS

4.1 METHODS OF DETERMINING ACTION EFFECTS

4.1.1 General For the purpose of complying with the requirements for the limit states of stability, strength and serviceability specified in Section 3, the design action effects in a structure and its members and connections caused by the design loads shall be determined by structural analysis using the assumptions of Clauses 4.2 and 4.3 and one of the methods of—

(a) elastic analysis, in accordance with Clause 4.4; or

(b) plastic analysis, in accordance with Clause 4.5; or

(c) advanced analysis, in accordance with Appendix D.

The design action effects for earthquake loads shall be obtained by an analysis complying with Item (a), (b) or (c). The earthquake loads calculated in accordance with AS 1170.4 shall be assumed to correspond to the load at which the first significant plastic hinge forms in the structure.

4.1.2 Definitions For the purpose of this Section, the definitions below apply:

(a) *Braced member*—one for which the transverse displacement of one end of the member relative to the other is effectively prevented. This applies to triangulated frames and trusses or to frames where in-plane stiffness is provided by diagonal bracing, or by shear walls, or by floor slabs or roof decks secured horizontally to walls or to bracing systems parallel to the plane of buckling of the member.

(b) *Sway member*—one for which the transverse displacement of one end of the member relative to the other is not effectively prevented. Such members occur in structures which depend on flexural action to limit the sway.

4.2 FORMS OF CONSTRUCTION ASSUMED FOR STRUCTURAL ANALYSIS

4.2.1 General The distribution of the design action effects throughout the members and connections of a structure shall be determined by assuming one or a combination of the following forms of construction:

(a) Rigid.

(b) Semi-rigid.

(c) Simple.

4.2.2 Rigid construction For rigid construction, the connections shall be assumed to have sufficient rigidity to hold the original angles between the members unchanged.

4.2.3 Semi-rigid construction For semi-rigid construction, the connections may not have sufficient rigidity to hold the original angles between the members unchanged, but shall be assumed to have the capacity to furnish a dependable and known degree of flexural restraint.

The relationship between the degree of flexural restraint and the level of the load effects shall be established by methods based on test results.

4.2.4 Simple construction For simple construction, the connections at the ends of members shall be assumed not to develop bending moments.

4.2.5 Design of connections The design of all connections shall be consistent with the form of construction, and the behaviour of the connections shall not adversely affect any other part of the structure beyond what is allowed for in design. Connections shall be designed in accordance with Section 9.

4.3 ASSUMPTIONS FOR ANALYSIS

4.3.1 General The structure shall be analyzed in its entirety except as follows:

(a) Regular building structures may be analyzed as a series of parallel two-dimensional substructures, the analysis being carried out in each of two directions at right angles, except when there is significant load redistribution between the substructures.

(b) For vertical loading in a multi-storey building structure provided with bracing or shear walls to resist all lateral forces, each level thereof together with the columns immediately above and below may be considered as substructures, the columns being assumed fixed at the ends remote from the level under consideration.

Where floor beams in a multi-storey building structure are considered as substructures, the bending moment at a support may be determined from the assumption that the floor is fixed at the support one span away, provided that the floor beam continues beyond that point.

4.3.2 Span length The span length of a flexural member shall be taken as the distance centre-to-centre of the supports.

4.3.3 Arrangements of live loads for buildings For building structures, the arrangements of live loads considered in the analysis shall include at least the following:

(a) Where the loading pattern is fixed, the arrangement concerned.

(b) Where the nominal live load (Q) is variable and not greater than three-quarters of the nominal dead load (G), the design live load (Q^*) on all spans.

(c) Where the nominal live load (Q) is variable and exceeds three-quarters of the nominal dead load (G), arrangements for the floor under consideration consisting of—

(i) the design live load (Q^*) on alternate spans;

(ii) the design live load (Q^*) on two adjacent spans; and

(iii) the design live load (Q^*) on all spans.

4.3.4 Simple construction Bending members may be assumed to have their ends connected for shear only and to be free to rotate. In triangulated structures, axial forces may be determined by assuming that all members are pin connected.

A beam reaction or a similar load on a column shall be taken as acting at a minimum distance of 100 mm from the face of the column towards the span or at the centre of bearing, whichever gives the greater eccentricity, except that for a column cap, the load shall be taken as acting at the face of the column, or edge of packing if used, towards the span.

For a continuous column, the design bending moment (M^*) due to eccentricity of loading at any one floor or horizontal frame level shall be taken as—

(a) ineffective at the floor or frame levels above and below that floor; and

(b) divided between the column lengths above and below that floor or frame level in proportion to the values of I/L of the column lengths.

4.4 ELASTIC ANALYSIS

4.4.1 General

4.4.1.1 *Assumptions* Individual members shall be assumed to remain elastic under th action of the design loads for all limit states.

The effect of haunching or any variation of the cross-section along the axis of a membe shall be considered and, where significant, shall be taken into account in th determination of the member stiffness.

4.4.1.2 *Second-order effects* The analysis shall allow for the effects of the design load acting on the structure and its members in their displaced and deformed configuration These second-order effects shall be taken into account by using either—

(a) a first-order elastic analysis with moment amplification in accordance wit Clause 4.4.2, provided the moment amplification factors (δ_b) or (δ_s) are not greate than 1.4; or

(b) a second-order elastic analysis in accordance with Appendix E.

4.4.2 First-order elastic analysis

4.4.2.1 *General* In a first-order elastic analysis, changes in the geometry are no accounted for, and changes in the effective stiffnesses of the members due to axial force are neglected. The effects of these on the first-order bending moments shall be allowed for by using one of the methods of moment amplification of Clause 4.4.2.2 o Clause 4.4.2.3 as appropriate, except that where the moment amplification factor (δ_b) o (δ_s), calculated in accordance with Clause 4.4.2.2 or Clause 4.4.2.3 as appropriate, i greater than 1.4, a second-order elastic analysis in accordance with Appendix E shall b carried out.

The maximum calculated bending moment (M_m^*) shall be taken as the maximum bending moment along the length of a member obtained by superposition of the simple bean bending moments resulting from any transverse loading on the member with the end bending moments determined by the analysis.

4.4.2.2 *Moment amplification for a braced member* For a braced member with zero axial force or a braced member subject to axial tension, the design bending moment (M^*) shall be calculated as follows:

$$M^* = M_m^*$$

For a braced member with a design axial compressive force (N^*) as determined by the analysis, the design bending moment (M^*) shall be calculated as follows:

$$M^* = \delta_b M_m^*$$

where δb is a moment amplification factor for a braced member calculated as follows:

$$\delta_b = \frac{c_m}{1 - \left(\frac{N^*}{N_{omb}}\right)} \geq 1$$

and N_{omb} is the elastic buckling load, determined in accordance with Clause 4.6.2, for the braced member buckling about the same axis as that about which the design bending moment (M^*) is applied.

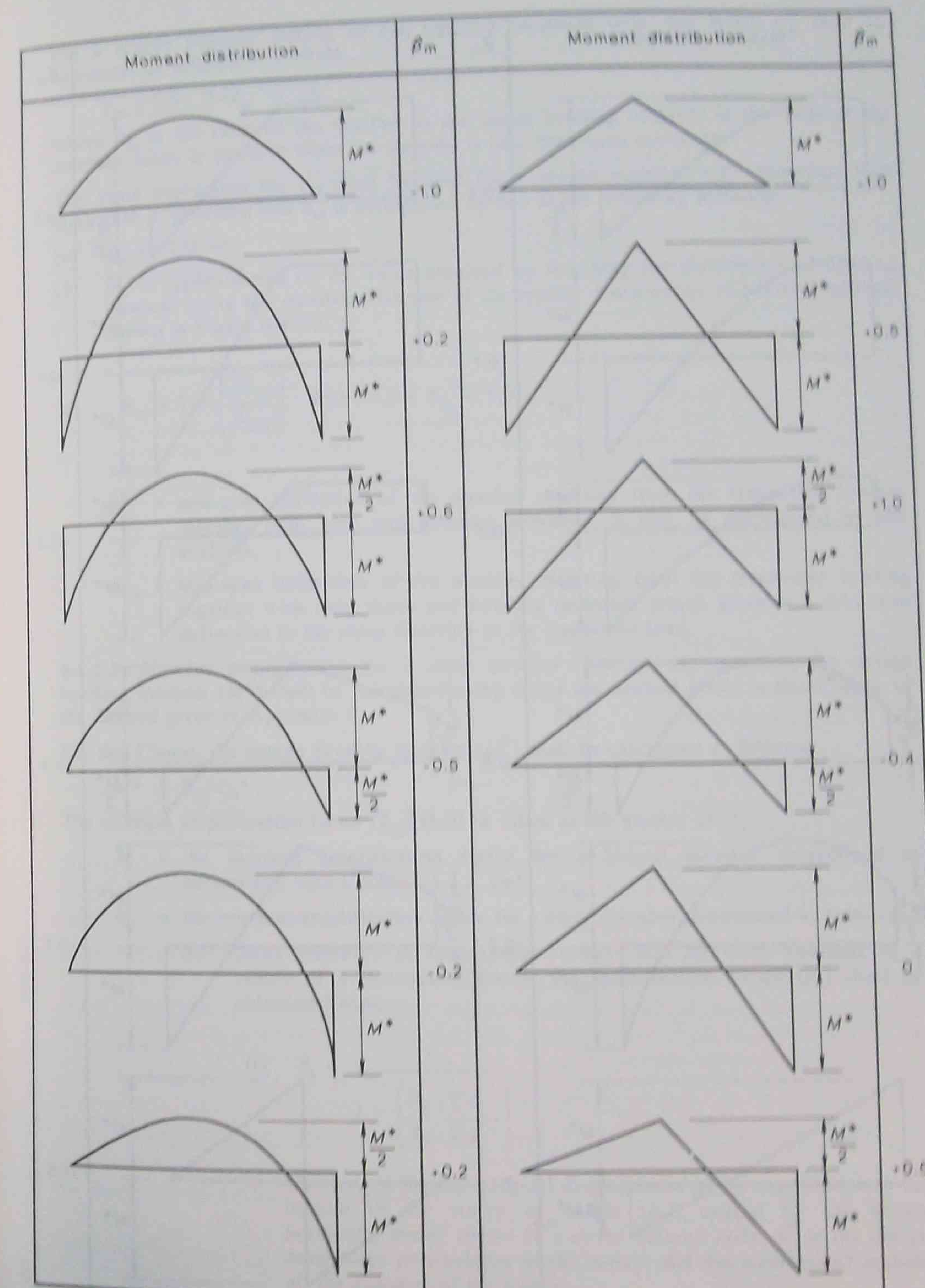


FIGURE 4.4.2.2 (in part) VALUES OF β_m FOR VARIOUS DISTRIBUTIONS OF BENDING MOMENT

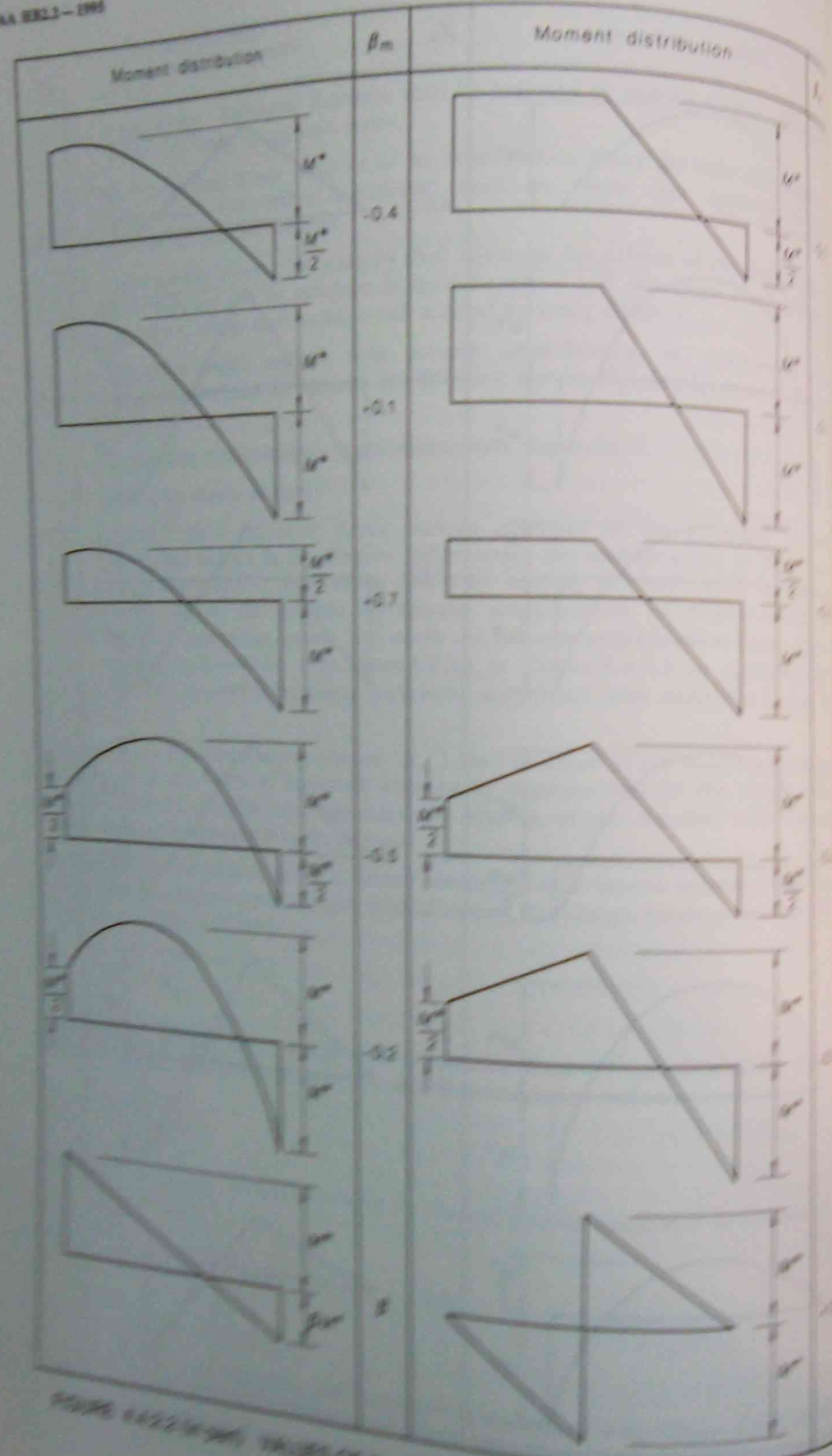


FIGURE 4.4.2.2 (in part) VALUES OF β_m FOR VARIOUS DISTRIBUTIONS OF BENDING MOMENT

For a braced member subject to end bending moments only, the factor c_m shall be calculated as follows:

$$c_m = 0.6 - 0.4\beta_m \leq 1.0$$

where β_m is the ratio of the smaller to the larger bending moment at the ends of the member, taken as positive when the member is bent in reverse curvature.

The same expression for c_m shall be used for a braced member with transverse load applied to it, provided that β_m is determined by one of the following methods:

(a) $\beta_m = -1.0$; or

(b) β_m is approximated by the value obtained by matching the distribution of bending moment along the member with one of the typical distributions of bending moment shown in Figure 4.4.2.2; or

(c) $$\beta_m = 1 - \left(\frac{2\Delta_{ct}}{\Delta_{cw}}\right) \quad \text{with } -1.0 \leq \beta_m \leq 1.0$$

where

Δ_{ct} = mid-span deflection of the member resulting from the transverse loading together with both end bending moments, if any, as determined by the analysis

Δ_{cw} = mid-span deflection of the member resulting from the transverse loading together with only those end bending moments which produce a mid-span deflection in the same direction as the transverse load.

4.4.2.3 *Moment amplification for a sway member* For a sway member, the design bending moment (M^*) shall be calculated using either the method given in this Clause, or the method given in Appendix F.

For this Clause, the design bending moment (M^*) shall be calculated as follows:

$$M^* = \delta_m M_m^*$$

The moment amplification factor (δ_m) shall be taken as the greater of—

δ_b = the moment amplification factor for a braced member determined in accordance with Clause 4.4.2.2, and

δ_s = the moment amplification factor for a sway member determined as follows:

(a) *Sway members in rectangular frames* For all sway columns in a storey of a rectangular frame, the amplification factor (δ_s) shall be calculated from—

(i) $$\delta_s = \frac{1}{1 - \left(\frac{\Delta_s}{h_s}\frac{\Sigma N^*}{\Sigma V^*}\right)}$$

where Δ_s is the translational displacement of the top relative to the bottom in the storey of height (h_s), caused by the design horizontal storey shears (V^*) at the column ends, N^* is the design axial force in a column of the storey, and the summations include all the columns of the storey;

(ii) $$\delta_s = \frac{1}{1 - \left(\frac{1}{\lambda_{ms}}\right)}$$

where the elastic buckling load factor (λ_{ms}) for the storey under consideration is determined in accordance with Clause 4.7.2.2; or

(iii) $$\delta_s = \frac{1}{1 - \left(\frac{1}{\lambda_c}\right)}$$

where the elastic buckling load factor (λ_c) is determined from a rational buckling analysis of the whole frame (see Clause 4.7.2).

(b) *Sway members in non-rectangular frames* The amplification factor (δ_s) for each sway member shall be taken as the value for the frame calculated as follows:

$$\delta_s = \frac{1}{1 - \left(\frac{1}{\lambda_c}\right)}$$

where the elastic buckling load factor (λ_c) is determined from a rational buckling analysis of the whole frame (see Clause 4.7.2).

4.5 PLASTIC ANALYSIS

4.5.1 Application The design action effects throughout all or part of a structure may be determined by a plastic analysis provided that the limitations of Clause 4.5.2 are observed. The distribution of design action effects shall satisfy equilibrium and the boundary conditions.

4.5.2 Limitations When a plastic method of analysis is used, all of the following conditions shall be satisfied unless adequate ductility of the structure and plastic rotation capacity of its members and connections are established for the design loading conditions:

(a) The minimum yield stress specified for the grade of the steel shall not exceed 450 MPa.

(b) The stress-strain characteristics of the steel shall not be significantly different from those obtained for steels complying with AS 3678 or AS 3679, and shall be such as to ensure moment redistribution.

This requirement may be deemed to be satisfied if—

(i) the stress-strain diagram has a plateau at the yield stress extending for at least six times the yield strain; and

(ii) the ratio of the tensile strength to the yield stress specified for the grade of the steel (see Table 2.1) is not less than 1.2; and

(iii) the elongation on a gauge length complying with AS 1391 is not less than 15%; and

(iv) the steel exhibits a strain-hardening capability.

(c) The members used shall be hot-formed.

(d) The members used shall be doubly symmetric I-sections.

(e) The geometry of the member sections shall comply with the requirements specified for a compact section in Clause 5.2.3.

(f) The members shall not be subject to impact loading or fluctuating loading requiring a fatigue assessment (see Section 11).

4.5.3 Assumptions of analysis The design action effects shall be determined using a rigid plastic analysis.

It shall be permissible to assume full strength or partial strength connections, provided the capacities of these are used in the analysis, and provided that—

(a) for a full strength connection, for which the moment capacity of the connection shall be not less than that of the member being connected, the behaviour of the connection shall be such that the rotation capacity at none of the hinges in the collapse mechanism is exceeded; and

(b) for a partial strength connection, for which the moment capacity of the connection may be less than that of the member being connected, the behaviour of the connection shall be such as to allow all plastic hinges necessary for the collapse mechanism to develop, and shall be such that the rotation capacity at none of the plastic hinges is exceeded.

4.5.4 Second-order effects Any second-order effects of the loads acting on the structure in its deformed configuration may be neglected where the elastic buckling load factor (λ_c) (see Clause 4.7) satisfies—

$$10 \le \lambda_c$$

For $5 \le \lambda_c < 10$, second-order effects may be neglected provided the design load effects are amplified by a factor δ_p

where

$$\delta_p = \frac{0.9}{1 - \left(\frac{1}{\lambda_c}\right)}$$

For $\lambda_c < 5$, a second-order plastic analysis shall be carried out.

4.6 MEMBER BUCKLING ANALYSIS

4.6.1 General The elastic buckling load of a member (N_{om}) for the particular conditions of end restraint provided by the surrounding frame shall be determined in accordance with Clause 4.6.2. The member buckling load (N_{omb}) is used in the determination of the moment amplification factor for a braced member (δ_b) in Clause 4.4.2.2, and the member buckling load (N_{oms}) in the determination of the elastic buckling load factor (λ_{ms}) in Clause 4.7.2.2 which is used in the determination of the moment amplification factor for a sway member (δ_s) in Clause 4.4.2.3.

4.6.2 Member elastic buckling load The elastic buckling load of a member (N_{om}) shall be determined as follows:

$$N_{om} = \frac{\pi^2 EI}{(k_e L)^2}$$

where k_e is the member effective length factor, determined in accordance with Clause 4.6.3 and L is the member length from centre to centre of its intersections with supporting members.

4.6.3 Member effective length factor

4.6.3.1 *General* The value of the member effective length factor (k_e) depends on the rotational restraints and the translational restraints at the ends of the member. In Figure 4.6.3.3(a) for a braced member, the translational restraint has been assumed to be infinite. In Figure 4.6.3.3(b) for a sway member, the translational restraint has been assumed to be zero.

The value of the member effective length factor (k_e) shall be determined in accordance with the following:

(a) Clause 4.6.3.2 for members with idealized end restraints.

(b) Clause 4.6.3.3 for Appendix G for braced members in frames.

(c) Clause 4.6.3.3 for sway members in rectangular frames with regular loading and negligible axial forces in the beams.

(d) Clause 4.6.3.5 for members in triangulated structures.

4.6.3.2 *Members with idealized end restraints* Values of the member effective length factor (k_e) which shall be used for some idealized conditions of end restraint for members are given in Figure 4.6.3.2.

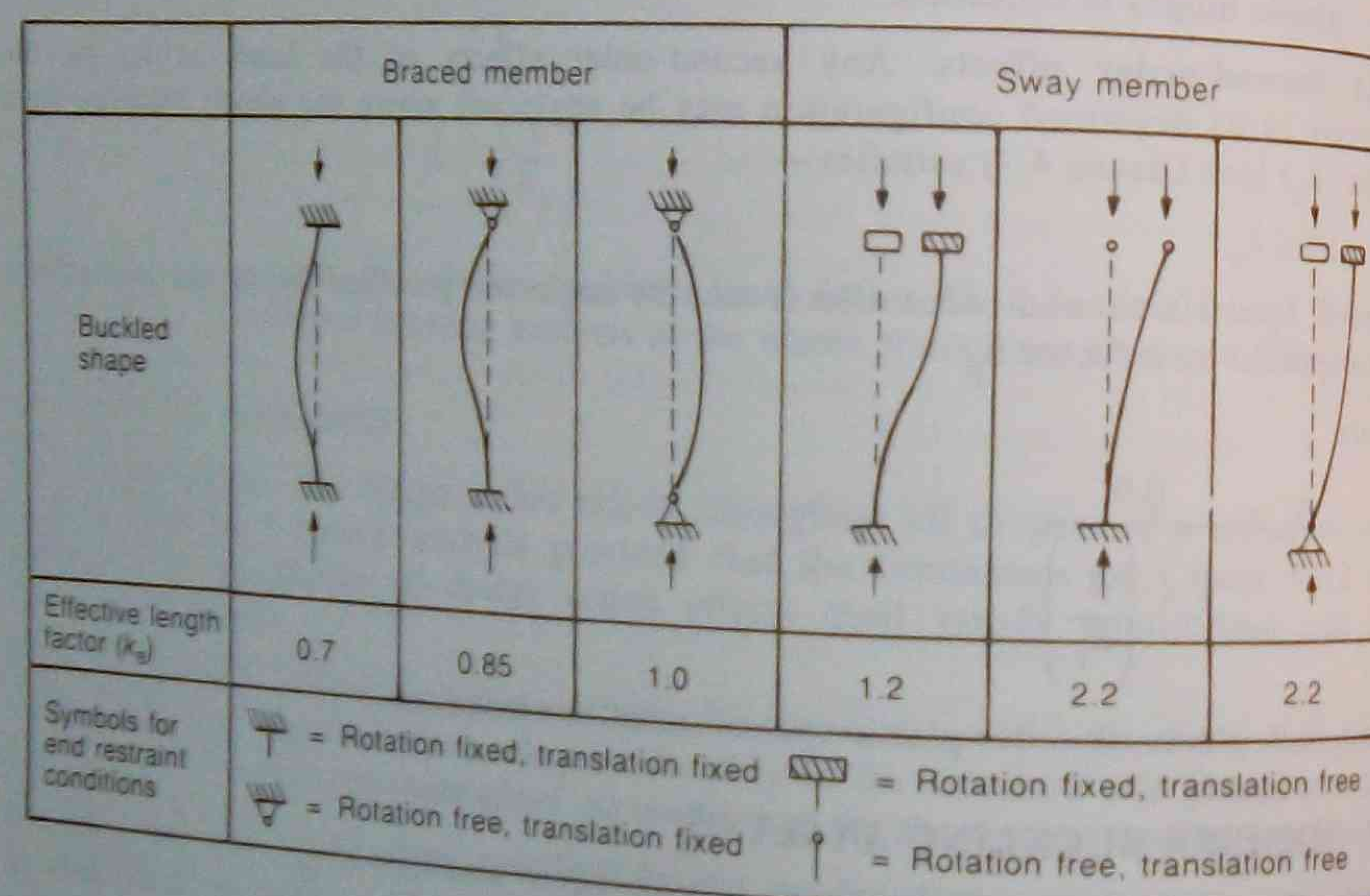
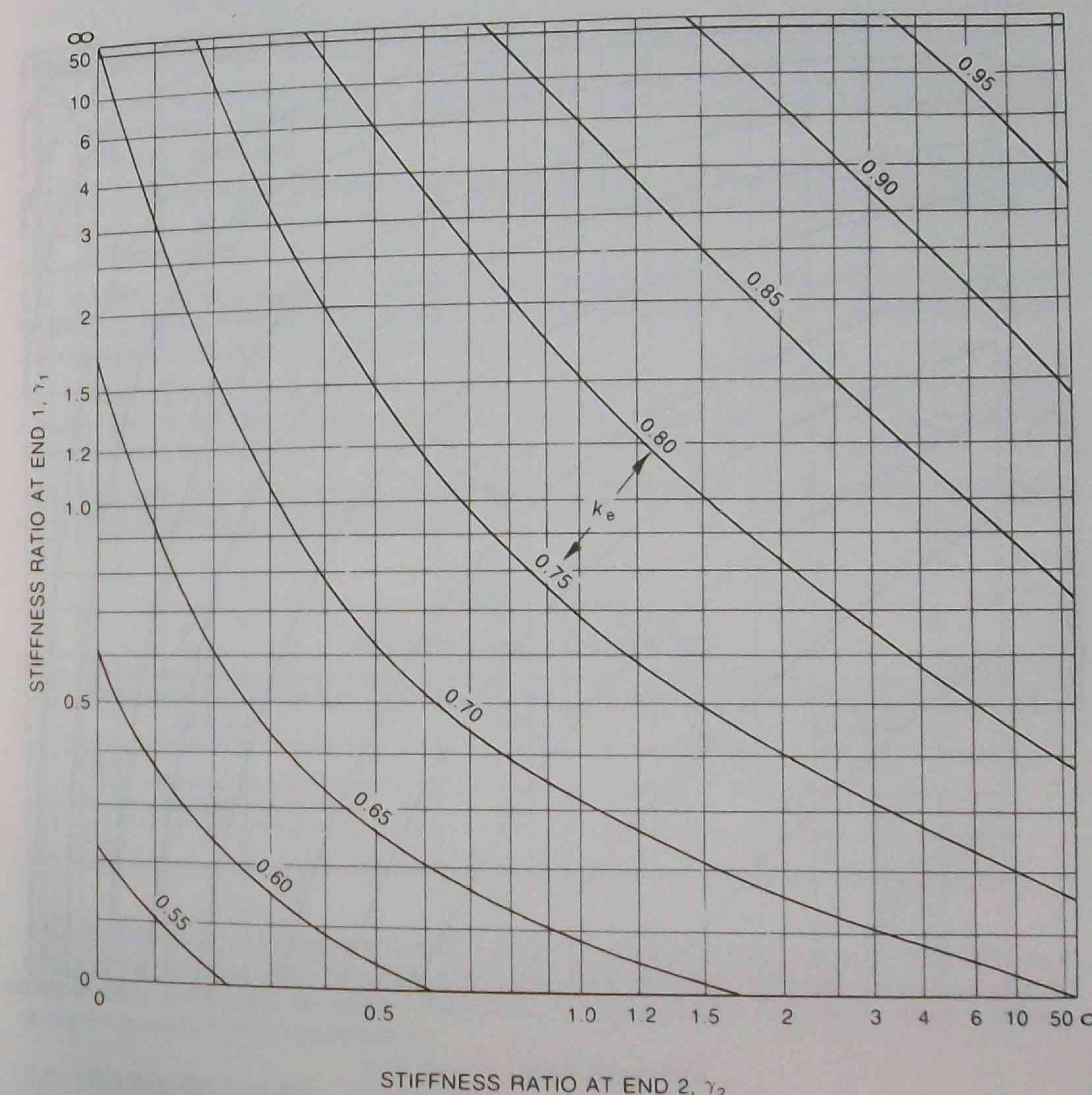


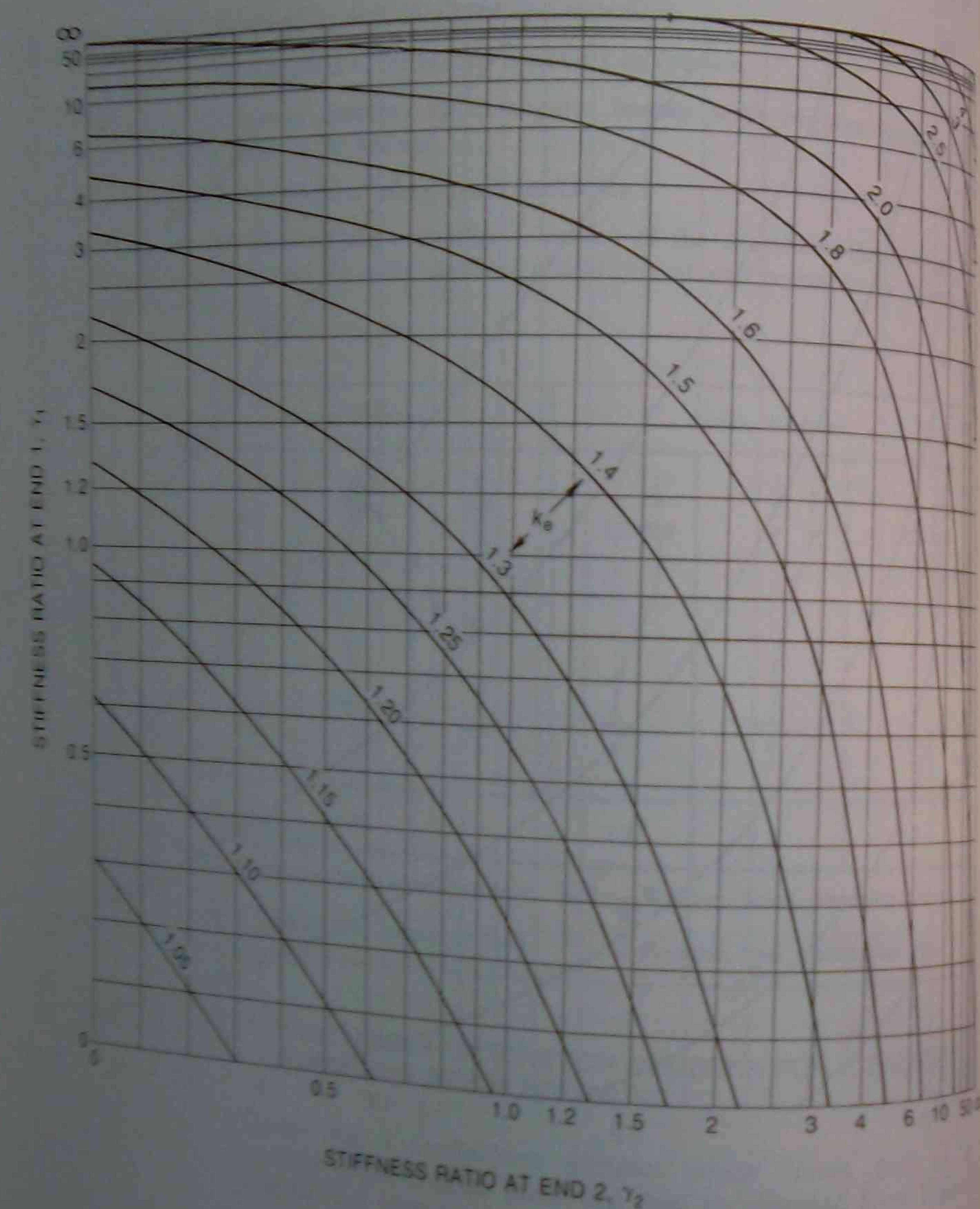
FIGURE 4.6.3.2 EFFECTIVE LENGTH FACTORS FOR MEMBERS FOR IDEALIZED CONDITIONS OF END RESTRAINT

4.6.3.3 *Members in frames* For a compression member which forms part of a rigid-jointed frame, the member effective length factor (k_e) shall be obtained from Figure 4.6.3.3(a) for a braced member and from Figure 4.6.3.3(b) for a sway member. In these figures, γ_1 and γ_2 are the ratios of the compression member stiffness to the end restraint stiffnesses. The γ-values shall be determined in accordance with Clause 4.6.3.4 or Appendix G, as appropriate.



(a) For braced members

FIGURE 4.6.3.3 (in part) EFFECTIVE LENGTH FACTORS



(b) For sway members

FIGURE 4.6.3.3 (in part) EFFECTIVE LENGTH FACTORS

4.6.3.4 *Stiffness ratios in rectangular frames* The γ-value of a compression member in a rectangular frame with regular loading and negligible axial forces in the beams shall be calculated as follows:

$$\gamma = \sum \frac{\left(\frac{I}{L}\right)_c}{\sum \beta_e \left(\frac{I}{L}\right)_b}$$

except that—

(a) for a compression member whose base is not rigidly connected to a footing, the γ-value shall not be taken as less than 10 unless a rational analysis would justify a different value; and

(b) for a compression member whose end is rigidly connected to a footing, the γ-value shall not be taken as less than 0.6, unless a rational analysis would justify a different value.

The quantity $\Sigma(I/L)_c$ shall be calculated from the sum of the stiffnesses in the plane of bending of all the compression members rigidly connected at the end of the member under consideration, including the member itself.

The quantity $\Sigma\beta_e(I/L)_b$ shall be calculated from the sum of the stiffnesses in the plane of bending for all the beams rigidly connected at the end of the member under consideration. The contributions of any beams pin-connected to the member shall be neglected.

The modifying factor (β_e) which accounts for the conditions at the far ends of the beams, shall be determined from Table 4.6.3.4.

TABLE 4.6.3.4

MODIFYING FACTORS (β_e)

Fixity conditions at far end of beam	Beam restraining a braced member	Beam restraining a sway member
Pinned	1.5	0.5
Rigidly connected to a column	1.0	1.0
Fixed	2.0	0.67

4.6.3.5 *Members in triangulated structures* The effective length (L_e) of a member in a triangulated structure shall be taken as not less than its length (L) from centre to centre of intersections with other members, unless shown otherwise by a rational elastic buckling analysis consistent with Appendix G.

4.7 FRAME BUCKLING ANALYSIS

4.7.1 General The elastic buckling load factor (λ_c) shall be the ratio of the elastic buckling load set of the frame to the design load set for the frame, and shall be determined in accordance with Clause 4.7.2. The elastic buckling load factor (λ_c) is used in the determination of the moment amplification factor for a sway member (δ_s) in Clause 4.4.2.3(b) and in establishing limits for the methods of analysis in Clause 4.5.4 and Appendix E.

NOTE: The value of λ_c depends on the load set.