Practical Restoration Handbook

Brickwork

by

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MORTAR MIXES
BASIC INGREDIENTS OF MORTAR

Building Sand

1. This is usually excavated from open cast pits hence the name usually given to this type of sand is pit sand, it should be free of clay and loam. It should never be obtained from the seashore as the sand would contain excessive amounts of salt which cause a white scum, known as efflorescence, to appear on the surface of the brickwork.

2. Pit sand is widely used and comes in a variety of colours e.g. red, brown, yellow, grey and silver.

3. The sand should contain fine small grains no larger than 0.5 to 1mm and it should not contain any large stones or grit because they would interfere with the laying of the bricks.

How to Store Sand

4. For long term use, find a suitable level site close to where you are going to use the material, with easy access for deliveries of sand and cement. Next lay a concrete base 3m by 3m by 100mm thick, then build a wall on three sides using either concrete blocks or old bricks about 1m high to retain the sand, use polythene or a tarpaulin to cover the sand to keep it dry and free from leaves, stones and frost.

5. For short term use have your supplier deliver the sand in 1 tonne bags which can be craned off the lorry to anywhere you need them. A deposit on the bag is usually required which is refunded when you return it.

Cement

6. Ordinary Portland Cement (OPC), sometimes known by brand-names such as Blue Circle and Rugby Cement, is the most commonly used cement for brickwork. It is made by burning a chalk and clay slurry in a rotary kiln about 90m long which produces a greyish clinker which is ground down to a fine powder, this powder is so fine it will pass through a sieve which has a mesh width of 90 microns. 100% passes 150 microns, 95% passes 75 microns.

7. Cement should be stored off the floor; ideally on a pallet and preferably inside a shed or container. If stored externally it should be carefully and tightly wrapped in tarpauline sheet which should extend under the pile of bags. Wrapping in tarpauline is also advisable when storing for long periods, even in sheds, since it prevents atmospheric moisture causing the cement to start to harden. Cement begins to set within 30 minutes of adding water with a gradual increase in strength which continues for at least two weeks. All mortar should be used within 2 hours of mixing and should never be remixed with water.

Lime

8. Lime was used before the introduction of cement, (which was not introduced until 1824 and even then it probably wasn't used because of the cost) so many of the canals built before this date were built using only sand and lime. Lime is produced from either chalk or limestone. When these materials are burnt at a very high temperature they turn into quicklime. The quicklime is not suitable for building with, so water is added to it , and this is called slaking. During slaking the quicklime produces heat and expands, and the water will integrate chemically with the quicklime changing it into hydrated lime. The setting times

depend on the impurities in the burnt lime. Active impurities in the lime render it independent of carbonation for its setting, and it is therefore capable of setting under water. This feature is named hydraulicity.

9. Non-hydraulic limes (rich limes) will not set under damp conditions. They set only by carbonation and develop little strength unless they are mixed with cement; this gives the mortar improved workability.

10. Semi-hydraulic limes, which will set partially under damp conditions, have a small amount of free lime (calcium oxide) and a percentage of hydraulic constituents, mainly derived from the clay content of the limestone. The slaking of this type of lime is much slower than that of a non - hydraulic lime. It is this which creates the action of setting; the hardening of the hydroxide being dependent on the carbon dioxide as in a rich lime.

11. Eminently hydraulic limes (which will set under damp conditions) are equivalent in chemical composition to portland cement, but contain a small amount of free lime. These limes do not harden so quickly as portland cement and do not reach such a high strength. Lime should be stored in the same way as cement.

Care must be taken at all times when handling cement and lime. Contact with wet cement or wet mortar may cause irritation, dermatitis or burns. Contact between cement powder and body fluids (e.g. sweat and eye fluids) may also cause irritation, dermatitis or burns. If cement comes into contact with eyes wash immediately with plenty of clean water and seek medical advice. If cement comes into contact with skin wash immediately with plenty of clean water.

Water

12. Preferably clean tap water should be used as canal water can contain impurities such as rotting plants and animals which can severely contaminate and discolour the mortar.

Plasticizers

13. These are a substitute for lime and when added to a mortar mix have the effect of entraining very small bubbles of air into the mortar and breaking down the surface tension, resulting in increased workability.

14. A 1:6 cement : sand mix with plasticizer is an alternative to a 1:1:6 cement : lime : sand mix. A plasticized mix weaker than 1:8 is not recommended.

15. Plasticizers may be used with sulphate resisting portland cements and with high alumina cement, and there is evidence that aerated mortars have greater resistance to sulphate attack than cement : lime : sand mortars of equal strength.

16. Evidence also shows that mortar plasticizers improve the resistance of freshly laid brickwork to frost. Mortar with plasticizer added can be either mixed by hand or mixed in a drum mixer, but prolonged mixing in a drum mixer can lead to excessive air entrapment which consequently leads to a weak mortar mix. Plasticizers can be obtained in liquid and powder form, but always read the information on the container for mixing instructions before using.

MORTARS FOR BRICKWORK

17. Requirements for mortar are as follows :-

    1. Good workability.

    2. Retention of plasticity long enough for bricks to be laid and adjusted, but stiffen within a reasonable time.

    3. Early development of strength.

    4. Mature strength should be adequate but no greater than is needed for the design, (mortar for a wall need be no stronger than the bricks).

    5. Adhere well to the bricks.

    6. Have adequate durability.

18. The final strength of the mortar used to build a wall has little effect on the actual strength or rigidity of the wall as might be supposed. A very strong mortar will centre any differential movement and produce fewer but wider cracks . A weak mortar will absorb small movements and produce hair line cracks in the joints.

19. As a result, mortar should only contain enough cement to attain adequate strength in the wall where it is being used, unless there is good reason for using a richer mortar i.e. in cold weather, where a richer mix attains strength more quickly to resist the effect of frost. When mixing mortar the sand and cement must be gauged out using a bucket or a small box so all the quantities are in the same proportion, this way every mix of mortar is the same strength and the colour of the mortar when dry is the same colour throughout the wall. Below is a useful table showing where mortar mixes are best suited and what time of year to use them.

MIX	USE	TIME OF YEAR
1C : 0 - 0.25 L : 3 S	Lock Chamber,top Cill Gate Recess Upper and Lower Wing Walls.	Winter
1C : 5S : P	Lock Chamber,top Cill Gate Recess, Upper and Lower Wing Walls	Summer Winter
1C : 3 - 4 S : P	Free Standing Walls, Parapets Etc.	Winter
1C :1L : 5 - 6 S	Free Standing Walls, Parapets Etc.	Summer
1C : 0.50 L: 4S*	Bridge Abutments and Arch Etc.	Winter Summer

* Note: English Heritage Recommend 1C:2L:9S for such highly visible locations

Key to Table

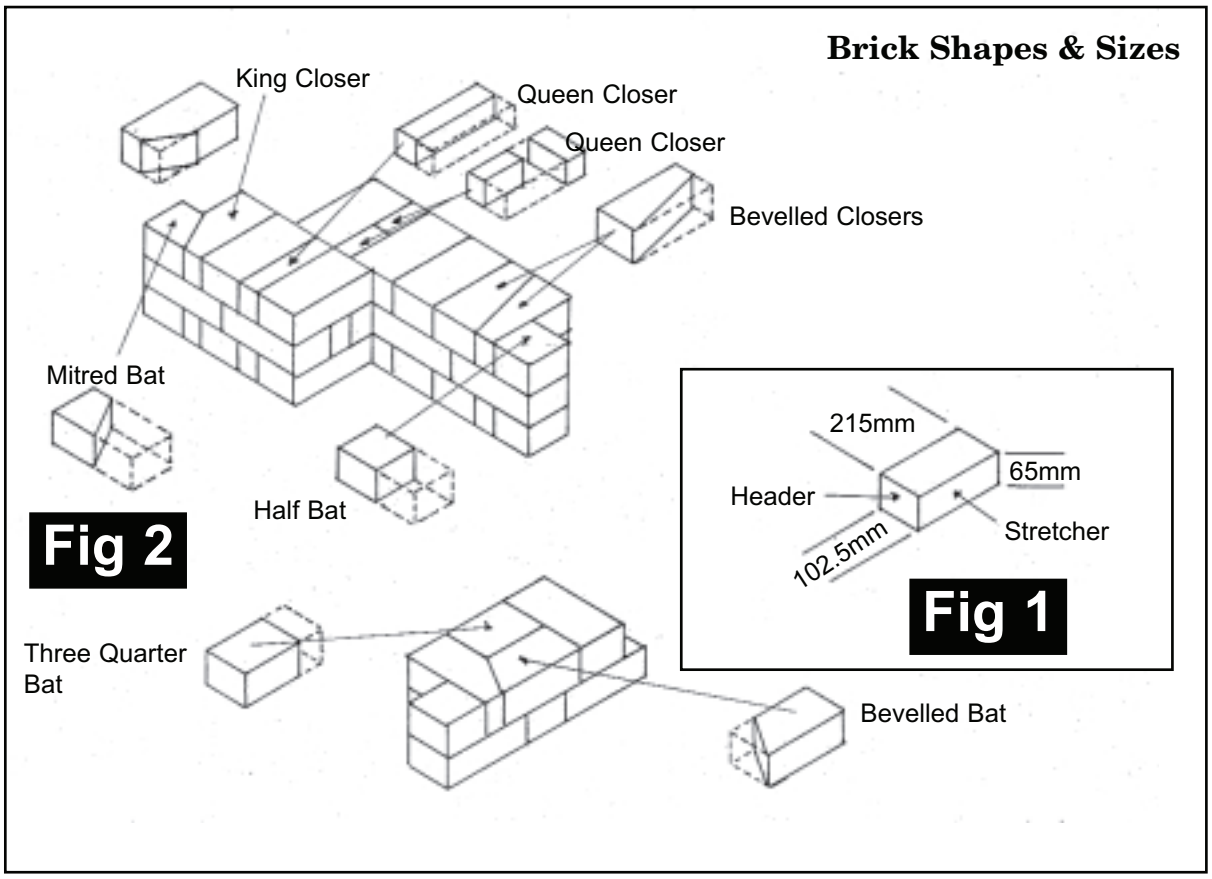
C : L : S = Cement : Lime : Sand.

C : S : P = Cement : Sand : Plasticizer.

BRICKS

Brick Shapes and Sizes

20. The nominal size of a brick is 215mm long, 102.5mm wide, 65mm high, *fig 1 (page 8)*. The average brick can be cut into eight different shapes to suit particular needs. They are as follows:-



A three-quarter bat which has a minimum size of 150mm long by 100mm wide

A half bat which has a minimum size of 100mm square

A queen closer which has a minimum size of 50mm wide by 215mm long. Closers which are 50mm wide by 100mm long

A king closer which has one corner cut off, a bevelled bat, mitred bat, bevelled closer. *See fig. 2*.

CLASSES OF BRICK

Engineering Bricks

21. Stock Bricks are made by machines pressing clay into moulds. Wire-cut bricks are made by machines forcing clay through a die to form an extrusion which is cut into slices (bricks) by a wire.

22. Engineering Class A bricks are impervious to water and are very hard and smooth to the touch. Their compressive strength is greater than 70N/mm^2 and their absorbtivity less than 4.5% by mass. They are

used where high strength, hardness, and moisture - resisting features are needed i.e. bridges, tunnels, retaining walls, damp - proof courses, load bearing piers, footings and manholes. Staffordshire blues are the most frequently used bricks on canals, the usual weight of these bricks is between 3.6 kg to 4.5 kg

23. It is advisable to use a stiff mortar when laying this type of brick as they tend to 'swim' because they do not soak up any moisture from the mortar. Another tip is to cover the face of the brick with oil or diesel before laying to keep the faces free of mortar smears. To assist in laying the bricks they need to be kept off the ground and covered well with tarpauline.

24. Engineering Class B bricks are not as strong as Class A. Their minimum compressive strength is 50N/mm^2 and their absorbtivity less than 7% by mass. They usually have either holes or indentations in the bricks to i.e. make the brick lighter and to form a key for the mortar. A useful tip when using these bricks. If the holes are full of water use cement powder to carefully fill the holes to soak up the water and then you don't get any horrible mortar streaks down the face of the brickwork when you start laying.

Special Bricks

Bullnose

25. These are used where rounded edges are needed i.e. top or bottom gate recesses, quadrants,small arches over bywashes and brick built bridges. In addition to the single and double bullnose there are various special use types as illustrated in *fig 3 (page 8)*.

BRICKLAYING IN COLD WEATHER

26. Brickwork which is damaged by frost is usually attributed to unsuitable mortar, wet bricks or bricklaying in freezing temperatures, it is unwise to lay bricks when the temperature is at or below 3^{o}C. Make sure when laying bricks that the temperature is at least 4^{o}C and rising when laid and afterwards keep the work covered for 48 hours, or longer if it is snowing, to keep it above freezing.

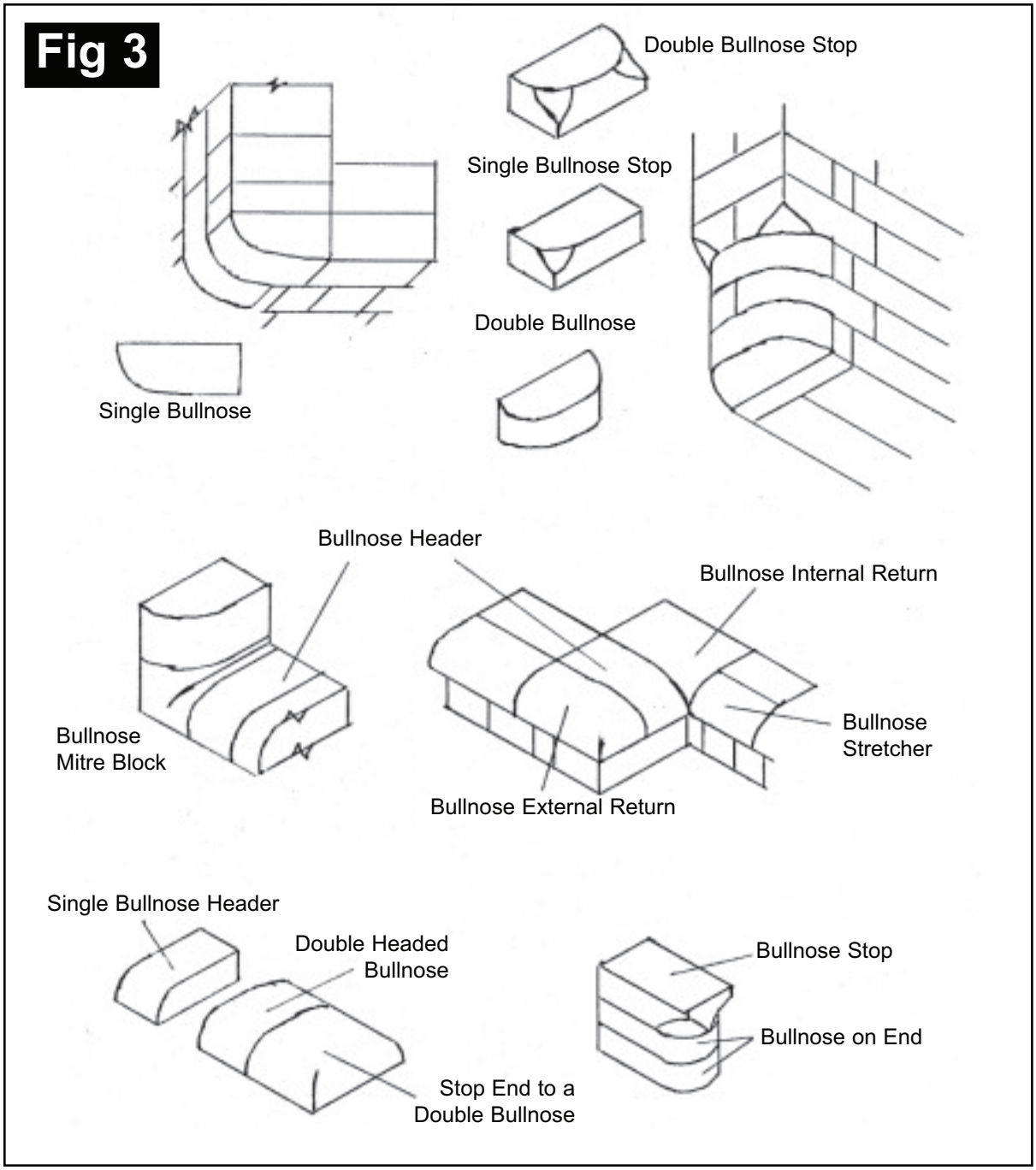
Effects of Frost

27. Water in the mortar expands on freezing disrupting the bond and causes cracks to appear in the joints. Likewise if you use wet bricks the frost can cause the face of the bricks and mortar to flake. The end result is a loss of strength in the wall.

28. Cement sets more slowly in cold weather (roughly half as fast for every 10^{o}C fall). If it rains when the mortar hasn't set, the rain can wash out the mortar from the joints and discolour the rest of the brickwork. All of these eventualities can be overcome by a bit of forethought in using a mortar mix suitable for cold weather and by keeping all materials, working areas and completed work covered up.

Protecting Materials from Frost

29. Bricks should be kept clear of the ground, preferably on wooden pallets and completely covered with tarpaulin. Sand should be covered immediately it is delivered with a tarpaulin. Cement should be stored off the ground preferably in a shed or a container.



Protecting Working Areas from the Weather

30. Working areas can be covered using polythene or clear tarpaulins to protect the bricklayer from the weather and to increase output, this is done by erecting a temporary scaffolding frame around the work area and covering this with the polythene or tarpaulin fixed to the frame.

Protecting New Brickwork

31. Freshly laid brickwork should be thoroughly covered with hessian to protect it from frost first then polythene in case of snow. If new work is to be left for a long period keep it well covered until the weather breaks.

Points to Remember

32. 1. Keep an eye on the weather and listen to weather reports.

2. Use a thermometer placed in the shade to get accurate readings of the daytime temperature.

3. All new work should be covered with hessian and polythene.

4. All materials should be kept covered at all times with tarpaulin.

5. When bricklaying in windy conditions check on the wind chill. This can have disastrous effects on brickwork, with even mortar on the trowel starting to freeze.

TOOLS

Brick Trowel

33. This tool is in constant use by the bricklayer, and varies in size from 225mm to 350mm. For a beginner a small trowel would be more suitable. Its main use is for picking up mortar and spreading it on the wall and on the ends of bricks to form perp joints, (perp = perpendicular) and for trimming the surplus mortar from the joints of previously laid bricks. The trowel can also be used for rough cutting soft bricks where they won't be seen.

34. The trowels can be obtained in both left and right handed versions, the right handed type being the most common. A right handed trowel is identified by the rounded edge of the blade being on the right hand side of the trowel with the handle nearest to you and vice - versa for a left handed trowel. The round edge of the blade is used for cutting bricks and the straight edge is used for trimming the excess mortar from the joints, *fig 4*.

A RIGHT-HANDED BRICK TROWEL

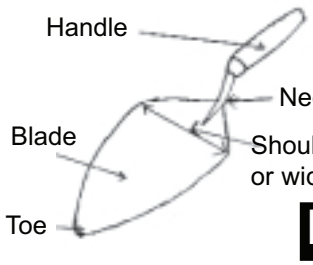


Fig 4

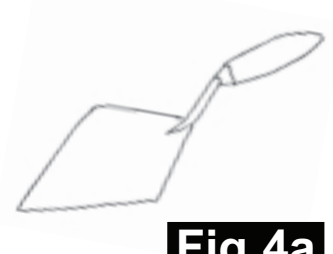


Fig 4a

Pointing Trowel

35. These range in size from 75mm to 150mm, and are the same shape as the brick trowel but without the cutting edge. They are used for pointing and jointing, an ideal size to aqquire would be a trowel size of 100mm, *fig 4a*.

Club Hammer

CLUB HAMMER OR
LUMP HAMMER

Fig 4b

36. Also known as a lump hammer, it can be obtained in various weights from 1kg to 2kg. It is best to buy a fairly light one as a heavier type would be tiring to use. The hammer is used for striking cold chisels and bolsters. The edges of the face should be chamfered, so if you miss the tool you are striking your hand will not be seriously injured. It is essential if you are doing a lot of cutting to wear gloves and eye protection, *fig 4b*.

Bolster

37. Also known as a boaster it is used for cutting bricks accurately and cleanly, it can be found in various sizes from 50mm to 100mm wide and should be made from good quality steel. A100mm wide bolster is a recommended size to purchase, especially when you have a large quantity of half bats to cut as you won't need to keep measuring them, *fig 4c*.

Fig 4c

Plugging Chisel

38. Is a long thin tool of about 240mm long with a flat narrow blade about 120mm long which is ideal for cutting out joints from around bricks when preparing to tie into old brickwork or for just cutting out one brick, *fig 4d*. This tool should also be made from good quality steel. It is best to keep a keen edge on all chisels or bolsters so when cutting bricks you will get a clean cut, and also keep the tops of the chisels and bolsters trimmed to prevent the heads from mushrooming with the danger of bits flying off when struck. For this you will need to use a bench grinder.

Fig 4d

Brick Hammer or Comb Hammer

39. A brick hammer has a square flat face at one end with a long narrow and slightly curved blade at the other end. The narrow blade is used for trimming bricks which have been cut with a hammer and bolster or for cutting bricks which are too hard to cut with the trowel, *fig 4e*.

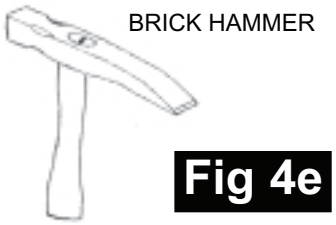


Fig 4e

40. A comb hammer has two identical arms each one having a slot into which can be slotted replaceable blades or combs which are very cheap to purchase. Can be used for the same purpose as the brick hammer with the added benefit of replaceable blades or combs.

Spirit Level

41. These range in size from 600mm up to 1800mm, a useful size to have is 1200mm. The level should have three vials altogether, one for levelling horizontal work, the other two for levelling vertical work. There also levels which have adjustable vials which are very useful for plumbing angled brickwork or plumbing the batter on a lock chamber wall. (A vial is a bubble tube). Modern levels are made from aluminium which makes them light and easy to use, *fig 5 (page 14)*.

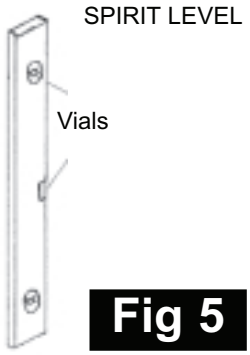


Fig 5

Boat Level

42. Also known as a torpedo level, they are usually 225mm in length with one vial for vertical and one for horizontal work. They can be made from wood, plastic or aluminium and are used for levelling one brick at a time, *fig 5a*.

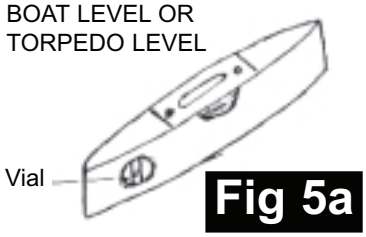


Fig 5a

Line, Pins & Tingle Plate

BUILDERS LINE & PINS

Fig 5b

43. The line you should use must be strong and elastic, and roughly 36m in length or longer. Do not use the bright orange nylon string as it has no give in it.

44. The pins should be made from hardened steel so they won't bend the first time you knock them into the wall, *fig 5b*.

TINGLE PLATE

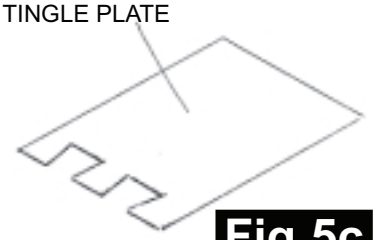


Fig 5c

45. A tingle plate is a flat piece of metal, 50mm by 100mm with two slots cut out of it on the short side so you can slide the line onto it. The idea is to set your line up at each end of the wall you are going to build. If you find after pulling the line as tight as you can it dips in the middle lay a level brick roughly in the centre of the wall, slide the tingle plate onto the line and rest the tingle on the brick weighted down with a loose brick and there you have one level line, *fig 5c*.

Tape Measure

46. Its best to have two tapes one about 3.5m long for measuring short distances and another tape about 30m long for all those extra long dimensions. Keep the tapes clean and workable by carrying a small oily rag and just run it up and down the tape now and again to keep them free from rust. Avoid dropping the steel tapes in water or mud as this will bring on rust with a vengeance and the tapes will be no good. You can buy long tapes of reinforced plastic or fabric.

Jointers

JOINTER OR RUBBING IN IRON

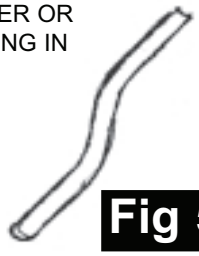


Fig 5d

47. Also known as a rubbing in iron, these can either be brought ready made or you can use an old bucket handle from a metal bucket or a length of rubber hose. They make a smooth inverted joint, *fig 5d*.

Bat & Closer Gauge

BAT & CLOSER GAUGE

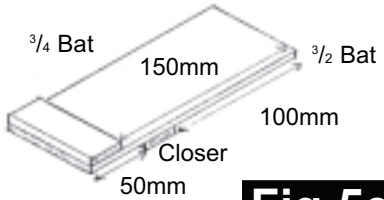


Fig 5e

48. To save time measuring closer's, half bats and three quarter bats this gauge is ideal To make the gauge all you need is a piece of hardwood i.e. oak, about 180mm long by 65mm wide by 10 or 15mm thick, two smaller strips of wood about 30mm by 65mm by 10 or 15mm and some panel pins. Now mark on one side of the piece of wood 100mm from one end this is for the half bat, then fix one small strip the other side of the mark that will be one side done giving you a gauge for a closer and a half bat. Next you fix the last strip of wood to the underside of the gauge at one end this is for the three - quarter cut thus making yourself a useful tool. The measurements used in making the gauge are the minimum sizes for the cuts, *fig 5e*

SMALL HAWK

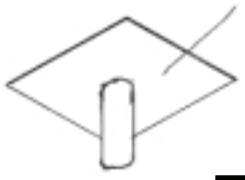


Fig 5f

Small Hawk

49. These are readily available from most tool shops and are made of plastic, but they are easy to make; all you need is a piece of ply

150mm by 150mm by 10mm and a small length of broom handle about 150mm long by 25mm diameter nailed to it centrally.

50. The hawk is generally used for repointing, by placing a small amount of mortar onto the hawk and using a pointing trowel you can guide small amounts of mortar into the empty brickwork joints, *fig 5f*.

Brush

51. It can be a hand brush or a broom head with medium to soft bristles. Never use a brush with stiff nylon bristles. The purpose of the brush is to brush the finished brickwork down after jointing, to remove any loose mortar from the face of the brickwork. It can also be used for clearing loose material off existing brickwork when preparing the surface for laying.

52. It is a good idea to keep all your tools clean and serviceable, this way they last a long time. Articles needed for this purpose are an oily rag, small piece of soft brick, wire brush and some brick acid better known as masonrycleaner. The oily rag is used for cleaning your tapes and keeping your trowel free from rust when not in use. The piece of soft brick is used when cleaning your trowel after use, wet the brick and rub it all over the blade of the trowel then wash it off with water. The wire brush is used to keep your level clean, and is used in conjunction with the acid to keep all your metallic tools clean if they become heavily deposited with mortar. ALWAYS USE GLOVES AND EYE PROTECTION WHEN USING ANY KIND OF ACID.

POINTING

Preparation

53. First remove any vegetation off the face of the wall and from the joints, then the old mortar must be chiseled out by using either a plugging chisel and club hammer or a mini angle-grinder to a depth of at least 13mm.

54. The next stage is to wash the wall down using a pressure - washer, making sure all the soil, loose mortar etc. is washed away, (always wear goggles and waterproof gear when using a pressure - washer).

55. After pressure-washing, the wall should be left to dry out for at least 24 hours before repointing. Then the wall will need to be moistened with water to prevent moisture being drawn from the mortar, so that the wall is damp but not saturated, this will ensure good adhesion.

56. The mortar mix should ideally be 1 : 3 and fairly stiff so it doesn't slip off the trowel, tools needed for pointing are a pointing trowel and a hawk.

TYPES OF JOINTS

Weather Struck Joint

57. This type of joint is suitable where the edges of the bricks have become un-even due to weathering. The actual joint is formed by filling the empty perp joints first then the bed joints with mortar (perp = perpendicular), then place the pointing trowel on the perp joint slightly angling it and draw the trowel downwards producing a smooth surface. After all the perp joints are finished. The bed joints can be filled,

place the trowel on the bed joint with a slight angle, and then press hard on the joint while moving the trowel along the bed joint to produce a smooth angled finish, see *fig 6a*.

Weather Struck and Cut Pointing

58. This type of joint is similar to the weather struck joint, but the perp joints are neatly trimmed using a pointing trowel and the bed joints are trimmed using either a pointing trowel or a Frenchman, see *fig 6b*.

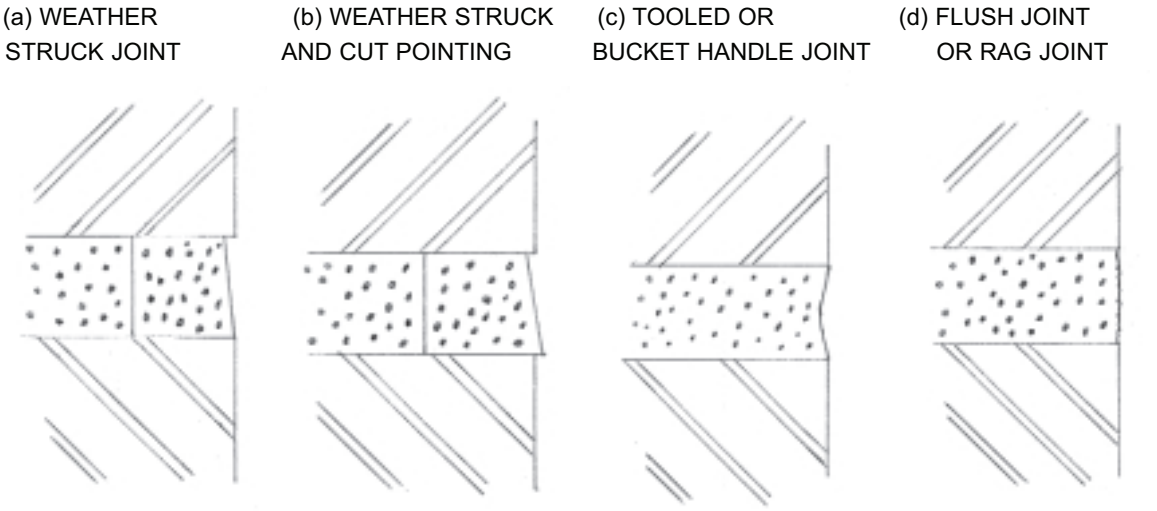


Fig 6

59. A Frenchman is a home made tool, all you need is an old table knife, cut the end to form a point and sharpen it, then heat the point and bend it 90^{o}, this should be used with a straight edge or a level, see *fig 6e*.

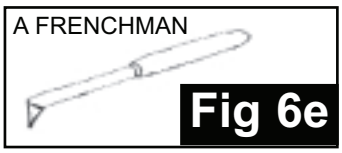


Fig 6e

Tooled or Bucket Handle Joint

60. This is the most widely used joint finish used today, and is quick and easy to do. Whenever donning up (slang term for jointing up) never press too hard as this will make the joint too deep, a nice shallow joint will be sufficient. The tool you use to make this joint can be anything tubular i.e. a rubber hose, an old type bucket handle or a piece of 10 or 12mm copper tube or a purpose made tool can be purchased to achieve this finish *fig 6c*.

Flush or Rag Joint

61. This type of joint should only be used above water level - the joint has not been sealed as in other joint types. The joint has a rough appearance and is made by rubbing a piece of rag or hessian along the joint, see *fig 6d (page 19).*

THE BONDING OF BRICKS

Bond

62. This is the sequence headers or stretchers in a wall to give a necessary pattern while retaining a satisfactory over lap.

Purposes of Bond

63. 1. To provide adequate strength and to guarantee that any load bearing on the wall is spread over the entire length and thickness of the wall.

2. To safeguard lateral stability and resist side thrust.

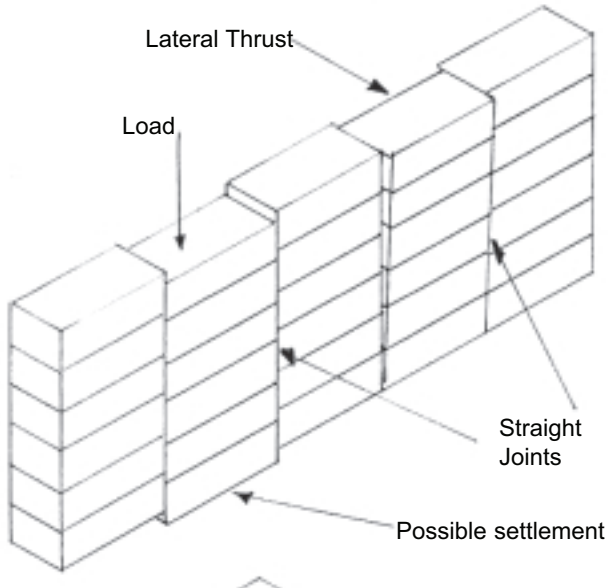
3. To give a pleasing effect to the overall presentation of the wall.

64. An unbonded wall is comparatively weak and liable to fail under a load or lateral thrust imposed upon it see *fig 7*. When the wall is bonded any load which is carried is distributed over the whole wall and there is greater resistance to side thrust, see *fig 7a*.

Rules of Bonding

65. 1. When setting out a wall it doesn't make any difference what thickness of the wall is so long as you make sure there are no straight joints internallyor externally, see *figs 8 and 9 (page 22)*. If you are using reclaimed imperial bricks for patchwork or continuing an existing wall, all you do is follow the bond that is already there. When using old bricks you will have to sort them out into different

Fig 7



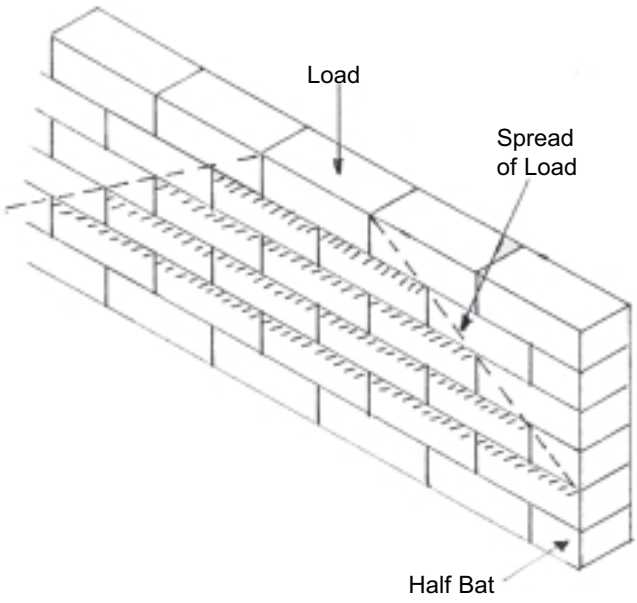
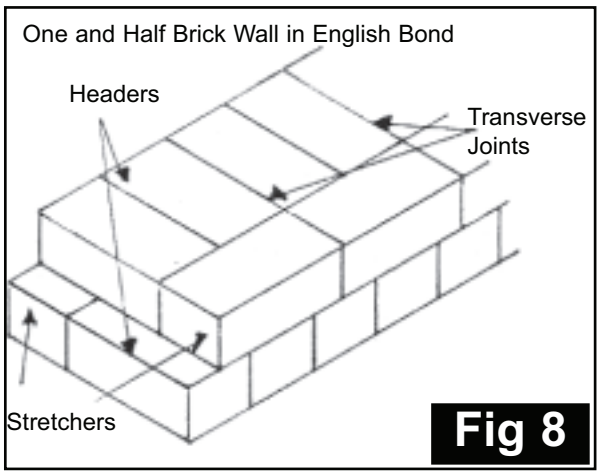
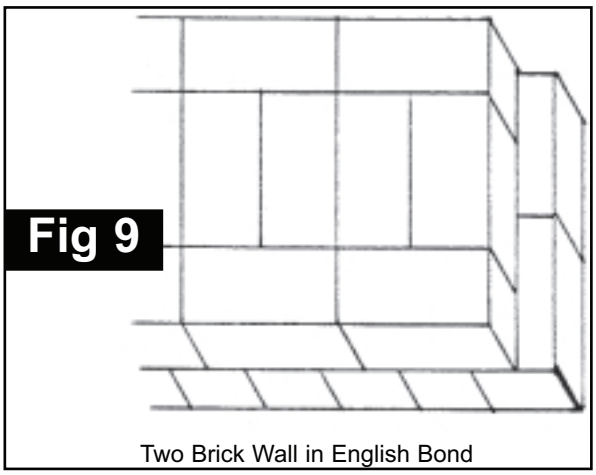
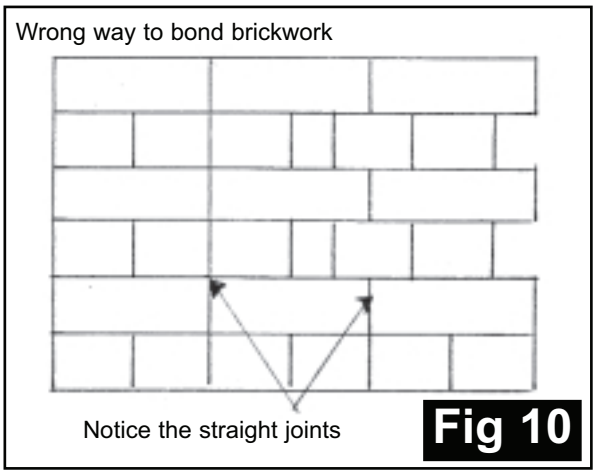


Fig 7a



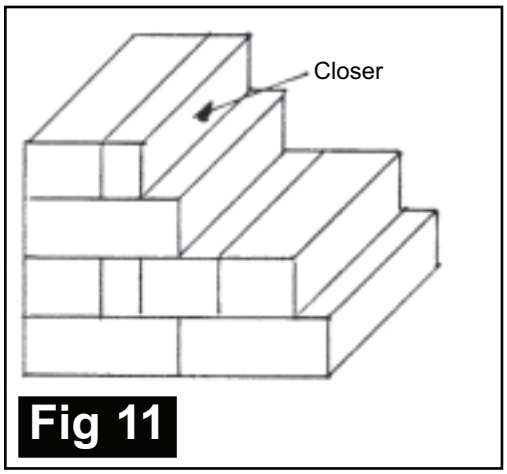


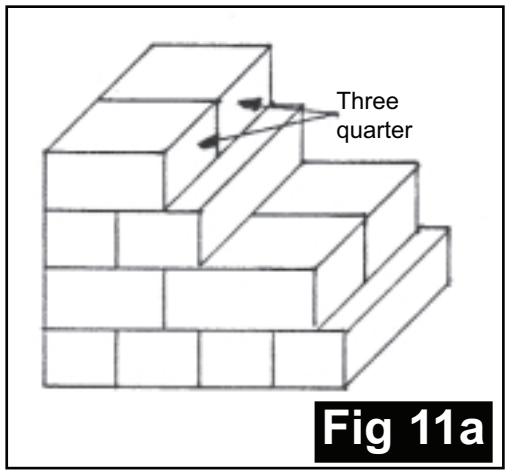
stacks i.e. large, small, headers, stretchers and badly chipped ones which can always be used in the back of the wall. Always remember when laying old bricks keep the joints tight,because otherwise you will end up with straight joints, see *fig 10*.



2. If for some reason you have to introduce a cut into the wall, (this applies when using new bricks as well as old) use either a half bat or one or two three quarter bats or a combination of the two, but NEVER EVER USE A CUT SMALLER THAN A HEADER IN THE MIDDLE OF A WALL, see *fig 10*, the only places where you would use a smaller cut is (i) at the ends of a wall where a closer is used next to a header to start the bond as in the case of English bond (see *fig. 11*) and (ii) where you have a ladder recess,or a ground paddle access hole where the bond also needs a closer next to the end header to maintain the bond or alternativly a three - quarter bat can be used on the stretcher course to start the bond see fig *11a*.

3. New bricks are slightly more difficult to use for patchwork as the two types of bricks are different sizes, the best way is not to use them at all for patchwork.





4. When using new bricks on an existing wall there is no way you will keep up with the existing bond, because all you will end up with is wide perp joints or several cuts in the wall which look very unsightly. The ideal way is to ignore what is below and start afresh, except where you are joining onto an existing wall, i.e. maintain the individual courses of headers and stretchers.

5. When setting out in English bond on a new wall i.e. a chamber wall with new bricks and a new concrete base or building off an existing wall you need to dry bond the first course, ideally using the header side of the brick to the front and spacing the bricks 10mm apart using a finger as a measure and also remembering to use a closer at the end of the wall to form the quarter bond, and also where a wall changes direction ie a ladder recess.

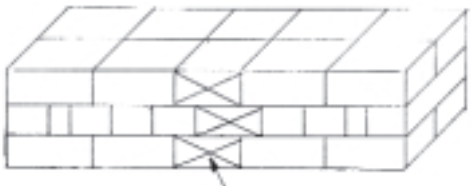


Fig 12

6. If the wall is such a length that a cut must be introduced, the cut must be placed in the middle of the wall this is known as broken bond, see *fig 12*.

7. When building a wall where part of the wall has to be left down, raking back is acceptable. (Raking back brickwork is when each subsequent course laid is a quarter brick or a three - quarter brick spaced back from the last course laid i.e. they form a step), see *fig 13 (page 24)*.

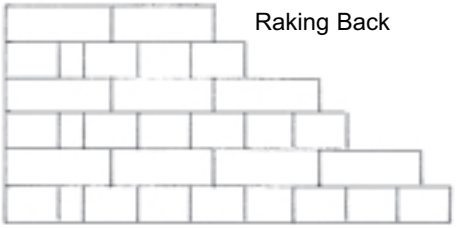


Fig 13

8. In the same situation as in "7" toothing is unacceptable, (toothing as the name suggests is when every other course is laid over hanging the last forming what I call a vertical zip joint which can lead to a weak point in the wall), see *fig 10 (page 22)*.

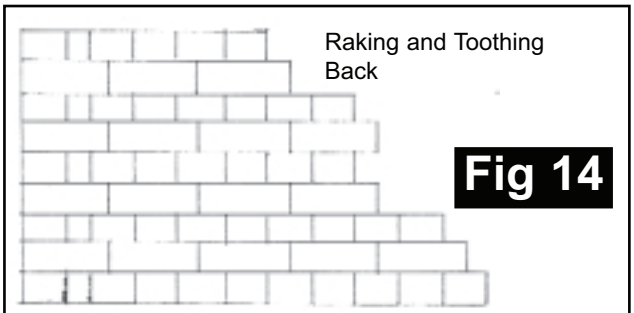


Fig 14

9. If you have the same problem as in "7", but need to leave a smaller gap a combination of raking back and toothing is acceptable, see *fig 14*.

BRICKWORK BONDS

English Bond

66. This bond has headers and stretchers in alternate courses, with a closer placed next to the quoin header to form the quarter lap (quoin = corner), or alternately a three -

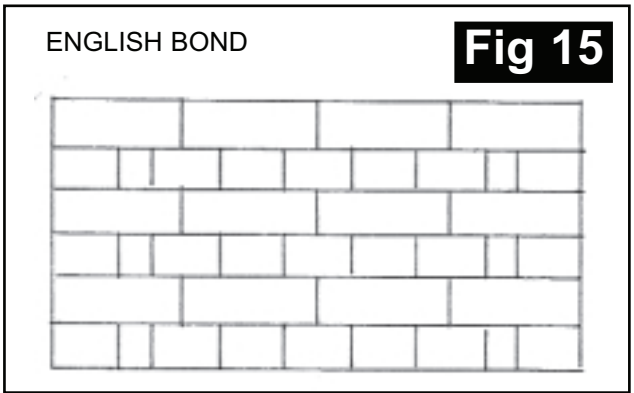
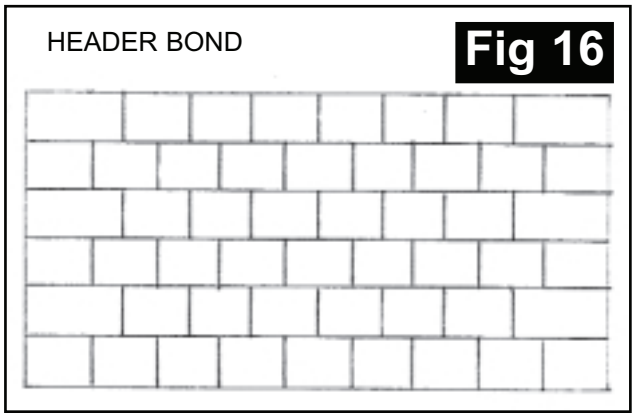


Fig 15

quarter bat can be placed at the quoin but only in the stretcher course. This is a very strong bond, with no straight joints appearing in any part of the wall. The face of the wall being monotonous to look at, it is used in walls where strength is preferable to appearance and always used in conjunction with engineering bricks, *fig 15*.

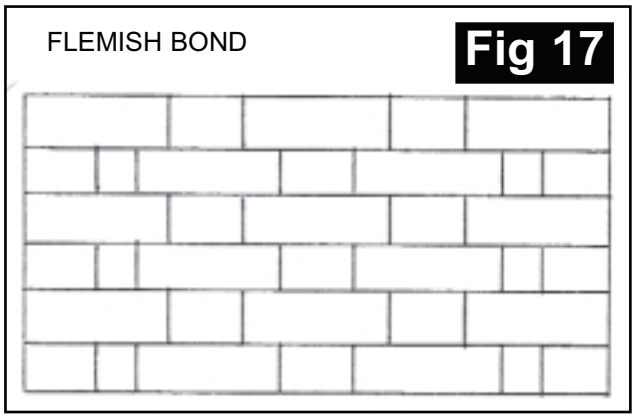


Header Bond

67. This is used in walls curved on plan. It consists of full bricks laid headerwise with a three - quarter bat on alternate courses or if you have a tight curve in a one brick thick wall you can use snapped headers on either side of the wall (snapped = half), *fig 16*.

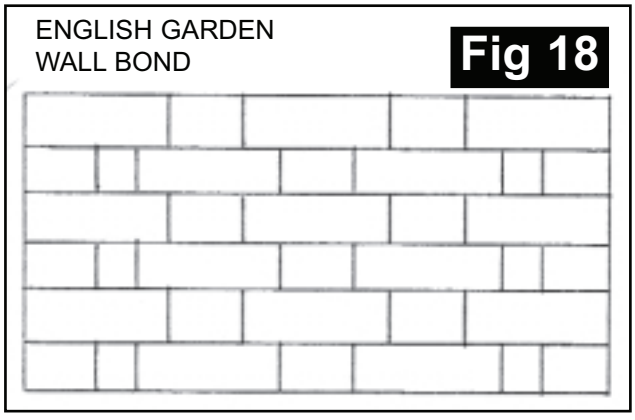
Flemish Bond

68. This consists of alternate headers and stretchers in the same course with the headers in one course being placed centrally over the stretcher in the course below. A closer is placed next to the quoin header to form the quarter brick lap. Flemish bond is used in walls of a decorative nature where strength is not important, as there are internal straight joints of a quarter - brick in length which appear at intervals along the wall, *fig 17*.



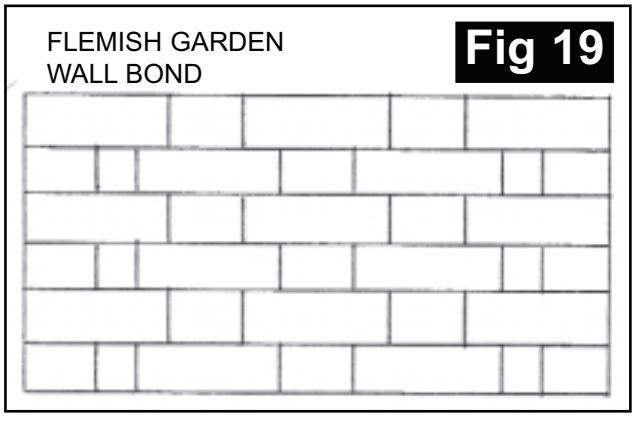
English Garden Wall Bond

69. This bond consists of three or five courses of stretchers to one header course, the stretcher course being laid half bond. It is mainly used as a one brick thick wall where a face side of neat brickwork is needed on both sides of the wall. An internal straight joint occurs throughout the entire length of the wall, *fig 18*.



Flemish Garden Wall Bond

70. This consists of three stretchers to one header in the same course. To maintain the bond, the header in one course must be in the centre of the middle stretcher in the courses above and below. Compared to English garden bond, Flemish garden bond is stronger as the headers are more evenly distributed, *fig 19*.



ARCHES

71. To use an arch to bridge an opening or a canal has a more pleasing effect than a concrete lintel or a concrete culvert. The term arch is taken from the word arc, which means part of the circumference of a circle. Arches have no need for any additional steel reinforcement like concrete lintels or concrete bridges, because the bricks are laid in such a way that with any load placed on the arch the stronger the arch will become.

72. Arches are usually organised into three main groups.

Rough Arches

73. In these arches the joints are wedge shaped not the bricks, these arches do not require such a high standard of finish. There is very little cutting if any, so the majority of canal accommodation bridges are in this group.

Fine Axed Arches

74. The word 'axed' in the above title means the bricks used in these arches are all cut to the same size and shape, and they are carefully worked out on a piece of marine ply which becomes the template for each brick. This type of arch is used in fine work where you can use either the same bricks as used in the normal face work or a brick which has a different colour or texture to make the arch stand out from the rest of the brickwork, *fig 20*.

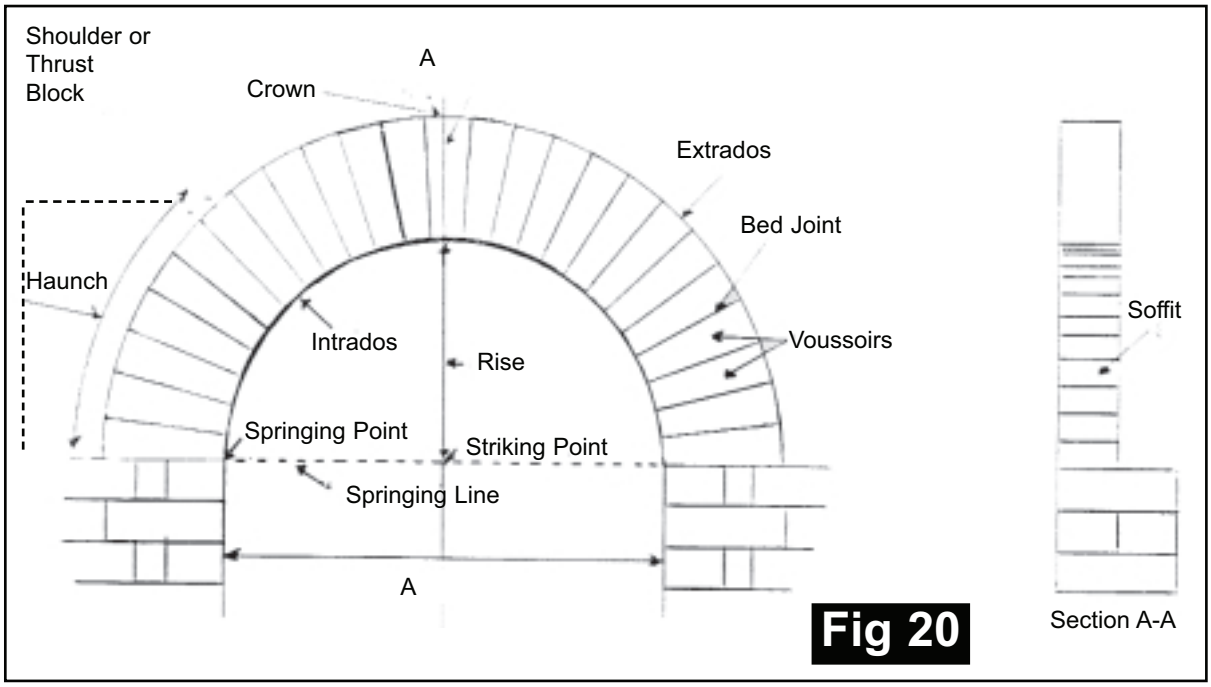


Fig 20

Gauged Arches

75. These arches are very fine and expensive so you won't find them on any canals, as the bricks need a lot of cutting and shaping. They are bedded using a very fine white powder mixed with cement, so the size of the joint will only be about 3 or 4mm.

Arch Terms

76. The following are the most frequently used terms in connection with building arches, see *fig 20*.

VOUSSOIRS are the bricks used in the arch.

SPAN is the distance between the two sides of the opening.

SOFFIT is the underside of the arch, see *fig 20* section A - A.

SPRINGING POINTS are the two lower points where the arch begins.

SPRINGING LINE is the horizontal line drawn through the springing points.

STRIKING POINT is the centre point of all arches, from which all voussoirs diverge from.

RISE is the distance between the springing line and the highest point of the soffit.

KEY BRICK is the last brick to be placed in the centre of the arch.

CROWN is the highest point of an arch where the key brick is placed.

INTRADOS is the underside edge of an arch when viewed in elevation.
The voussoirs for a rough arch are usually set out on the intrados.

EXTRADOS is the outer edge of the arch as viewed in elevation.
The voussoirs for fine axed and gauged arches are set out on the extrados.

HAUNCH is a name given to the part of the arch from the springing line to halfway to the crown.

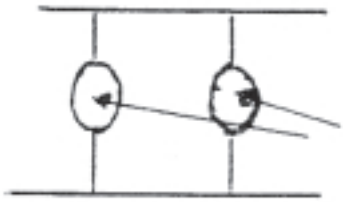
THE SHOULDER OR THRUST BLOCK is behind the haunch and is normally of brickwork or mortared random rubble.

BED JOINTS are the joints between the voussoirs.

JOGGLE JOINTS : in a few cases when cutting arches, after the voussoirs have been cut to shape, a deep groove is cut into all the bricks on both sides of the bed joint, *fig 22*, if they are soft bricks then you can use a coarse half round file. If you are using hard bricks then a comb hammer can be used. When all the voussoirs have been laid in the arch the joggle joint can be filled with a strong (1:1) cement /sand mix, *fig 23*.

JOGGLE JOINT FORMED IN A SOFT BRICK WITH A RASP

Fig 22



Joggle Joints filled with cement grout

PLAN

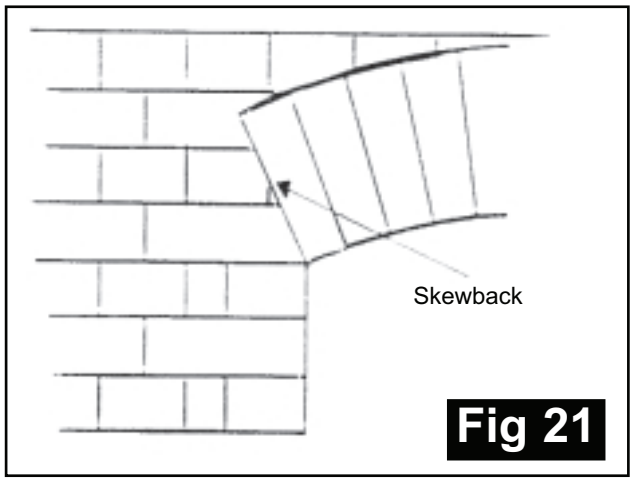
Fig 23

FACE JOINTS are the cross joints in bonded arches.

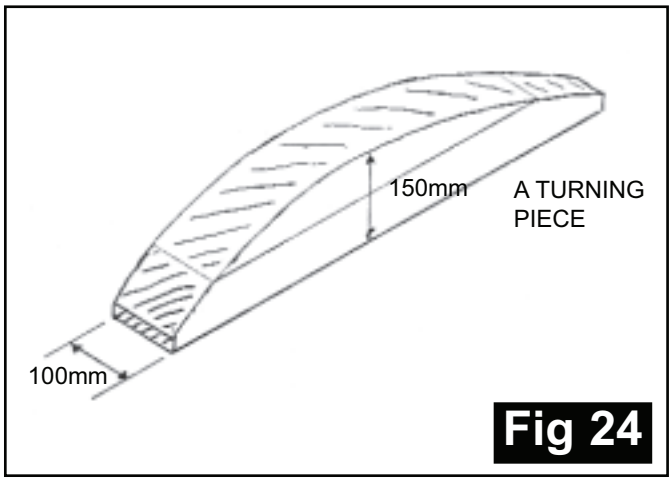
SKEWBACK is the sloping abutment from which an arch springs, *fig 21*.

How to Support Arches

77. 1. A turning piece is cut from two pieces of wood into the shape of the arch, this type of support is normally only used for segmental arches which only have a small span and rise, *fig 24*.

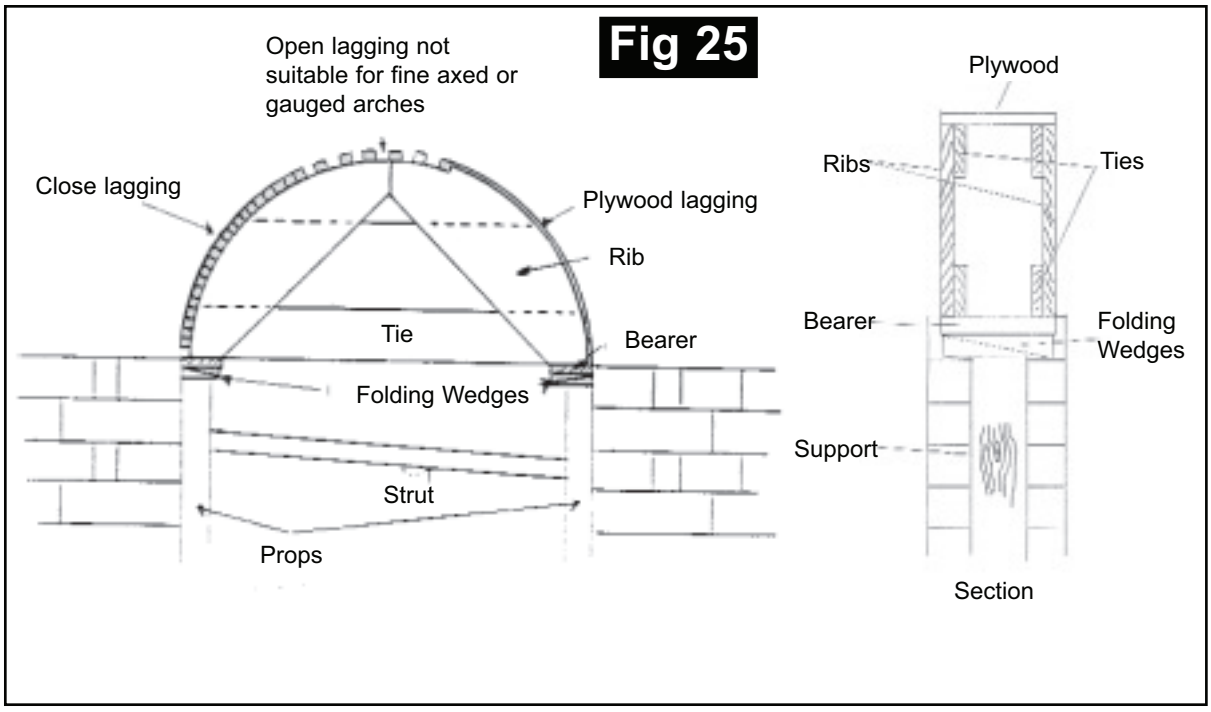


2. An arch centre or former is used in much the same way as the turning piece as a temporary support to carry the arch while it is being built. It can either have small - section timber members cut to the required shape close together or open, or when building an arch for a bridge you would use thin ply so you could easily form the curve. The advantage of using arch centres over turning pieces is the centre can be used over longer spans and for higher arches, *fig 25 (page 30)*.



Terms Used in Conjunction with Arch Centres

78. See *fig 25* and section.



RIBS are the semi - circular members which are used to make the shape of the arch.

TIES these are fixed across the lower and upper part of the centre to stop the ribs from spreading.

LAGGINGS are small pieces of wood which are fixed across the ribs to carry the voussoirs, they may be close or open - lagged.
Or alternatively you can use thin plywood of about 3 - 5mm nailed onto the ribs, this will provide a uniform surface to work on.

BEARERS are flat pieces of wood which are fixed underneath the ties to stop the ribs from coming apart.

PROPS are used to support the arch centre in the opening, two are usually required for a small arch.

STRUTS are used to keep the props in an upright position.

FOLDING WEDGES these are placed between the bearers and the props so that you are able to adjust the centre to the required height before starting the arch, and they make it easier to extract the centre after the arch is finished, four are usually required.

COPING STONES

79. Coping stones can vary in size from 300mm square up to 1.8m long by 900mm wide by 450mm thick. The copers (slang term) are usually dressed on two sides top and face side so they should be easily identifiable when they have been taken off the walls.

How to Remove Coping Stones

80. The first advisable thing to do is to erect a scaffold adjacent to where you are going to work i.e. in the lock chamber. You will then need to uncover the rear of the stones, when this has been done you may need a 110v demolition hammer and generator to remove any original early type of concrete holding the stones in place. In some cases the stones may be loose or even in the bottom of the lock chamber, so you might not need any demolition tools apart from a crow bar and a wrecking bar or a putlog.

81. When the stones are fairly loose, use the crow bar and wrecking bar together to get the wrecking bar as far under the stone as possible so at least two persons can prise the stone up so another person can put a half brick beneath it. Then two people can lift the stone towards them or the stone can be levered further. If the stones are to be removed a short distance away it is a good idea to paint some numbers on the undersides of the stones to help identify them at a later date. When removing stones everybody involved has to work as a team to avoid crushed hands or fingers.

How to Replace Coping Stones

82. Once all the brickwork has been completed and the wall has been back filled with concrete the copers can be cleaned down ready for relaying.

83. Start at one end lower the first coper down onto some bricks so you can easily manoeuvre it into position using the wrecking bar or putlog. If you stored the copers a distance away from the wall use some short scaffold tubes under the copers to manoeuvre them into position. When the coper is roughly in position lift the front edge up and place some pieces of broken tiles or similar to form a joint of about 25mm under the coper making sure the coper is level. Now you will have to lift the back of the coper up and place one

or two bricks underneath, depending on the shape of the coper whilst holding a level or a straight edge against the face of the wall so when the face side of the coper touches the level that is it. Now do the same the at the other end of the wall and fix a line between the two copers and start laying the remaining stones from one end to match the line. After all the copers have been replaced, concrete behind them and completely fill the gaps left between and under the stones with lean-mix. This is a fairly dry mix of 1 cement : 6 all-in 20mm Aggregate. Finally face-up the joints around the stones with a stiff 1 cement : 3 sand mortar mix, then using a pointing trowel draw it along the joints leaving a smooth finish**.** Then the area around the stones can be landscaped.

DETERMINING WALLS FOR DEMOLITION

84. If the external face of the wall looks all right this doesn't mean the wall is in a satisfactory condition internally. There could be voids or, in some cases where the half brick face of the wall has been rebuilt at some earlier date and not tied back to the main wall, then it could possibly fall away.

85. To check the wall for possible voids tap the wall with a club hammer to see if there is any sounds of a hollow ring. Other possible signs to look for are cracks either horizontal or vertical, or if you look length ways down the wall and see the wall leaning out from the top or bulging in various places then the wall needs to be demolished; how far depends upon the state of the wall near the bottom. In some cases the lower part of the wall which was protected by either mud or water can sometimes be left as it has been protected against the ravages of the weather.

86. The majority of locks I have worked on, have at one time or another had the front face of the chamber walls replaced with a new skin of brickwork from about lower water level upwards. They are easily identifiably by the different type of brick used compared to the original and the mortar would be harder because it contained cement.

DEMOLISHING WALLS AND CUTTING OUT BRICK TIE-INS

87. First erect scaffolding along the entire length of the wall which is to be demolished, then take off all the coping stones. Proceed to take the wall down to a firm base using demolition hammers. You will need to allow 460mm from the face to the rear of the wall to allow for a new double skin of brickwork measuring 215mm and 245mm of concrete backfill.

88. To tie the new brickwork back to the original brickwork, there are various methods available. The first one being the cheapest is to cut out 225mm square by 225mm deep pockets arranged in a diamond configuration thoughout the entire wall. These pockets would be completely filled with brickwork as and when the new wall reaches them tying the new wall to the old brickwork, then the void behind would be filled with vibrated concrete.

89. Another method is to drill holes into the existing brickwork to accept 10 or 12mm diameter " L" shaped reinforcing rods which you grout into the holes. The grout can be obtained from your local builders merchant in the form of epoxy resin and a dry powder which need to be mixed together thoroughly and used immediately. Then butterfly wall ties are built into the rear of the new wall, and some sheets of reinforcing mesh are placed between the new brickwork and old brickwork. Tie the wall ties to the mesh, and the mesh to the " L " shaped bars using tie wire and fill the void with vibrated concrete.

90. The last method is simply to use wall ties bedded into the rear of the new wall and tied to mesh and back filled with vibrated concrete.

91. The last two methods can only be used when the entire wall is demolished and the new wall is started off on a concrete base where the mesh is placed in the concrete before it sets.

92. When using any of the above mentioned methods it is advisable not to build a void more than six courses high before backfill since it can then be very difficult to clean soil and rubbish from the bottom of the pour. Such rubbish creates a zone of weakness which no amount of alternative reinforcement can compensate.

SETTING UP AND FIXING PROFILE BOARDS

93. Profile boards are used where there is a long stretch of wall to build i.e. a lock chamber wall. They should be of such a length to accommodate the entire height of the new wall and be straight and true, e.g. a scaffold board. They need to be fixed at the top and bottom, the top should be fixed to a length of timber at right angles to the profile and then this should be fixed to a post firmly knocked into the ground. Then another piece of timber should be fixed to the piece of timber which is at right angles to the profile and be diagonal to it, fixed to another post firmly knocked into the ground.The bottom of the profile should be temporally concreted to the bottom of the lock. The batter or backward slope on the wall is typically 1" in 40" or 25mm in 1015mm. To set the actual profile up, if you have only taken down the top half of the wall simply rest the narrow edge of the board against the wall and fix. If the whole wall has been taken down then you need to mark on your level 1015mm, place this on your profile vertically, adjust the level until it reads vertical and from the mark made on the level measure 25mm between level and profile and adjust profile to suit. It is always best to follow the original batter if possible (unless there is evidence that the wall has moved in the past). The original batter can be retained by erecting profiles before the original wall is demolished.

A GUIDE TO ESTIMATING QUANTITIES

MATERIALS

Bricks

94. Estimating brick quantities for English bond for example, are as follows.

There are 124 bricks to a square metre of English bond one brick thick including 5% for cutting / wastage.

95. So for a one brick thick wall in English bond 18m long by 3.450m high you would need 7,700 bricks.Calculate as follows :-

18m x 3.450m = 62.10 sq. metres x 124 = 7,700.

Mortar

96. On average between one and one and a half cubic metres of mortar are needed to lay two thousand five hundred bricks, depending upon the type of brick to be used e.g. if they are solid or if the bricks have holes which will take up a small percentage of mortar.

97. Calculating the amount of sand, lime and cement for a cubic metre of mortar can only be roughly estimated, as shrinkage occurs when water is added to dry materials.

98. It is widely accepted that one cubic metre of sand will make one cubic metre of mortar as the adding of lime or cement does not make any difference to the mass. So for a 1 : 3 mix you would require one cubic metre of sand, and a third of a cubic metre of cement and / or lime. For a mortar mix of 1 : 4 you would require one cubic metre of sand and a quarter of a cubic metre of cement and / or lime.

99. To calculate the actual amount of cement or lime for a 1 : 1 : 4 mix / one cubic metre of mortar, It is widely regarded that cement is equal to 1440kg per cubic metre and lime is equal to 722kg per cubic metre. So the following materials would be needed :-

1.00 cubic metre of sand.
0.25 x 1440kg of cement = 360kg
0.25 x 722kg of lime = 180kg.

A SIMPLE GUIDE TO BRICKLAYING

The Basics

100. To keep mortar off your hands it is best to wear a pair of gloves, not a thick pair but a thin pair of rubber gloves - the type you use for washing up.

101. The bricks should be stacked no more than 600mm away from the wall in a two by two stack to provide sufficient working space for the bricklayer. The mortar board (spot board) should be at least 600mm square.

102. The mortar board should be then placed on twelve bricks placed flat, three bricks at each corner so as to provide a convenient level to work off.

103. The mortar should be placed in the centre of the board so you can have plenty of room to pick up the mortar with your trowel. The method of picking up the mortar with your trowel is as follows:-

- Angle the blade so it is vertical then press it firmly down through the side of the mortar pile then draw it towards you moving the trowel in a back and forth direction to the side of the board.

- Then place the trowel flat on one side of the portion and with a quick movement slide the trowel under the mortar and pick it up. You must have enough mortar on the trowel to lay two bricks, if not it will take a long time to lay just a few bricks.

- To lay the mortar from the trowel to the wall, first position the trowel over where you want to put the mortar then with a quick flick of the wrist and a backward movement the mortar should land on

the wall, spread the mortar by using the point of the trowel and drag it along the wall forming a ‘ V ‘ groove in the mortar.

♦ Cut off any surplus mortar overhanging the edge of the wall with the straight edge of the trowel angled away from the wall so as not to smear the face of the other previously layed bricks, this mortar can either be used to form a perp joint on the bricks or can be discarded back to the mortar board.

HOW TO LAY A STRETCHER

104. Pick up a brick holding it in your left or right hand with your thumb on the stretcher face and your four fingers on the rear of the brick. Lay the brick on the mortar bed gently pushing the brick back and forth or if the mortar is fairly stiff tap the top of the brick with the blade of the trowel.

105. If you have a line set up you just push the brick down until it is level with the top of the line and parallel with the line. If you are laying free hand push the brick down and use a steel tape measure and check from the top of the brick to the underside of the joint that you have 75mm, the correct height for a metric brick.

106. When the brick is in position cut the surplus mortar from the bed joint and either wipe it onto the brick you have just laid or wipe it onto the end of the next brick you will lay, pick up the next brick and position it next to the previously layed brick pushing back and forth so as to squeeze the mortar in the perp joint to a uniform 10mm.

HOW TO LAY A HEADER

107. You will need to put mortar on the full thickness of the wall, then take hold of the brick with your hand with your thumb on one stretcher face and your four fingers on the other stretcher face. Lay the brick on the mortar bed with the header face towards the face of the wall. Push down on the brick with your hand and as mentioned before either use a tape measure to check the height of the brick or if you are using a line align the top of the brick with the top of the line and keep it parallel with the line. Take hold of the next brick with your hand as described above, holding the brick with your thumb nearest to you. Using the trowel in your other hand pick up some mortar with it and either wipe the mortar onto the side of the brick you have just laid, or wipe it onto the side of the brick in your hand either side of your thumb. Then place the brick next to the first brick and gently but firmly press the brick up against it and tap into position remembering to keep it parallel with the line and flush with the top of the line.

108. When building a wall in any bond you must always keep the vertical joints of the various alternate courses in line. If for some reason after you have laid a course of bricks some are dipping on the front edge just tap the back edge of the brick with your trowel so the front face of the brick is flush with the rest of the wall.