CHAPTER 7

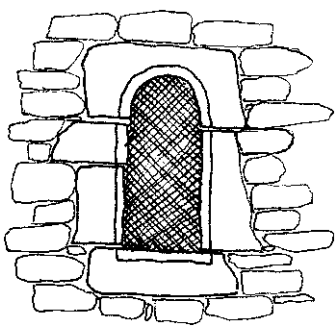
ARCHES

Romanesque

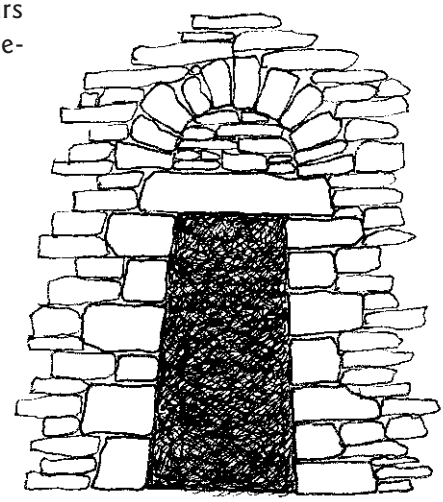
The first arches to appear in Ireland were not true arches but arch shapes cut in solid stone lintels. Appearing first somewhere between the seventh and tenth centuries in small Early Christian churches, they were simple, un-ornamented and Romanesque in style, being semi-circular. Arch shapes like these, cut in solid stone, persisted long afterwards and can be seen on castles built much later.

True arches made up of individual stones (called voussoirs) were seen first in the Early Christian period as relieving arches over stone lintels.

The first true ornamented arches in Romanesque style appeared in Ireland in the twelfth century. A short wonderfully inventive period followed when Romanesque architecture took on a distinctive Irish style. Within this style arches were semi-circular and the voussoirs cut from the softer stone varieties such as sandstone.



Early Christian (medieval).



Early Christian relieving arch.

The semi-circular arch was also used in vaulting of this period. By its nature the semi-circular arch causes horizontal thrust near its springing point. To resist this thrust, walls were built quite thick with only small window and door openings.

Gothic

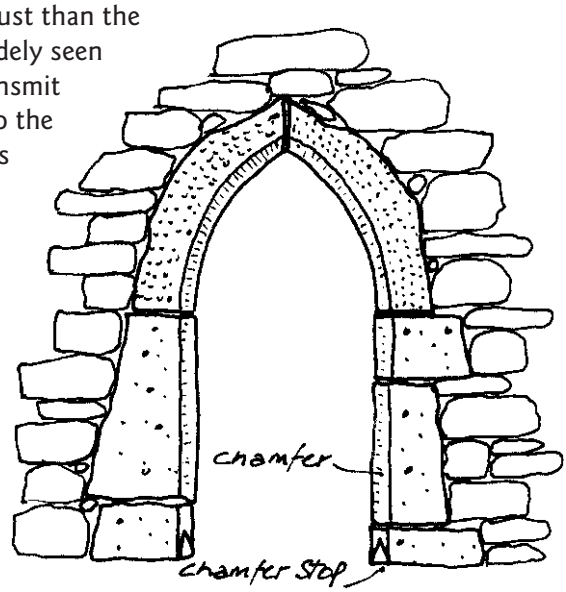
By the end of the twelfth century Gothic influence had arrived and with it the pointed Gothic arch. These are still to be seen throughout Ireland on castles and monasteries, over doors and windows not built with multiple voussoirs but often as two single stones cut to a Gothic curve and meeting at the centre top in a point. The extrados, or outer edge of these arches, was invariably 'softened' or unworked, a feature also seen on quoins and door and window jambs where no unnecessary work was done.

Chamfers were common on the intrados to prevent accidental damage to the arris and also as a simple decorative device, sometimes finishing in a carved chamfer stop at the bottom of the jamb, which allows them to be dated.

Over the top of the extrados a projecting hood was sometimes used to provide shelter and decoration. These ended in a variety of styles called hood stops or label stops, some of which were carved.

The Gothic arch has less thrust than the semi-circular form and is widely seen in vaulting, using ribs to transmit weight to walls or directly to the ground, thereby freeing walls to be opened up as windows allowing light in.

Primitive vaulting from the fourteenth to the sixteenth centuries on castles in Ireland often shows the remains of wickerwork mats still underneath. These were obviously used as part of the centering or support system while the vault was being built. The mats could be laid over



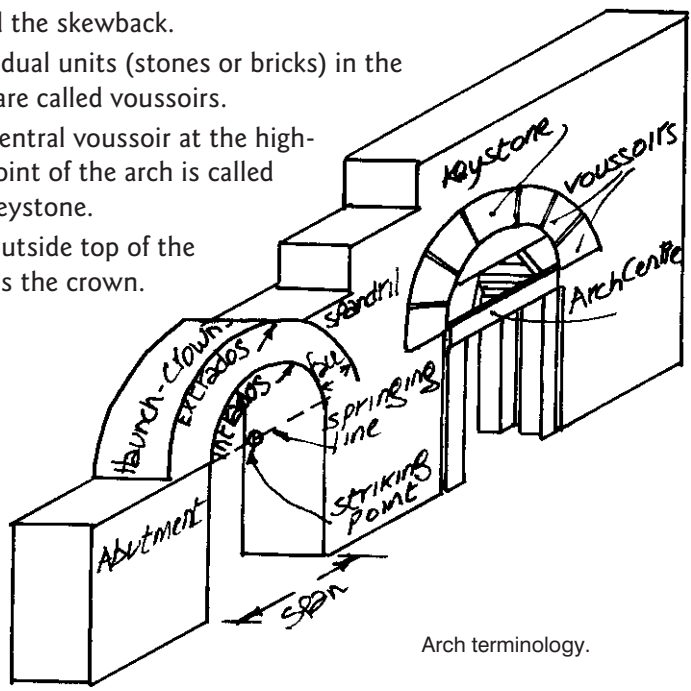
Gothic arch (medieval).

timber formwork only partly planked, as the mats were quite strong over short spans. Alternatively, solid centering built from stone, mortar and earth could be used. Mats would be placed over this to form the curve on which to build the vault.

ARCHES – SETTING OUT

The following points are general to all arches:

- All arches, except the true ellipse (which cannot be drawn with a compass), radiate from a centre point or points. These centre points vary from one to four depending on the style of the arch. The centre point in arch construction is called the striking-point.
- The base line of an arch, or the point from which an arch is built, is called the springing-line.
- The distance from the springing-point to the highest point on the underside of the arch is called the rise.
- The horizontal distance between springing-points is the span.
- The sloped sides of the wall, cut and radiated to the striking-point of some arches, act as an abutment and are called the skewback.
- Individual units (stones or bricks) in the arch are called voussoirs.
- The central voussoir at the highest point of the arch is called the keystone.
- The outside top of the arch is the crown.



Arch terminology.

- The outside bottom sides are called the haunches.
- The bottom or internal curved face arris is called the intrados.
- The top or external curved face arris is called the extrados.
- The face of an arch is the vertical part seen, which is measured between the intrados and extrados arrises or lines; these are not always parallel so the face width can vary.
- The solid work between two arches is called the spandril.
- The solid work on either side of an individual arch is called an abutment.
- The arch support used for the construction of the arch is called the arch centre.

Semi-circular arches

Semi-circular arches are seen in a whole variety of places, from rough relieving arches reducing the weight on stone and timber lintels underneath, to ashlar cut work, carved and decorated.

The semi-circular arch considered here is of the simple, cut, undecorated type. If a chamfer is required see section on cutting a chamfer in Chapter 6, Stonecutting.

The work involved from the set-out to the cutting and building is discussed here in detail so that it will not have to be repeated on other arches, which, although different in shape, follow more or less the same approach.

The semi-circular arch is set out from a single centre point at mid-span. The rise is half the span which is equal to the radius.

The voussoirs radiate to the centre point of the arch. When the voussoirs are cut wedge-shaped their sides radiate to the centre point of the arch.

Semi-circular arch in porphyry stone, Lambay Island, Dublin.

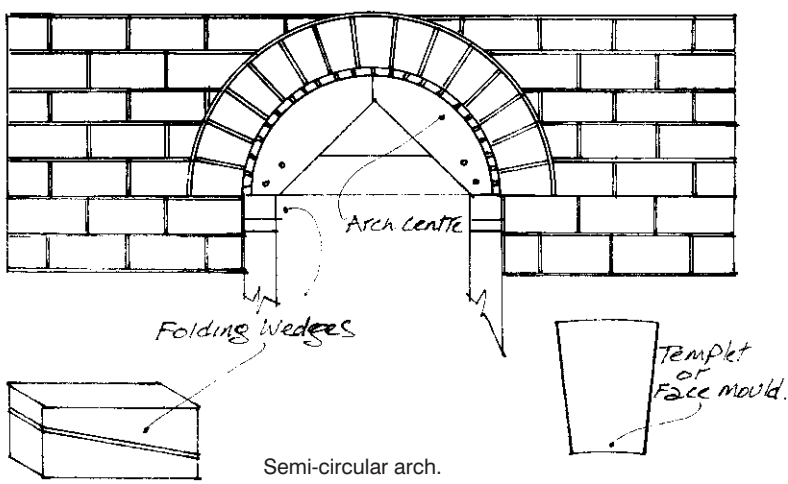
The following is the procedure required to set out, cut and build a semi-circular arch.

1. Given the span and the face height of the voussoirs, set out the arch full-scale on a flat sheet of wood or on a timber floor or similar surface. This is best accomplished with a trammel, which can be as simple as a wooden lath with a nail fixed through to the wooden floor. From this point, measure the rise to give the intrados, and the face height to give the extrados. Radiate the trammel with a pencil held at these points to give two concentric semi-circles.
2. The arch is now divided into the required number of voussoirs. An uneven number will result in a central one at the point of the arch acting as a keystone.

   We will assume the arch has fifteen voussoirs which includes the keystone, a span of 2 metres, and a face width from intrados to extrados of 400mm. The diameter of the arch to the extrados line is 2 metres + 2 x 400mm = 2.8 metres. The joint width between voussoirs is 6mm.

   In practice, a pair of dividers is used to walk the extrados curve until it takes fifteen steps to travel from the springing point on one side of the arch to 6mm short of the springing line on the other. This takes less time than one might think.

   The reason for measuring or stepping out voussoirs on the



Semi-circular arch.

extrados rather than the intrados curve is that the greatest width of stone is here and this will, therefore, determine availability, ordering and so on.

3. Draw a perpendicular from the striking-point to the centre top of the arch. Set out the keystone, centred on this line.
4. Step out and mark the seven voussoirs on the extrados curve each side of the keystone.
5. Mark out the joint width, ie, 6mm; there should be sixteen joints.
6. Draw the fifteen voussoirs and their sixteen joints from the extrados towards the striking point, finishing on the intrados.
7. Make a templet in stiff plastic the same size and shape as one of the voussoirs (minus the joint). The same templet is used to mark all the voussoirs in the arch.
8. This templet is now used to mark the face shape of the voussoirs which are then pitched and their beds, and tops and bottoms squared off the face, similar to the cutting of a quoin stone.
9. As each voussoir is cut it is stood on the full-scale set-out on the floor and checked.
10. The arch centre is constructed of wood, well-braced and finished with narrow-width wooden laths laid and fixed to the curve with gaps in between. The position of each of the fifteen voussoirs is marked out on the centre (intrados curve), working from the full-scale set-out and using a dividers to ensure the keystone is exactly central.

    The centre is fixed in position on top of wooden supports with folding wedges underneath to make removal of the centre easy.

    The centre is levelled along its base and plumbed on its face. It is critical that the centre does not move as the arch is being built. Unless fixed securely centres have a tendency to go off plumb, bringing the voussoirs with them.
11. The building of the arch is commenced at both springing-points, laying each voussoir to the marked wooden centre.

    A string line or trammel is radiated from the striking-point of the arch to check that each voussoir is radiated correctly

towards the striking-point.

A second line is used along the face of the wall to check that the arch is being built plumb, in line with the wall.

12. The last stone laid is the keystone (in vaulting, the 'boss'). It is important when laying voussoirs that mortar beds are spread in advance of laying, and not inserted afterwards when they will most likely fall out at a later date. In the case of the keystone the two adjoining voussoirs should be buttered with mortar, then the voussoir mortared on both its beds, so that when inserted it will squeeze into position tightly, compressing the mortar.

13. The wall either side and over the crown of the arch is built at the same time as the arch or at a later stage, depending on the size, stability and safety of the arch itself.

The cuts along the extrados line must be accurate and run with the curve. When cutting machinery is used for this purpose it is often noticeable how straight the cuts are, acting as tangents and not running with the curve of the extrados.

Assuming a joint size of 6mm there is little tolerance for error as the eye will notice the smallest deviation.

14. The timber arch centre is dropped by removal of the folding wedges. This should be done when the mortar has set quite hard, but at times is done fairly quickly on smaller arches so as to clean and point the underside of the arch. The centre to a semi-circular or Gothic arch can usually be dropped earlier than that of most segmental or semi-elliptical arches.

15. All voussoirs in the example given were the same size and shape, but often the keystone is larger and may project on the face, top and sides and be carved or lettered. This presents no problem except that the timber arch centre must be constructed with an allowance on top to take the dropped keystone.

Segmental arches

A segmental arch is less than a semi-circle or, in other words, its rise is always less than half its span. A common rise is $^1/_6$ the span, so a span of 4 feet (1200mm) has a rise of 8 inches (200mm).

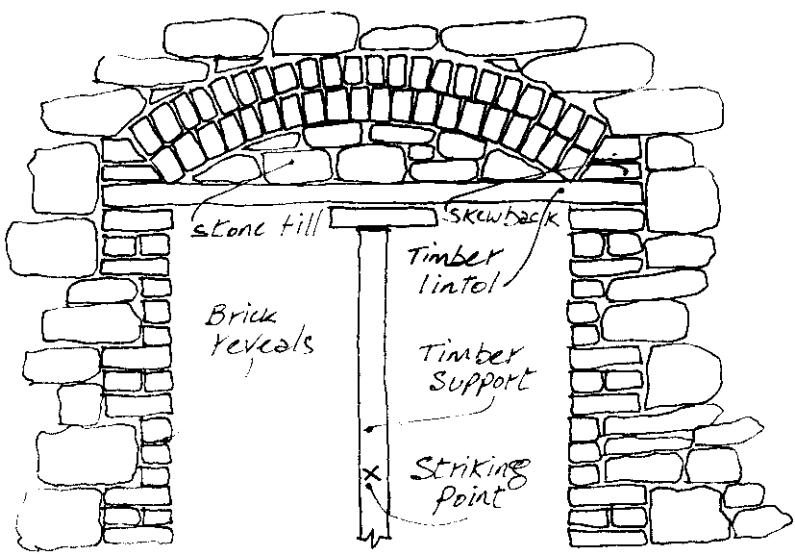
Segmental arches are very common as face or relieving arches. They are probably the most commonly-used relieving arch over window

and door openings, but they are also found in a whole variety of other places as well, including over heavy wooden beams on shop fronts hidden under renders.

The description given previously of the setting out, construction of the arch centre, stonecutting and laying are all applicable to the segmental arch. The only difference is the setting out, cutting and building of the skewback before the first voussoir is laid. This is done full-scale as before, with the arch set out and pre-cut in advance. There should be little difficulty in doing this as the procedure is self-explanatory.

What we will consider here instead is the more commonly found internal, rough, relieving arch in brick over a window, which will be later hidden under plaster.

1. The width of the opening is 4 feet 6 inches (1350mm) and, as in traditional work, a timber lintel or lintels have been placed across the opening on which to build the arch centre in stone/brick. Often these timber lintels are very slight in depth, sometimes only 2inches (50mm), as they have to carry only the small amount of masonry between their top and the underside of the arch. These timbers are sometimes found in a poor state and require replacement. New timbers should be treated before building in.



Segmental relieving arch.

2. The timber lintel/s are bedded into position with lime mortar and propped in the centre to prevent deflection, until the work overhead has hardened or set.
3. The striking-point of the arch will be somewhere down the vertical centre of the opening and should give a rise of about one-sixth of the span, which in this case is 9 inches or 225mm.
   The striking-point for rough, relieving arches is normally found quickly by trial and error. This can be done by trying various points down the vertical prop with a string line, until an arc can be drawn from the two springing-points reaching a point 9 inches above the springing-line. A nail is driven in at this point and the string line attached.
   In better-class work the finding of the exact centre is crucial. Given a span and a rise this can be done by bisecting the line from the springing-point to the top of the rise, and extending the bisector down until it meets the vertical centre line. This will be the striking-point of the arch.
   This is best done full-scale on a floor or sheet of wood.
4. Build the skewback, in this case using brick. This is done by first building then marking out the skewback on the brick, dismantling, cutting and re-building.
5. The centre to support the arch is constructed of brick or small stone, again using the string line to strike the curve.
6. The voussoirs, in this case bricks, are laid across the solid centre starting at each skewback, checking with the string line to their centres that they radiate to the striking-point. The bricks are not cut to shape but, instead, 'V' shaped mortar joints are used. Brick on edge is used in two rings rather than full bricks on end because the overall 'V' size of the joint is reduced.
7. The arch, as it is being built, is lined-in with the rest of the wall, using a second string line.
8. The work over the arch is now completed.
9. When the lime mortar has hardened, the props under the timber lintels can be removed.