Fig. 9.9. Britannic House, Finsbury Circus, London.

which do not carry the weight of the wall. As this is a seven-storey building, the 'regulation thickness' at ground floor level is about one metre. The cost and time involved in the construction of such thick walls led to the abandonment of load bearing walls in multi-storey buildings, and their replacement by infill walls to steel frames. There is, in principle, no reason why the backing could not be blockwork or *in situ* concrete. Blocks were however not available in the heyday of this form of construction, and concrete would have to be cast in shallow pours, a few courses deep at a time. There are therefore few, if any, examples of these alternative backings to stone faced walls.

9.2.1.5. Mortar, its function and influence on masonry properties

Whilst this book is primarily about the use of stone, the mortar affects so many aspects of the performance of masonry, that some discussion here is appropriate. In the dry-jointed masonry, mentioned in §9.2.1.1, each block of stone was cut and dressed to very precise dimensions and then laid directly on the blocks below and against the adjacent block without any intervening layer of mortar. This was a very laborious process, but necessary to ensure stable bedding of the stones, in the absence of mortar.

The technique has another drawback. However meticulous the dressing of the stone, it is often impossible to insert a thin knife blade anywhere in the joints, the stones only bear on each other over a small proportion of the bed joint surface so that the bearing stresses at the contact points are very high indeed. This does not create any problems away from the edges; the lateral components of the stresses, as they spread out from the contact points, cancel out each other; there are no stresses to cause load splitting. If, however, a 'hard' point occurs at the edge of the bedding surface, i.e. at the face of the wall, then the inclination of the stresses, as they converge towards the contact point, produces a horizontal force, which is only resisted by the tensile strength of the stone. If that is overcome, a thin sliver of stone is split off: the face of the stone spalls, see Fig. 9.10.

The introduction of mortar joints overcomes these problems. It eliminates the need to produce very smooth and plane bedding surfaces on the stones and the hardened mortar provides contact, and hence load transfer, over the entire area of the bed joints, with elimination of the high stresses at the contact points. This highlights one of the prime purposes of mortar: to keep the stones apart; **Not**, as is sometimes assumed by engineers, to glue them together. Another purpose of mortar is to seal the joints to keep the weather out of the building. All these benefits are, however, not achieved without some disadvantages. The mortar joints limit the strength of the masonry and ingredients of some mortars may react chemically with the stone.

When a body of any solid material is compressed, it becomes shorter in the direction of the compressing force and slightly wider at right angles to the direction of the force: this is easily demonstrated by squeezing a soft rubber. This deformation is displayed by stones as well as mortar joints but, because most stones are less deformable than the hardened mortars, the joints tend to spread out more than the stones. The tendency of the

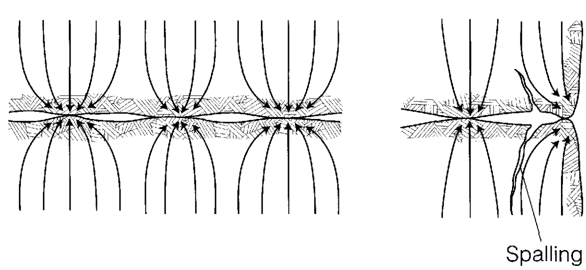

Fig. 9.10. Stress flow in dry-jointed masonry.

Stress, strain and modulus of deformation

The compressive bearing stress on a bed joint is the vertical load on the joint, divided by the area of the joint. This stress is the same for the stone and for the mortar joint.

The compressive strain of a mortar joint is the amount the joint becomes thinner under stress, divided by the original thickness. The compressive strain of a stone is the amount its height reduces under stress, divided by its original (unloaded) height. For the same stress, the compressive strain of the mortar joint is usually greater than that of the stone.

The modulus of deformation is the stress divided by the strain. This is usually higher for stone than for mortar.

The lateral strain of any material is the amount it expands at right angles to the direction of the primary stress. This is proportional to, but smaller than, the compressive strain. The lateral strain of the mortar in a joint is usually larger than that of the stone.

These definitions do not apply to all materials under all stress conditions; they are, however, adequate for the purpose of this chapter.

mortar to spread out more than the stone, coupled with the fact that the relatively rough surfaces of the stones prevent the mortar sliding between the stones, leads to the mortar exerting a horizontal outward drag on the stones. When this drag overcomes the tensile strength of the stones, which is always much less than the compressive strength, the stones crack, the wall or pier splits into slender skins or shafts which then buckle, see Fig. 9.11. It is this mechanism, which is more pronounced for weak mortars than for strong ones, that causes failure of masonry, not crushing of the stones. The net result of the above is that the compressive strength of masonry, depending on the mortar, may be no more than 20 to 40% of the compressive strength of the stone.

As the strength reduction is less severe for strong mortars, there may be a temptation to use strong mortars, based on Portland cement. This temptation must, however, be resisted for two reasons:

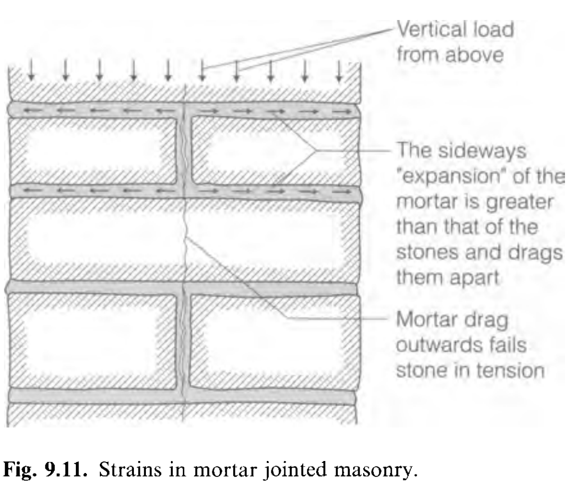

Fig. 9.11. Strains in mortar jointed masonry.

Firstly, if subsequent to construction, foundation movement should take place, any cracks would follow the joints, usually in a diagonal zigzag pattern, provided that the mortar was not too strong. With too strong a mortar, however, the cracks will go through the stones and be far more difficult to make good in a visually acceptable way.

Secondly, some of the constituents of Portland cement may react deleteriously with certain stones, accelerating decay. Furthermore, being very impermeable, cement mortars may interfere with the natural draining down of absorbed rainwater and thus accelerate damage, due to frost and salt crystallisation.

Pure lime mortar is, however, not without problems of its own: The lime is made by first heating limestone so as to convert the calcium carbonate (calcite) to calcium oxide, so-called 'quicklime'. This is then slaked with water to produce calcium hydroxide 'slaked lime', which is subsequently mixed with sand to produce the mortar. The slaked lime takes up carbon dioxide from the atmosphere and reverts to calcium carbonate. This is what causes the mortar to harden, but it is a very slow process. It is in fact so slow that in new construction, the use of pure lime mortar dictates the height of wall that can be raised in a week. It also means that the mortar joints are vulnerable to weather erosion for quite a long time after completion. The Roman builders overcame this drawback by substituting crushed fired clay brick for some of the sand; this acted as a pozzolan and enabled the mortar to begin to harden in the absence of air. Many naturally occurring limes contain impurities which have the same effect on the lime. Because they enable the lime to harden under water, they are called hydraulic limes.

Many of the limes, used from mediaeval times up to the 19th century, would have contained such impurities to a greater or lesser degree. This could explain why lime mortars were used successfully in old construction, whilst repairs made with modern 'pure' lime, mixed with washed silica sand, free from clay, have been known to be short-lived. Another factor could be that the compaction, given to mortar when re-filling eroded joints (re-pointing), has not been as thorough as during construction, when the stone is bedded into the mortar.

There is also a general consensus that lime slaked the old-fashioned way by being thrown into a pit, or deep vessel, filled with water, and left to settle for some weeks, is superior to 'hydrated lime', produced by blowing steam through the powdered quicklime. The explanation for this is that the 'quenching' in water of the quicklime produces a different crystalline structure and grain size of the slaked lime from that of the steam-hydrated. It could also be that the steam treatment exposes the freshly hydrated lime to atmospheric carbon dioxide whilst it is hot and hence more reactive; this would mean that the lime in the mortar, subsequently made, is already partly carbonated and therefore has lost some of its cementing action. In contrast, the traditionally slaked lime, being saturated with water, is only exposed to the air after being mixed into mortar, laid and dried out.

9.2.2. Masonry facades to framed buildings

As mentioned in §9.2.1.4, the thickness, required by the building regulations for load bearing walls, made this form of construction too slow and expensive for buildings more than two or three storeys high. With the introduction of steel and reinforced concrete frames, the problem was overcome by supporting not only the floors, but also

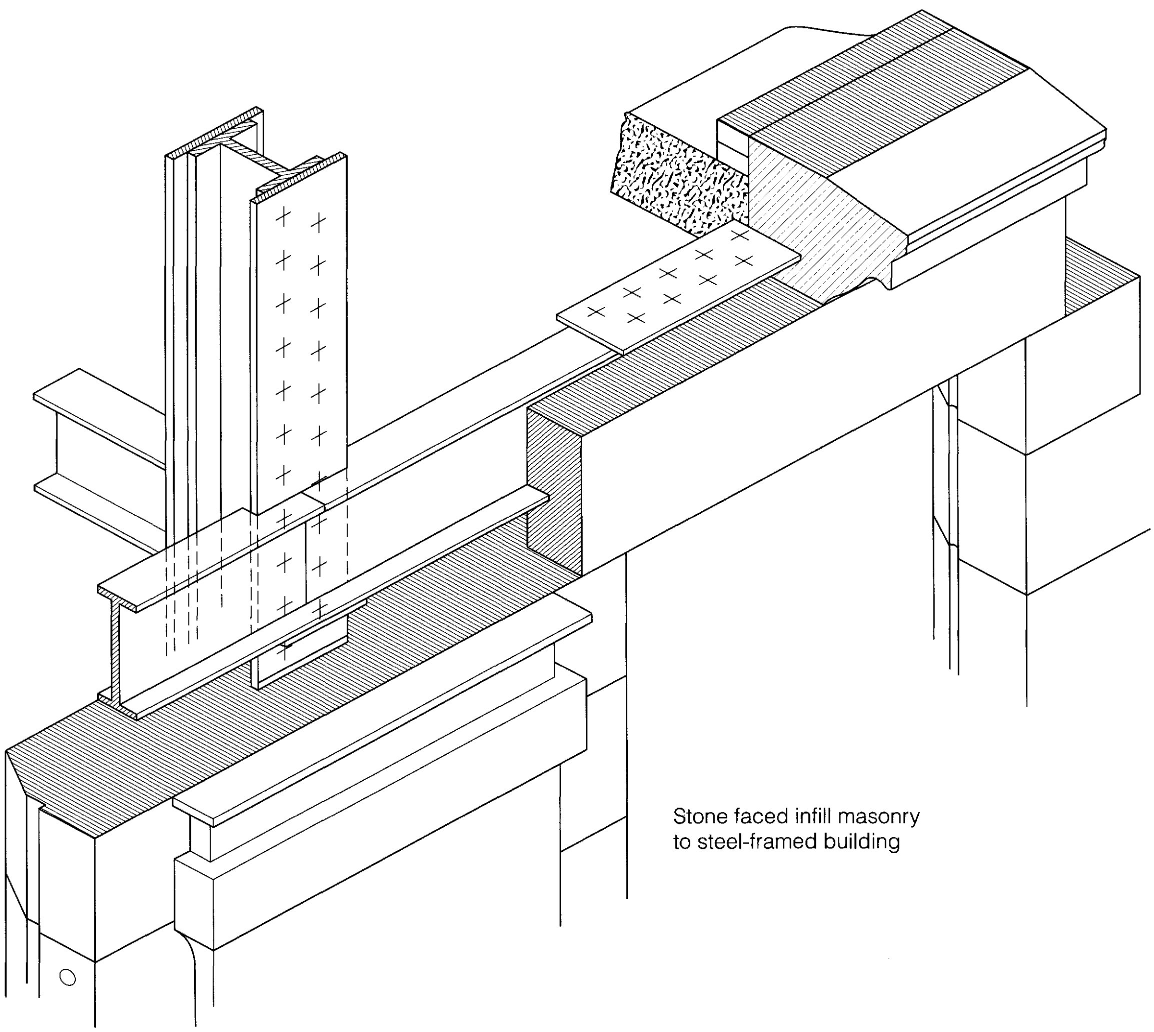

Fig. 9.12. Isometric section/elevation of a masonry wall supported by a steel frame.