"FRANKA" AS A STRUCTURAL MATERIAL

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IT IS NOT unusual nowadays for an architect to be commissioned to design a building 10 storeys high. The most economical form of construction to be adopted is a hybrid structure, with a concrete frame on the lower floors and a masonry structure above.

With so many floors, local masonry is being stressed to its limit. It is now very important that the properties of our local *franka* stone be properly understood and researched.

The properties a material must have for it to be classified as a structural one are load bearing capacity; fire-resistant properties; and durability performance.

Unlike other structural materials our masonry profits from satisfactory performance under the above three conditions. Concrete suffers from the durability problem, while steelwork has a fire-resistance problem.

These problems may be highlighted by the concrete spalled columns in the University of Malta arcades, a building not much older than 20 years, while the tragedy of the Main Hall at the Conference Centre, Valetta, demonstrates the non-existent fire-resistant properties of steelwork.

It is to be noted that nowadays local residential apartment blocks and commercial premises are utilizing structural steelwork frames as they are more economical than concrete frames. The exposed structural steelwork ought to be fireproofed to give a fire resistance of 1½ hours, if not, people's lives are being endangered. This fireproofing reduces the economic savings achieved by structural steelwork.

Buildings, nowadays, are designed to have a minimum design life of 60 years. If a building develops problems before this period, the expected rate of return of the developer is diminished.

This article is intended to discuss the fire resistance and durability properties of *franka*. The strength of local masonry was discussed in a previous article[1].

Franka, the local building stone, is obtained from the lowest of the three distinct beds of Globigerina limestone, each bed being separated by a phosphorite conglomerate horizon. Globigerina limestone occurs mostly in the south-eastern part of Malta, covering approximately two-thirds of the surface area.

From the geographical map published by Pedley *et al* it may be noted that the outcrops of Globigerina limestone are mostly of the lower bed. Its maximum thickness is about 100 metres. The quality varies along this depth and at every approximately 13m a "sol" layer is encountered.

The whole stratum has been formed organically by the deposition of calcium carbonate, from the cementing together on the seabed of the shells of Globigerina and other foraminitera. The calcium carbonate content varies between 65 and 95 per cent and traces of iron oxide exist in some deposits. It is not strongly bedded, hence its name freestone (*franka*).

From microphotographs of a thin section of Globigerina limestone, one may notice the similarities in pore structure to Portland stone (U.K.). It is probable that good quality *franka* would be acceptable for use in a more aggressive environment, such as that in the U.K.

Fire resistance

The temperature rise at any particular depth below the surface of a wall exposed to fire depends on the intensity of the fire, on the period of exposure and on the thermal diffusibility of the material. The intensity of fire in a store with inflammable materials would be higher than that inside a church.

Building stones have a low thermal diffusibility. Hence the rate at which the temperature rises within the body of the wall is correspondingly slow. This high temperature would not exist within even a moderate depth below the surface. This difference in temperature between the outer and inner parts of masonry creates a steep temperature gradient which may cause cracking or spalling. It is damage of this kind that calls for repairs, mostly in columns, window-jambs, cornices, sills, mouldings, and similar projecting features.

For temperatures up to 400C, heat causes the development of a pink or reddish-brown coloration, for *franka* containing iron-oxide. For *franka* free from iron-oxide it becomes greyish in colour. The depth of this coloration seldom exceeds 2cm.

At higher temperatures, in the region of 600C, the colour disappears and calcination starts. Calcination involves the driving off of carbon dioxide, from the limestone calcium carbonate and leaves a residue of calcium oxide or quicklime. Considering the width of the coloured stone referred to above, and the temperatures indicated, one does not expect any considerable degree of calcination of limestone in a building fire. Calcined limestones have a dull, earthy appearance, differing from the original limestone.

It has been proved that there is no significant reduction in crushing strength of limestone for temperatures up to 400/450C. Thereafter the strength decreases and at 600 C the masonry retains 60 per cent of its original strength[2]. Since, in a building fire, the effects are confined to the outer layers, no serious loss occurs to the strength of the masonry unit. But in staircases, which are stressed in tension, it will be better to rebuild any masonry staircase exposed to fire, unless it can be shown otherwise by loading tests.

It is usually considered safe to rebuild on existing walls, after considering the effects of any lateral movements of masonry wall induced by thermal expansion or stresses resulting from collapse or partial collapse of roof or walls. It is also to be ensured that no future damage exists from falling fragments.

Durability

There are many fine buildings which have been erected over 400 years ago and are still in a structurally safe condition. St. John's Co-Cathedral and the Auberges are proof of this. But even in the same building, some masonry units weather to a different degree than others. It may be due to its position. Sills, balustrades, stone courses between ground level and damp-proof membrane and courses immediately below a cornice are

THE FIRE-RESISTANT PROPERTIES of Maltese stone are superior to those of steel or concrete.

known to deteriorate more than masonry in other locations.

The reason for this faster deterioration may be due to causes such as being exposed to weather on all faces for balustrades, or being sheltered from the wash-down effect of rain on courses below a cornice. But when in a wall panel there exist masonry units with different deterioration effects, then the cause must be due to the internal matrix composition of the *franka* unit. In this case, tests will be required for the selection of better quality *franka*.

Exposure tests carried out by the Building Research Station in 1958 (3) have shown that *franka* is susceptible to salt attack. The closer the masonry is to the sea, the higher the durability of the specified masonry ought to be. Terraced houses built about 40 years ago on the Birzebbuga sea-front, have badly decayed masonry. The probability is that masonry was supplied from a nearby quarry which tests have proved to be of an inferior quality. A good damp-proof membrane is a requisite, as salts from the ground are also known to cause deterioration. An interesting fact is that rock-faced stone (*gidra*) deteriorates less than fair-faced stone.

From the same work carried out in 1958, it was concluded that any sulphate attack on the stonework through atmospheric pollution was small and of little consequence. Is this true nowadays, if one considers the Hamrun Marsa area being subjected to pollution due to the burning of coal for the power station?

The principal acid products of the combustion of coal are carbon dioxide and sulphur dioxide. Carbon dioxide exists in the atmosphere and its effect on limestone masonry is considered to be of relatively little consequence. The production of acid sulphur gases by the combustion of coal is more important. Coal contains on average one to two per cent of sulphur, which on combustion is oxidised to sulphur dioxide or sulphur trioxide, which in contact with water forms sulphurous and sulphuric acids.

Not all the sulphur escapes into the air, some remains in the ash or the chimney soot, neither does all the sulphur dioxide which escapes enter into combination with limestone in buildings. Nevertheless, actual damage is caused, and its severity will have to be ascertained by future tests. Soot deposits cause disfiguration and due to acid materials which it brings into close contact with the *franka* under projecting features, accumulating into thick black encrustations also causing chemical disintegration.

Due to *franka* not being strongly bedded, the difference in weathering due to units placed on sides differing from its bedding plane is not so marked, but varies according to quality of masonry. The better type of *franka* showing slighter or no difference.

The Building Research Station have a standard method of examination for the selection of natural building stone (4). Below are listed a number of tests, which ought to apply for our environment and type of stone. In 1958 (3) (5) a limited number of tests were carried out on *franka* samples together with further tests in 1985 (6) and results are discussed.

Limestones have a broadly similar chemical composition. Chemical analysis is of no use to durability assessment. It is the internal structure of a limestone

(Continued on page XXVIII)

Measuring durability

(Continued from page XXVII)

rather than its composition, that gives the clue to durability.

Indirect measures of pore structure

Porosity is the volume of pores within a stone, expressed as a percentage of the total volume. It is conveniently measured by vacuum saturation with water. Values around 10 to 20 per cent although may be as high as 40 per cent. The value for *franka* samples was around 35 per cent. A 'sol' sample gave a low 27.8 per cent[6]. Values for coral limestone are in the region of 10 per cent[5].

Porosity gives no indication of the way the pore space is distributed, namely whether there are many fine pores or otherwise.

Saturation co-efficient is measured by drying stone used for porosity test. It is then soaked in water for 24 hours. The saturation co-efficient is the proportion of pore space that becomes filled with water during soaking. Values range from 0.4-0.95, the high value indicating a high proportion of fine pores, being a stone of low durability, whereas a value of 0.4 would be a stone of high durability. The value for *franka* samples was around 68 per cent, being a grey region as on its own the saturation co-efficient is an unreliable guide to durability.

Microporosity is the proportion of the total pore space of pores having an effective diameter less than five microns. A stone with high proportions of very fine pores is less durable than a stone that has mainly coarse pores. The two methods most widely used for the distribution of pore sizes is the mercury porosimetry and the suction plate technique, the underlying principle being that the pressure required to force mercury into an empty pore (or suck water out of a full pore) is dependent upon the size of the pore. The value for *franka* samples fell between a grey middle of 50 to 80 per cent which on its own merit may not be used to classify its durability characteristics.

An improved indication of durability may sometimes be obtained by combining two properties.

For the *franka* samples tested it was concluded[5] that a wet/dry compressive strength ratio of 0.58 appears to mark a dividing line between a better and a poorer stone. This value appears to be confirmed also by tests carried out by Cachia[6] comparing his values of wet/dry strengths with his descriptions of the respective quarries. One anomaly appears in an Mqabba quarry which is described as of poor quality masonry, but the wet/dry ratio works out at 0.7. The tests on this sample were carried out perpendicular to bedding plane not normal to bedding plane as in the other tests. Could this be the reason for the anomaly?

The dividing line between a very poor sample (0.56) and a very good sample (0.59) is too fine and a better indication of durability appears to be obtained by dividing the wet/dry strength ratio by microporosity and multiplying the result by 105. A tentative value has been established at 1050[5]. More tests are required to confirm this result.

Direct tests of durability

Direct tests are intended to subject the stone to the same conditions that it will encounter in use, but in a more aggressive form.

The crystallisation test is one. A stone sample is subjected to cycles of immersion in sodium sulphate, followed by drying in an oven. The test is comparative and the loss in weight obtained must be compared with the result of a standard stone, known to have good durability characteristics. For the *franka* samples tested, the change in weight was between 20 and 30 per cent, with a poor sample being as high as 49 per cent. A high proportion of micro pores, together with a high loss in weight due to crystallisation test, indicates stone to be less durable.

It is a fact that the quality of local *franka* varies as it is a natural material. *Franka* is used exactly as it is found, there is no processing or manufacturing involved, which may change its quality. However the customer ought to be advised in his selection. For instance, *franka* used in an inland location, such as Rabat, may not be suitable for use on the Sliema seafront due to the deleterious action of sea-spray. Nor

THE USES of Maltese *franka* should be developed for an improved architectural design.

is it suitable in the Marsa area because the pollution there produces harmful acids.

The *franka* used on the wall panel of a façade may not be suitable for the balcony balustrading or the overhead cornice. Ideally, the *franka* obtainable from a quarry should be graded according to its durability. A list should be compiled indicating the suitable use of *franka* from a particular quarry, taking into consideration its durability, the environment where the *franka* is to be used and its location in the building fabric.

Having convinced ourselves of the favourable properties of *franka*, we must use it as a truly structural material, not as an infilling wall panel. Its obvious use is as a wall panel transmitting loads vertically downwards, but its geometrical layout may be utilized to transmit horizontal wind or earthquake forces to the ground.

In shed buildings, fin or diaphragm walling may be used for the side and gable walls. Reinforced masonry may be used for retaining walls, while post-tensioned masonry, extending the structural capabilities of masonry, is yet to be taken advantage of in Malta.

The above-mentioned methods are more economical locally when compared to other more evolved structural systems. Developing the structural uses of *franka* would also lead us towards an improved architectural design, as then *franka* would be more functional.

REFERENCES.

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(3) BRE — Note B188, *The Maltese Islands, use of limestone for building.*

(4) BRE — *The selection of natural building stone.*

(5) BRE — Note C965..

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