Globigerina limestone ("franka") as a structural material

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OUR BUILDING STONE has always been used as a structural material, even when other countries had discarded the structural strength of masonry and used it only as an infill material in between a concrete or steel frame. We are fortunate in having a soft limestone that may be easily dressed forming aesthetically pleasant wall panels.

From the turn of the century till past the middle of this century, the trend in building has been to produce a jungle of concrete buildings or a steel skeleton hidden by a glass façade. An increase in research during the past decade, helped by the energy crisis, has helped the "Brick (masonry) is Beautiful" campaign. It is now accepted that masonry forms an attractive durable cladding with good thermal and acoustic insulation and excellent fire resistance. Besides, it is an economical structural material that can be built faster, more cheaply and more easily than its rivals, steel and concrete.

Of the properties mentioned above concrete suffers from durability. The matrix of steel bars and concrete creates corrosion and spalling problems. Eminent engineers have been known to blush during their lifetime, not because of errors in structural calculations but because of the deterioration of concrete buildings or bridges. They are being maintained, but concrete repairs are a very expensive item, not envisaged as part of the required maintenance during the design stage.

Our university is facing such a problem, as concrete columns instead of masonry piers were used in its covered walkways under existing buildings. Concrete repairs are being done to these spalled columns, a building not much older than twenty years. Our churches and palaces built over 400 years ago, are proof of the good durability of our local *franka*.

Steelwork has low fire resistance, specialized labour would be required to erect a steel-frame. Ignoring fabrication time it is true that a steel frame has a short site erection time, but no other construction work can take place during the erection period. This is not the case with masonry structures where there is a continuous follow on of other trades.

Large open space structures, such as factories, sports halls etc., have traditionally been constructed in a steel or concrete portal, with infilling sheeting or masonry. With the development of new structural forms in masonry diaphragm or fin walling, the roofing system may now be supported directly on the masonry. The structural form of masonry adopted caters for all the vertical load and wind forces. This efficient and economical form of construction can provide the structure, the cladding and insulation in one material erected by the main contractor using only one trade.

A disadvantage in using masonry would be an increase in the obstructed area over steel or reinforced concrete. There is no reason why piers in department stores or similar structures are not constructed in masonry, having a higher compressive strength. Lower coralline limestone has a compressive strength, but is weak in tension. Reinforced and post-tensioned masonry may be used successfully where tension develops. Such structures are retaining walls, silos, etc.

ARCHES

The masonry arch was a very important structural element, spanning large distances. Before the advent of steelwork, the first railway bridges were masonry arches. Masonry arches then went out of fashion and the theory of arches was almost forgotten. Further advances in the theory of arches were evolved during the past wars, as checking of these arches for heavier loading was required. Today there is an awakening and also a revival of interest in the old structural form of the arch.

Currently research work is being carried out on the limit state design of masonry arches[1], a method which will facilitate the tedious arch calculations. This may revive the demand amongst architects for arched ceilings due to their aesthetic appeal.

The composite action between masonry panels supported on concrete beams[2] should also be investigated as this will effect greater economies. A hotel block is normally a hybrid structure, the upper bedroom floors constructed in masonry, whilst the ground floor being the foyer requires large open floor areas supported on a concrete frame. The concrete beams and upper masonry walling are not to be designed as separate elements, but as a composite structure. The whole unit is to be designed as a deep beam, with the reinforcement in the concrete beam taking the tensile forces and masonry walling above taking the compressive forces. In this way the lever arm is increased with a corresponding decrease of steel required.

Well designed structural forms in masonry are more robust and more resistant to progressive collapse due to the inherent arching capabilities of masonry than other structures. For high-rise buildings the plan layout should be disposed to give a high rigidity against horizontal wind loading. An example is the eight-storey Qawra Point block.

STRENGTH OF LOCAL MASONRY

Masonry is a composite material. Its strength is dependent on the crushing strength of the masonry block and of the infilling mortar used. It also depends on the workmanship. The most common workmanship defects are:

(1) The horizontal bed joints should be filled completely with mortar. Incompletely filled bed joints may reduce the strength of masonry panels by 33 per cent. Failure to fill vertical joints has little effect on the compressive strength but is undesirable for weather exclusion and sound insulation.

(2) Mortar bed joints should not be thicker than 12mm (½"). Bed-joints of 16-19mm thickness result in a reduction of compressive strength of up to 30 per cent as compared with 10mm thick joints.

(3) Before laying mortar the block is to be well wetted to reduce its suction rate; also, a proportion of lime in the mortar mix will help the mortar mix to retain its water. A high absorbent block will result in a weaker mortar, with a resulting weaker wall panel.

The relevant code of practice for structural masonry[3], after taking into consideration masonry unit strength, mortar strength and degree of workmanship available gives values for the compressive strength of masonry panels.

From tests carried out by J. Cachia[4] on local masonry blocks, collected from various quarries, the highest average crushing value on a dry sample was 32.9N/mm^2 whilst the corresponding lowest was 15N/mm^2. The highest value was obtained on a "sol" sample. The sol sample was the densest and had the lowest void ratio and porosity. When tested in the fully saturated state the compressive strengths obtained were on average 39 per cent lower. One may assume internal walling to have dried to its dry state, whilst for exposed walling an intermediate value is to be taken for the fully dry and completely saturated state.

From a different source[5] the crushing strength of coral limestone is given as 75N/mm^2.

From tests carried out by W. Debattista[6] on local mortars the commonly used cement mortar mix having proportions 1:2:10 of cement, to coralline limestone sand to fine globigerina sand had

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ı average crushing strength at ȝ days of 1.85 N/mm². A stronger ɛment mortar mix having proɔrtions of 1:2:6 had an average ushing strength at 28 days of 5N/mm². He also carried out sts on lime mortars and a comɔsite cement, lime mortar.

The results obtained demonrated that lime mortars were ɩperior with regard to retention water and consistency, air cont of freshly mixed mortar and ɔw. On the other hand cement ortars have higher flexural ıd compressive strengths, tother with a longer setting time.. he composite lime-cement ortar exhibited intermediate orkability and strength ıaracteristics. The reintroducon of lime into our mortar mixes ; to be encouraged due to better roperties achieved.

With reference to the Code of Practice on structural masony[3], the following information is ;iven:

Four mortar types are defined ccording to crushing strengths chieved after 28 days — Type (i) aving a strength of 16 N/mm²; i) having a strength of 6.5 /mm²; (iii) having a strength of 6 N/mm²; (iv) having a strength f 1.5 N/mm².

So our 1:2:10 mortar mix is classified as type (iv) mortar, and the 2:6 mortar mix classified as ʼpe (iii).

As stated previously the comressive strength of a wall panel

depends on a combination of the respective mortar and masonry unit strength. The greater the proportion of mortar/unit area of block, the lower the strength of the wall panel. The code of practice therefore gives different values for 6" or 9" masonry units.

The following two tables derived from the Code of Practice[3] gives wall panel strengths for a given masonry block and a given mortar designation.

The values of the ultimate strengths of wall panels are to be divided by the relevant factors of safety to obtain the allowable working load. An average value for loading is 1.5, whilst for material strength with average workmanship a value of 3.0 is quoted. So the global factor of safety to be used is approximately 4.5.

Tests on 26 different one-third scale wall panels have been crushed to destruction by P. Buhagiar[7]. Masonry blocks used were from three different quarries having different strengths. The Mqabba blocks had an average of 20N/mm², Naxxar blocks 22.5N/mm², whilst the Siggiewi blocks had 17N/mm².

TABLE 1 - Estimated Compressive Strength of Masonry for 9" blocks (N/mm²).

Mortar Designation	Compressive Strength of Unit N/mm²			
	Globigerina			Coralline *
	18	20	23	75
(i)	9.5	10.3	11.4	26.3
(ii)	8.2	8.9	9.7	20.8
(iii)	7.6	8.0	8.8	18.0
(iv)	6.8	7.2	7.8	15.2

TABLE 2 - Estimated Compressive Strength of Masonry for 6" blocks (N/mm²)

Mortar Designation	Compressive Strength of Unit N/mm²			
	Globigerina			Coralline *
	18	20	23	75
(i)	12.3	13.3	14.7	34.4
(ii)	10.7	11.5	12.6	27.0
(iii)	9.9	10.4	11.4	23.4
(iv)	8.9	9.3	10.0	19.3

* Value for coralline wall panels were extrapolated from the Code of Practice, as a block having such a high crushing strength is not quoted.

Two mortar mixes were used a cement mortar (1:3:12) having a crushing strength after 28 days of 1.75N/mm² (type (iv)) and a composite cement lime mortar (1:1:2:4) having a crushing strength after 28 days of 5.9N/mm² (type (iii)). The greatest variation from the Code of Practice was on the 6" blocks.

Another anomaly was that the blocks from Naxxar quarry, with the highest crushing strength, achieved the lowest wall panel loading. By further tests conducted by P. Buhagiar, this is attributed to a high initial rate of absorption, which as mentioned earlier on would affect the mortar strength.

Buhagiar concludes that the same strength should be used for the 6" and 9" local masonry blocks, disregarding the higher values attributed to the 6" masonry blocks. A 6" thick unit is more slender than the 9" unit, so could not have slenderness effects reduced the crushing load? It must be borne in mind, that during the tests the mortar beds were fully filled, which does not occur in practice.

From the above, it may be concluded that for preliminary design calculations a masonry block, having a crushing strength of 20N/mm² may be adopted.

On a 5.0m masonry structural grid spacing a 9" masonry block may support five floors, using grade (iv) mortar; if grade (iii) mortar is specified, then six floors may be supported.

The tests conducted plus the knowledge imported from overseas, should help us in being more creative with our only natural material available. Our island should become a showpiece in structural masonry. This would require further experimenting and a higher degree of site control, if stronger mortars are to be specified.

This should not be too difficult to attain, as Malta has always had the required expertise in design and workmanship as evidenced by the Knights' reluctance to employ foreign help, except for their defensive construction works required.

REFERENCES:

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