DESIGN INFORMATION FOR PRELIMINARY SELECTION OF BLOCKS AND MORTARS FOR LOADBEARING WALLS

by

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Abstract

Production and use of cement blocks are gaining considerable popularity. The availability of different sizes, cross-sectional shapes and compressive strengths requires a decision on selection of a block type and mortar mix for a particular application. The design process leading to selection is, however, complex and laborious. Thus a need exists to simplify that task.

The study undertaken was aimed at helping the user to face a variety of decision making situations that may arise in using blocks. Stepwise procedure presented enhances simplicity of treatment. Assumptions made were stated and how accuracy can be fully retained when a particular step is by-passed, with calculations on the actual structure, was highlighted. Further, the material in BS 5628 superflous in the local context was pruned out and, where necessary, enlarged by justifiable extrapolation or interpolation.

The use of design information was illustrated by examples, and further extensions possible to widen the scope were also noted.

1.0 Introduction

Production of cement blocks is gaining popularity now throughout the country due to (a) financial facilities available for self employment projects and for leasing of equipment; (b) manufacture of blockmaking equipment locally; (c) availability of imported blockmaking equipment for purchase or lease; (d) poor quality and spiralling cost of bricks; (e) faster rate of construction possible with blocks; and (f) ready acceptance of blocks as an excellent walling material. Due to greater use of blocks and the availability of blocks with a variety of sizes, cross-sectional shapes and strengths, there is a need to familiarise the users on how block and mortar can be selected for the more common applications. However, the design process leading to recommendation of blocks and mortars for various applications is a complex procedure as specified in BS 5628[1], which depends on many factors such as width of block, block density, ratio of height/least horizontal dimension, area of hollows, block type whether hollow or solid, mortar designation and compressive strength of block. Often it is necessary to evaluate not just one variable, but several variables simultaneously thus making a mathematical approach rather complex. It is possible to surmount this obstacle by providing design information with formulas and tables in a simple manner for preliminary selection of blocks and mortars for loadbearing walls in up to 8-storey buildings or similar structures. This paper endeavours to provide such design information, prune out material of BS 5628[1]

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superflous in the local context, and, where necessary, extend its design philosophy by justifiable extrapolation or interpolation.

2.0 Objective of the Study

The main objective of the study was to evolve design information to carry out the following tasks with simplicity and ease :

a) to determine the required compressive strength of block and a suitable mortar designation for blocklaying, for a block of specified dimensions to be used in a building (more favourable than the typical building considered or same as the typical building : see 3.1) of specified number of storeys;

b) to compare products of different manufacturers with the same outer dimensions but varying prices, cross-sectional shapes and strengths as regards economy for use in a building (more favourable or same as the typical building considered) of specified number of storeys;

c) to determine the number of storeys of a building (more favourable or same as the typical building) where a particular type of block of known compressive strength and density with a specified mortar designation can be used;

d) to consider a variety of blocks of different sizes, compressive strengths and prices, and to select the best block and mortar designation for a building (more favourable or same as the typical building);

e) to determine whether for a given hollow block, it is necessary to fill the cavities when used with a suitable mortar designation for blocklaying in a building (more favourable or same as the typical building);

f) to select a suitable mortar mix for blocklaying with a given block (where dimensions and compressive strength are known) to be used in a building (more favourable or same as the typical building) of specified number of storeys;

g) to proportion a new hollow block satisfying the recommended values for outer dimensions, a specified compressive strength, a specified mortar designation for blocklaying and suited for a building (more favourable or same as the typical building) of specified number of storeys;

h) to determine the required compressive strength of block and mortar designation for blocklaying when characteristic compressive strength of masonry of a structure and block dimensions are known; and

i) to check whether a block of specified dimensions and compressive strength with a specified mortar designation for blocklaying is adequate for a given structure where characteristic compressive strength of masonry in the structure is known.

3.0 Derivation of design information

3.1 General

The following assumptions were made in the derivation of the design information:-

(a) For evaluation of loads and calculation of stresses the typical building was taken as 7.0m wide by 9.0m long with 3.0m spacing between crosswalls and 3.0m tall storey heights; (b) the overhang of the eaves and the verges of the roof was taken as 1.0m each measured in plan; (c) concrete floor slabs of 150mm thick spanning one way to crosswalls; (d) The roof of the building was taken to be gabled and of corrugated asbestos sheets with a roof angle of 12°; (e) Imposed load on roof as 0.25 kN/m² and imposed load on floors[6] as 3.0 kN/m²; (f) Basic wind speed[6] of 33.5 m/sec and ground roughness (1) category; (g) Partial safety factor for material strength as 3.5; (h) BS 5628[1] Table 2 can be extended from blocks of compressive strength 2.8 N/mm² to cover blocks as low as 1.2 N/mm² as (i) the relationship in that region is approximately linear, (ii) this region is applicable mainly for single-storey buildings carrying low loads, and (iii) the influence of block compressive strength on the compressive strength of a wall, in this region, is insignificant.

In a general study like this it is not possible to do away with such assumptions as design information cannot be developed that is applicable to any building since (a) wind loads depend on the geometry of the building and its location; (b) stresses due to dead and imposed loads on floors and roofs also depend on plan geometry; (c) imposed loads on floors depend on intended use; (d) crosswall spacings may be different; and (e) storey heights may be different.

The important consideration is to make assumptions that will lead to conservative but realistic approximation of the true result. It should also be noted that accuracy can be fully retained if the designer can by-pass the steps 2 and 3 (see 3.4 and 3.5) and obtain characteristic compressive strength of masonry by calculation using the actual structure.

The design information provided in this paper is valid for any building which is more favourably stressed than the typical building assumed. A building can be considered more favourable than the typical building when (a) length/width ratio of the building does not exceed 4.0; (b) height/width ratio of the building does not exceed 6.0; (c) width of the building is not less than 5.8m for up to 4-storey buildings or 7.0m for other taller buildings; (d) spacing between crosswalls does not exceed 3.0m; (e) storey height does not exceed 3.0m; (f) depth of floor slab does not exceed 150mm; (g) roof is gabled at not less than 12°to the horizontal or flat; (h) imposed load on any floor does not exceed 3.0 kN/m²; (i) basic wind speed does not exceed 33.5 m/sec; (j) roofing material is calicut tiles or round tiles on corrugated asbestos provided imposed load on any one floor is not greater than 2.4 kN/m² rather than 3.0 kN/m². Otherwise design wall stresses in Tables 3 and 4 should be increased by .031, .021 and .016 N/mm² respectively for 100, 150 and 200mm wide blocks.

3.2 Range of each variable

The variables which affect the compressive strength of blocks were considered and range of each variable was evaluated to cover conditions in Sri Lanka as given below:

(i) Wall thickness (t)-Values recommended in BS 6073[2] are 75, 100, 115, 125, 140, 150, 175, 190, 200, 215, 220, 225 and 250mm. Of these 100, 150 and 200mm were selected as they represent the currently available sizes and since blocks are used only is stretching bond, larger thickness values are not required.

(ii) Number of storeys (n) - The value was varied from 1 to 8 to cover common applications of blockwork structures. It should be noted that more common values are 1 up to 5, but although few, 8-storey structures also exist.

(iii) Percentage volume of solid material in the block (r) - According to BS 2028, 1364[3] and SLS 855[4], solid blocks have solid material not less than 75% of the total volume of the block calculated from the overall dimensions and hollow blocks have solid material between 50% and less than 75% of the total volume of the block calculated as above.

Thus 'r' varies from 50 to less

than 75 for hollow blocks and 75 to 100 for solid blocks.

This variable is necessary to determine block density (if it is not known by actual weighing), and also to convert block strength based on net area to that on gross area where cavities of hollow blocks are to be filled.

(iv) Block density (ρ) - Block density is determined by weighing and measurement as specified in BS 6073[2] or SLS 855[4]. Unfortunately, block density values of local blocks are not available freely and often designer has to estimate it. In Sri Lanka, research has shown that solid density in blocks range from 18 to 22 kN/m³ in contrast to concrete solid density of 24 kN/m³. As compressive stresses are more significant than tensile stresses in the structural types used here, a higher block density leads to greater safety in design. Thus a solid density of 22 kN/m³ is recommended. As solid material in a solid block may not be less than 75%, its block density may vary from 16.5 to 22 kN/m³. Similarly, as solid material in a hollow block may be between 50% and a value less than 75%, its block density may vary from 11 to a value less than 16.5 kN/m³. As the block density of 11 kN/m³ is rare, block density was varied from 12 to 22 kN/m³.

(v) Mortar designation - The four mortar designations specified in BS 5628[1] were used. Mortars used locally are classified[5] into respective mortars designations as follows:

Mortar designation (i)- 1 cement : 2 sand
Mortar designation (ii) - 1 cement : 3 sand; or 1 cement : ½ lime : 4 sand; or 1 Masonry cement : 2½ sand
Mortar designation (iii) - 1 cement : 5 sand; or 1 cement : 1 lime : 5 sand; or 1 Masonry cement : 4 sand
Mortar designation (iv) - 1 cement : 8 sand; or 1 cement : 2 lime : 9 sand; or 1 Masonry cement : 5 sand.

The mixes based on masonry cement are not used in Sri Lanka presently due to its non-availability.

(vi) Ratio of height divided by least horizontal dimensions (s)
BS 5628[1] gives design information for values of this ratio ranging from 0.6 to 4.0. However, for hollow blocks produced here, this ratio takes the values 1.0, 1.33 and 2.0, while ratio for solid blocks takes the value 2.0.

3.3 Determination of block density (Step 1)

This step is unnecessary and block density need not be calculated if it is known experimentally.

This step relates block density (ρ) to the variable r (see 3.2(iii)) by the formula:

$$\rho = 0.22\ r \quad \text{where } \rho \text{ is in kN/m}^3$$

Thus substitution of value of variable r, which can be obtained by measurement of cavities, in the formula yields the required value of ρ.

3.4 Determination of design compressive stress of the wall (Step 2)

This step relates design compressive stress of the wall (f_w) to the variables: number of storeys (n), wall thickness (t) and block density (ρ). See below for units of these terms.

The approach followed is given below:

(i) The most critical wall was identified after study as an interior crosswall;

(ii) The stress (d in N/mm²) on the wall due to dead load is given by,

$$d = \frac{[(1.19 + 3.37\rho t) + (n-1)(10.62+3\rho t)]}{1000t}$$

(iii) The stress (i in N/mm²) on the wall due to imposed load is given by,

$i = \frac{[0.96+9(n-1)]\ A}{1000t}$ where A = [1-(n-1)0

where A = [1-(n-1)0.1] but not less than 0.4.

(iv) The stress (w in N/mm²) on the wall due to wind load on walls is given by,

$$w = \pm \frac{3M}{98000t}$$

where M = 7.11(for n= 1); 65.69(for n = 2); 171.34(for n = 3); 394.1(for n = 4); 671.07(for n = 5); 1032.44(for n = 6); 1467.24(for n = 7); and 1976.0 (for n = 8).

(v) the stress (u in N/mm²) on the wall due to wind uplift on the roof is given by,

$$u = \frac{F}{1000t}$$

where F = 2.17(for n = 1); 2.83(for n = 2); 2.78(for n = 3); 2.39(for n = 4); 2.47(for n = 5); 2.55(for n = 6); 2.72(for n = 7); and 2.66(for n = 8).

(vi) the design stress was found to be the worst of the combinations: 1.4 dead + 1.6 imposed; 0.9 dead + 1.4 wind; 1.2 dead + 1.2 imposed + 1.2 wind.

In the formulae given above units used are: t(metres); ρ(kN/m³); M(kN.m); and F(kN).

The design stresses (f_w) are shown in Table 1. Thus if the above three variables are known, design stress can be read from the table. For the applications on the left hand side of the dark line across Table 1, the critical load combination was "1.4 dead + 1.6 imposed", while for the rest "1.2 (dead + imposed + wind)" was critical. If the designer wishes to use the design stress in the actual structure under consideration, rather than that of the typical building considered here, then the calculated design stress can be used as the design stress of this step and thereafter in the succeeding steps. The latter method will be obviously more accurate.

3.5 Determination of characteristic compressive strength of masonry (Step 3) -

This step relates characteristic compressive strength of masonry (f_k) to design compressive stress of the wall (f_w). The relation is given by the formula;

$$\frac{\beta f_{k.t}}{\gamma_m} \geq f_{w}.t$$

where β & γ_m have usual meanings[1].

This can be expressed as $f_k = K.f_w$

where $K = \frac{3.5}{\beta}$. The relevant K values are shown in Table 2.

Thus if design stress of the wall (f_w) is known, characteristic compressive strength of masonry (f_k) can be determined using Table 2.

3.6 Determination of compressive strength of block (Step 4) -

This step relates compressive strength of block to characteristic compressive strength of masonry (f_k). The relation is given in tabular form in BS 5628[1]. The necessary information is presented in Tables 3 and 4, after extension of the relation by extrapolation to cover low strength units as low as 1.2 N/mm². In conducting the extrapolation following considerations were used:- (a) The lowest compressive strength of block specified[4] in Sri Lanka is 1.2 N/mm²; (b) Block of ratio s = 2.00 can develop a f_k value equal to compressive strength of the block itself; (c) Block of ratio s = 1.00 can develop a f_k value of 1.8 N/mm² for a block of compressive strength 2.8 N/mm². Maintaining this same relationship will give a f_k value of 0.8 N/mm² for a block of compressive strength

Density ρ in kN/m^3	Wall thick-ness t in mm	n = number of storeys							
		1	2	3	4	5	6	7	8
12	100	0.089	0.419	0.718	0.989	1.231	1.546	1.866	2.267
	150	0.078	0.315	0.532	0.729	0.908	1.120	1.346	1.628
	200	0.072	0.261	0.438	0.598	0.752	0.905	1.087	1.309
14	100	0.099	0.435	0.743	1.024	1.274	1.590	1.916	2.324
	150	0.088	0.333	0.558	0.764	0.950	1.164	1.398	1.687
	200	0.082	0.279	0.463	0.632	0.787	0.949	1.139	1.368
16	100	0.108	0.454	0.770	1.058	1.318	1.634	1.968	2.383
	150	0.098	0.351	0.583	0.798	0.993	1.208	1.450	1.745
	200	0.092	0.297	0.490	0.667	0.830	0.992	1.189	1.427
18	100	0.118	0.472	0.797	1.093	1.360	1.679	2.020	2.442
	150	0.108	0.368	0.610	0.833	1.037	1.253	1.500	1.804
	200	0.102	0.316	0.517	0.702	0.874	1.037	1.241	1.484
20	100	0.127	0.490	0.823	1.128	1.403	1.722	2.071	2.501
	150	0.116	0.386	0.637	0.868	1.080	1.296	1.552	1.862
	200	0.110	0.332	0.543	0.737	0.917	1.082	1.292	1.543
22	100	0.136	0.507	0.848	1.163	1.447	1.766	2.122	2.558
	150	0.126	0.404	0.663	0.902	1.122	1.340	1.603	1.921
	200	0.120	0.351	0.568	0.770	0.959	1.134	1.344	1.602

Table 1 - Design stress f_w (in N/mm^2)

t(mm)	100	150	200
K	5.8577	4.0698	3.7037

Table 2 - Values of K where $f_k = K.f_w$

Mortar design-ation (see(v) of 3.2)	Ratio of height to least horizontal dimension (s)	Compressive strength of hollow block (N/mm^2)							
		1.2	2.8	3.5	5.0	7.0	10	15	20
(i)	1.00	0.8	1.8	2.1	3.2	4.1	4.9	6.2	7.4
	1.33	0.9	2.1	2.5	3.8	4.6	5.3	6.4	7.5
	2.00	1.2	2.8	3.5	5.0	5.7	6.1	6.8	7.5
(ii)	1.00	0.8	1.8	2.1	3.2	3.9	4.6	5.5	6.4
	1.33	0.9	2.1	2.5	3.8	4.4	5.0	5.7	6.5
	2.00	1.2	2.8	3.5	5.0	5.5	5.7	6.1	6.5
(iii)	1.00	0.8	1.8	2.1	3.2	3.8	4.5	5.2	5.8
	1.33	0.9	2.1	2.5	3.8	4.3	4.8	5.4	5.9
	2.00	1.2	2.8	3.5	5.0	5.4	5.5	5.7	5.9
(iv)	1.00	0.8	1.8	2.1	2.8	3.4	3.9	4.6	5.2
	1.33	0.9	2.1	2.5	3.3	3.8	4.2	4.8	5.3
	2.00	1.2	2.8	3.5	4.4	4.8	4.9	5.1	5.3

Table 3 - Characteristic Compressive strength of masonry f_k (N/mm^2) of walls with hollow blocks

Mortar designation (see (v) of 3.2)	s	Compressive strength of solid block(N/mm²)							
		1.2	2.8	3.5	5.0	7.0	10	15	20
(i)	1.00*	0.8	1.8	2.1	3.2	4.4	5.7	7.7	9.5
	1.33*	0.9	2.1	2.5	3.8	5.2	7.0	9.1	11.3
	2.00	1.2	2.8	3.5	5.0	6.8	8.8	12.0	14.8
(ii)	1.00*	0.8	1.8	2.1	3.2	4.1	5.4	6.8	8.2
	1.33*	0.9	2.1	2.5	3.8	4.9	6.4	8.1	9.7
	2.00	1.2	2.8	3.5	5.0	6.4	8.4	10.6	12.8
(iii)	1.00*	0.8	1.8	2.1	3.2	4.1	5.3	6.4	7.5
	1.33*	0.9	2.1	2.5	3.8	4.9	6.2	7.6	8.8
	2.00	1.2	2.8	3.5	5.0	6.4	8.2	10.0	11.6
(iv)	1.00*	0.8	1.8	2.1	2.8	3.6	4.5	5.7	6.7
	1.33*	0.9	2.1	2.5	3.3	4.3	5.3	6.7	7.9
	2.00	1.2	2.8	3.5	4.4	5.6	7.0	8.8	10.4

* Only for use when assessing hollow blocks with cavities filled, as solid blocks are not available in Sri Lanka for these ratios

Table 4 - Characteristic compressive strength (N/mm²) of walls with solid blocks or hollow blocks with cavities filled

1.2 N/mm^2; and (d) Block of ratio s = 1.33 can develop a f_k value of 2.1 N/mm^2 for a block of compressive strength 2.8 N/mm^2. Maintaining this same relationship will give a f_k value of 0.9 N/mm^2 for a block of compressive strength 1.2 N/mm^2. These extrapolated values have to be used till such information on local blocks are made available by research workers.

Thus if characteristic compressive strength of masonry (f_k) is known, compressive strength of hollow blocks can be found from Table 3, while that of solid blocks can be found from Table 4. When hollow blocks are filled with mortar or concrete of compressive strength not less than that of blocks compressive strength of hollow blocks is determined by multiplying the value obtained from Table 4 by the ratio net area of block divided by the gross area.

3.7 Determination of the cost of wall (Step 5) -

This step relates cost of the wall to cost of block, cost of cement/lime/sand used for mortar at joints, cost of cement/lime/sand used for plaster (where applicable). Length and height of all the blocks available in Sri Lanka are 400 and 200 mm respectively.

Notation used in the formulae with some typical values of prices or rates (shown, where applicable, inside brackets) is given below:-

a - Proportion of lime in the mortar mix; b - Proportion of sand in the mortar mix; B - Cost of a block (Rs.8.00); C - Cost of 50Kg of cement (Rs.120.00); L - Labour cost per 8 hour day (Rs.45.00); Li - Cost of one bushel of lime (Rs.45.00); M - Wage for a mason per 8 hour day (Rs.75.00); S - Cost of one cube of sand (Rs.285.00); T - Width of block in mm; W - Cost of a litre of water (Rs.0.00066); X - Bamboo (for scaffolding) cost per linear foot (Rs.1.25).

Cost of a wall is given by the following formulae :-

(a) <u>Cost of blocks per square of wall (F1)</u>

$$F1 = 120B$$

(b) <u>Cost of materials in mortar (see (v) of 3.2) joints, per square of wall (F2)</u>

$$F2 = T\,\frac{(0.03189C+0.02615(a)(Li)+0.00039(b)S + 0.9567W)}{(1.62 + 0.251\,a + 0.849b)}$$

(c) <u>Cost of labour for laying blocks, per square (F3)</u>

$$F3 = 1.5\,(2M + 5L)$$

(d) <u>Cost of labour for plastering; per square (Internal plaster of 1 lime: 2½ sand - F41; External plaster of 1 cement : 1 lime : 5 sand - F42)</u>

$$F41 = 0.75M + 1.5L$$

$$F42 = M + 3L$$

(e) <u>Cost of materials for plastering, per square (Internal plaster of 1 lime : 2½ sand - F51; External plaster of 1 cement : 1 lime : 5 sand - F52)</u>

$$F51 = 3.25(Li) + 0.07\,S$$

$$F52 = 0.8C + (Li) + 0.07\,S$$

(f) <u>Scaffolding cost (F6)</u>

$$F6 = 215\,(X)$$

(g) <u>Total Cost</u>

It can be worked out as shown

by examples below :-

i) Cost of blockwork (with no plaster) per square = F1+F2+F3+F6

ii) Cost of blockwork (with one side internal plaster and other side external plaster) per square = F1+F2+F3+F41+F42+F51+F52+F6

iii) Cost of blockwork (with internal plaster on both sides) per square = F1+F2+F3+2(F41)+2(F51)+F6

3.8 Selection of the most economical block and bedding mortar (inclusive of plaster, if any) for the wall (Step 6) -

The costs obtained from the previous step, for the different wall systems considered, are used to select the most economical wall composition.

4.0 Use of design information

4.1 General

The process of using the above design information is self evident. It is possible to move forward or backward through different steps. In each application, the first operational step after the entry and the last operational step just before the exit should be identified. For applications listed in Section 2, the above details are given in Table 5. Some examples are given in the succeeding sections.

4.2 Example 1

Hollow blocks 400mm long x 200mm wide x 200mm high with block density of 13.2 kN/m³ and compressive strength of 4.5 N/mm² are available. Mortar of 1 cement : 5 sand is to be used for blocklaying. The building is of loadbearing masonry, 10.0m long x 8.0m wide, and roof is gabled with asbestos corrugated sheets at a slope of 22° to the horizontal. It satisfies all the other conditions given in 3.1 to qualify as a building more favourable than the typical building. Determine the number of storeys these blocks can carry.

The process to be used (see 2c of Table 5) - Backward travel; First operational step at entry = Step 4; Last operational step before exit = Step 2.

Step 4

Inputs at entry to step 4: compressive strength of hollow block = 4.5 N/mm²; s = 1.00; mortar designation = (iii) (see (v) of 3.2). Output from step 4 (Table 3): $f_k = 2.1 + \frac{1.1}{1.5} \times 1 = 2.83$ N/mm²

Step 3

Inputs at entry to step 3 : t = 200mm; $f_k = 2.83$ N/mm²
Outputs from step 3: K = 3.7037 (from Table 2); $f_w = \frac{2.83}{3.7037} = 0.765$ N/mm²

Step 2

Inputs at entry to step 2: $\rho = 13.2$ kN/m²; t = 200mm; $f_w = 0.765$ N/mm²
Outputs from step 2: f_w for 5-storeys = $0.752 + \frac{0.035}{2.0} \times 1.2 = 0.773$ N/mm²
(from Table 1); n = 4

Number of storeys the block can carry = 4

4.3 Example 2

A loadbearing masonry building is 3-storeyed and, in all other respects, it is identical to the typical building considered in 3.1. The following block types are available:-
(a) Block type 1 - 400mm long x 100mm wide x 200mm high; solid without cavities; Price = Rs.10.00 per block; compressive strength = 5.0 N/mm²;
(b) Block type 2 - 400mm long x 200mm wide x 200mm high; hollow with 55% of solid material; Price = Rs.11.00 per block; compressive strength = 3.5 N/mm². Walls are not to be plastered. Price/rates are as given in 3.7, except for blocks. Identity the most economical block and mortar mix for the building.

Application (Code number as listed in section 2)	Direction of travel through various steps	First operational step after entry	Last operational step before exit
2a	Forward	Step 1(see 3.3)	Step 6(see 3.8)
2b	Forward	Step 1(see 3.3)	Step 6(see 3.8)
2c	Backward	Step 4(see 3.6)	Step 2(see 3.4)
2d	Forward	Step 1(see 3.3)	Step 6(see 3.8)
2e	Forward	Step 1(see 3.3)	Step 4(see 3.6)
2f	Forward	Step 1(see 3.3)	Step 6(3.8)
2g	Backward	Step 4(see 3.6)	Step 1(see 3.3)
2h	One step only	Step 4(see 3.6)	Step 4(see 3.6)
2i	One step only	Step 4(see 3.6)	Step 4(see 3.6)

Table 5 - Use of design information for different applications

The process to be used (see 2d of Table 5) - Forward travel; First operational step at entry = Step 1; Last operational step before exit = Step 6.

(a) Apply the process to block type 1

Step 1

Input at entry to step 1 : r = 100
Output from step 1 : ρ = 0.22x100
= 22 kN/m³

Step 2

Inputs at entry to step 2 : = 22 kN/m³
t = 100mm; n = 3
Output from step 2 (from Table 1):
f_w = 0.848 N/mm²

Step 3

Inputs at entry to step 3: t = 100mm;
f_w = 0.848 N/mm²
Outputs from step 3: K = 5.8577 x 0.848
= 4.967 N/mm²

Step 4

Inputs at entry to step 4: s = 2.00;
Compressive strength of block = 5.0N/mm²;
Type of block = Hollow
Outputs: f_k for mortar designations (i), (ii), (iii), (iv) (from Table 4) = 5.0, 5.0, 5.0, 4.4 N/mm² respectively; Recommended mortar = mortar designation (iii); Possible mortar mixes (from (v) of 3.2) = 1 cement : 5 sand or 1 cement : 1 lime: 5 sand; economical mortar mix = 1 cement: 5 sand (In this case economical mix can be obtained before step 6 by inspection).

Step 5

Inputs at entry to step 5 : B = Rs.10.00;
other prices/rates = as given in 3.1;
mix proportion = 1 cement : 5 sand; no plaster.
Output: Cost = F1 + F2 + F3 + F6;
Cost of wall per square = Rs. 2105.98

Step 6

Not necessary as economical mortar mix was found earlier.

(b) Apply the process to block type 2

By repeating the above procedure for block type 2, it can be shown that blocks require mortar designation (iv), and mortar mix 1 cement: 8 sand or 1 cement : 2 lime: 9 sand (from (v) of 3.2) is suitable. The cost of wall per square is Rs. 2263.39 for the former mix and Rs. 2298.36 for the latter mix. Hence 1 cement: 8 sand mix is the most economical for block type 2.

(c) Identification of the most economical block and mortar mix

By considering costs of (a) and (b) above, it is clear that the most economical wall composition is block type 1 with 1 cement: 5 sand mortar for blocklaying.

5.0 Further extensions possible

It is possible to extend this treatment to masonry structures other than buildings such as clock towers, temple bell towers and water tank towers. To accomplish this task it is necessary to modify the contents of step 2 so that design compressive stress of masonry can be related to appropriate variables such as height, block density, and leading cross sectional dimensions of the masonry structure.

Ordinary bricks and wirecut bricks can also be included by modifying steps 2 and 3 (to include new wall thicknesses), and steps 4 and 5 (to include brick units as well).

Structures in zones of Sri Lanka other than where basic wind speed is 33.5 m/sec can be covered by modifying relationships in Step 2 to allow for the higher basic wind speed.

In situations where same building type is built repeatedly at various locations in Sri Lanka, selection of blocks and mortar can be simplified by modifying step 2 to cover the actual building under consideration.

6.0 Closure

The paper (i) presented necessary design information for preliminary selection of blocks and mortar, while highlighting the various stages of its development; (ii) eliminated design information that is superflous in the local context; (iii) interpolated or extrapolated realistically to cover Sri Lankan needs; (iv) illustrated by examples the use of design information; and (v) highlighted the limitations and outlined means by which further extensions can be incorporated to enlarge its range of applications.

7.0 References

1. BS 5628: Part 1: 1978, "Code of practice for the structural use of masonry - unreinforced masonry", BSI, London.

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6. CP 3: Chapter V: Part 2: 1972, "Basic data for design of buildings - Wind loads", BSI, London.