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Soil Cement Blocks For Low Cost Housing -- Correlation of Experimental Results With Site Observations

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SOIL CEMENT BLOCKS FOR LOW COST HOUSING - CORRELATION OF EXPERIMENTAL RESULTS WITH SITE OBSERVATIONS

By

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1. INTRODUCTION

The soil has been a basic material for the construction of walls in housing throughout the world for many centuries. The method of combining ordinary soils with a stabilising material has been extensively used. The walls constructed out of this, if well compacted, have adequate compressive strength under dry conditions. However, it may lose strength under adverse moisture movement when heavy rain beats against the walls. Small crevices and hair cracks in the external surface of a wall will lead the water into the wall and make it soft. The intermittent wetting and drying conditions would make the blocks to erode and finally deteriorate. In such cases, the outer face of the external walls should be treated with water-proofing material in order to avoid the erosive effect.

2. SOIL - CEMENT BLOCKS

The soil consists of sand, clay and silt. The proportion of sand and clay in the soil widely varies from place to place. It has been found by past investigators that the soil which contains 30% - 35% clay gives reasonably good results. As much as 70% of sand is used in South American countries. If a soil contains sand and clay in proportions outside the above range adjustments could be made to raise the proportions of the soil to the required level by the addition of sand or clay as the case may be. The presence of large percentage of silt has detrimental effect on the walls. Hence the use of soils containing large percentage of silt should be discouraged.

Cement is used as the stabilising agent for the soil blocks. The percentage by weight of cement varies with the type of soil used. Normally this is between 5% and 10%. The quantity of water used for the mixture will depend on the type of soil used. The mixture should neither be too dry nor too wet. The workability is poor if it is too dry; but if it is too wet shrinkage cracks will develop as the block sets. Therefore, just the right amount of water should be used to make the mixture easily workable. Experience has shown that water between the limits of 10% and 20% by weight is satisfactory.

3. STRENGTH REQUIREMENTS

The Building Institute at Addis Ababa, Ethiopia, had recommended that the minimum strength of soil cement blocks should be 300 lbf/in^2 (21 Kgm/c.m^2). In the case of houses built in Western Africa, strengths as low as 200 lbf/in^2 (14 Kgm/c.m.^{2}) have been accepted. It was found that the strength decreased with age, and also decreases under wet conditions. The percentage of water absorption would depend on the quantities of sand, clay, silt and cement. Blocks having high water absorption should be protected by water-proofing. It is possible to improve the strength and durability of blocks by increasing the cement content. However, the use of larger quantities of cement (more than 10%) will make the construction expensive.

4. PILOT LOW COST HOUSES IN TRINIDAD AND TOBAGO.

About 6 years back some 200 pilot houses using Cinva-Ram (soil cement) blocks were built in various locations, where there was a programme of house building in large numbers. The walls, foundations and ground floor slabs were constructed using the above blocks. The soil available near the site was used for making the blocks and 10% cement by weight was used in the manufacturing of all blocks. The block size was: 3 5/8" x 5 5/8" x 11 5/8". The Cinva-Ram machine (developed in 1956 by the Inter American Housing Centre in Bogota, Columbia) was used for the making of these blocks. Soil cement mixture was compressed in the above machine by applying a force of 40,000 lbf (18 metric tons). Even though the Inter American Housing Centre recommended a thickness of 6in for walls, only 4in thick walls were used in the above pilot houses.

Within 2 years after the completion of the above houses, difficulties were experienced in the external walls at certain locations due to rain beating on the surface of the walls. Erosion followed by disintegration of foundations and walls took place in the case of certain houses. The author and a U.N. expert were called upon to investigate all the pilot houses.

5. TESTS ON WALL BLOCKS AND OBSERVATIONS AT THE SITE

Visits were made to the sites and almost all the houses were inspected and observations made. The wall blocks used for these houses were tested in the Civil Engineering laboratory of the University of the West Indies for:

(a) Compressive Strength

(b) Water Absorption

(c) Silt Content (at certain sites only).

The test results in the laboratory and the observations made on the houses are given for various site locations.

6. SITE LOCATION 1.

The test results on the blocks used in the site are given in Table 1. Under dry conditions the compressive strength varied between 208 lbf/in^2 and 757 lbf/in^2 and the average was 432 lbf/in^2, and under wet conditions the stresses were reduced. The average was 268 lbf/in^2. The water absorption was between 3.7% and 6.3% with an average of 5.1%. The silt content was below 10%

The walls at the site were found to be in good condition two years after the work was completed. Even at the end of 5 years, most of the walls were in a satisfactory condition. However, a few houses had deterioration in a few blocks in the external walls. This was mainly due to the fact that the rain was beating regularly on these walls, and as a result these external walls that were affected had to be repaired. Wherever protection was given by plastering there was no erosion due to the water beating on the walls. In the case of the internal walls, these were in good condition and therefore did not need any protection.

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7. SITE LOCATION 2.

The maximum, minimum and the average compressive strengths under dry conditions were 510, 208 and 348 lbf/in^2 respectively. The corresponding water absorption percentages were: 10.0, 2.5 and 5.6. The average strength of blocks under wet conditions was: 318 lbf/in^2.

The houses built using the above blocks were generally satisfactory, and at the end of 5 years no erosion of external walls were seen. Two coats of lime wash were applied to many of these houses at regular intervals and the external walls in these cases were in a very good condition.

8. SITE LOCATION 3.

The test results are given in Table 3. The compressive strength under dry conditions varied between 156 lbf/in^2 and 426 lbf/in^2, and the average was 315 lbf/in^2. The average under wet conditions was 222 lbf/in^2. The water absorption percentage varied between 4.2 and 12.4 and the average was 7.9. The silt content was below 10%.

The houses built using these blocks for walls were found to be in a satisfactory condition at the end of 5 years. No trace of erosion was found in the outer surface of the external walls.

9. SITE LOCATION 4.

The test results are given in Table 4. The crushing strength under dry conditions varied between 184 lbf/in^2 and 475 lbf/in^2 and the average was 300 lbf/in^2. Under wet conditions the strength of the blocks dropped to almost one half of the original strenght. The water absorption varied between 8.2% and 11.1% and the average was 9.3%.

The external walls erected using these blocks were found unsatisfactory. Erosion of the outer surface of these walls took place within 5 years due to intermittent beating of rain water on the surface. As recesses were allowed in the blocks on the outer surface, rain water beating on the recesses penetrated through the blocks and the inner face of the outer walls were found to be wet. Because of the fast deterioration of the external walls, they subsequently had to be rebuilt using concrete blocks. Test of blocks and site observations were made in two other locations and the results were similar to those given under Location 4.

10. SITE LOCATION 5.

The test results are given in Table 5. The maximum, minimum and average crushing strength under dry conditions were 431, 327 and 375 lbf/in^2. Under wet conditions the strength dropped considerably and most of the blocks had a strength below 200 lbf/in^2. The water absorption percentage varied between 12.0 and 15.6 and the average was 13.9. The silt content was in the range 30% - 35%.

The external walls (4in thick) were in a very bad condition at the end of 2 years. The recesses on the outer face of the walls, though they gave the houses a pleasing wall pattern, aggravated the erosion of the blocks by allowing water to penetrate through the recesses. Serious deterioration took place just above the ground level of the exterior walls and also below the window sills. This was mainly due to the beating of rain water and splashing of the water from the ground to the walls. The foundation blocks disintegrated due to partial stagnation of water. Some blocks crumbled when crushed between the hands. This was primarily due to the presence of high percentage of silt in the soil used. The parapet walls eroded easily as there was no protection against weather. Within 6 months after the above observations were made, the external walls in most of the houses collapsed under heavy rain. These walls were subsequently re-built using concrete blocks. There was wear and tear in the floor slabs.

There were a few houses which were plastered and painted before the deterioration took place and these were found to be reasonably satisfactory. However, deterioration had been observed in projecting walls exposed to the rain. It was found in some cases that there was no proper adhesion between the blocks and the plastering, and cracks in the plaster were observed.

11. DISCUSSION AND CONCLUSIONS

From the test results obtained in the laboratory and the observations made on the behaviour of wall blocks in the site under adverse atmospheric conditions it is now possible to correlate the two results. In Locations 1 and 2 the average compressive strength under dry conditions was above 300 lbf/in^2 and under wet conditions it was above 250 lbf/in^2. In both cases the average water absorption percentage was below 6 . In Location 3 the strength under dry conditions was above 300 lbf/in^2. The average water absorption was below 8%. In all the above cases the blocks were found to be generally good even at the end of 6 years in spite of the heavy rainfall in the area. This was mainly due to the fact that the silt content was below 10%. From the above observations it is reasonable to conclude that load-bearing wall blocks having an average compressive strength of 300 lbf/in^2 under dry conditions and 250 lbf/in^2 under wet conditions, and water absorption of below 8% are good. In these cases no protection is necessary in the way of water-proofing for the walls. However, in places where the rainfall is heavy, protecting of the outerface of the external walls will give long life to the structure.

At Location 4, even though the average strength was 300 lbf/in^2 under dry conditions, the strength dropped to below 200 lbf/in^2 under wet conditions. The average water absorption percentage was above 9. Due to rain beating on the external walls erosion took place and with time disintegration occured. If the wall thickness were made 6in instead of 4in the loss of strength would have been minimised. Similar observations were made in two other locations. The silt content was observed to be high in these locations. Wherever protection to the outer face of the external walls was given by the application of two coats of lime-wash the blocks were found to be satisfactory and erosion was arrested.

At Location 5, even though the average strength under dry conditions was much above 300 lbf/in^2, it dropped to below 50% of the above strength under wet conditions. The water absorption percentage was above 12. The recesses on the outer face of the external wall let water into the walls, and intermittent wetting and drying led to complete disintegration and failure of the structure within 3 years. The foundation also disintegrated in many places. This was primarily due to the presence of 30% - 35% silt content. The position was made worse by the use of 4in thick wall instead of 6in thick wall. Protection of these

blocks will be expensive and economically prohibitive. The blocks with the above characteristics are bad and are unsuitable to be used for load bearing external walls. The internal walls, though 4in thick and even without protection were found to be in a satisfactory condition in all the pilot houses.

12. RECOMMENDED SPECIFICATIONS

In the light of the observations made in 200 pilot houses using soil cement blocks and the information obtained in other countries, the author recommends the following specifications for use in developing countries:

A. LOAD BEARING WALLS AND EXTERNAL WALLS

1. The silt content in the soil should be less than 10%. The percentage of sand and clay are variable from place to place and soils containing sand up to 70% may be used.
2. The cement content should not be more than 10% and not less than 5%.
3. The minimum thickness of all walls should be 6in.
4. No groove or recess should be allowed in the outer face of the external walls, and the face should be made plane.
5. The average compressive strength should be 300 lbf/in^2 for 5 units (dry), and 250 lbf/in^2 for a single block.
6. The water absorption should not exceed 12%. Blocks with a water absorption of less than 8% may not need any protection against weather. Blocks having a water absorption between 8% and 12% should be water-proofed.
7. The use of soil cement blocks for foundations should be avoided in places where there is heavy rainfall.
8. A damp-proof course should be provided at least 3in above the ground level.
9. Adequate drainage should be allowed to drain off stagnant water near the external walls.

NOTE: In general it is desirable to make the outer face of all external walls water-proof to have long life for the structures. Two coats of lime wash at regular intervals may be satisfactory. (In India, an application of Hydroplast, a Clay Bitumen Emulsion, to external walls has been found to be satisfactory for surface protection against dampness. Also an application of Sylex, an extract from the cashew nut shell, has been found to be effective. This material is termite-proof as well as water-proof.

For non-load bearing internal walls the above specifications may be relaxed depending on the site conditions.

13. ACKNOWLEDGEMENT

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TABLE 1 LOCATION 1

VALUES	DRY OR WET	DRY WT. LB	CRUSHING STRESS lbf/in^2	WATER ABSORPTION %		REMARKS
				After 1 HOUR	After 24 HOURS	
MAXIMUM	DRY	17.52	757	-	-	Silt Content <10%
MINIMUM		16.69	208	-	-	
AVERAGE OF 8		17.07	432	-	-	Blocks Good
MAXIMUM	WET	17.70	407	4.3	6.3	Satis-factory
MINIMUM		16.42	171	2.1	3.7	
AVERAGE OF 8		17.09	268	3.2	5.1	

TABLE 2 LOCATION 2

MAXIMUM	DRY	17.23	510	-	-	Blocks Good
MINIMUM		15.62	208	-	-	
AVERAGE OF 8		16.51	348	-	-	
MAXIMUM	WET	18.10	439	9.1	10.0	Satis-factory
MINIMUM		15.34	156	1.8	2.5	
AVERAGE OF 8		16.87	318	4.6	5.6	

TABLE 3 LOCATION 3

VALUES	DRY OR WET	DRY WT. LB	CRUSHING STRESS lbf/in2	WATER ABSORPTION %		REMARKS
				After 1 HOUR	After 24 HOURS	
MAXIMUM	DRY	16.07	426	-	-	Silt Content <10%
MINIMUM		14.90	156	-	-	
AVERAGE OF 6		15.45	315	-	-	Blocks Good
MAXIMUM	WET	16.28	302	11.6	12.4	Satis-factory
MINIMUM		14.84	135	2.7	4.2	
AVERAGE OF 8		15.58	222	6.1	7.9	

TABLE 4 LOCATION 4

MAXIMUM	DRY	16.64	475	-	-	Strength Good
MINIMUM		15.50	184	-	-	
AVERAGE OF 9		16.15	300	-	-	
MAXIMUM	WET	16.55	276	11.1	11.1	Unsatis-factory
MINIMUM		15.46	89	7.0	8.2	
AVERAGE OF 8		16.26	169	8.8	9.3	

TABLE 5 LOCATION 5

VALUES	DRY OR WET	DRY WT. LB	CRUSHING STRESS lbf/in^2	WATER ABSORPTION %		REMARKS
				After 1 HOUR	After 24 HOURS	
MAXIMUM	DRY	16.05	431	-	-	Silt Content 30%- 35%
MINIMUM		15.10	327	-	-	
AVERAGE OF 7		15.36	375	-	-	Strength Good
MAXIMUM	WET	15.70	260	14.1	15.6	Blocks Bad
MINIMUM		14.15	123	11.3	12.0	
AVERAGE OF 8		15.05	168	13.3	13.9	

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