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RENDERING FOAMED CONCRETE WALLS

Experimental Studies at the Central Building Research Institute

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In view of the reported failures of renderings applied to foamed concrete partition walls, a study of the compatibility of different types of renderings was carried out at the Central Building Research Institute, Roorkee.

The nature and magnitude of the movements of the renderings and backing were observed under simulated tropical conditions. The present study indicates that, while the movements of the renderings were in step with those of the backing, the magnitude of the movements was related to the composition of the renderings. The resistance of the renderings to cracking was determined from the ratio of the tensile strength at rupture to the actual tensile stress imposed by the restrained shrinkage. The values were found to be 2·00, 1·99, *and* 2·17 *for* 1 : 4, 1 : 6, *and* 1 : 6 (*air-entrained*) *cement-sand renderings,* 3·17, 3·47, *and* 4·29 *for* 1 : 1: 6, 1 : 2 : 9, *and* 1 : 3 : 12 *cement-lime-sand renderings, and* 3·79 *for* 1 : 2 *gypsum-sand rendering.*

Weak cement-lime-sand mixes such as 1 : 2 : 9 *and* 1 : 3 : 12 *are therefore recommended for rendering foamed concrete walls.*

IN India foamed concrete 'Vayutan' is being manufactured by the prefoaming method.[1] Fully autoclaved blocks of unit weight about 40 lb/ft^3 have been increasingly used for building partition walls. Cracking of the renderings, however, has been a serious drawback throughout even though the specifications were modified from time to time.

According to Saretok,[2] failures may originate either in the rendering itself or in the carcass of a building. Since reasonably dry blocks and a weak mortar (1 : 2 : 9 cement-lime-sand) were used for walls which were built with adequate rigidity,[3] failure of the rendering was considered to be more probable. Suitability of different types of renderings for the foamed concrete backing was therefore investigated.

Arrangement of Experiments

The properties of the foamed concrete blocks were tested according to British Standard 2028 : 1953 for Precast Concrete Blocks. The composition of the renderings studied is given in the first column of *Table* 2, ordinary Portland cement conforming to IS 269 : 1951 and lime conforming to IS 712 : 1956 being used in their preparation. The aggregate component of the renderings was a well graded natural sand conforming to BS Standards 1198, 1199. The proportioning of the mixes was done on a weight basis. For determining the physical and strength characteristics of the renderings, the mixes were brought to a workable consistency by the addition of a quantity of water such as to give a flow of 100 to 115 when tested according to ASTM Designation C109—54T. The rendering based on gypsum as a binder was brought to a standard consistency in accordance with specifications given in ASTM Designation C 26-54.

In respect of curing, the following schedule was followed. The specimens of all the mixes, with the exception of 1 : 2 gypsum-sand, were cured at a relative humidity of not less than 90 per cent for the first 24 hours, under water (at 27 ± 2°C) for a further period of 6 days, and finally at a relative humidity of 50 ± 5 per cent for 21 days. In the case of the 1 : 2 gypsum-sand mix, the specimens were cured for the first seven days at a relative humidity of not less than 90 per cent, and subsequently at 50 ± 5 per cent humidity till the weight of the specimens showed negligible loss.

The testing of specimens for strength was done according to normal procedures. The dynamic modulus of elasticity was determined by finding the resonant frequency of prismatic specimens (10 in × 2 in × 2 in) excited in the flexural

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TABLE I. Test conditions for the exposure of the rendered foamed concrete blocks

Serial No	Test condition	Total time elapsed since plastering	Remarks
A.	In moist closet of not less than 90 per cent relative humidity	8 hours	Only measurement of the movement of the blocks, was possible at this stage, the rendering being too weak.
B.	Rendered surface in continuous contact with water	24 hours	The first reading of the rendering was taken and henceforth movements in the blocks as well as in the rendering were recorded.
C.	As above	7 days	Movements were recorded after every 24 hours.
D	Rendered blocks exposed to relative humidity of 50 ± 5 per cent, temp. 27 ± 2°C	28 days	Movements were recorded at an interval of 3 days.
E.	Rendered blocks dried at 40 ± 2°C and a relative humidity of 17 per cent	—	Till such time that there was no further dimensional change.

TABLE 2. Properties of the renderings

Composition of the renderings (by vol)	Compressive strength lb/in²		Flexural strength lb/in²		Tensile strength lb/in²		Bond tensile strength lb/in²	Shrinkage per cent
	7 days	28 days	7 days	28 days	7 days	28 days	28 days	
1 : 4 cement-sand	624	916	306	445	104	148	25·0	0·122
1 : 6 cement-sand	450	784	114	202	55	75	20·0	0·139
1 : 6 cement-sand (air-entrained)	230	448	103	190	51	71	11·0	0·112
1 : 1 : 6 cement-hydrated lime-sand	405	660	100	176	80	114	18·0	0·159
1 : 2 : 9 cement-hydrated lime-sand	107	186	42	73	29	43	15·0	0·139
1 : 3 : 12 cement-hydrated lime-sand	37	53	10	21	20	27	13·0	0·128
1 : 2 gypsum-sand	159	165	77	77	26·8	26·3	29·0	0·052 (expansion)

mode.[4] The adhesive strength of the renderings to the foamed concrete backing was determined by casting disc specimens of 2 in dia and 1 in thickness on the backing and pulling them apart from the backing after 28 days of curing, the first 7 days at 99 per cent relative humidity and the subsequent 21 days at 50 ± 5 per cent humidity.

To study the relative movements of the various renderings, they could either be applied to individual blocks or to a panel constructed of them. The former was preferred because of the better control of the test conditions. Menzel also has indicated his preference for individual blocks in a similar type of investigation.[5] For testing the renderings, each one was brought to the standard workability (flow of 100 to 115) and then applied immediately to the face of at least three blocks after cleaning and wetting the faces with an adequate quantity of water which was found by trials to be 3 per cent of the weight of the block. Each rendering was applied in a single coat to an average thickness of $\frac{3}{8}$ in. The movements in the renderings as well as on the faces of the rendered blocks were recorded with the aid of a Huggenborger deformeter of 10 in gauge length and a reading accuracy of 0·0001 in. The value of each movement reported in the paper is an average of at least nine values.

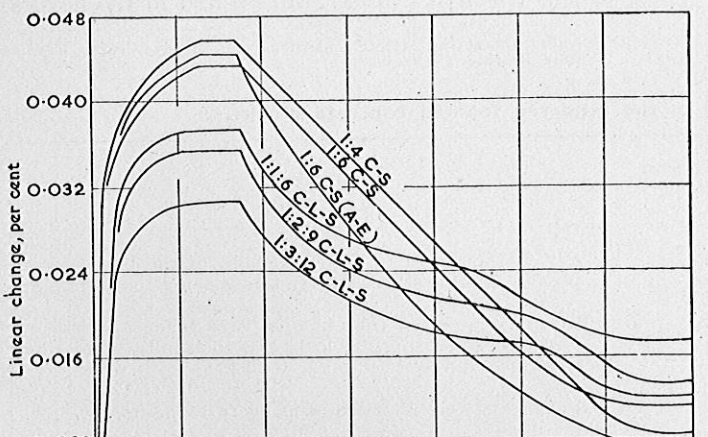

Fig 1

The movements were measured under various test conditions (*Table* 1) which were formulated with a view to simulating not only the practical conditions of the setting, curing and final drying but also the prevailing atmospheric conditions. While curing in the field is done by sprinkling water on the rendering for seven days, in the laboratory it was done by bringing the rendered surface in contact with water as the former method lacks reproducibility. Similarly though renderings in the field undergo a variety of temperature and humidity conditions, in the laboratory the Indian standard temperature of 27 ± 2°C was chosen. For determining ultimate shrinkage, the blocks were dried at a temperature of 40 ± 2°C and a humidity of 17 per cent to simulate the extreme conditions of the hot summer months.

Results and discussion

For a rendering to be durable under a particular set of climatic conditions, it is desirable that it is compatible with the backing, *i.e.*, a good degree of adhesion is obtainable, that its strength bears some relation to that of the backing and finally its movements are in step with those of the backing.[2] The experiments were designed to obtain information on these points.

Properties. The physical and strength characteristics of all the renderings studied are reported in *Table* 2 and the results are self-explanatory.

Melegan A, manufactured by Imperial Chemical Industries Ltd, India was used for entraining air in the 1 : 6 cement-sand mix. The amount of air entrained was found to be ... per cent when determined as per ASTM Designation C1... 55T. The foamed concrete blocks were tested as per specifications given in BS 2028 : 1953 for type C blocks. The average compressive strength was found to be 238 lb... and the transverse strength test carried out on 2-in th... blocks gave the average breaking load of 139 lb. The values of the moisture movement and drying shrinkage were found to be 0·08 to 0·11 per cent and 0·10 to 0·14 per cent respectively, when determined according to the ... procedure prescribed in the abovementioned standard. ... values are rather high.

The expansion of the faces of the blocks on wetting ... found to be 0·041 to 0·065 per cent depending upon ... initial moisture content of the blocks which absorbed 10-... per cent water by volume in 24 hours. When the blocks were exposed to 99 per cent humidity, the moisture absorption was 6·2 per cent and the corresponding expansion as 0·026 per cent. Since the absorption of moisture by

TABLE 3. Linear changes in the rendered blocks of the foamed concrete

Change in test condition	Per cent linear changes in the renderings and the backing: 1 : 4 cement-sand		1 : 6 cement-sand		1 : 6 cement-sand (air-entrained)		1 : 1 : 6 cement-hydrated lime-sand		1 : 2 : 9 cement-hydrated lime-sand		1 : 3 : 12 cement-hydrated lime-sand		1 : 2 gypsum-sand	
	Rendering	Backing	Rendering	Backing	Rendering	Backing	Rendering	Backing	Rendering	Backing	Rendering	Backing	Rendering	Backing
From A to B	+0·014	+0·014	+0·011	+0·012	+0·015	+0·015	+0·019	+0·017	+0·014	+0·014	+0·017	+0·015	*	nil
From B to C	+0·009	+0·010	+0·012	+0·009	+0·010	+0·0105	+0·009	+0·008	+0·008	+0·008	+0·009	+0·007	+0·005	+0·005
From C to D	—0·037	—0·037	—0·032	—0·032	—0·0373	—0·0370	—0·019	—0·020	—0·021	—0·021	—0·020	—0·019	—0·018	—0·018
From D to E	—0·031	—0·031	—0·0355	—0·035	—0·035	—0·036	—0·0417	—0·0410	—0·021	—0·022	—0·0206	—0·022	—0·019	—0·024

\+ denotes expansion.
— denotes shrinkage.
* First reading was taken at 24 hours in this case.

foamed concrete affects its thermal insulating quality and the foamed concrete is known to have poor resistance to the diffusion of water vapour,[2] it is desirable to protect it by a suitable rendering.

Movements. The movements of the rendered blocks over a period of 28 days are shown in *Fig* 1. During the first eight hours of their application the renderings lost moisture mostly to the backing (the loss to the surrounding atmosphere of high humidity would be small) which showed expansion to varying degrees. Both the rate of expansion and the total expansion were highest in the case of cement-sand renderings. The cement-lime-sand renderings come next in order and the gypsum-sand renderings gave the lowest values, being + 0·008 per cent at eight hours, + 0·013 per cent at 7 days and + 0·005 per cent at 28 days.

The quantity of the moisture lost by the renderings to the backing was found to be related to its water retaining capacity. The latter in turn was found to depend on the composition of the rendering. The pattern of expansion of the backing on wetting the rendered surface with water did not change, *i.e.*, it was maximum for the cement renderings, minimum for 1 : 2 gypsum-sand rendering and the cement-lime renderings had intermediate values. The expansion of the cement-lime-sand renderings can be related to the cement content. The greater the amount of the cement, the greater the expansion. These findings are in agreement with those of Voss.[6]

Subsequent drying in a relative humidity of 50 ± 5 per cent resulted not only in a higher rate of drying but also a higher value of total movement from 7 to 28 days for cement renderings when compared to those containing lime and cement both. The curves also show that the latter type of renderings dried in stages. In short, cement-lime renderings are superior to those containing only cement as binder.

The nature and magnitude of the dimensional changes in the renderings are reported in *Table* 3 together with the corresponding values for the backing. The results show that, in general, the movements of the renderings were in step with those of the backing implying a good degree of bond between the two. The difference in the two movements in some cases may be an experimental error or may indicate the existence of shear stresses. If the latter is correct, the stresses do not seem to be of any consequences.

Unrestrained shrinkage. Plummer[7] and others[8,9] have shown that if the test specimens are cast in absorbent moulds instead of the normal metallic ones, the shrinkage may be reduced as much as 50 per cent. Saretok[2] has emphasized the need of standardizing the dimension of the test specimens and the method of measuring shrinkage. Therefore, to obtain a more realistic value, the shrinkage of the renderings cast on the foamed concrete backing was measured. For this purpose the specimens were prepared exactly as described earlier except that the bond between the rendering and the backing (the faces of three foamed concrete blocks) was broken by placing a fine strong cloth in between before applying the rendering to the backing. The specimens were then subjected to the various test conditions (*Table* 1), and readings were taken as before. The values of the unrestrained shrinkage thus obtained (column 2 of the *Table* 4) were found to be about 30-60 per cent of the values obtained by the normal method.

Resistance to Cracking. If, at any time, the shrinkage stresses in the rendering become greater than its tensile strength, the rendering will crack. The relative resistance of the various renderings to cracking is reported in *Table* 4 and was calculated from the ratio of the tensile strength at rupture to the actual tensile stress imposed by the restrained shrinkage. The former was determined by testing the briquettes which were cast in the moulds lined with the foamed concrete. The values thus obtained were found to be two to three times the values obtained by the normal method, *i.e.*, casting the specimens in metallic moulds (column 3 of

TABLE 4. Relative resistance of the renderings to cracking

Rendering	Unrestrained shrinkage, e, per cent	Restrained shrinkage, e, per cent	Unit shrinkage prevented, $(e' - e) \times 10^{-2}$	Modulus of Elasticity (sonic), $lb/in^2 \times 10^6$	Stress, p, lb/in^2	Ultimate tensile strength, p′, lb/in^2	Resistance to cracking R = p′/p
1 : 4 cement-sand	0·0730	0·0680	0·0050	2·79	139·5	280·0	2·00
1 : 6 cement-sand	0·0723	0·0675	0·0048	1·78	85·4	170·0	1·99
1 : 6 cement-sand (air-entrained)	0·0765	0·0723	0·0042	1·67	69·3	151·0	2·17
1 : 1 : 6 cement-hydrated lime-sand	0·0660	0·0607	0·0053	1·20	63·6	202·0	3·17
1 : 2 : 9 cement-hydrated lime-sand	0·0460	0·0420	0·0040	0·72	29·0	100·5	3·47
1 : 3 : 12 cement-hydrated lime-sand	0·0445	0·0406	0·0039	0·55	21·5	92·2	4·29
1 : 2 gypsum-sand	0·0400	0·0370	0·0030	1·16	34·8	132·0	3·79

Table 2). The actual tensile stress imposed was calculated by multiplying the unit shrinkage prevented by the backing with the corresponding values of the modulus of elasticity.

The resistance to cracking or the factor of safety has been determined in the past from the ratio of the extensibility (or ultimate breaking strain) of the mix and its maximum shrinkage subsequent to hardening.[10] In the light of the findings of the present study, this method is perhaps not realistic as it does not take into account the influence of the backing and the conditions prevailing in the field.

The two specifications which have been followed mostly for rendering foamed concrete walls in actual construction are 1 : 5 or 1 : 6 cement-sand over hecked cement washed surface, or an undercoat of 0·12 in (3 mm) thick 1 : 6 cement-sand and a finishing coat of 1 : 1 : 6 cement-lime-sand. Though such specifications have been recommended by one manufacturer,[11] the present study indicates the value of R as about 2 for cement-sand compositions. If the curing of the cement renderings in the field is not done sufficiently and carefully, the rate in gain in strength may not be sufficient to withstand the ever increasing shrinkage stresses and this may ultimately lead to the appearance of cracks. This may explain why cement-sand renderings did not show a good performance under practical conditions.

Of the various cement-lime-sand renderings, any of them may be used; however, 1 : 2 : 9 or 1 : 3 : 12 are to be preferred. Foamed concrete panels (4 ft × 6 ft) plastered with 1 : 2 : 9 and 1 : 3 : 12 renderings have not shown any cracks for the last one year. The 1 : 2 gypsum-sand rendering requires a finishing coat and as such may not be economical. Also the use of gypsum plaster under tropical conditions is not recommended.[12]

Conclusions

In the case of walls constructed with lightweight concrete blocks of relatively low strength, the choice of the right type of rendering is important and an estimation of the relative resistance of various types of renderings to cracking has been found helpful in making a selection. In general, weak renderings such as 1 : 2 : 9 and 1 : 3 : 12 cement-lime-sand a recommended for the foamed concrete 'Vayutan'.

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