ELSEVIER

0958-9465(95)00019-4

Cement & Concrete Composites 17 (1995) 301–310

0958-9465/95/$9.50

Strength, Durability and Shrinkage Characteristics of Cement Stabilised Soil Blocks

P. J. Walker*

Department of Resource Engineering, University of New England, Armidale, Australia

(Received 16 January 1995; accepted 15 May 1995)

Abstract

The paper outlines results of a comprehensive investigation undertaken to assess the influence of soil characteristics and cement content on the physical properties of stabilised soil blocks. The dry density, compressive and flexural strength, durability and drying shrinkage of over 1500 block tests are outlined in the paper. Experimental results are compared with current specifications and used to develop empirical guidelines for cement content requirements for a range of soil plasticity characteristics. An empirical relationship between compressive and flexural strength is proposed as a simple means of field assessment.

Keywords: Clay content, compressive strength, dry density, durability, modulus of rupture, ordinary portland cement, plasticity index, shrinkage, stabilised soil blocks.

INTRODUCTION

Most soils in their natural condition lack the strength, dimensional stability and durability required for building construction. These inherent deficiencies may be overcome through a process of stabilisation by mechanical compaction and addition to the soil matrix of chemical binders, such as cement or lime, or waterproofing agents, such as bitumen. In comparison with most conventional building materials cement stabilised soil blocks offer a number of advantages for low cost residential construction. They maximise utilisation of local materials, require simple construction methods and offer high thermal and acoustic insulation. Typically cement stabilised soil blocks require less than 10% of the input energy used to manufacture similar fired clay and concrete masonry units.[1]

Despite these advantages the use of stabilised soil blocks is often restricted. The lack of standard performance criteria and adequate guidelines for both manufacturers and builders are major problems. Stabilised soil blocks are typically excluded from national masonry design codes. These deficiencies are reflected by the general lack of published material on the physical properties of stabilised soil blocks.[2]

In response to such restrictions a two year research program was undertaken at the University of Zimbabwe to study the physical characteristics of cement stabilised soil blocks. The results of this systematic investigation are summarised in this paper. The influence of soil properties and cement content on compressive and flexural strength, durability and drying shrinkage characteristics are discussed. Experimental results are compared with current specifications, and used to derive empirical guidelines for cement content requirements for a range of soil types.

MATERIALS

To assess the influence of constituent materials on block properties a range of modified soils, with a broad spectrum of plasticity characteristics, were formed by mixing together a clay soil and a river sand. The particle size distributions of these soils are summarised in Table 1. The total loss on ignition of the clay soil and river sand samples was 10·5% and 0·2% respec-

*Formerly: Department of Civil Engineering, University of Zimbabwe, Harare, Zimbabwe.

tively. By using modified soils, as opposed to a variety of natural soils, greater control over extraneous factors such as organic content was achieved.

The clay soil and river sand were dry mixed (by volume) in varying proportions between 100% clay : 0% sand and 15% clay : 85% sand. The full range of modified soils used and their plasticity characteristics are outlined in Table 2. Modification of the clay soil with sand provided a full spectrum of soils suitable for stabilisation with cement. In addition to the modified soils, blocks were also produced using three natural soils (denoted soil B, E and M). These additional tests were undertaken to check the general applicability of the modified soil test results. Ordinary portland cement was used throughout for chemical stabilisation. For each modified soil mixture cement was added in proportions of 1: 10, 1: 15 and 1: 20 (cement : soil by dry volume), covering the full range typically used for cement soil blocks. At greater than 10% cement content stabilisation generally becomes uneconomical. Blocks containing less than 5% cement are often too friable for easy handling.

MANUFACTURE OF TEST BLOCKS

Initially the modified soils were formed by combining the clay soil and river sand, and only after thorough mixing was the cement added. Once the dry ingredients were thoroughly mixed water was gradually added until the optimum moisture content was attained. For each soil:cement mix a total of 35–40 blocks were produced. The total production time from initial materials mixing to pressing of the final block was typically 45 minutes.

A manually operated constant volume block press was used throughout (Fig. 1). The study was limited to manual block presses, as these are most widely used. Under normal operation the single acting ram develops compaction pressures in the range 2–4 MN/m^2. In the investigation maintenance of consistent compactive effort was achieved between different soil : cement mixes by careful operation of an experienced press operator. Once the required compactive effort had been achieved the amount of material fed into the mould was volume batched. The press used produced blocks with nominal dimensions, in their as pressed

Table 1. Soil grading

Soil type	*Fine gravel (2–6 mm)*	*Sand (0·06–2 mm)*	*Silt (0·002–0·06 mm)*	*Clay (<0·002 mm)*
Clay soil	6%	31%	13%	50%
River sand	20%	76%	3%	1%
	13%	40%	27%	20%
Soil B				
Soil E	7%	80%	12%	1%
Soil M	3%	21%	53%	23%

Table 2. Soil properties

Clay soil content (Vol %)	*River sand content (Vol %)*	*Liquid limit*	*Plasticity index*	*Linear shrinkage*
100	0	60	35	17%
80	20	56	32	13%
70	30	50	29	13%
60	40	46	26	12%
50	50	45	23	9%
40	60	35	20	4%
35	65	33	18	4%
30	70	31	16	3%
25	75	28	14	3%
20	80	24	10	3%
15	85	22	Non-plastic	2%
		51	27	12%
Soil B				
Soil E			Non-plastic	1%
Soil M		29	15	6%

aspect, of 295 mm (length) x 140 mm (width) x 130 mm (height).

After compaction the fresh blocks were extruded from the press and stored for curing. Primary curing of the blocks was undertaken for the first seven days after pressing, during which the blocks were placed onto precast concrete plinths and moisture cured under polythene. After seven days the blocks were stacked and curing completed under polythene sheeting. All blocks were tested 28 days after pressing.

TESTS

All block testing was undertaken in accordance with standard methods.[3,4,5] The blocks used in any test were randomly selected from the consignment of units produced from each soil: cement mix. During preparation for each test dry densities were routinely determined, using

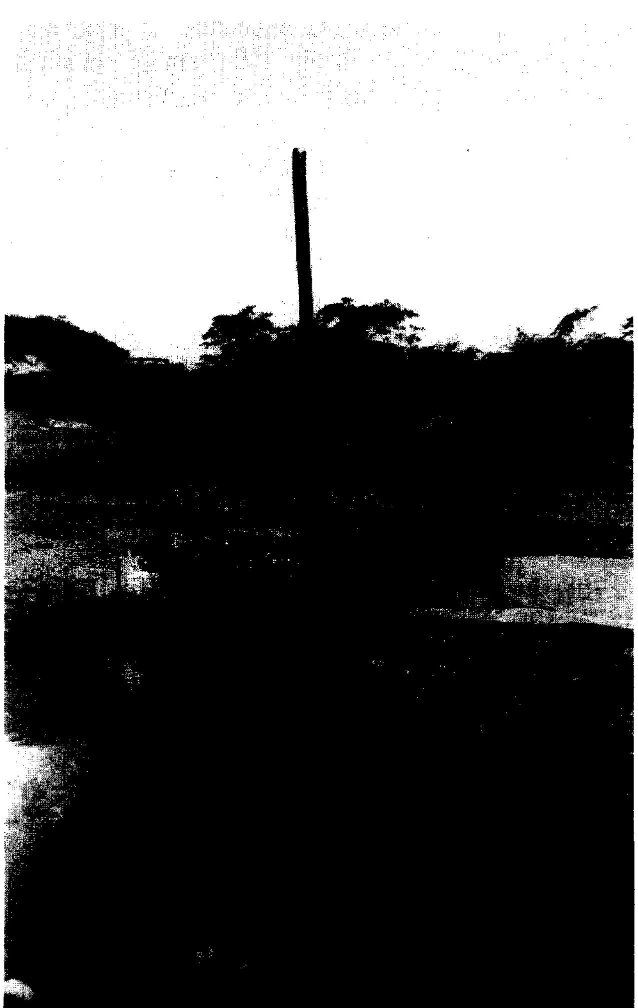

Fig. 1. Block press.

the averaged external dimensions and net oven dried mass of each block.

Both saturated and dry uniaxial unconfined block compressive strengths were determined. Saturated specimens were immersed in water for 24 hours prior to testing. The dried samples were placed in an oven set at 105 °C for 48 hours, after which they were air cooled for approximately 3 hours prior to testing. All blocks were tested in compression uncapped between two 3 mm thick sheets of plywood, in their normal, as pressed, bed face aspect. Using a 2500 kN capacity Avery testing machine, load was applied continuously at a steady rate of 3·5 $N/mm^2/min$ up to failure. The compressive strength of each block was determined from its failure load and averaged bed face area.

Laboratory testing is expensive and often inappropriate for low cost housing schemes. A series of flexural strength tests was therefore undertaken to assess the feasibility of using block modulus of rupture as an indirect means of estimating compressive strength. A total of five blocks from each mix consignment were tested for modulus of rupture. All blocks were tested saturated, in their as pressed aspect, under central point loading and simply supported over a span of 200 mm. Loading was applied continuously at a rate of 2 kN/min up to failure using a screw jack and recorded with a 10 kN proving ring. Modulus of rupture was determined from the failure load and averaged central cross-section dimensions.

The average drying shrinkage of three blocks from each mix was determined in accordance with BS 6073.[3] Shrinkage movements were assessed using a 200 mm demec gauge, with studs placed along the longitudinal faces of each block. Initially the blocks were prepared by immersion, for 96 hours, in a water tank set at 23 °C. After removal from the water initial demec readings were taken. Each block was then placed in a ventilated oven set at 50 °C. The demec gauges were periodically recorded, for approximately 14 days, until constant readings were attained. Drying shrinkage was determined by subtracting the final dry from the initial saturated demec strain gauge readings.

Determination of the resistance to water erosion was undertaken using the wire brush test specified in ASTM standard D559-89.[5] This test was restricted to one block from each consignment. Initially the block was immersed in water at 23 °C for 6 hours, after which it was removed and placed in a ventilated oven, set at 70 °C, for 42 hours. After drying the block was abraded twice using the specified wire scratch brush. The exerted brush pressure was maintained at 1·5 kg using a set of scales. Two full strokes of the brush were exerted on all surfaces. Immersion, drying and abrasion constitutes one test cycle. After brushing the blocks were re-immersed in water for 6 hours to commence the next cycle. After a total of twelve cycles the dry mass of each block was recorded, and the reduction in mass due to the accelerated weathering determined. Weathering resistance is considered acceptable if the total mass loss does not exceed 10%. Comparisons with field performance show the test to be severe, and thus a generally conservative indicator of weathering resistance.[2]

EXPERIMENTAL RESULTS AND DISCUSSION

Dry density

Block dry density is largely a function of the constituent material's characteristics, moisture content at pressing and the degree of compactive effort applied. Average densities for each mix are given in Table 3. As expected, dry densities were closely related to the clay soil content, generally decreasing with increasing clay content, and relatively independent of cement content.

A series of tests was undertaken to check the consistency of compactive effort applied during production. Consistency in compactive effort is clearly important for a meaningful comparison of material performance. Samples of each soil:cement mixture were compacted in the laboratory using an Avery actuator and a mild steel mould having the same dimensions as the manual press. The moisture content of the soil:cement mixture, applied loading rate and drainage corresponded to those used in production. Tests indicated that the compactive effort for all blocks produced varied between 2·0–3·5 MN/m^2, with an average for the majority of consignments of 2·5 MN/m^2.

Saturated compressive strength

The failure mode in uniaxial compression for all soil blocks tested is shown in Fig. 2. Block compressive strength was, as expected, a function of both cement and clay content (Table 3). Average saturated compressive strength decreased with a reduction in cement content and increasing plasticity index (Fig. 3). Reduction in compressive strength due to increasing clay content was most pronounced for soil plasticities between 15–25. Compressive strength was relatively unaffected by clay content for plasticity indices below 15. These experimental data are in general agreement with previously reported trends.[2]

Compressive strength reduction with increased clay content is primarily attributed to the weakening effect of the clay minerals on bonding between the cement paste and sand/fine gravel matrix. Although cement does react with and tend to stabilise clay minerals, the strength of this colloidal/cement structure is significantly weaker than the granular/cement matrix. As clay content increases and so the sand and fine gravel content decreases, block strengths are reduced. The effectiveness of cement, or indeed any stabiliser, is also impaired by the presence of aggregations of cohesive soil formed during mixing. Although after testing pockets of unstabilised soil were not observed, it is likely that small amounts were present, especially in the higher clay content mixes.

A typical relationship between unit saturated compressive strength and dry density is presented in Fig. 4. Within the relatively limited range of densities recorded the expected correlation between compressive strength and block den sity is well defined, and similar to that recorded elsewhere.[2] It is clear that in order to optimise the properties of any given soil:cement mix the available compactive effort should be fully utilised in production. Heathcote has proposed using the correlation between dry density and compressive resistance as a means of estimating strength.[6] However, given the inherent variability of the material any relationship is likely to be approximate at best and certainly no substitute for physical testing.

Recommended and specified values for the minimum acceptable average saturated compressive strength of cement stabilised blocks vary between 1·0–2·0 N/mm^2. [2,7,8,9] Whilst, a large number of the blocks tested demonstrated adequate strength in accordance with these publications, the coefficients of variation recorded were typically greater than the 20% deemed acceptable for concrete units.[3] Thus, in addition to average values the 95% characteristic values for compressive strength have also

Table 3. Summary of block test results

Soil-cement ratio	Clay soil content	Plasticity index	Average dry density (kg m^{-3})[a]	Saturated compressive strength (N mm^{-2})			Dry compressive strength (N mm^{-2})			Dry/saturated (average)	Modulus of rupture (N mm^{-2})			Modulus of rupture/compressive strength (characteristic)	Average drying shrinkage[e]	Wire brush test (% dry mass)
				Average[a]	Coeff. var.	Characteristic	Average[b]	Coeff. var.	Characteristic		Average[b]	Coeff. var.	Characteristic			
10:1	100%	35	1706	1·45	25·4%	0·95	4·44	18·8%	3·07	3·1	0·13	32·5%	0·07	0·074	0·552%	11·0
	80%	32	1733	1·88	29·6%	1·14	4·22	19·1%	2·90	2·2	0·22	22·3%	0·13	0·114	0·220%	12·0
	70%	29	1725	1·82	8·6%	1·54	5·05	14·8%	3·82	2·8	0·31	12·1%	0·24	0·155	0·150%	7·2
	60%	26	1784	1·74	9·1%	1·46	4·17	27·5%	2·29	2·4	0·31	9·2%	0·24	0·164	0·135%	8·5
	50%	23	1839	2·50	16·6%	1·76	5·37	37·8%	2·04	2·1	0·28	39·0%	0·13	0·074	0·100%	6·5
	40%	20	1851	4·01	20·8%	2·51	7·21	16·7%	5·23	1·8	0·46	20·6%	0·28	0·112	0·020%	3·0
	35%	18	1870	4·37	21·4%	2·79	7·86	23·2%	4·87	1·8	0·81	37·2%	0·30	0·108	0·030%	3·4
	30%	16	1835	4·35	21·9%	2·55	7·12	10·5%	5·89	1·6	0·68	39·3%	0·27	0·106	0·005%	3·1
	25%	14	1896	4·51	13·5%	3·36	6·94	19·5%	4·72	1·5	0·57	11·1%	0·43	0·128	0·040%	1·6
	20%	10	1888	4·58	18·5%	3·14	7·79	30·1%	3·94	1·7	0·64	48·3%	0·17	0·054	0·020%	1·2
	15%	Non-plastic	1848	4·51	19·2%	3·20	7·14	13·7%	5·54	1·6	0·71	24·6%	0·38	0·136	0·025%	1·0
	Soil B	27	1704	2·92	20·1%	1·92										
	Soil E	Non-plastic	1906	4·49	9·3%	3·70										
	Soil M	15	1785	3·48	15·0%	2·56										
15:1	100%	35	1791	0·92	25·0%	0·51	4·73	32·5%	2·21	5·1	0·16	18·2%	0·11	0·216	0·345%	19·4
	70%	29	1668	1·27	9·4%	1·06	4·11	9·9%	3·44	3·2	0·23	12·8%	0·17	0·160	0·170%	5·4
	60%	26	1715	1·47	5·3%	1·32	3·52	6·6%	3·14	2·4	0·14	35·0%	0·06	0·045	0·125%	2·6
	50%	23	1712	1·59	19·0%	1·09	3·00	21·5%	1·94	1·9	0·15	27·9%	0·08	0·073	0·110%	6·7
	40%	20	1857	4·52[c]	32·7%	1·92	6·41[d]	44·9%	1·69	1·4	0·38	12·5%	0·28	0·146	0·025%	1·6
	35%	18	1813	3·38	23·2%	2·05	4·40	14·3%	3·34	1·3	0·36	29·5%	0·14	0·068	0·010%	—
	30%	16	1831	3·01	23·6%	1·75	4·49	17·0%	3·23	1·5	0·29	27·1%	0·15	0·089	0%[f]	4·2
	25%	14	1850	3·02	24·1%	1·88	3·93	16·2%	2·88	1·3	0·33	20·1%	0·20	0·141	0%[f]	3·9
	20%	10	1841	2·87	20·0%	1·92	5·42	22·9%	3·38	1·9	0·49	28·1%	0·27	0·141	0%[f]	3·4
	15%	Non-plastic	1848	2·87	27·3%	1·81	5·39	49·4%	3·31	1·9	0·37	12·6%	0·27	0·149	0%[f]	1·1

Table 3. — *contd.*

Soil-cement ratio	*Clay soil content*	*Plasticity index*	*Average dry density* $(kg\ m^{-3})$[a]	*Saturated compressive strength* $(N\ mm^{-2})$			*Dry compressive strength* $(N\ mm^{-2})$			*Dry/saturated (average)*	*Modulus of rupture* $(N\ mm^{-2})$			*Modulus of rupture/compressive strength (characteristic)*	*Average drying shrinkage*[e]	*Wire brush test (% dry mass)*
				Average[a]	*Coeff. var.*	*Characteristic*	*Average*[b]	*Coeff. var.*	*Characteristic*		*Average*[b]	*Coeff. var.*	*Characteristic*			
20:1	100%	35	1607	0·66	20·7%	0·37	5·07	22·9%	3·18	7·7	0·14	21·0%	0·08	0·216	0·560%	29·5
	80%	32	1690	0·85	15·5%	0·62	3·58	25·6%	2·80	4·2	0·11	24·5%	0·06	0·097	0·230%	22·5
	70%	29	1672	0·80	11·2%	0·64	2·53	16·9%	1·83	3·2	0·13	8·8%	0·11	0·172	0·150%	21·9
	60%	26	1670	0·80	13·5%	0·58	2·84	12·2%	2·27	3·6	0·11	15·0%	0·08	0·138	0·135%	17·6
	50%	23	1788	1·32	18·9%	0·88	2·93	14·2%	2·25	2·2	0·14	8·4%	0·11	0·125	0·075%	8·8
	40%	20	1821	2·38	31·4%	1·14	3·88	17·7%	2·75	1·6	0·22	30·8%	0·10	0·088	0·010%	7·9
	35%	18	1844	2·68	30·1%	1·34	3·54	23·3%	2·19	1·3	0·21	9·5%	0·16	0·119	0·015%	16·1
	30%	16	1835	2·34	34·7%	1·10	4·21	27·4%	2·32	1·8	0·21	55·4%	0·05	0·045	0·010%	11·7
	25%	14	1833	3·12	20·4%	1·31	4·84	5·2%	4·43	1·6	0·19	27·6%	0·10	0·076	0%[f]	6·9
	20%	10	1849	2·99	29·2%	1·57	4·43	14·8%	3·35	1·5	0·23	43·6%	0·05	0·032	0%[f]	11·0
	15%	Non-plastic	1836	2·91	21·0%	1·60	—	—	—	—	0·19	22·1%	0·12	0·063	0%[f]	11·0
	Soil B	27	1703	1·45	27·7%	0·80										
	Soil M	15	1822	2·17	15·1%	1·57										

[a] Average of 10 sample tests.
[b] Average of five sample tests.
[c] Test result omitted from Fig. 3.
[d] Test result omitted from Fig. 6.
[e] Average of three sample tests.
[f] No discernible shrinkage recorded.

been determined; calculated in accordance with BS 5628 Part 2.[10]

The relationship between characteristic compressive strength, soil properties and cement content is similar to that obtained using average values. The influence of constituent materials is, however, more clearly defined (Fig. 5) and the decrease in compressive strength due to plasticity index more gradual. Additional block tests, using soils B, E and M, show reasonable agreement with the general trend of the modified soil test results; the agreement is generally improved using the characteristic results. To date the general trend has been to use average values when specifying minimum performance requirements of stabilised soil blocks. However, characteristic values are more appropriate, as they take into account inherent variability in quality control of both the manufacturing process and, more importantly, the materials used.

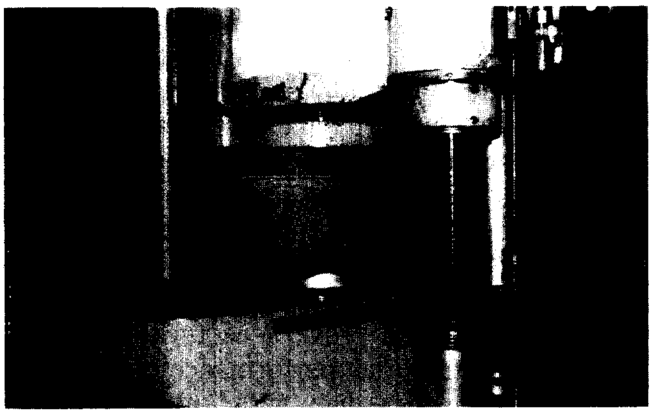

Fig. 2. Typical failure in compression.

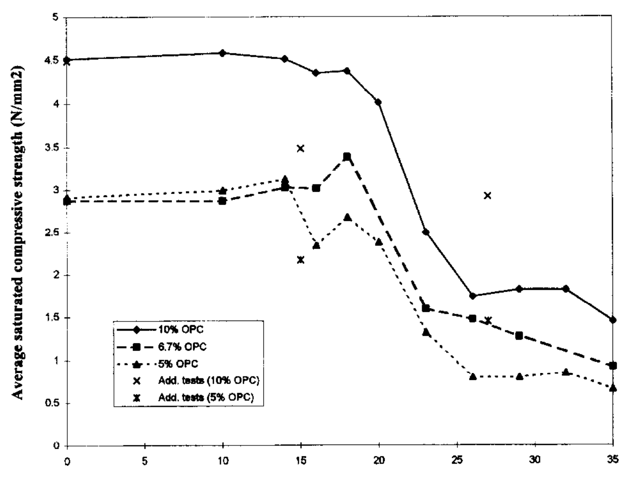

Fig. 3. Variation of average saturated compressive strength with plasticity index.

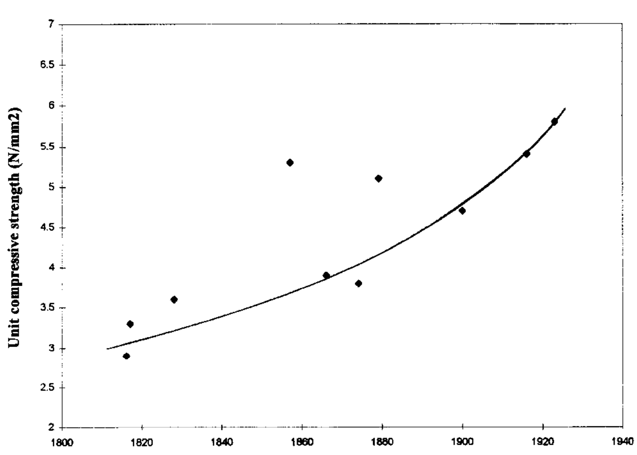

Fig. 4. Typical relationship between unit compressive strength and dry density (Mix: 10% OPC, PI=18).

Dry compressive strength

Compression testing is generally undertaken in the saturated condition, as this yields least strength, and for this reason the strength of soil blocks is most often specified using saturated performance. Reduction in compressive strength with saturation can be attributed to the development of pore water pressures and the liquefaction of unstabilised clay minerals in the block matrix. In contrast to most proposals, the current Australian recommendation specifies the minimum compressive strength (2 N/mm^2) in terms of both dry and characteristic performance.[11]

Results for dry compressive strength testing are given in Table 3. For all cases considered the dry compressive strength obtained was greater than the corresponding saturated value. The ratio between average dry and saturated

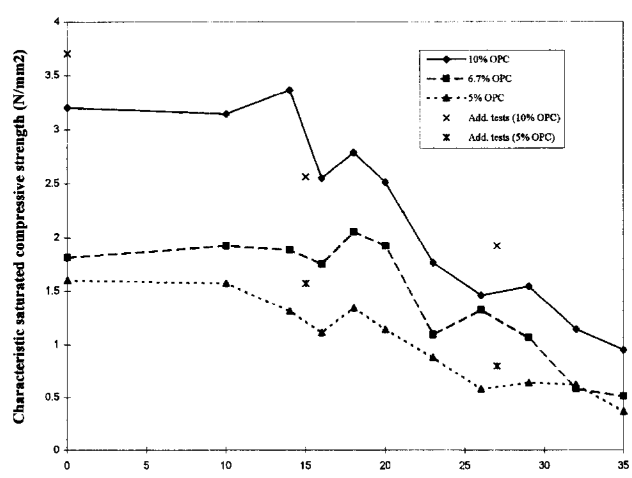

Fig. 5. Variation of characteristic saturated compressive strength with plasticity index.

compressive strengths varied between 1·3 and 7·7, and, as expected, was largely dependent on clay content. Although cement content still had a significant influence on dry compressive strength, the detrimental effects of clay were less obvious (Fig. 6). Clays have an inherent uniaxial dry compressive strength which is lost with saturation. To avoid these apparent ambiguities in material performance, the compressive strength of stabilised soil blocks should be uniformly obtained under saturated conditions.

Modulus of rupture

Under central point loading all blocks failed in flexure with development of a tensile crack in the middle third span. Central point loading may therefore overestimate flexural strength, as modulus of rupture was evaluated using the value for peak bending moment at failure. Block flexural strength was closely correlated with cement and clay content, and as expected values for modulus of rupture exhibited similar trends to compressive strength behaviour (Table 3). For example, at 10% cement content the average flexural strength decreased from 0·64 N/mm^2 to 0·31 N/mm^2 as the plasticity index increased from 10 to 29. This corresponds to a 52% decrease in flexural strength, compared to a 60% decrease in compressive strength over the same range.

The correlation between the characteristic values for saturated modulus of rupture and saturated compressive strength is presented in Fig. 7. Experimental results are compared with a proposed specification that modulus of rupture shall equal at least one-sixth of the corresponding compressive strength.[9] Despite a relatively large scatter in the data most of the results fall below the one-sixth relationship; all blocks violating this relationship have inadequate saturated compressive strength (Table 3). The relationship would seem to represent an upper bound performance limit, rather than a lower bound as implied by the proposal.

On the basis of the experimental data the one-sixth relationship provides a relatively simple means, by flexural testing, for indirect assessment of block compressive strength. Flexural testing should prove a useful and reliable indicator of material performance, particularly if undertaken together with other measurements suited to field analysis, such as density and durability assessment. It is not, however, a substitute for direct compressive strength testing, as the relationship may prove unnecessarily conservative.

Drying shrinkage

The results for average block shrinkage are given in Table 3 and Fig. 8. Drying shrinkage of the blocks was primarily governed by the plasticity index of the constituent soil, and to a lesser extent by cement content. For soil plasticity index below 20 there was a steady increase in drying shrinkage with increasing clay content. Once the plasticity index exceeded 20, drying shrinkage increased rapidly as the clay content also increased. As expected, drying shrinkage at low plasticity also noticeably increased with

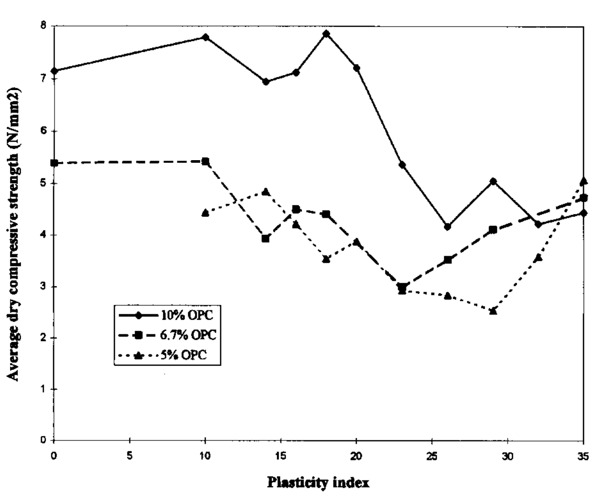

Fig. 6. Variation of average dry compressive strength with plasticity index.

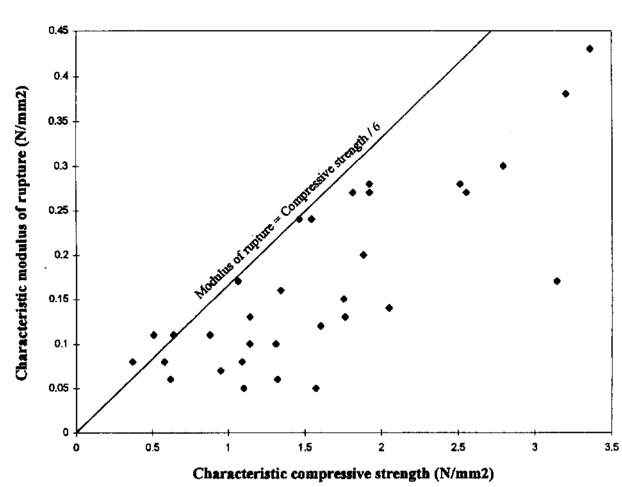

Fig. 7. Relationship between compressive strength and modulus of rupture.

cement content. Adopting 0·10 % as a limiting value for the drying shrinkage of cement soil blocks, based on similar requirements for concrete units, [3,4] the suitability of a mixture is governed primarily by the soil properties rather than cement content. On the basis of these data drying shrinkage requirements are satisfied by using soils with plasticity index less than 20.

Durability

Resistance to weathering tests were undertaken on one block randomly sampled from each mix consignment (Table 3). As with strength characteristics durability was improved by increased cement content and reduced clay content. Cement acted to bond the soil particles together, improving durability, whereas the clay minerals disrupted this action. The occurrence of unstabilised material was likely to be particularly detrimental to the durability of the blocks.

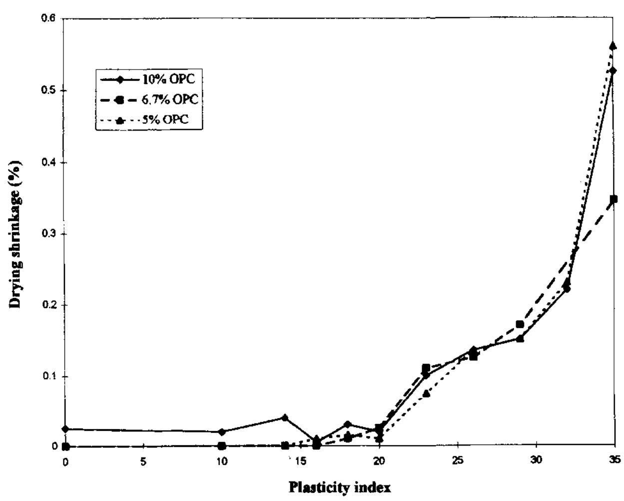

Fig. 8. Relationship between drying shrinkage and plasticity index.

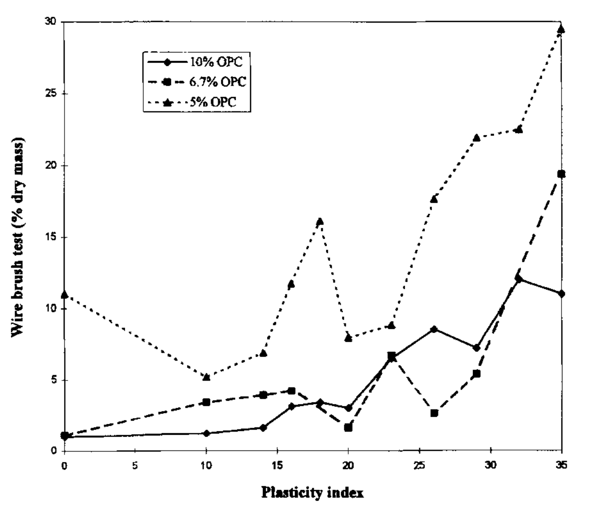

Fig. 9. Relationship between durability and plasticity index.

In accordance with the ASTM test[5] durability was generally satisfied by the 10% and 6·7% cement content mixes, except for those with very high clay contents, (Fig. 9). The observed variation in experimental performance can be attributed to the conditions of the block surfaces prior to testing; blocks previously damaged in some way will generally exhibit higher losses in the abrasive test cycle. For the range of cement contents used, adequate durability performance is generally assured for soils having plasticity index below 15–20. Higher clay contents require increased cement stabilisation, and 10% cement is likely to prove adequate for soils with a plasticity index up to 25. Since the ASTM test is considered severe in comparison with actual field performance,[2] the suitability of a soil for cement stabilisation is, therefore, most likely to be determined by considerations of strength and shrinkage, rather than durability.

SUMMARY AND CONCLUSIONS

The experimental data presented in this paper gives an important insight into the relationships between cement content, soil properties and the physical characteristics of stabilised soil blocks. Although these data are necessarily limited in their coverage of soil constituents and compaction pressures, they provide the basis for developing cement content guidelines for block manufacturers and assist in the development of standard criteria.

Both saturated strength and durability of cement stabilised soil blocks are improved by increased cement content and impaired by clay content. The most ideal soils for cement soil block production have a plasticity index between 5 and 15. Soils with a plasticity index above 20–25 are not suited to cement stabilisation using manual presses, due to problems with excessive drying shrinkage, inadequate durability and low compressive strength.

On the basis of the experimental results cement content requirements, in the range 5–10%, to meet saturated characteristic compressive strengths of 1·0, 2·0 and 3·0 N/mm^2, using a manual press, are outlined below. Due to the inherent variability of soils these recommendations can only provide basic guidelines for cement requirements. It is unlikely that constitutive relationships for stabilised soil blocks will ever be as well defined as those, for example, of concrete and mortar.

Plasticity Index	Recommended cement content (% Vol.)		
	1 N/mm^2	2 N/mm^2	3 N/mm^2
<15	5%	7%	10%
15–20	5%	10%	Unsuitable
20–25	6·5%	Unsuitable	
25–30	8·5%		
30–35	10%		
>35	Unsuitable		

Strength testing of soil cement specimens should be undertaken in a saturated condition, as the inherent strength of dry clay content may provide a misleading impression of compressive resistance. Due to the inherent variability of the main constituent material strength values should be specified in terms of 95% characteristic rather than average values. Although the test can prove conservative, adopting a one-sixth relationship between modulus of rupture and compressive strength provides the basis for rapid and inexpensive field assessment.

Although limited, much of the work undertaken on stabilised soil blocks to date has concentrated on the properties of the individual units. Further work is required to consider the suitability of mortars for construction and the properties of stabilised block masonry under compressive and lateral loading.

ACKNOWLEDGEMENTS

The author wishes to thank: the Intermediate Technology Development Group (Zimbabwe) and in particular Peter Tawodzera, Ken Pakathi and Kelvin Mason; the staff of the Department of Civil Engineering, University of Zimbabwe, for their assistance with the experimental work.

REFERENCES

1. Worthing, G. W., Samarasinghe, W. & Lawrence, S. J., Pressed earth blocks in Australia — A review. In *Proc. Fourth International Seminar 1992, Structural Masonry for Developing Countries*, ed. R. Ambalavanan & B. P. Sinha, Tata McGraw-Hill, New Delhi, pp 211–216.
2. Houben, H. & Guillaud, H., *Earth Construction — A comprehensive guide*. Intermediate Technology Publications, London, 1994.
3. British Standard 6073, *Precast concrete masonry units*. British Standards Institution, London, 1981.
4. Australian Standard 2733, *Concrete Masonry Units*. Standards Australia, Sydney, 1984.
5. ASTM D559, *Wetting and Drying Compacted Soil-Cement Mixtures*. American Society for Testing and Materials, Philadelphia, 1989.
6. Heathcote, K., Compressive strength of cement stabilised pressed earth blocks. *Building Research and Information*, **19**, 2 (1991) 101–105.
7. Fitzmaurice, R., *Manual on Stabilised Soil Construction for Housing*. United Nations, New York, 1958.
8. International Labour Organisation, *Small-scale Manufacture of Stabilised Soil Blocks*. Technical Memorandum No. 12, Geneva, 1987.
9. United Nations Centre for Human Settlements, *Kenya Specification for Stabilised Soil Blocks*. Nairobi, 1989.
10. British Standard 5628, *Use of masonry, Part 2. Structural use of reinforced and prestressed masonry*. British Standards Institution, London, 1985.
11. Middleton, G. F. & Schneider, L. M., *Bulletin No. 5 — Earth Wall Construction*. Fourth Edition, National Building Technology Centre, Chatswood, NSW, 1987.