# Chapter 7
# Characteristics of Flowable Stabilised Earth Concrete

**K. Gourav and S. N. Ullas**

## 7.1 Introduction

Soil has been extensively used for various construction purposes since ages. Soil is one of the most abundantly available materials used for the production of construction products such as adobe, cob, stabilized soil block and rammed earth. Generally, rammed earth technique is used to produce load-bearing monolithic walls (Verma and Mehra 1950; Walker et al. 2005; Easton 1982, 2008; Hall 2002; Kotak 2007; Reddy and Kumar 2009, 2011; Reddy et al. 2017). But, rammed earth construction demands rigid formwork.

Concrete made with soil is being used for pavements and non-structural components. Studies of Arooz and Halwatura (2018) have used mud–concrete for the production of blocks and have checked the durability aspects of the block. Damme and Houben (2017) have attempted to improve the workability and the strength of raw earth by controlling the dispersion of its fine fractions. There are hardly any studies on the workability and strength of lean and rich flowable earth concrete mix proportions.

The scope of the present study focusses on examining the influence of soil content on workability and compressive strength of lean and rich concrete mixes.

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## 7.2 Materials and Methods

### *7.2.1 Materials Used in the Experimental Investigations*

Following materials were used:

i. Ordinary Portland Cement (OPC) confirming to BIS IS 12269-2013 (2013)
ii. Aggregates:
   a. Fine aggregates—Manufactured sand (M-Sand)
   b. Coarse aggregates—Crushed granite
iii. Soil: Red loamy soil having clay, silt and sand size fractions of about 30, 13 and 57%, respectively.

Figure 7.1 shows the particle size distribution curves for soil and M-Sand used in the investigation.

### *7.2.2 Experimental Programme and Testing Procedures*

Two nominal mix proportions of 1:3:5 and 1:5:8 (cement: fine aggregate: coarse aggregate) by mass was chosen as control mix considering the nominal mix proportions given in BIS IS 456-2000 (Reaffirmed 2005) (2005). Two mix proportions were selected, namely Mix 1 (1:3:5) and Mix 2 (1:5:8). The coarse aggregates used were 20 and 12 mm in size, in equal proportions. The fine aggregates in the mix were

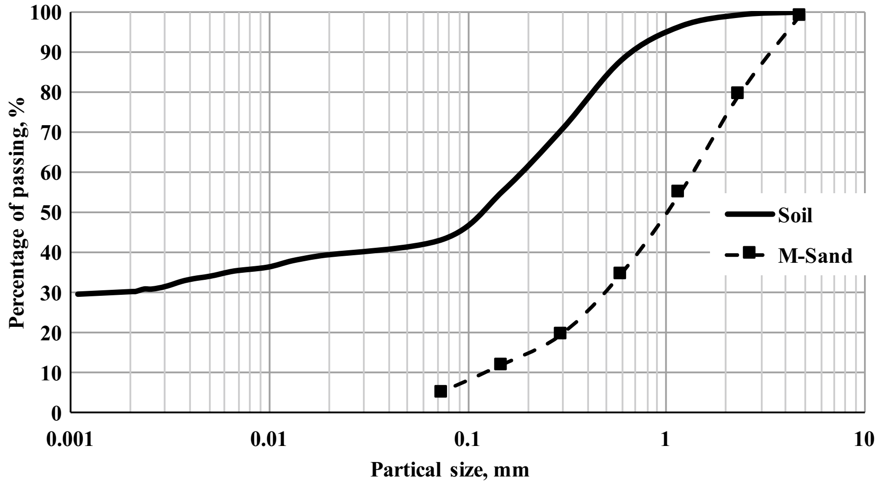


**Fig. 7.1** Particle size distribution of soil and M-Sand

**Table 7.1** Mix proportions used in the investigation

| S. No. | Designation | Soil (%) | Mix proportions: by mass | | | | |
|---|---|---|---|---|---|---|---|
| | | | Cement | Fine aggregates | | Coarse aggregates (50%—20 mm: 50%—12 mm) | |
| | | | | Soil | M-sand | | |
| 1 | Mix 1 | A | 0 | 1 | 0 | 3 | 5 |
| 2 | | B | 35 | 1 | 1.05 | 1.95 | 5 |
| 3 | | C | 50 | 1 | 1.50 | 1.50 | 5 |
| 4 | | D | 65 | 1 | 1.95 | 1.05 | 5 |
| 5 | Mix 2 | A | 0 | 1 | 0 | 5 | 8 |
| 6 | | B | 35 | 1 | 1.75 | 3.25 | 8 |
| 7 | | C | 50 | 1 | 2.50 | 2.50 | 8 |
| 8 | | D | 65 | 1 | 3.25 | 1.75 | 8 |

replaced by 0, 35, 50 and 65% with soil. The soil contents of 0, 35, 50 and 65% are designated as A, B, C and D, respectively, in both the control mixes. The details of the mix proportions used in the investigation are given in Table 7.1.

Workability and compressive strength of Mix 1 and Mix 2 having various percentages of soil were investigated. BIS IS 456-2000 (Reaffirmed 2005) (2005) recommends a range of 50–100 mm slump for medium workability. Hence, water/cement ratio of the concrete mix was controlled to have a slump value in the range of 50–100 mm. The workability and compressive strength of the concrete were determined following the BIS IS 516-1959 (Reaffirmed 2004) (1959) guidelines. The concrete cube specimens of 150 × 150 × 150 mm were used for determining the compressive strength upon 28 days curing period.

## 7.3 Results and Discussion

### *7.3.1 Workability and Compressive Strength of FEC*

Workability of the mix proportions was examined by conducting standard slump test, by varying the water content. Water/cement ratio corresponding to 80–90 mm slump was noted, and 150-mm cube specimens were cast to determine the compressive strength. The water/cement ratio and the compressive strength of the Mix 1 and Mix 2 for various soil replacements are given in Table 7.2. The slump and the compressive strength values given in Table 7.2 are average of three tests.

Mix 1 A, B, C and D required a water/cement ratio of 0.8, 0.95, 1.07 and 1.13 for a slump value between 80 and 90 mm. The corresponding compressive strengths of the Mix 1 are 24.82, 22.52, 15.56 and 14.81 MPa, respectively. Similarly, Mix

**Table 7.2** Workability and compressive strength of FEC

| S. No. | Mix proportions | | Slump (mm) | Water/cement ratio | Compressive strength (MPa) |
|---|---|---|---|---|---|
| 1 | Mix 1 | A | 81 | 0.80 | 24.82 (0.43) |
| 2 | | B | 88 | 0.95 | 22.52 (1.72) |
| 3 | | C | 83 | 1.07 | 15.56 (1.27) |
| 4 | | D | 89 | 1.13 | 14.81 (1.07) |
| 5 | Mix 2 | A | 82 | 1.15 | 14.82 (1.79) |
| 6 | | B | 83.5 | 1.55 | 10.27 (0.63) |
| 7 | | C | 84 | 1.65 | 8.68 (0.68) |
| 8 | | D | 83 | 1.8 | 8.31 (0.33) |

*Values given in parenthesis are standard deviation

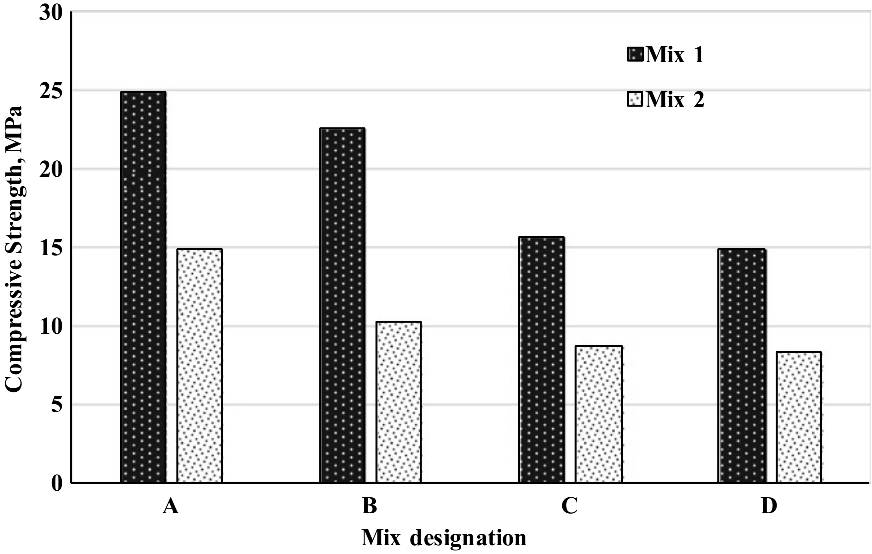


**Fig. 7.2** Compressive strength of mix proportions

2 A, B, C and D required a water/cement ratio of 1.15, 1.55, 1.65 and 1.8 for a slump value between 80 and 90 mm. The corresponding compressive strengths of the Mix 2 are 14.82, 10.27, 8.68 and 8.31 MPa, respectively. Figure 7.2 shows the plot of compressive strength of Mix 1 and Mix 2 for various percentages of soil replacement. Mix 2 requires higher water/cement ratio than the Mix 1. In both the mixes, an increase in soil content to replace the fine aggregates demands higher water/cement ratio for achieving required workability. This may be attributed to increase in fine particles such as clay and silt at higher soil content. Hence, strength falls with an increase in soil content.

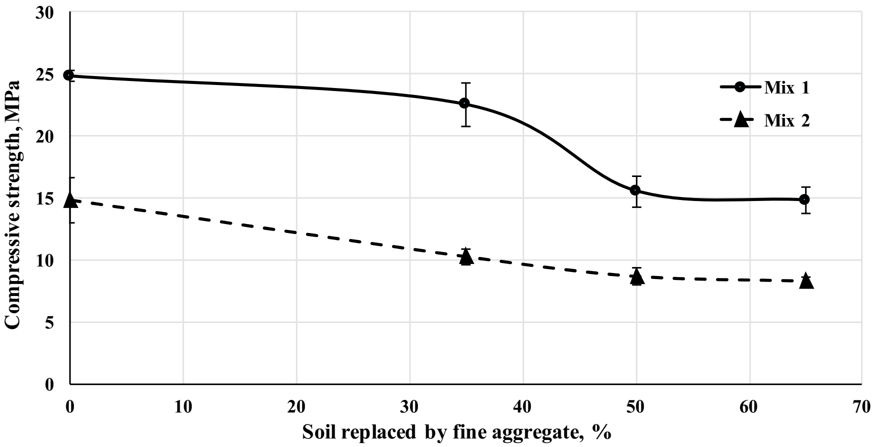


**Fig. 7.3** Compressive strength versus fine aggregate replacement by soil

### 7.3.2 *Influence of Soil on Strength of FEC*

Figure 7.3 shows the plot of compressive strength versus the soil replacement by fine aggregate. Compressive strength of both the mixes (Mix 1 and Mix 2) decreases with increase in soil content in the mix. There is about 40% decrease in compressive strength from 0 to 65% soil replacement in Mix 1 and about 43% decrease in compressive strength in case of Mix 2.

## 7.4 Comparison with Strength of CSEB and CSRE

The objective of the present investigation was to explore FEC as an emerging material for masonry construction. As discussed in the earlier section, CSEB and CSRE have gained acceptance as alternative masonry materials and the engineering properties of CSEB and CSRE have been widely explored. Since FEC concrete also is a soil-based product, it may be worth comparing some of the properties of FEC, CSEB and CSRE. The compressive strength of FEC, CSEB and CSRE with respect to clay content and cement percentage is reported in Table 7.3. From the results presented in Table 7.3, it may be observed that in CSEB and CSRE, the clay content examined is in the range of 5–20%, cement content for stabilisation is in the range of 5–12%, and the clay and cement content in FEC examined in the present study is also within such range. However, it may be noted that the CSEB and CSRE can be produced with various densities and the strength is sensitive to density achieved, whereas FEC is compacted by vibration to achieve maximum compaction similar to conventional concrete making practice.

**Table 7.3** Comparison of properties of CSEB, CSRE and FEC

| Type of material | | Clay content[a] (%) | Cement content (%) | Compressive strength (MPa) | Source |
|---|---|---|---|---|---|
| CSEB | | 11 | 5 | 6.4 | Walker (2004) |
| | | 11 | 10 | 10.3 | |
| | | 20 | 5 | 5.4 | |
| | | 21–24 | 4–5 | 3.3–6.6[b] | |
| | | 9 | 6 | 3.13 | Reddy and Gupta (2006) |
| | | 9 | 8 | 5.63 | |
| | | 9 | 12 | 7.19 | |
| | | 5.4 | 8 | 4.54 | Reddy et al. (2007) |
| | | 10.9 | 8 | 4.99 | |
| | | 16.3 | 8 | 4.73 | |
| | | 21.7 | 8 | 4.42 | |
| CSRE | | 9 | 8 | 2.32 | Reddy and Kumar 2011 |
| | | 12.6 | 8 | 2.45 | |
| | | 15.8 | 8 | 3.2 | |
| | | 21.1 | 8 | 2.82 | |
| | | 14.3 | 7 | 3.44–4.6[b] | Reddy et al. (2017) |
| | | 14.3 | 10 | 5.01–7.44[b] | |
| FEC Mix 1 | B | 10.5 | 11.12 | 22.52 | Present study |
| | C | 15 | 11.12 | 15.56 | |
| | D | 19.5 | 11.12 | 14.81 | |
| FEC Mix 2 | B | 10.5 | 7.14 | 10.27 | |
| | C | 15 | 7.14 | 8.68 | |
| | D | 19.5 | 7.14 | 8.31 | |

[a]Clay content in mixture of soil and sand; [b]For a range of densities achieved

## 7.5 Practical Significance of FEC

The FEC was expected to yield compressive strength similar to that of CSEB and CSRE and the results obtained during the present study are promising. Hence, FEC can be a potential material for wall construction in general, and in particular, it can be a convenient material for mass construction needs such as sanitary units and soak pits, pavements and water storage sumps because raw materials are locally available, formwork needed is simple, and construction is quicker. There have been some attempts in using FEC for such applications and are shown in Figs. 7.4 and 7.5.

**Fig. 7.4** FEC sanitary unit in IISc Campus, Challakere, Karnataka state, India

**Fig. 7.5** FEC sanitary soak pit in Kudapura village, Challakere, Karnataka state, India

## 7.6 Concluding Remarks

The following conclusions can be drawn from the present study.

(a) Mix 2 (relatively leaner mix) demands higher water/cement ratio when compared with Mix 1 to achieve required workability.
(b) Increase in soil content to replace fine aggregates results in a reduction in compressive strength in both the mixes. This may be attributed to need for higher water/cement ratio at higher soil contents to achieve required workability.
(c) The workability and compressive strength of FEC can be tweaked by varying soil content in the mix for monolithic wall construction.
(d) It is worth exploring other properties of FEC such as flexural strength, creep, shrinkage and durability parameters.

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