Fresh and Hardened Properties of Earth Concrete

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doi: https://doi.org/10.21467/proceedings.156.19

ABSTRACT

The building sector is expanding daily on a global scale with several environmental problems. The implementation of sustainable methods in the sector is also becoming more relevant at the same time. Concrete is one of the most abundantly used building material, which is made up of fine and coarse aggregate held in place by cement paste. In the present study, soil is used as fine aggregate. Cement, soil and coarse aggregate are used in the proportion 1:0.85:3.60 to prepare the earth concrete. The study focuses on investigating the properties of the earth concrete in its fresh and hardened states. Workability, pulse velocity, and compressive strength are assessed to determine the performance of earth concrete. The effect of dosage of superplasticizer on the properties on earth concrete at fresh and hardened states is also studied. The findings shows that earth concrete is capable of achieving various relevant materialistic properties comparable to that of ordinary concrete and could replace normal concrete in certain applications.

Keywords: Earth concrete, Sustainable, UPV test.

1 Introduction

Many of the building practices used today have an adverse impact on the environment, such as rapid depletion of natural resources, high energy consumption and increased carbon footprints. Scarcity of natural resources has gradually resulted in higher prices for building materials. As a result, shifting to more sustainable options is essential [1]–[3]. When compared to today's conventional methods, the use of soil in construction is a sustainable and cost-effective technique. Since ancient times, earth has been used in a variety of ways as a building material since it was readily accessible [4]. Soil is also used as a sustainable building material in modern scenario. Some of the new technologies used today include rammed earth and earth blocks [5] which are manufactured by applying compressive forces. On the strengths and properties of earth concrete, various investigations have been conducted. However, several areas still remain unexplored.

Earth concrete is a proportionate mixture of cement, soil, coarse aggregate, and water. Fibres could also be incorporated to enhance the material properties [6]–[8]. Earth concrete is a type of building technique in which soil and other additives are transformed into a flowable form, like conventional concrete, which may be cast into a variety of shapes with the help of forms [9], [10]. In earth concrete fine aggregate is completely replaced with soil available from site. It could be possible to employ earth concrete for structural applications. The addition of super plasticizer could improve the workability, density, and compressive strength of earth concrete making it a more viable construction material [11].

Proceedings DOI: 10.21467/proceedings.156; Series: AIJR Proceedings; ISSN: 2582-3922; ISBN: 978-81-961472-7-3

Since earth concrete is a novel concept, its performance and effectiveness should be compared to those of normal concrete. Workability, pulse velocity, and compressive strength are taken into account in the current study to evaluate the performance of earth concrete. By employing ultrasonic pulse velocity test, one can identify the quality of concrete and has become one of the most used non-destructive techniques in recent years. However, it is a poor method for determining the strength of concrete [12]. The study explores if the similar behaviour occurs in earth concrete as well. Super plasticizer dosages ranging from 0% to 3% was employed to examine the impact of superplasticizer dosage on earth concrete.

2 Materials and Methods

2.1 Materials

Earth concrete is typically made by combining cement, soil, coarse aggregates, and water. In this study, laterite soil collected from Malappuram district of Kerala, India is used. The soil is sieved through 10 mm sieve to remove larger particles. To remove any moisture that may be present, the soil is oven dried before usage. Crushed stone with a nominal size of 20 mm is utilized as coarse aggregate and Ordinary Portland Cement (OPC) of grade 53 conforming to IS 12269 is adopted as the binder. For mixing and curing, water that is free from acids, oils, alkalis, vegetables, and other pollutants is utilized. Ceraplast 300, a super plasticizer based on naphthalene that complies with IS 9103, is used to improve the workability characteristics of the earth concrete matrix. Manufacture recommended dosage of Ceraplast300 is about 0.3 % to 1.2 % by weight of cement and maximum dosage is 3% of cement weight. For the study, mixes with dosages of 0%, 1%, 2%, and 3% are considered. Figure 1 shows the various materials used for the study.

a *b* *c* *d*

Figure 1: *Samples of* ***a)*** *Cement,* ***b)*** *Soil,* ***c)*** *Coarse aggregate,* ***d)*** *Superplasticizer*

2.2 Methods

In the study, an earth concrete mix containing cement, soil, and coarse aggregate in the proportion 1:0.85:3.60 is used. Water cement ratios ranging from 0.45 to 0.70 at increments of 0.05 are considered. Super plasticizer quantities of 0%, 1%, 2%, and 3% by weight of cement are taken into consideration at various water cement ratios. The constituents are dry mixed in a mechanical pan mixer until it attains a uniform hue and then required amount of water, mixed with measured amount of superplasticizer, is added gradually. Once the mixing has been completed, compaction factor test is performed on the prepared mix. The mixture is then filled into standard 15×15×15 cm mould in three layers. The matrix is compacted in between each layer by using a conventional tamping rod of 16 mm diameter and 60 mm length. For each mixture, five cubes are cast, and they are demoulded after 24 hours. The specimens are then stored in curing tanks for 28 days. The various stages of cast specimens are shown in Figure 2.

Proceedings DOI: 10.21467/proceedings.156
ISBN: 978-81-961472-7-3

Series: AIJR Proceedings
ISSN: 2582-3922

a *b* *c*

Figure 2: ***a)*** *Specimen before demolding,* ***b)*** *Specimen after demolding,* ***c)*** *Specimen during curing*

2.3 Testing of Specimens

The slump cone test is one of the most used techniques for assessing the workability of concrete, however it has been found to be unsuitable for testing earth concrete due to its excessive stiffness and low flowability. Hence, compaction factor testing is used to determine the workability of the freshly created mix, in accordance with IS 1199. The ratio of weights of partially compacted to the fully compacted concrete matrix is noted as its compaction factor.

All the cast specimens are subjected to compressive strength and UPV tests. UPV test provides a measure of the quality of the concrete. The process for the UPV test includes the transmission of pulsed ultrasonic waves into the concrete. Pulse waves of frequency in range of 40 kHz to 50 kHz is passed through each specimen and pulse velocity values through the specimens are determined. The compressive strength of concrete cube specimens is determined using a compression testing machine in accordance with IS 516 [13], [14]. Failure load of each specimen is noted and the average strength of five cubes is reported. Figure 3 shows the experimental setups for workability, compressive strength and UPV tests.

a *b* *c*

Figure 3: *Experimental setup for* **a)** *Compaction factor test,* **b)** *Compressive strength test and* **c)** *UPV test*

3 Results and Discussions

The results of the compaction tests for the mixtures with various water-cement ratios are shown in Figure 4. Within the range of water-cement ratios considered in the study, the compaction factor is found to increase linearly as the water content is increased. The addition of water changes the rheology of the mix and improves its workability. On the other hand, the dosage of the superplasticizer is also found to increase the workability significantly.

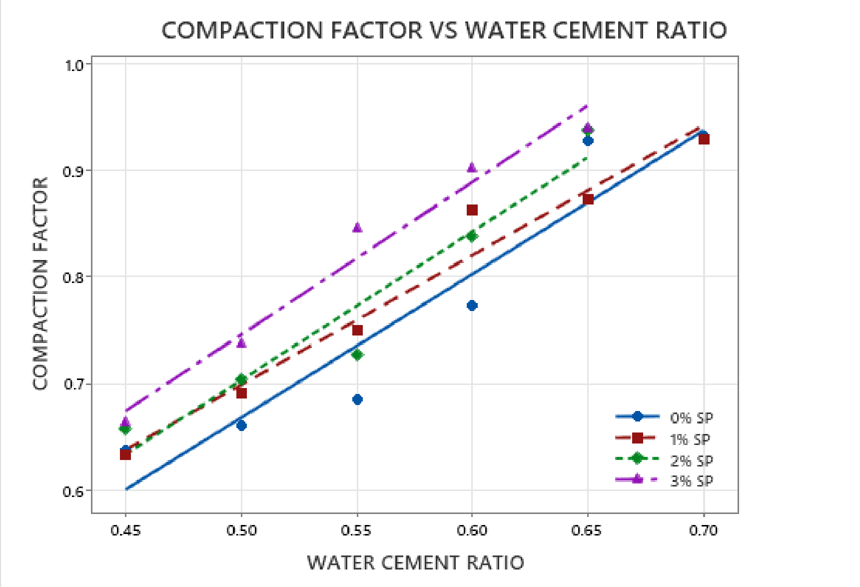

Figure 4: *Compaction factor vs Water cement ratio*

Figure 5 illustrates the relationship between compaction factor and compressive strength. Lower compaction factor values indicate less workable concrete. The less workable mixture results in porous structure of specimen. This causes concrete specimens to quickly fail under compression. All superplasticizer dosages, with the exception of 3%, yield the best compressive strength when a compaction factor between 0.75 and 0.85 is obtained. The exception of 3% could be accounted to the fact that the water cement ratio for attaining the maximum strength is lower than the water cement ratio required to achieve the surface saturation of the various particles present in the matrix and produce a flowable matrix. Mixtures become flowable and bleeding of water occurs when the compaction factor exceeds 0.85. These specimens also fail in compression at a lower load due the particle arrangement with increased gaps in between the particles developed because of the larger electrostatic forces imparted by the superplasticizer. Hence the optimum compaction factor for the proposed earth concrete matrix should be in the range of 0.75 to 0.85. As soil is capable of absorbing large quantities of water, for site applications of earth concrete, it will be easier to arrive at the desired workability and fix the corresponding water cement ratio accordingly rather than going the other way around which is typically adopted for ordinary concrete.

Figure 6 shows the variation of pulse velocity with the variation of water-cement ratio. From the study the maximum value attained is in the range of 3.5 to 4.5 km/s which represents good quality of concrete as per IS 1331-1 for normal concrete. Increase in water content enhances the quality of concrete produced. Higher velocities indicate good quality and continuity of the material, while lower velocities indicate concrete with a larger number void. It is to be noted that quality in this context refers to the absence of voids and not necessarily the compressive strength aspect. Figure 7 illustrates the relationship between compaction factor and the pulse velocity. The pulse velocity increases until it reaches a certain value of compaction factor, after which it slightly decreases. Thus, even though the concrete is highly workable, there is a possibility of lower quality in terms of compressive strength that may arise due to the increased electrostatic forces generated by the superplasticizer or the presence of larger quantities of water than what is actually required.

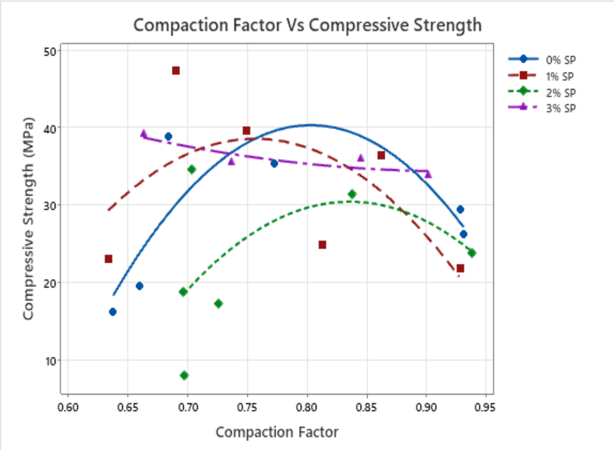

Figure 5: *Compaction factor Vs compressive strength*

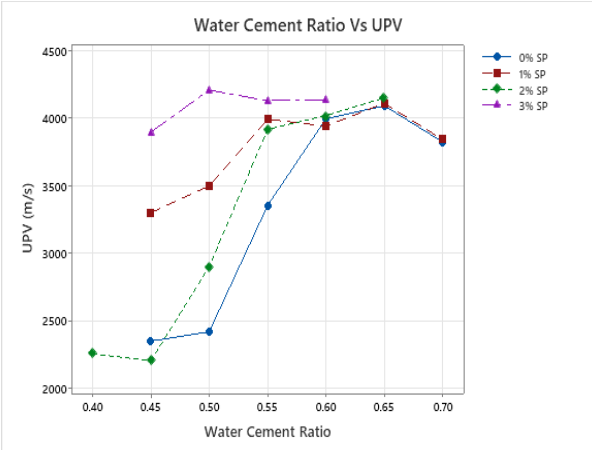

Figure 6: *Water cement ratio Vs UPV*

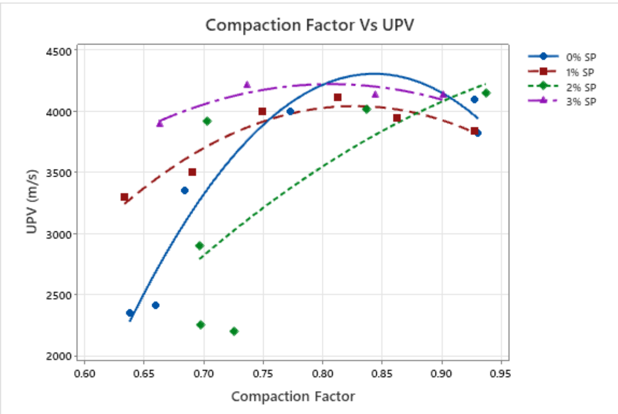

Figure 7: *Compaction factor Vs UPV*

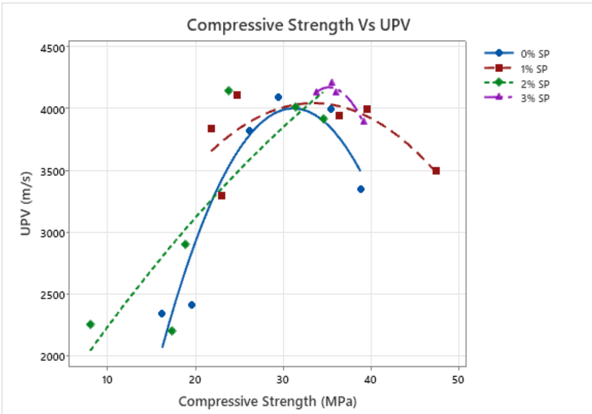

Figure 8: *Compressive strength Vs UPV*

Figure 8 shows the relationship between compressive strength and concrete quality expressed in terms of UPV values. It can be observed that UPV of earth concrete is not fully correlated with its compressive strength. Even high-quality concrete might be insufficient in terms of compressive strength. For the mix with the recommended dosage of 1% of superplasticiser, UPV is found to be in the range 3500 – 4000 m/s to obtain earth concrete with required workability capable of developing the maximum achievable strength.

4 Conclusion

The workability and compressive strength of earth concrete with different dosage of super plasticizer investigated in the present study. Quality of concrete is also analysed using UPV test. From the results, the following conclusions can be drawn:

1) The mixes become more workable due to increase in the water-cement ratio as well as due to the addition super plasticizer.
2) The pulse velocity of good quality earth concrete is found to be in the range of 3.5 to 4.5 km/s, which represents good quality concrete in normal concrete as well.

3) The maximum compressive strength is achieved by 1% dosage of Ceraplast 300. As recommended by the manufacturer, the dosage of Ceraplast 300 superplasticizer may be limited in the range of 0-1%. Superplasticizer dosage of more than 1% is found to reduce the compressive strength of earth concrete.
4) Similar to regular cement concrete, compressive strength cannot be directly predicted using the pulse velocity. Pulse velocity serves as an indicator to the arrangement of particles within the matrix in its hardened stage.

As evident from the results obtained, the earth concrete considered in the present study is observed to be having properties similar to that of normal concrete. Hence it has the potential to be used for structural applications. However, the durability and long-term strength characteristics of earth concrete need to be assessed before recommending earth concrete for structural applications.

5 Declarations

5.1 Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

5.2 Study Limitations

A primary limitation of the study is that it cannot be generalised for all earth concrete. The observations are specific to the materials and proportions employed. The study is aimed at identifying a procedure and serve as a guide for assessing the quality of earth concrete that could be adopted in general and not to determine the actual materialistic properties and empirical relations.

5.3 Publisher's Note

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How to Cite

Ravi *et al.* (2023). Fresh and Hardened Properties of Earth Concrete. *AIJR Proceedings*, 137-143. https://doi.org/10.21467/proceedings.156.19

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