Study of Cast Earth as a Structural Material

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Abstract - *Cast earth is a natural material made with cast earth and calcined gypsum. This is a new development, not yet completely reduced to practice but put into limited field use from late 2003. There needs a serious research on the mix design of cast earth especially with local soils of Kerala, for promoting its local use. The research opens an environment friendly solution that leads to a sustainable development in the construction industry. The primary goal of this research is to address the suitability of cast earth as a structural material. In the secondary phase, a cast earth module compared to the conventional laterite masonry. This can help to develop technologies that are energy saving, eco-friendly and more sustainable.*

Key Words: Cast earth, Sustainable development

1. INTRODUCTION

Extensive environmental concern related to buildings is rising day by day as more and more infrastructures develop. A large percentage of material resources taken from nature are building related and over 50 % of national waste production comes from the building sector. Cast earth is an innovative green concept, which can use as a structural building material.

1.1 Research Motivation

Cast earth construction industry is in a start-up stage, which crawls in industry due to the reasons of unawareness, lack of labor and technology.

Which is the optimized mix for cast earth construction? What are the compounds to add for better strength? How to make cast earth construction economical? These hurdles need to rectify for the exposure of this new technology so that it can use with local soils of different countries.

1.2 Scope of the Study

Cast earth technique creates a new green space in the construction industry for non-load bearing walls, especially partition walls that accommodates a huge portion of walls in a building. Cast earth is an eco-friendly material obtained from the nature or from the construction site. If cast earth proves to use in field within acceptable from time and cost frame, it will be a good step in the sustainable development. It creates neither chaos of the earth removed nor the problems related to laterite quarry works. Detailed research on cast earth construction is necessary so that locally available resources can utilized fully in most effective way.

1.3 Objective of the study

The primary objective of this research are,

1) To confirm the scope of cast earth as a structural building material considering local soils of Kerala.

2) To compare rate analysis for a wall module with and without cast earth technique.

2. RESEARCH METHODOLOGY

In order to fulfill all the project objectives, methodology adopted is in Fig – 1.

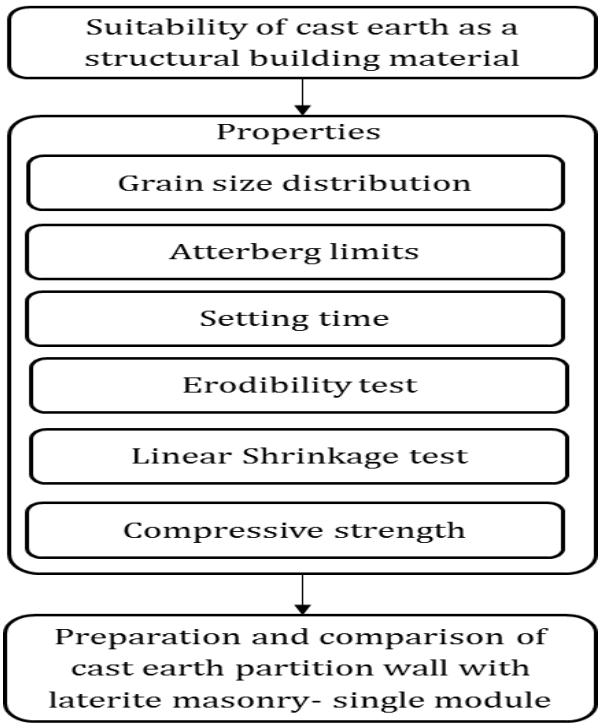

Fig – 1: Research methodology flow chart

3. CONCEPT OF CAST EARTH

Cast earth is a natural building material made with earth and calcined gypsum developed by *Harris Lowenhaupt* and *Michael Frerking* in mid-1990s. Cast earth construction differs from conventional earth constructions in many aspects and is a relatively new technology. It uses calcined gypsum as an admixture to impart strength and to control the setting time. It can replace wood or steel framing in residential and light commercial buildings, yielding energy and environmental benefits.

3.1 History of Cast earth

Soil has been a choice of building since time immemorial. Earth has pressed many ways into service as shelter for humans. Rammed earth is a widely used historic building material, found in Mediterranean regions, along the Silk Road, and in parts of the Himalayas. While guidelines exist for the construction of new rammed earth structures, there is very little guidance for the structural analysis of historic structures. Later on in 1993, cast earth concept introduced as a structural building material.

The cast earth method utilizes gypsum and a proprietary retardant to stabilize mixtures and reduce shrinkage, allowing for the use of existing concrete industry. When walls poured with the cast earth mixture, the forms can remove on the same day as the pour, since the wet material sets quickly. Cast earth does not involve laying bricks or blocks or slowly compacting earth by mechanical or pneumatic action; instead, it consists of rapidly pouring an entire building in place, removing forms shortly after the pour. What makes this possible is calcined gypsum's fast set rate to a wet strength sufficient to support a wall. Around 15 % of calcined gypsum as reported to provide good strength immediately after setting. Steel reinforcement not needed in cast earth construction of walls.

3.2 Properties of Cast Earth

Local soil samples from two district areas in Kerala (India), *Malappuram* and *Kozhikode*, are studied. Soil selected from *Malappuram* is a laterite soil and that from *Kozhikode* is a silty soil. The performance of cast earth produced with these two samples along with addition of varying percentages of gypsum and other additives need to study. Following experiments identifies the properties of cast earth and helps to check the suitability as a building material.

3.2.1 Grain Size Distribution

Cast earth from two distinct locations subjected to sieve analysis. The result obtained summarized in Table-1. Based on the results obtained from the tests conducted, the gravel fraction is more for laterite soil from Malappuram and percentage of clay is less for both samples.

Table -1: Grain size distribution of soil sample from Malappuram and kozhikkode (Final result)

Percentage fraction	Soil Sample from Malappuram	Soil Sample from Kozhikkode
Gravel	29.40 %	12.60 %
Sand	66.60 %	82.60 %
Silt and Clay	4.00 %	4.80 %

3.2.2 Atterberg Limits

Atterberg limits such as liquid limit, plastic limit and shrinkage limit found as in Table – 2. The liquid limit and plastic limit of sample with mixture of plaster of Paris and gypsum increases with increase in their percentage. The addition of gypsum decreases the initial and final setting time. Setting time decreases with increase in percentage of gypsum and Plaster of Paris in both samples. In the experiments conducted, two types of local soils are studied.

Table -2: Atterberg Limits of test samples (Final result)

Properties	Sample from Malappuram	Sample from Kozhikkode
Liquid Limit	39.00 %	32.30 %
Plastic Limit	40.00 %	50.00 %
Shrinkage Limit	1.32 %	1.32 %
Specific gravity	2.47	2.44
Swelling Index	0.04	0.03

3.2.3 Setting time

Setting time of cast earth with Gypsum and Plaster of Paris checked for various proportions 0 %, 5 %, 15 % and 20 %. Firstly, the variation in setting time due to addition of gypsum and Plaster of Paris measured separately. Weight of the sample taken is 200 g. 2 % excess water with the present water content. The results obtained indicated in the Table – 3 to Table - 8 .

Table – 3: Cast earth with Gypsum (Malappuram sample)

No	% of Gypsum	Name of Sample	Initial Setting time	Final Setting time
1	0	SMG0	15 hours	> 24 hours
2	5	SMG5	11 hours	> 24 hours
3	10	SMG10	10.5 hours	23 hours
4	15	SMG15	10 hours	21 hours
5	20	SMG20	10 hours	16 hours

Table – 4: Cast earth with Plaster of Paris (Malappuram)

No	% of Plaster of Paris	Name of Sample	Initial Setting time	Final Setting time
1	0	SMGP0	15 hours	> 24 hours
2	5	SMGP5	11 hours	22 hours
3	10	SMGP10	9 hours	16 hours
4	15	SMGP15	6 hours	15 hours
5	20	SMGP20	5 hours	11 hours

Table – 5: Cast earth with Gypsum (Kozhikode)

No	% of Gypsum	Name of Sample	Initial Setting time	Final Setting time
1	0	SKG0	26 hours	> 24 hours
2	5	SKG5	18.5 hours	> 24 hours
3	10	SKG10	19 hours	23 hours
4	15	SKG15	18.5 hours	21 hours
5	20	SKG20	17 hours	16 hours

Table – 6: Cast earth with Plaster of Paris (Kozhikode)

No	% of Plaster of Paris	Name of Sample	Initial Setting time	Final Setting time
1	0	SKP0	26 hours	> 24 hours
2	5	SKP5	16.5 hours	> 24 hours
3	10	SKP10	15 hours	19 hours
4	15	SKP15	13 hours	18.5 hours
5	20	SKP20	10 hours	16 hours

Table – 7: Cast earth with Gypsum and Plaster of Paris (Malappuram Sample)

No	% of Gypsum & Plaster of Paris	Name of Sample	Initial Setting time	Final Setting time
1	0	SMGP0	13 hours	> 24 hours
2	5	SMGP5	10.5 hours	22 hours
3	10	SMGP10	8 hours	16 hours
4	15	SMGP15	5.5 hours	15 hours
5	20	SMGP20	4 hours	11 hours

Table – 8: Cast earth with Gypsum and Plaster of Paris (Kozhikkode Sample)

No	% of Gypsum & Plaster of Paris	Name of Sample	Initial Setting time	Final Setting time
1	0	SKGP0	13 hours	> 24 hours
2	5	SKGP5	10.5 hours	22 hours
3	10	SKGP10	8 hours	16 hours
4	15	SKGP15	5.5 hours	15 hours
5	20	SKGP20	4 hours	11 hours

The mixture of Gypsum and Plaster of Paris provides better results than individual additions. Seeking the optimum value, we go for the mixture of gypsum and Plaster of Paris.

3.2.4 Erodibility test

The result of erodibility test is in Table – 9.

Table – 9: Erodibility test on soil samples

Soil sample	Pit Depth, D (mm)	Erodibility index
SKP5	20	5
SKP10	17	5
SKP20	14	4
SMP5	16	5
SMP10	13	4
SMP20	11	4

If Pit Depth is greater than five are, sample considered as failed. At least 20 % Plaster of Paris need to add to withstand erosion.

3.2.5 Linear Shrinkage test

The result of linear shrinkage test is in Table 10.

Table-10: Linear shrinkage test with mixture of Gypsum and Plaster of Paris.

Soil sample	Wet length (mm)	Dry length (mm)	Shrinkage (%)
SKGP5	400	382	4.50
SKGP10	400	385	3.75
SKGP20	400	390	3.25
SMGP5	400	385	3.75
SMGP10	400	390	3.25
SMGP20	400	392	2.00

Linear shrinkage decreases with increase in the percentage of Plaster of Paris. The soil sample with mixture of Gypsum and Plaster of Paris shrink less with increase in their percentage.

3.2.6 Compressive strength

Compressive strength of cast earth is tested using cube test. Three numbers of 15 cm X 15 cm X 15 cm test cubes are prepared and their compressive strength on 3 days, 7 days and 28 days is calculated. Compressive strengths of cast earth cubes with Gypsum with various percentages is in Table-11; with Plaster of Paris in Table – 12 and with the mixture of both Gypsum and Plaster of Paris is in Table-13.

Fig – 2 gives a snap of testing of cast earth specimen SKP5 and SKP15 (Soil sample from Malappuram district with 5 and 15 % Plaster of Paris content).

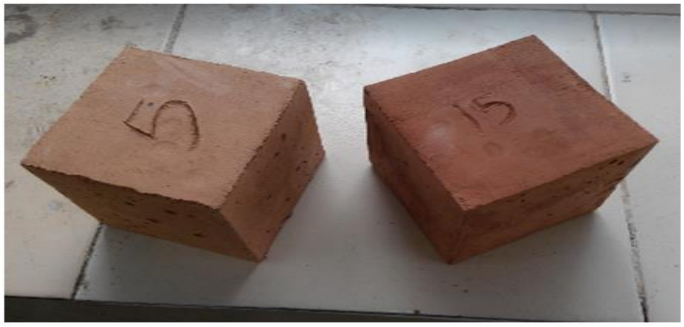

Fig – 2 : Cast earth cube SMG5 and SMG15

Cast earth cubes tested using UTM (Universal Testing Machine) as seen in Fig – 3.

Fig – 3: Cast earth cube ready for cube test in UTM

Table – 11: Compressive strength with Gypsum

Soil Sample	Compressive Strength (N/mm²)
SKG5	0.752 N/mm²
SKG10	0.816 N/mm²
SKG20	0.888 N/mm²
SWG5	0.616 N/mm²
SWG10	0.653 N/mm²
SWG20	0.680 N/mm²

Table – 12: Compressive strength with Plaster of Paris

Soil Sample	Compressive Strength (N/mm²)
SKP5	0.934 N/mm²
SKP10	1.088 N/mm²
SKP20	1.433 N/mm²
SWP5	0.834 N/mm²
SWP10	0.943 N/mm²
SWP20	1.315 N/mm²

Table – 13: Compressive strength with Gypsum and Plaster of Paris in 1:1 proportion.

Soil Sample	Compressive Strength (N/mm²)
SKGP5	0.943 N/mm²
SKGP10	1.115 N/mm²
SKGP20	1.442 N/mm²
SWGP5	0.852 N/mm²
SWGP10	0.967 N/mm²
SWGP20	1.342 N/mm²

The compressive strength of soil sample with Plaster of Paris alone and mixture of Plaster of Paris and Gypsum were almost same.

4. CAST EARTH PARTITITON WALLS

Cast earth can be used as partition walls as it gives acceptable strength of 1.4 – 1.6 N/mm^2 with addition of Plaster of Paris. A simple cast earth module is prepared

4.1 Cost comparison of cast earth & laterite

Cast earth construction is economical than laterite as the material for cast earth construction is mainly obtained from the site itself. Sample module of partition wall prepared is in Fig- 4.

Fig – 4: Sample partition wall using cast earth and laterite

The rate analysis for unit module construction of a wall using laterite is in Table – 12.

Table – 12: Cost of unit module using laterite as wall material

Construction material	Cost in INR
Laterite (20 Nos)	20 x 40 = Rs.800.00
Cement (2 bags)	2 x 410 = Rs.820.00
Sand (8 bags)	8 x 200 = Rs.1600.00
Labor	Rs.2000.00
Total	Rs.5220.00/module

Table – 13 gives the unit module construction cost of cast earth partition wall.

Table – 13: Cost of unit module of cast earth partition wall

Construction material	Cost in INR
Soil	Available in site
Excavation charges - Labour	Rs.2000.00
Gypsum/Plaster of Paris (Bag)	Rs.600.00
Labour	Rs. 2000.00
Total	Rs. 4,600.00/module

Mould and accessories in case of cast earth construction can be reusable. It can make available in Rs.4000.00 per module if properly planned. Skilled labor is necessary in case of cast earth construction.

5. CONCLUSIONS

Research concludes that cast earth can apply to construction industry as it gives acceptable results. Addition of Gypsum has limited influence on liquid limit. The liquid limit and plastic limit of sample with mixture of Plaster of Paris and Gypsum increases with increase in their percentage. Addition of Gypsum decreases the initial and final setting time and the presence of gypsum more than 5 % by weight of soil do not have much significant change. Soil sample with 20 % of alternatives by weight of soil has lower erodibility index. Shrinkage of soil decreases with increase in the percentage of Plaster of Paris. Soil sample with mixture of both Gypsum and Plaster of Paris shrink less with increase in their percentages. Compressive strength of soil sample with Plaster of Paris alone and mixture of Gypsum and Plaster of Paris are almost same.

Cast earth is a true 'breakthrough technology', producing a product with all the properties of traditional earth construction, having superior aesthetics, rapid construction, and affordable cost. However, there lies a need for serious research on mix design of cast earth especially with local soils of different area, for promoting its use. The possible use of eco-friendlier materials as an alternative to the use of gypsum also needs further studies.

REFERENCES

[1] M. Frerking, "Cast Earth: A Revolutionary building concept," Building Standards, Jan-Feb 2000, p. 37-39.

[2] B. Windstorm and A. Schmidt, "A Report of contemporary Rammed Earth construction and Research in North America," Sustainability, Vol-5, 2013, P. 400-416.

[3] P.A.Jaquin and C.E. Augarde, "Analysis of Historic Rammed Earth Construction," Structural Analysis of Historical constructions, New Delhi 2006, p. 1091-1098.

[4] A.Suresh and K.B. Anand, "Strength and Durability of Rammed Earth for Walling", Architectural Engineering, Vol.23, Issue 4, 2017.

[5] G. Kandamby, "Developments of Rammed Earth Walling Technology,"IJETT, Vol.50, 2017, p.243-250.