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MORATUWA

CEMENT STABILIZED RAMMED EARTH FOR WALL JUNCTIONS OF TWO STOREY HOUSES

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Abstract: Today the whole world is faced with environmental issues due to unsustainable use of natural resources, especially for construction activities. Finding alternative materials and methods is vital to minimize the impacts and protect the environment from natural disasters. Further increase in demand as well as the rising cost of building materials in Sri Lanka has compelled the general public to use alternative materials. Rammed earth is an ancient technology that has been used in all part of the world to construct different types of civil engineering structures such as buildings, houses, roads and dams. In the current research, rammed earth technology was developed as a means of stabilizing soil with cement to produce an alternative material for building houses due to its valuable characteristics such as affordability, environment friendly, comfort, strong and durability.
The mouldis placed in between two columns made out of compressed stabilized earth blocks (CSEB) which were manufactured as per the newly established Sri Lanka Standards. It was found that performances of CSEB columns with CSRE walls were not very successful due to differential shrinkage. Further, this study revealed that the development of wall junctions is necessary to satisfy the design aspects and to avoid the present construction issues in order to popularize this technology. "L" and "T" junctions made with CSRE and timber mouldswas introduced as an alternative method for making wall junctions to overcome the above-mentioned issues. Method of constructing CSRE walls with CSRE junctions would encourage people to accept this technology because it is economical and simple.

1. Introduction

Cement stabilized rammed earth has been introduced for load bearing walls of two storey houses as it complies with the structural properties given in BS 5628-1:2005. Design analysis can be satisfactorily performed as this code requires that fixed vertical joints are essential for high lateral loads for safety, especially for constructions that fall in Wind Zone 03, whereas it is essential for houses constructed in Wind Zone 01. Introduction of new methods for providing good fixity leads to better acceptability of this technology anywhere in the island.

Vertical joints of wall junctions in single storey houses were inspected and it was found that cracks have appeared along vertical edges because of the separation between rammed earth and compressed brick columns. It does not show good fixity at vertical wall joints. Cracks have been repaired at few locations with the same materials to overcome this problem. The following pictures describe the behavior of vertical joints between compressed brick columns and rammed earth walls.

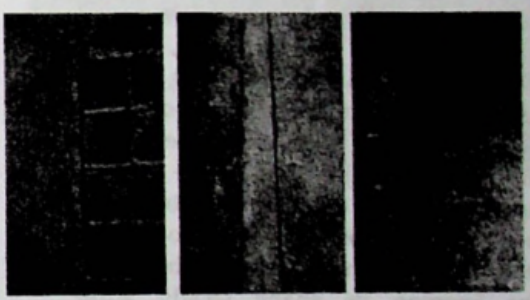

Fig 1: Separation racks at wall junctions

Use of compressed bricks for making wall junctions is necessary as slip-form is currently used as a mould for constructing rammed earth walls. Earth compressed bricks are available mostly in Colombo and suburbs and price of a brick is about Rs. 30.00. Transporting these materials to rural area for only building up wall joints would not be a good solution due to reasons of affordability. Cement stabilized rammed earth is a cost effective method which can be used effectively in house construction if wall junctions are developed for the satisfaction of the design parameters. It is understood that use of the same material for making wall junctions would be a good solution to overcome the issues in both design and cost aspects.

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Hiring facility for steel slip-form has to be provided throughout the island as fabricating steel mould is not economical for constructing one or two houses. Making steel slip-form set for building a house is another issue as it requires at least Rs 26,000.00. Alternative economical method for making this mould is a good solution for popularizing this technology especially in rural areas. By considering design and construction issues, a type of timber mouldwas introduced for constructing walls and wall junctions.

2. Experimental Program

2.1 Fabricating the timber mould

Formwork for rammed earth must be stable and well-built in order to resist pressure and vibration resulting from ramming. Small and a simple design form will assist effectively for easy fabricating, assembling, erecting, dismantling and cleaning. The same mould can be used several times and be repaired whenever necessary.

Timber is usually used for temporary works in constructions as it can resist both tension and compressive stresses and can be used to fabricate any shape. It is also a good workable material as it enables ease handling, cutting and fabricating. By considering these properties of timber, it was suggested to use plywood sheets along with timber bearers to make moulds for wall junctions. Since "L" and "T" shape junctions are common in house construction, one set of "T" shape mouldswas fabricated with the arrangement of bolts and nuts for keeping its shape steady while ramming earth. This mouldwas used for casting earth panels in the laboratory for testing purposes.

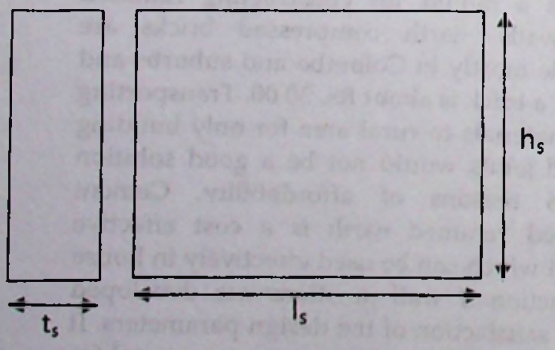
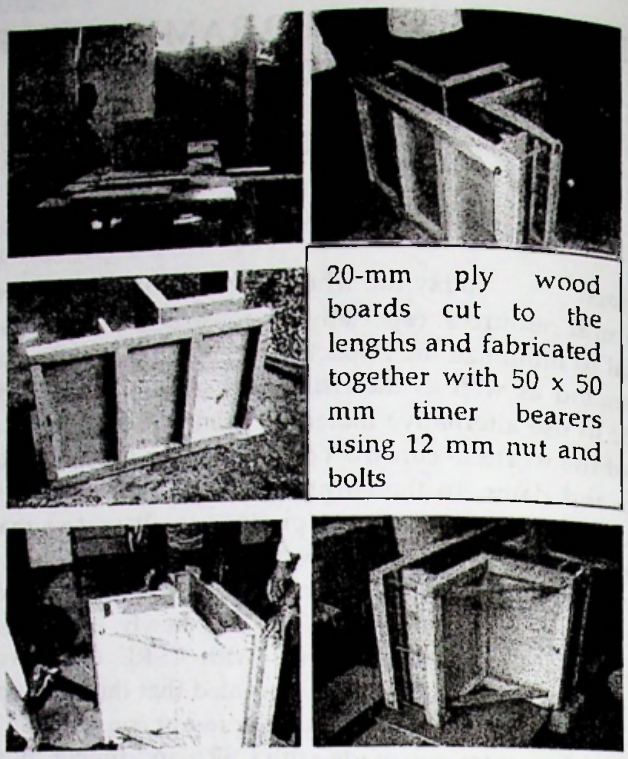


Fig 2: Dimension of wall specimen



20-mm ply wood boards cut to the lengths and fabricated together with 50 x 50 mm timer bearers using 12 mm nut and bolts

When fixing boards at 90° angles, line and level was kept neatly by wire nailing. 38 x 38 mm timber groves are provided to all vertical sides

Fig 3: Timber moulds for "T" and "L" shaped wall junctions

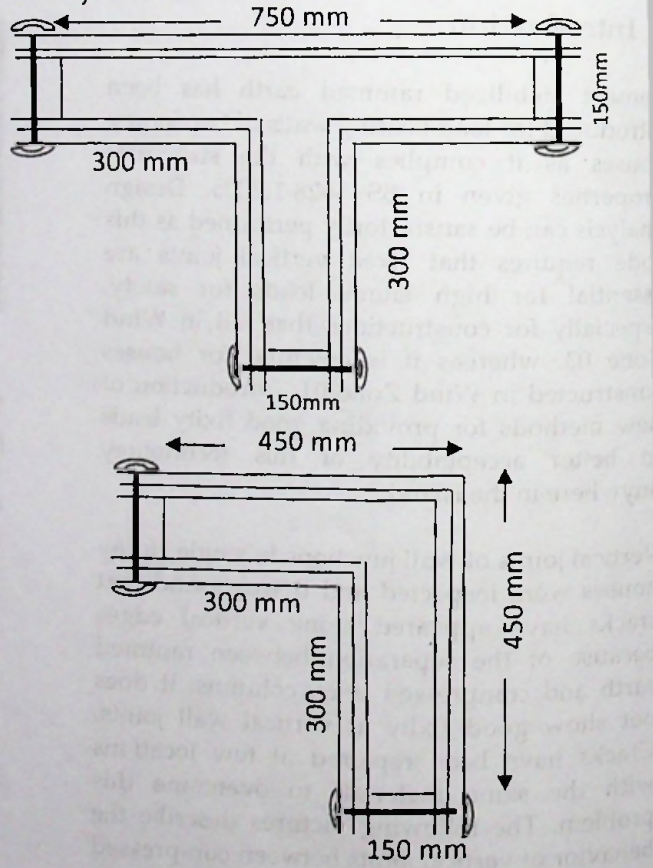


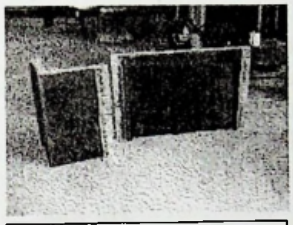
Fig 4: Sketches of timber moulds for "T"and "L" shaped wall junction

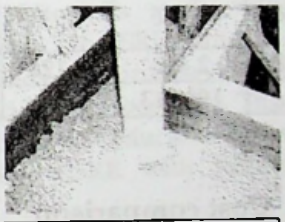
2.2 Construction of "L" and "T" junctions

Arrangements were made with The Soil Mechanics Laboratory of University of Moratuwa to perform testing to determine the properties of cement stabilized rammed earth wall junctions using timber moulds. Seven specimens were cast by making two "T" shaped wallets, three "L" shaped wallets and two straight wallets with 1:10 cement and soil mixture.

The main objective of this testing program was to find the compressive strength of wall junctions made with cement stabilized rammed earth by supporting with the timber mould. It should show sufficient strength for adoption in two storey house construction, which may be a cost effective method as the mould was made with timber. Following parameters have been determined under this testing program in order to satisfy the overall behavior of rammed earth construction in load bearing wall constructions.

1. Compaction ratio achieved in making rammed earth work manually in timber moulds
2. Compressive strength of 'L' and 'T' shaped wall junctions made with 1: 10 cement and soil rammed earth
3. Density of cement stabilized rammed earth wall





Mould oil has been applied all over inside surfaces for easy removal of mould prior to casting wallets

20 x 500 x 500 mm plywood sheet base placed about 100 mm above floor for casting panels. 1:10 cement and soil mixture put in to the mould layer-by-layer while tampingadequately

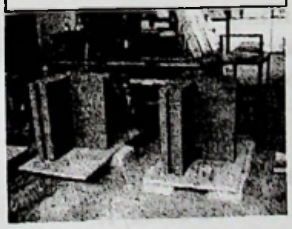


Fig 5: Wall specimens casted in the laboratory for testing

3. Testing

Thick timber planks and steel plates were placed to ensure the load distribution faces of the specimens are flat and parallel to one another and at right angles to the main axis of the specimen. The specimen was placed centrally in the testing machine and both the top and bottom of the specimen were in full contact with the testing machine.

Loading was applied uniformly to the top and bottom of the specimen and the load was increased steadily so that failure was reached after 15 min to 30 min from the commencement of loading.

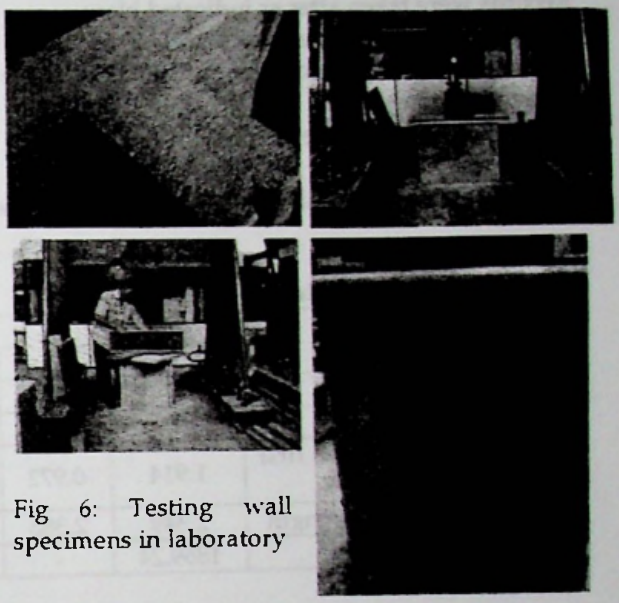


Fig 6: Testing wall specimens in laboratory

Table 2: Experimental records for testing program

Description	Specimens						
	1	2	3	4	5	6	7
1) Shape of the panel	T	L	L	L	T	Straight	Straight
2) Height of the specimen in mm	600	600	600	600	600	600	600
3) Weight of the specimen in Kg	173.40	-	-	-	-	130.13	125.35
4) Load at first crack in KN	313.00	99.40	241.90	263.30	284.60	120.90	113.70
5) Load at Ultimate crack in KN	384.20	278.90	273.20	273.20	313.00	216.30	133.70

Jar test was performed for two soil samples and found that the soil is good for wall construction. Records were taken after as indicated blow.
Two set of panels were casted and tested as the results of the first set could not be realistic due to some failures. Loads recorded in first testing program are also given below.

4. Summary of the Results

Results obtained from all specimens are summarized in Table 3 below.

Table 3: Results of testing program

Description	Specimens						
	1	2	3	4	5	6	7
Shape of the junctions	T	L	L	L	T	Straight	Straight
Compaction Ratio	1.69	1.54	1.70	1.67	1.57	1.70	1.58
Crushing strength at first crack	1.914	0.972	2.150	2.326	1.933	1.04	0.973
Ultimate crushing strength	2.349	2.383	2.428	2.413	2.126	1.861	1.144
Density of CSRE wall	1869.24	-	-	1908.13	-	1865.66	-

5. Evaluation of Results

1. One key factor that governs the strength parameter of CSRE is the degree of compaction. Laboratory testing was done by following the usual method of construction and it was found that the average was 1.64 of compaction ratio.
2. Maximum vertical stress on DPC level was found to be 1.17 N/mm^2. Ultimate crushing strength obtained for "L" and "T" junctions were in the range of 2.13 N/mm^2 and 2.43 N/mm^2 and it was found that these junctions can be applied for construction satisfactorily.
3. Average value of unit weight of CSRE was found to be 1,881 kg/m^3 which is also at the satisfactory range.

6. Cost comparison

Determination of cost for making walls with cement stabilized rammed earth technology is very essential as it is one of the new methods having less information for cost analysis. Detailed work studies were conducted at several occasions when building houses and analyzed for the cost of making rammed earth walls. Summary of the costs for different methods are given below.

1. Cost for making 145 mm thick CSRE wall with hired slip-form = Rs 89.50/ft^2
2. Cost for making 150 mm thick CSRE wall with timber mould = Rs. 64.50/ft^2

Cost for plaster is not necessary to be added for 1 and 2 methods above.

3. Cost for 4" thick cement block work with plaster on both faces = Rs.144.50/ft²
4. Cost for 4 ½" thick brick wall with plaster on both faces = Rs.157.50/ft²

By comparing the above basic costs of different walling methods it can be seen that CSRE gives the lowest cost and it will be the most affordable method for making walls. CSRE made with timber moulds gives the lower cost than making walls with hiring slip-forms. Soil is often available in rural area at no cost where this technology canbe applied economically and effectively.

7. Conclusion

Wall junctions built with CSRE using timber moulds provide good lateral support at vertical joints of walls and hence building structure is strong enough in terms of all parameters of engineering importance.

The compaction ratio and unit weight parameter of wall junctions made with CSRE with timber moulds gave a satisfactory value and therefore this technology can be applied satisfactorily when making load bearing walls in two-storey houses.

Cost reduction in CSRE walls made with timber moulds with respect to CSRE with slip-form, cement block walls and ordinary brick walls are 38%, 46% and 50%, respectively. This shows the considerable cost reduction when walls are made using CSRE with timber moulds.