FEASIBILITY STUDY ON A MUD BLOCK WITH STRAW

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Abstract

When, trying to establish "Sustainability" within local built environment, it is important to understand prevailing methods that are using. As a result, concentrating on "methods of wall construction", it was found that, "mud", was used over many centuries in traditional architecture. Therefore, concentrating on "mud wall construction", the goal was set to be developed, a "mud block", which has more structural durability, less weight, low cost, together with high performance with respect to indoor air quality. However, as an initial attempt of the ultimate invent of "mud block", this research was carried out to analyse, the correct proportions to invent such block. During the research mainly two types of mud blocks were casted; partially compacted mud block and poured mud block. During the casting process soil, cement, straw were mixed with water in different proportions to understand the best particle mix for the proposed block and compared the compressive strengths of each sample. From the analysis it was found that, there is a high possibility of inventing a effective mud block which has required strength for a load bearing dwellings, while minimizing the structural cast with less weight and low cost with simple manufacturing process.

Key words: *Sustainability, Mud wall construction, Mud block*

1.0 INTRODUCTION

The global concentration was given to establish Sustainable Built Environment as a new concept, which was invented to safeguard scares resources which became highly demanded, due to complicated modern developments which are dealing with extremely multifaceted modern technologies. Sri Lanka, as a country which is developing fast, concentrating more on built environment, it is important to pay attention on this new concept of “sustainability”, to overcome most of daunting challenges that can be faced due to new tools and techniques which can be created economically adverse conditions to the country by draining our resources to procure sophisticated technologies from developed countries. Therefore, when trying to establish this new concept within our local built environment, it is important to understand the traditional methods that were used and as a result concentrating on “methods of wall construction”, it was found that, “mud”, as a wall construction material, which has been used, over many centuries in traditional architecture.

Mud is one of humankind’s oldest and most universally used construction materials. Even at the dawn of humanity, people were building with mud, using it to form protective walls shielding the entrances to their caves. Following this stage, the first known cities constructed on open field were built with mud, and were located close to the Tigris River in the southern Mesopotamian Kingdom of Sumer, in the Near East. Mud construction occurs throughout the majority of the world’s different cultures, and for many it continues to be the main method of construction in use today. At present, one third of the world’s population lives in mud constructions. When developing countries alone are considered, this percentage increases to 50% [1, 2].

The constructional technologies used for the earth houses change with the geographical zone and with the historical period. The technology called ‘‘torchis’’ is based on the use of branches of shrub to build the frame of the habitation and the mud is used to fill the cavity between the branches. In another technology, called ‘‘pisè’’ [3], the earth wall is made compacting the earth into wood formworks which are moved during the progressive realization of the wall. A typical technology, called ‘‘a maltoni’’, used in the past century in the rural areas of the Marche region (Italy) is characterized by the use of cylindrical elements of earth [4]. The constructive system called ‘‘adobe’’ is based on the use of mud bricks to make earth buildings and it has been utilized in the Mediterranean area since the ancient era [5–7].

. It is low cost, locally available and recyclable, adapted to a large variety of soils, presents good thermal and acoustic properties, and is associated to simple constructive methods that require reduced energy consumption [8].For many centuries hand moulded un-burnt mud blocks, adobes, have been used for load bearing masonry structures. Though adobes are most used for lightly loaded single and two-storey residential building, adobes have also been used to construct 10-storey high buildings in Yemen [9]. Over the past fifty years compressed earth blocks have developed and been increasingly used, especially in developing countries such as Mayotte [10, 11].

At the present time the researches on earth bricks concern the conservative repair of cultural heritage and, for modern buildings, the bio-climatic architecture. In fact, one advantage of earth is that it has good thermal and acoustic insulation properties [12], so that it can be used also for non-structural elements in modern buildings. Moreover, in general, the raw earth materials are produced using very low consumption of energy and low emission of CO_2 [13]. Also the possibility of a complete reuse and the biodegradability of the material, at the end of useful life of the earthen structure is very important.

However, the use of mud bricks for structural elements of buildings is subjected to an assessment of its mechanical properties, the investigation of which constitutes the aim of this work. Recent researches in this area dealt with the determination of the compressive strength and the assessment of the influence of the type of fibres and their orientation, the volume fraction of fibres, the aspect ratio of the specimens and the procedure of compression test. Binici et al. [14] have shown that the utilization of plastic fibres increases the compressive strength in comparison to the use of straw fibres. Some researches highlighted that the increase of straw fibres decrease the compressive strength [15, 16] and the weight of the specimens, but the strain capacity (some kind of ‘‘ductility’’) rises. Previous studies have reported strength is improved by compactive effort (density) and cement content (generally linear correlation), but reduced by increasing moisture content and clay content (cement stabilized blocks). [17-20].

2.0 OBJECTIVES AND METHODOLOGY

The key objective of this research is to find out the possibility of inventing a new “mud block” which has required strength for load bearing walls while satisfying less weight and low cost together with simple manufacturing process, by varying the mixing proportions of mud, cement and straw with water.

The following methodology was developed to achieve the objective of the research;

The selected soil was tested using standardized test methods: “Sieve Analysis”, “Bottle test” and “Atterberg limit test”, to find out the properties of the selected soil. After sieving the selected soil using 13 mm riddle (Figure 1), Bottle test was carried out, to find out whether the clay, silt, sand and gravel content of the soil, satisfies the properties that have to be in the soil for developing the required block [21]. The plasticity index and liquid limit of the selected soil was analyzed from the Atterberg limit test [22].

Figure 1 : Sieved soil

Two types of mud blocks were developed using the selected soil type: Partially compacted mud block and poured mud block.

2.1 Casting of partially compacted mud block with straw

2.1.1 Preparation of rice straw - straw, which was used to mix with soil, was decided to trim in length of two inches, since the size found easy to mix with the soil and cement and then the trimmed straw were sun dried. The straw was cleared well to get free from debris and deleterious parts. (Figure 2)

2.1.2 Preparation of the mixture - Soil, cement and straw were thoroughly mixed as shown in Figure 3, with water, maintaining water cement ratio constant at 0.5 during the casting process and proportions were stated in Jayasinghe(2009) [23] and illustrated in Table 1.

Figure 2: Trimmed rice straw

Figure 3: Mixture

Mix type	Proportions	
	cement	Straw (%)
1	8%	0.5
		0.75
		1.25
		1.75
2	10%	0.5
		0.75
		1.25
		1.75
3	12%	0.5
		0.75
		1.25
		1.75

Table 1: Mixing proportions of soil, cement and straw

2.1.3 The mixture was filled manually, into pre-casted moulds and then compacted in three layers, using tamping rod. Once the casting process was completed, the compacted mud blocks; were soaked on a regular basis for curing for seven days and kept in stacks for 28 days to gain strength, as given in SLS 1382 (2009) [21].The casted blocks were shown in Figure 4.

Figure 4: Casted, compacted mud block

2.2 Casting of mud block without straw

Two types of mud blocks without straw were casted.

2.2.1 Partially compacted mud block;

Soil preparation was same as stated in 2.1, but without straw. Cement proportions that were used were same as stated in Table 1 and same methodology stated in 2.1.3 was used for casting the blocks.

2.2.2 Poured mud block;

Same soil which was used for other blocks was used to cast the block. Mixing was carried out to achieve the workability nearly as concrete. Then the mixture was poured in to the moulds without compaction. Blocks were cured up to 28 days and tested according to SLS 1382 [21] (Figure 5).

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Figure 5: Mud concrete block

3.0 DATA ANALYSIS AND FINDINGS

From the readings collected from "Sieve Analysis", following graph in Figure 6 with cumulative percentage passing was obtained and 75% of the soil particles within the range of sand. Therefore used soil sample can be categorized as the sandy soil.

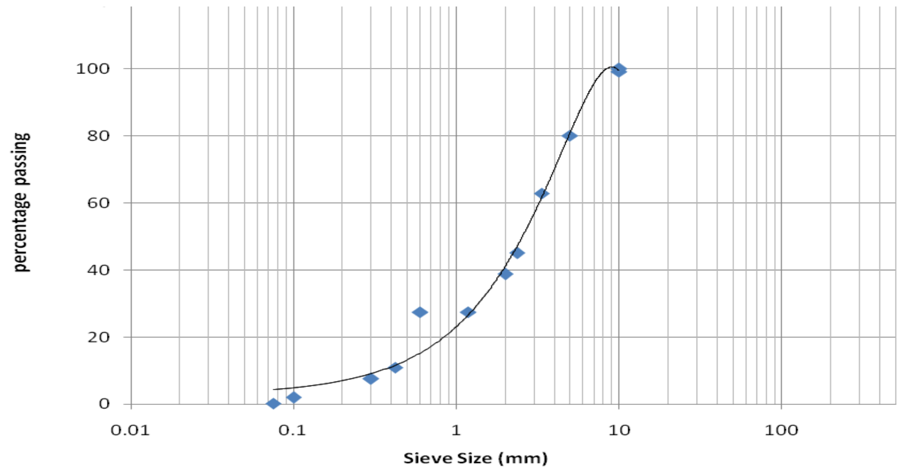

Figure 6: Sieve Analysis Graph with cumulative percentage passing

Particle type in selected soil	Height (mm)	Percentage %
Total height	72	
Clay and silt content	28	38.8%
Sand and gravel content	44	61.2%

Table 2: Summery of soil description of selected soil

From the "Bottle test" following results in the Table 2, were obtained.

According to Table 2, the selected soil contained 38.8% of clay and silt and 61.2% of sand and gravel. As per, NERD researches [21], required percentage of clay and silt is <40% and sand and gravel is > 60%. Therefore, it was found from the Bottle test, that selected soil satisfies the requirement of the soil type, which need for cast blocks.

According to the results, obtained from the Atterberg Limit test shown in Table 3, the plasticity index, liquid limit and plastic index were compared with the ASTM standards(2012)[22], to classify the soil, and the selected soil can be classified as with medium plasticity.

When casting mud blocks with different, soil, cement and straw proportions, mainly 4 types of mixing proportions; 0.5%, 0.75%, 1.25%, 1.75%, were tried out with 8%, 10% and 12% cement proportions, as per shown in Table 1.

Summery sheet	
Description	Value %
Liquid limit	58.9
Plastic limit	42.1
Plasticity index	16.8

Table 3: Summary of Atterberg Limit test

But during the casting process, only 0.5%, 0.75%, 1.25% straw proportions were compatible with 8%, 10% and 12% cement proportions and were able to achieve blocks, with acceptable quality. When 1.75% straw were mixed with the 8%, 10% and 12% cement proportions, the blocks were failed. The results illustrated in Table 4.

Mix type	Proportion		Quality
	cement	Straw (%)	
	8%	0.5 0.75 1.25 1.75	acceptable acceptable acceptable cannot be casted
2	10%	0.5 0.75 1.25 1.75	acceptable acceptable acceptable cannot be casted
3	12%	0.5 0.75 1.25 1.75	acceptable acceptable acceptable cannot be casted

Table 4: Results from different mixing proportions of soil, cement and straw in partially compacted mud block with straw

Further, when casting the poured mud block, the moisture content of the mixing was carried out to achieve the workability nearly as concrete and moisture content was measured at the end of the casting and the readings were stated in Table 5.

Mix type	cement percentage (w.r.t weight of soil)	moisture content (w.r.t weight of dry mix)
1	8%	24.8%
2	10%	25.6%
3	12%	20.5%

Table 5: Mixing proportions of soil, cement and water, in poured mud blocks

4.0 DISCUSSION

During the analysis following comparisons were carried out on casted blocks, with respect to dry strength, wet strength and strength reduction due to water absorption and results were illustrated in Figure 7, 8 and 9 as follows;

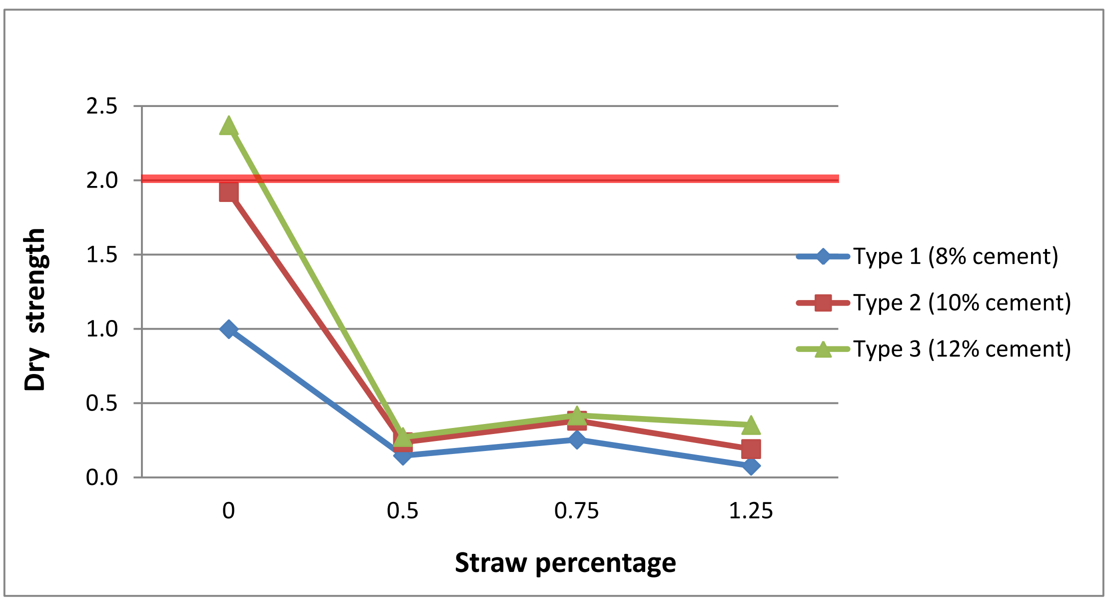

Figure 7: Dry compressive strength vs. straw percentage

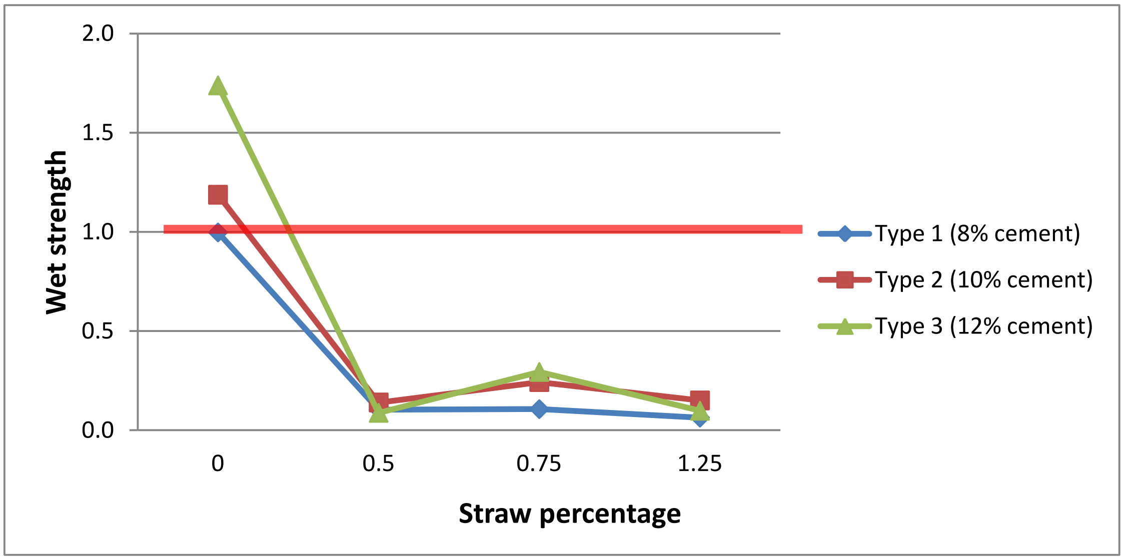

Figure 8: Wet compressive strength vs. straw percentage

According to standards, for a load bearing construction, minimum dry compressive strength should be greater than 2 N/mm^{2}andwet compressive strength should be greater than 1 N/mm^2[21, 24] and these standards were shown in red continuous line in above graphs. According to Figure 7 and 8, when compared the partially compacted mud blocks with mix type 1, 2 and 3 with added straw, they were not capable of satisfying even the minimum required compressive strength for load bearing constructions with respect to dry and wet strengths. But in mix type 1; blocks with 8% cement and without straw was able to reach the requirement with respect to wet compressive strength only. In mix type 2; blocks without straw and with 10% cement were able to achieve the wet strength, while almost reaching the requirement for dry strength as well. In mix type 3; blocks without straw and with 12% cement achieved the required strengths with respect to both dry and wet strength. Therefore, in future research, 12% cement can be considered as the minimum cement requirement that need, to cast mud blocks for load bearing construction.

Further, according to Figure 7 and 8 in all 3 mix types, the strength drastically drops with the addition of straw and non of the blocks were achieved the required strength for load bearing construction. However, all of the blocks were identified as constructible and this can be easily use for partitioning and non load bearing walls, with slight modifications in the mixture and that need to be further researched by varying the soil, water content and size of the straw. In addition it was noted that the cement percentage also can increase, since adding of straw can reduce the unit cost of the block.

According to figure 9, remarkable increase in strength reduction was observed in poured mud blocks without straw. The reason can be, with high clay content it was essential to add more water to make the mixture to a pouring mode. But at the same time, adding more water reduces the strength of the mud block, due to internal cavities and less bond between soils with cement. Always, lesser the bonds and more holes absorb more water and that will result a lesser strength in the blocks. Further, even by adding more cement strength cannot expect to be increased with the used mix, because of the high clay content and high water content.

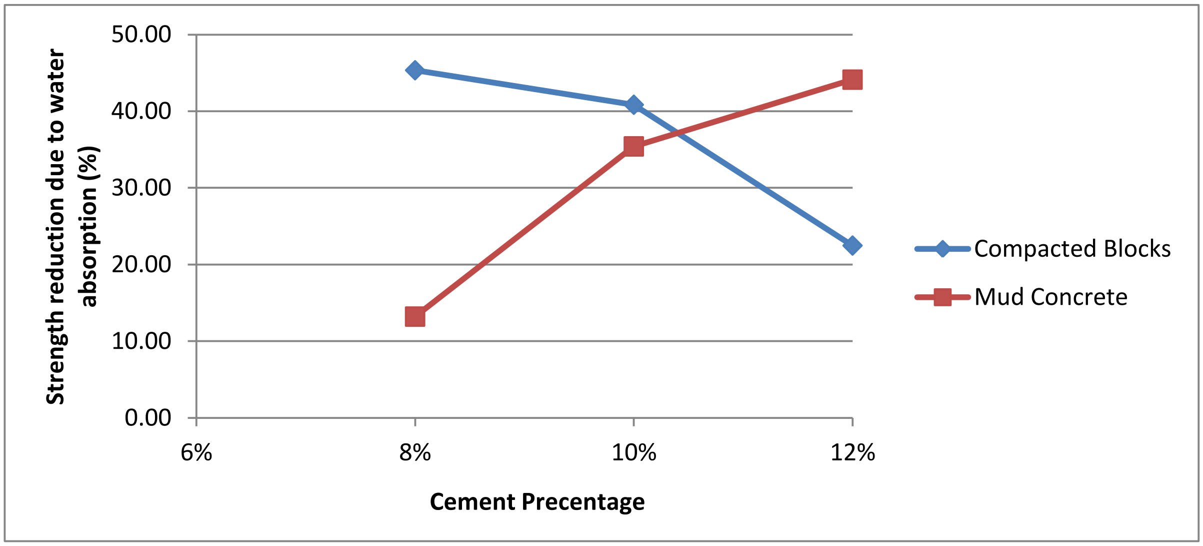

***Figure 9: Comparison of percentage strength reduction in Partially compacted mud block and poured mud block*.**

Conversely, during the comparison with respect to strength reduction due to water absorption in both partially compacted and poured mud blocks, illustrated in figure 9, a contradictory results were observed as percentage of strength reduction due to water absorption decreases in partially compacted mud blocks, while percentage of strength reduction due to water absorption increases in poured mud blocks. Therefore, compaction can be considered as another important aspect that has to be analysed with respect to increase the strength in mud blocks. This can be further analysed in figure 10; as in partially compacted mud blocks compressive dry and wet strengths are higher than poured mud blocks.

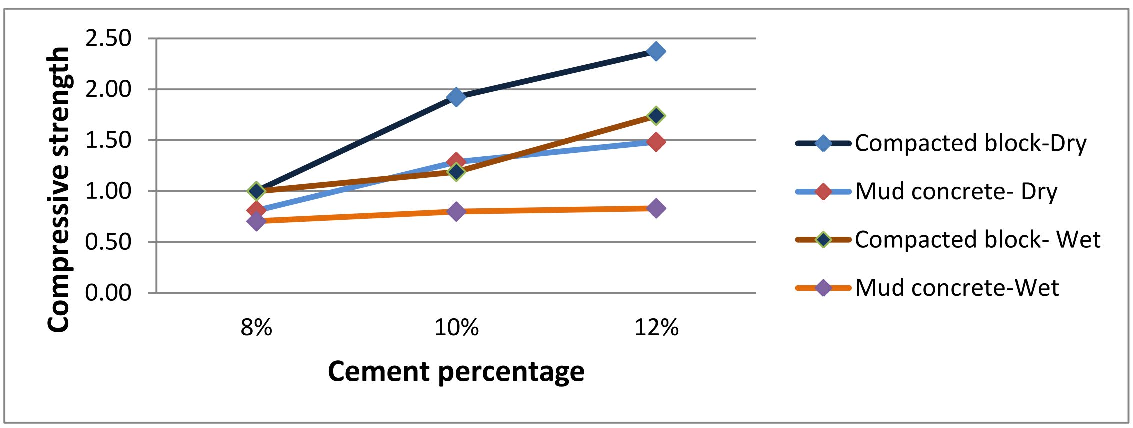

Figure 10: Comparison of compressive strength variation.

Therefore, the next focus has to be adopting a methodology to reduce these two; clay and water content and invent a practical mix for a proposed mud block. Moreover, as a part of discovering the correct practical mix for the mud block, when analyzed the sieve analysis curve (figure 6), it showed more flat due to more fine particles than large particles. This explained that the soil has to be improved by removing fine particles and adding larger particles (practical size >10 mm) to achieve standard grading curve.

Further, weight reduction due to water absorption was analyzed in both partially compacted mud blocks without straw and poured mud blocks (Figure 11).

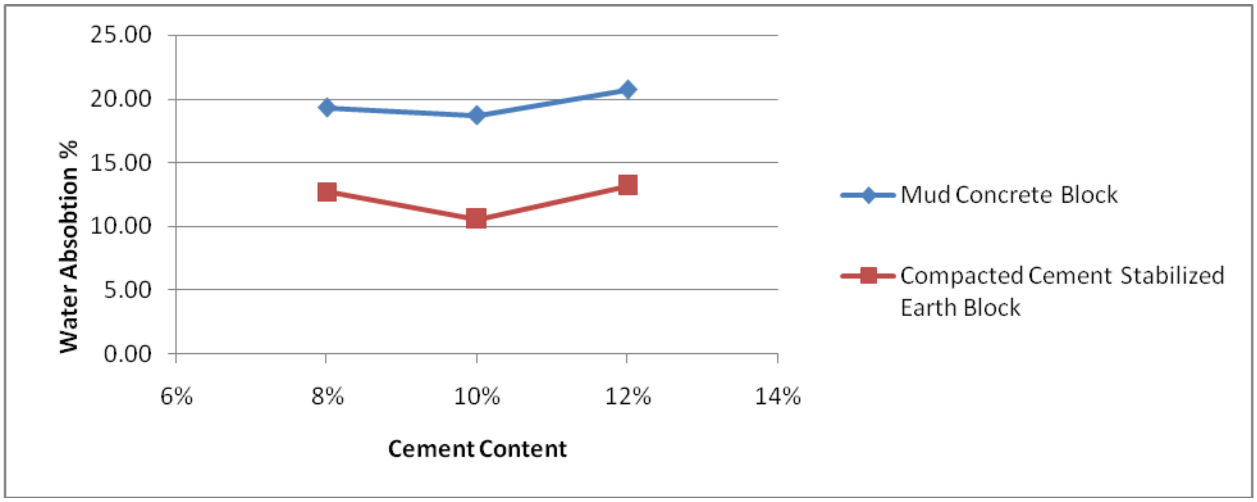

Figure 11: Comparison of weight reduction

According to figure 11, poured mud blocks were high in weight with compared to partially compacted blocks. Though, the highest weight reduction due to water absorption observed in blocks with 12% cement in both blocks types, the less weight reduction observed in blocks with 10% cement than blocks with 8% cement. Therefore, one of the future concerns has to be, to do more analysis taking more samples increasing cement percentages, to find out on weight reduction due to water absorption in more logical manner. However, when compared the average weight of partially compacted mud blocks with straw with average weight of the mud blocks without straw following table 6 was obtained.

Block type	Average weight (kg)
Mud block with straw	8.0
Mud block without straw	14.8

Table 6: Comparison of average weight

According to Table 6, the average weight of the mud blocks with straw was half of the weight of the mud blocks without straw. That explained, straw can be reduced the weight of the block. Though, this weight reduction is within the desirable range, the strength of these blocks is much lesser than the required strength. Therefore, in future research the focus has to be given to identify the suitable straw percentage, to achieve most desirable strength and weight as well.

4.1 Future concerns

However, from the research it was found that following important areas have to be concerned, when conducting further research on inventing the "mud block".

1. Analysis on suitable type and the length of straw that have to be used to cast the blocks.
2. Analysis on more efficient and accurate compaction method rather than manual compaction using tamping rod.
3. Fabrication on more accurate block moldings using steel plates rather than using plywood sheets.
4. More research on casting the blocks using more varieties of soil to decide the best properties that have to be in the soil for straw based mud block.

5.0 CONCLUSION

The key objective of the research is "to find out the possibility of inventing a new "mud block" which has required strength for load bearing walls while satisfying less weight and low cost, by varying the mixing proportions of mud, cement and straw". From the investigations carried out during the research, though the correct proportions of mud, cement and straw, for such block could not found, the research was capable of obtaining important findings that can be further improved in future research, on inventing the "mud block".

From the research it was found that, though the mud block casted without straw to gain strength, using pouring mode of the mixture, the blocks cannot achieve the required strength, due to internal cavities and less bond between soils with cement. In addition, it was found that even the cement percentage increases, compacted mud blocks have higher strength than poured mud block and that justified "compaction" is very important to achieve a mud block with required strength.

Further, from the weight comparison, it can be concluded that, by mixing straw the weight can be drastically reduced and by reducing clay and water can be further achieved high strength blocks. Therefore, there is a high possibility of introducing a block with law weight and having enough strength by selecting a proper mix on cement, straw, soil and water. This should be only possible with carefully plan set of new mixtures.

Therefore, during the future researches, the challenge is to understand the proper mixture that can be used to achieve the mud block with required strength without compaction. As a result, this needs improvements in the mix, while carefully controlling clay content and course particles of soil and controlling water. However, the idea is to make the manufacturing procedure simple, so this can be made in villages and to lead for low cost sustainable construction, due to non transportation. Further, by inventing such block and introducing it to the industry the advantages of reduction of the dead load of the structure and, by achieving that can leads to reduce the size of the structural element and reduce the cost of ground improvement. Further, job can be completed faster due to ease of handling. In addition, common injuries associated with heavier blocks can be avoided. Finally, when conclude all the advantages that can be gained from the proposed "mud block", it has a high tendency of getting establish as economically viable sustainable product within the industry.

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