6.1 Summary and Conclusions

The salient conclusions arising out of this research work are summarized in this section. The study on the influence of composition and block making mechanism on mud blocks described here basically come under four stages viz. (i) density and the strength of blocks (ii) studies on mud block masonry (iii) sorption characteristics such as the water absorption and the sorptivity; (iv) erosion studies. (v) suggested mix proportion. The conclusions from the experimental investigations are grouped under these sections, which are applicable to the characteristics of materials used and that of the parameters investigated.

6.1.1 Density

- Measured density of the specimens was found to vary from 1.846 to 1.958 g/cc. These values are above the desirable limit for producing a stabilized mud block which is specified as 1.8 to 1.85 g/cc
• When the cement content varied up to 15 %, there is an increase of 2.2 to 3.7 % in density.

• For given cement content, as moulding pressure increases, the dry density increases. There is an increase of density of about 6 % when the moulding pressure is increased from 1.25 to 7.5MPa.

• The marked increase in the density witnessed in modified specimens could have been due to the salient factors like (i) Pore filling effect (ii) Increased homogeneity (iii) Improved bonding and (iv) Reduced voids.

• Effect of the fibre content was less pronounced on the density, where there is only small change in the density (0 to 1.87%) over the range of fibres added.

6.1.2 Compressive Strength

• Compared to raw soils blocks, fibre reinforced cement stabilized soil blocks have shown an increase of 20 to 121% in compressive strength.

• Compared to the stabilized samples, the Fibre reinforced stabilized samples showed an increase of 59 to 89 % in the Compressive strength, for a Cement content of 7.5% and 64 to 118%, in the
Case of a cement content of 10%, for the range of moulding pressures from 1.25 to 7.5 MPa.

- The effect of fibres is pronounced in kit fibres having 2 cm length and 0.1% by weight of the dry soil.

- An optimum cement content of 7.5% by weight of the dry soil is required to meet the minimum requirement of strength.

- The maximum quantity of cement may be limited to 10% by weight of the dry soil, considering the rate of increase in strength and the cost.

- About 20 to 50% increase in the compressive strength was observed, when the moulding pressure was increased from 1.25 to 7.5 MPa. This shows that along with cement stabilisation, higher moulding pressure also was found to influence the strength of the fibre-blocks.

- Influence of fibres on the compressive strength was found to be significant, the increase in strength was in the order of about 45%, when stabilised with cement. This shows that cement, acting as the binder of the composite material, was found to influence the strength of the fibre-blocks along with fibre type, length and volume.
• The plastic fibres chopped from carry bags perform better than that from PET water bottles in enhancing the compressive strength. Lower effectiveness of fibres made out of bottle may be due to the following reasons: (i) the type of surface finish which result in lack of bond with soil and slips from soil, (ii) due to the stiffness of the fibres, during mechanical compression, the soil particles may laterally move apart leaving air space between the fibres and that of soil creating weaker planes.

• Stabilised cylindrical specimens and fibre reinforced stabilized cylindrical specimens at higher moulding pressure showed a strength values of 3.5 to 4.41MPa, a value which is highly satisfactory compared to that of minimum compressive strength of 3.5MPa for a well burnt brick as per BIS 1077 and minimum compressive strength of soil block for general building construction as per BIS:1725 – 1982

• Compressive strength of the blocks varied between 3.8 to 5.5MPa for the range of stabilizers and fibres added. Compared to the compressive strength of cylindrical specimens, all blocks are having higher compressive strength. The ratio of block strength to cylinder strength varied from 1.068 to 1.247. This increase in strength (6.8 to 24.8 %) may be due to the platen effect that is due
to friction along the interface between the platen and test specimen resulting in confinement to lateral expansion of the specimens.

6.1.3 Split Tensile Strength

- For given moulding pressure, as cement content increases, the tensile strength increases.

- Fibre addition increases the split tensile strength. This increase in strength, also depends upon the moulding pressure.

- Compared to raw specimens, compacted reinforced cement stabilized specimen shows an increase of 4.5 times in its tensile strength. This is one of the major advantages of addition of fibres, to the compressed stabilised specimens.

- From the observations of failure pattern it can be concluded that the benefits of fibre reinforcement includes both improved ductility and inhibition of large crack propagation after initial formation.

6.1.4 Compressive Strength of Masonry

- For given cement content, the ratio of masonry strength to block strength varied from 0.38 to 0.52 for low and 0.45 to 0.72 for high moulding pressure.
For given cement content, the ultimate stress increases with the addition of fibres. The strains at ultimate stress for masonry are more for blocks containing fibres.

Above observations and failure pattern show that the fibre reinforced mud block masonry behaves more resilient and ductile, so that the masonry can store more elastic energy compared to mud blocks without fibre, which renders it more resistant to earthquakes.

6.1.5 Water Absorption

• Raw specimens were disintegrated during water absorption test, clearly suggesting the essentiality of cement stabilisation, if the blocks were meant for exterior use without protection

• When static compaction using 7.5MPa stress was used, water absorption reduces from 12.4 to 7% when the cement content is increased from 5 to 15%. At the same time, at lower moulding pressure of 1.25MPa, the water absorption reduces from 13.8 to 10.7%, when the cement content is increased from 5 to 15%.

• The positive effect of the combination of chemical and mechanical stabilisation seems to have on one hand, cemented the soil particles together and filled in the pore space in the soil and on the
other hand, prevented the reorientation and flocculation of soil particles, which precluded formation of enlarged pores and cracks.

- Fibre addition increases the water absorption. As percentage of fibre increases water absorption increases. Water absorption increases with length of fibre also. These observations show that fibre forms interconnected channels and helps in increased water absorption when the specimens are completely submerged in water.

- But in the blocks containing fibre, as moulding pressure increases water absorption decreases. This may be due to the more compaction of soil and due to the considerable reduction of the air spaces between fibres and soil at high moulding pressure.

- More water absorption is observed in blocks, made out of bottle fibres. This may be attributed to the gap between fibre and soil resulted from the poor bond and lateral movement of fibres after releasing the moulding pressure because of the stiffness of bottle fibres.

- In any case, the water absorption of samples with 10 to 15% cement stabilisation was less than the specified value of 15% by weight as per IS 1725-2002: Specifications for Soil based blocks used for general building construction.
6.1.6 Sorptivity

- The sorptivity values varied from 0.984 to 0.304 mm/√min, for different combinations of stabilizers and fibres.

- The combination of mechanical and chemical stabilization has resulted in a reduction in sorptivity by 63 to 69% in soil specimens without fibre addition.

- Fibre addition increased the sorptivity as it increases the interconnecting channels. This observation was found, especially when the fibre content was lower. Compared to kit fibre, bottle fibre showed more sorptivity.

- But when fibre percentage was increased and at higher fibre length, the sorptivity was less, even less than that of the specimens without fibres. This exceptional behaviour may be due to the increased path length for capillary water because of the obstruction due to large amount of randomly oriented fibres.

6.1.7 Erosion Studies

- The unstabilised specimens prepared even at higher moulding pressure exhibited pitting damage upon accelerated erosion test.

- No measurable pitting or other damage was observed in any of the samples which were stabilised or stabilised and fibre reinforced. A
few small pits/patches were seen on the faces of the samples which were reinforced with 0.2% bottle fibre and compacted at low moulding pressure.

- But all of these specimens satisfy the weathering test criteria specified in IS 1725-1982, which says that when tested as per the code, the maximum loss weight shall not be more than 5% and the limiting diameter of the pit formed is to be within 1 cm for passing this weathering test.

- Spray erosion test indicates that the stabilized plastic reinforced blocks possess adequate resistance against rain erosion and these stabilized blocks can be used in walls without any water-proof coatings and plastering.

### 6.1.8 Suggested Mix Proportion

For the type of soil selected for the study which is more sandy in nature, the following mix proportion may be considered.

- Soil at a max dry density of 1.84g/cc
- Cement 7.5%
- Fibres made out of carry bags (Kit fibres) 0.1% by weight of dry soil having length of 2cm
- Moulding pressure 5MPa
- Potable water to achieve an Optimum Moisture Content of 14%
6.2 Scope for Future Work

This study forms an initial part in the ensuing long-term investigations on mud blocks. The areas on which continued research can be undertaken to provide a better understanding of the material and thus be of more use to the construction industry are:

- Similar studies on different types of soils are to be done to get a wide sustainable construction application of this technology

- Study on the microstructure to understand better the bond between soil matrix and fibre and an investigation on the effect of fibre orientation inside the soil matrix is required.

- This work has focused on mechanical and weathering properties (wind-driven rain erosion) of stabilized earth. Further tests such as drying shrinkage, thermal conductivity, long term durability studies to understand resistance to other degradation factors, are to be done in order to assess sustainability and practicality of extending its use to any environmental and climatic conditions

- Research is needed on improvements to the standard mix designs. Potential research options include alternative stabilizing agents or reinforcing options.
• Investigations on the bond, compressive strength and deformations characteristics of mud block masonry with different types of masonry mortar is also required.

• A theoretical study (analytical and numerical) to facilitate the design process, and to allow the inclusion of these materials in building codes and engineering design standards, is required.

• As the Kit fibres are versatile in imparting better Compressive strength, whereas the Bottle fibres assist more in imparting the Tensile strength of the Compressed Stabilised Earth Blocks, a combination of these two fibres at definite proportions may probably lead to interesting results.