EXPERIMENTAL STUDY OF THE UTILIZATION OF PLASTIC WASTE IN MASONRY BLOCKS CONSTRUCTION

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Abstract

The recyclable properties of plastic waste can be used to recycle this waste and create a new product with less negative impact on the environment. One of the options for recycling plastic waste is to mix plastic with sand to make plastic bricks, which can be used to replace traditional bricks.

Keywords: Mix, Plastics, Impact, Bricks etc.

1.1 General

Block is a building material used to make walls, pavements and other elements in masonry construction. In the past, block were mainly made of clay and nowadays it is widely used to denote that block is a masonry unit made of clay, concrete material, lime, fly ash, sand. Our main objective of the project is to develop eco-friendly block which can be purchased by the common man, reusing the waste plastic in an efficient manner. Therefore, the following readily available materials are purchased and used during our experiments:

In this chapter we will discuss the analysis of experimental investigations carried out on the effect of composition and composition of clay, cement, fiber and molding pressure on the strength characteristics of cylinders, blocks and masonry. Experiments were carried out for different molding pressures, cement content, type of fibers, their length and amount to determine the density, compressive strength, tensile strength. The role of each component and its properties were determined on these variables. The strength of masonry is determined using a masonry prism. To understand the behavior of clay plastic fiber reinforced blocks, the results of experiments by varying the components, their proportion, properties and molding pressure are investigated.

Natural river sand is directly procured and the following tests are done for the sand used in making plastic sand block:

1.1 Plastic waste (HDPE Granule)

Our main aim of research study and project is to reduce plastic waste and utilize in efficient way. Therefore, we used reprocessed High-Density Polyethylene (HDPE) plastic in granule form and mixed with other composition in different ratios. We used HDPE instead of LDPE to achieve greater compressive strength and has property of high Melting Flow Index (MFI). The plastic granule is collected from R K Plastic & Company located at Baddi, Himachal Pradhesh.

Figure 1.1: HDPE Granule

1.2 Testing For Sand Grading Zone

The grading zone of the sand was determined by sieve analysis method as per IS:383-1970 mentioned below and the results indicate that the sand grading is confirmed for Zone II.

Figure 1.2: Weighing Machine and IS Sieve Apparatus

Table 1.1: Best aggregates as per IS:383 – 1970

IS Sieve	**Percentage Passing by Weight**			
	Grading ZoneI	**Grading Zone II**	**Grading Zone III**	**Grading Zone IV**
10 mm	100	100	100	100
4.75 mm	90-100	90-100	90-100	95-100
2.36 mm	60-95	75-100	85-100	95-100
1.18 mm	30-70	55-90	75-100	90-100
600µm	15-34	35-59	60-79	80-100
300 µm	05-20	08-30	12-40	15-50
150µm	0-10	0-10	0-10	0-15

Table 1.2: Observation data for grading zone of sand

IS Sieve Size	**Weight of Aggregates Retained**				**% Retained**	**Cumulative % Retained**	**% Passing**
	Determinations No. (Gram)						
	I	**II**	**II**	**Average**			
10 mm	0	0	0	0	0	0	**100**
4.75 mm	24.8	26.1	22.7	24.53333333	2.453333333	2.453333333	**97.54666667**
2.36 mm	37.6	41.6	43	40.73333333	4.073333333	6.526666667	**93.47333333**
1.18 mm	45	46.3	50.8	47.36666667	4.736666667	11.26333333	**88.73666667**
600 µm	438.1	501.9	490.1	476.7	47.67	58.93333333	**41.06666667**
300 µm	346.6	268.4	280.4	298.4666667	29.84666667	88.78	**11.22**

150 µm	49.6	52.6	55.5	52.56666667	5.256666667	94.03666667	**5.963333333**
75 µm	45.7	49.6	45.3	46.86666667	4.686666667	98.72333333	**1.276666667**
PAN	12.6	13.5	12.2	12.76666667	1.276666667	100	**0**
Total	**1000**	**1000**	**1000**	1000	100		

1.3 Bulking Value of Sand

The increase in the amount of sand due to increase in moisture content is called sand heaving. A film of water is formed around the sand particles which forces the particles to push against each other and thus increase in volume. The amount of sand increases as the moisture content of the sand increases. Thus, the bulk of the sand depends on the moisture present in the sand. A sand pile is nothing but loose sand without compaction. The bulk price of sand experiment is carried out as per IS Code Reference: 2386 (Part III) - 1963 and the following results are obtained.

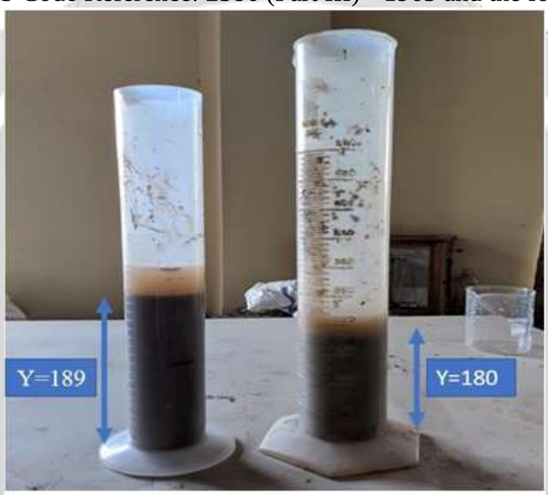

Figure 4.3: Measuring cylinder of silt content experiment

The bulking of sand is calculated by using formula:

Bulking of sand (%) = [(200 – Y) x 100]/ Y

Table 1.3: Determination of bulking value (%) of sand

SI. No	**Description**	**Sample No**		
		Sample I	**Sample II**	**Sample III**
1	Volume of loose sand (ml)	200	200	200
2	Volume of saturated sand, Y(ml)	180	189	191
	Bulking of sand (%)	11.11	5.82	4.71

The sand bulkage value for above observation is = (11.11% + 5.82% + 4.17%) / 3=7.21%

Therefore, the bulk value of the sand comes to around 7.21% which shows that the moisture content in the sand is negligible. The sand is oven-dried before the start of the test which interferes with the low value of bulk percentage.

1.4 Silt Content in the Sand

Silt is a very fine particle whose size is less than 150 microns. The amount of silt is decreasing and increasing due to weather conditions. So, it will affect the strength and block structure will crack. Excessive accumulation of silt leads to water absorption which causes the block to shrink and expand. It also affects the bonding between the cement and the aggregate. Therefore, it is extremely important to know the amount of silt in the sand before making sand block. The silt material is tested as per IS Code Reference: 1386 (Part II) - 1963 and the following results are obtained:

Figure 1.4: Sodium chloride and measuring cylinder

Amount of silt in sand = (V2/V1) x 100

Table 1.4: Determination of silt content (%) in sand

SI. No	Description	Sample No		
		Sample I	**Sample II**	**Sample III**
1	Volume of sample (V_1) ml	96	96	84
2	Volume of sample (V_2) ml	4	4	5
	Silt Content (%)	4.17	4.17	5.15

From the above observation table, silt percentage = (4.17 + 4.17 + 5.15)/3 = 4.5% < (6% or 7%)

The permissible silt content of the sand is 6% or 7%. The silt content in the sand is about 4.5% which is within the acceptable limit. Thus, it was concluded that river sand can be used for construction purposes.

1.5 Red Clay

Red mud is defined as a mixture of minerals consisting primarily of aluminum oxide bound to one or more water molecules (hydrated aluminum oxide). They are diaspore, boehmite and gibbsite. With small amounts of impurities such as SiO_2, K_2O, Fe_2O_3, TiO_2, CaO, MgO and Na_2O. Red mud is the primary source for industrial aluminum and alumina production by the Bayer process.

Red clay is also used for the production of refractory block, during firing of red clay below 1200 °C, its structure changes to dense granules consisting mainly of corundum (- Al_2O_3). The mullite phase is formed as a result of the reaction between silica and alumina at temperatures within (1250–1350) °C. Gibbsite or hydrargilite lists its hydrate at (290–340) °C and transforms into boehmite, and below (1200–1300) °C it transforms into corundum.

Table 1.5: Chemical Analysis of Red Soil

Compound	Percentage (%)
Al_2O_3	53.00
Fe_2O_3	04.50
CaO	02.70
SiO_2	01.70
TiO_2	02.40
LOI	30.60

1.6 Aluminum Dust

In these studies, attempts have been made to manufacture plastic sand block using aluminum powder to see properties such as physical and mechanical properties of the block. Accordingly, the above properties are reviewed by adding aluminum dust. And this block are reduced in weight and found to be light in weight.

Alumina is the main constituent of a good block clay. A content of about 20% to 30% is required to make good quality block clay. It provides plasticity to the earth so it helps in molding the block clay. If alumina is present in excess with an insufficient amount of sand, the raw block shrink and deform during drying, becoming very hard when fired. Therefore, it is important to have the optimum content of alumina.

Table 1.6: Properties of aluminum powder

S. No	Parameters	Properties
1	Appearance	Fine Powder
2	Colour	Silver Gray
3	Chemical Composition (CC)	Aluminum (min 99.3%), copper (max. 0.1%), iron (max 0.4%) silica (max 0.2%)
4	Atomic Weight	26.98g
5	Density at 25^oC	$2.7 g/cm^3$
6	Crystal structure	Face-Centered Cubic (FCC)
7	Purity	99%

Water

Water is one of the most important elements in construction and is required for mortar, preparation of block, mixing and curing of cement concrete etc. The quality of water used has a direct impact on the strength of motor and cement concrete in construction work. The water used for treatment and mixing should be free from high concentration of alkali, acid, oil, salt, sugar, organic matter, vegetable growth etc. which may be harmful to block, concrete or iron. Portable water will be used for mixing concrete. The suspended solids in water should not exceed 200 mg/l. The pH value of water should not be less than 6. The quantity and quality of water required is referred from IS Code Recommendations: Water Quality for Building Construction (IS 456:2000).

1.7 Physical properties of used soil for sample

Standard gradation tests were carried out on the soil collected for block making and the summary of the test results are given in Table 1.1 and the grain size distribution curve is given in Figure 1.5.

Table 1.7: Physical properties of used soil for sample

Sl. No.	Property	Value
1	Specific gravity	2.68
2	Grain size distribution	
	(a) Clay (<0.002 mm)	6%
	(b) Silt (0.002 – 0.075 mm)	42%
	(c) Sand (0.075 – 4.75 mm)	52%
3	Standard Proctor Test Results	
	(a) Optimum Moisture Content	14%
	(b) Maximum dry density	1.84 g/cc
4	Atterberg limits: Liquid limit Plastic limit	47% 40%

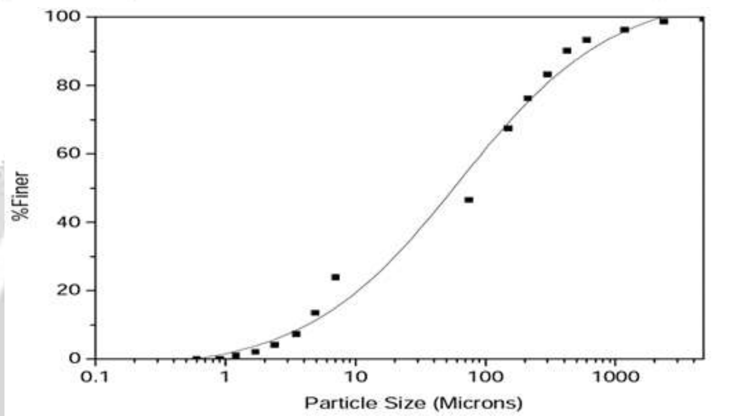

Figure 1.5: Grain Size distribution curve for the soil

The main objective was to compare the properties and performance of the two categories of samples, namely, the base sample and the modified sample. Modified samples differ from the original samples in their composition, such as the presence and type of fibers, types of additives, molding pressure, and hardening of the samples. We can use OPC (Grade 43) as a chemical stabilizer. The properties of cement used are given in Table. Two types of fibers are used and obtained from plastic bottles (waste plastic bottle) and carry bags (pick up bags), as shown in Figure, as they are called 'bottle fibers' and 'kit fibers' respectively. These plastic wastes are cut into short lengths of approximately uniform minimum width of 2 to 3 mm to form fibres. The lengths of the fibers used for the investigation were 1 cm and 2 cm. The fiber content was taken as 0.1 and 0.2% by weight of the dry soil used. Research has been conducted into possible fiber combinations and lengths with the percentages of fibers stated above. The molding pressure (compaction) was controlled by a digital compression testing machine, with a capacity of 1000 kN and a minimum count of 100 N. Experiments were performed for molding pressures from 1.25 to 7.5 MPa at 1.25 MPa intervals.

Table 1.8: Cement Properties

Sl No.	Properties tested	Values	BIS Specifications (BIS 8112-1989)
1	Normal Consistency	32%	-
2	Initial Setting Time	42 minutes	Not less than 30 minutes
	Final Setting Time	123 minutes	Not more than 600 minutes
3	Compressive Strength, 3 days	25MPa	Not less than 23MPa
	Compressive Strength, 7 days	36MPa	Not less than 33MPa
	Compressive Strength, 28 days	49MPa	Not less than 43MPa

Kit fiber Bottel Fiber

Figure 1.6: Types of fibers

1.8 Mixing and Casting

Several mixing methods were given in the literature review. But before mixing the soil should be prepared by preliminary air drying, the lumps of dry soil are broken manually and proper sieving is done to remove particle size above 4.75 mm. A homogeneous mixture was prepared before pouring dry soil and cement water into the tray. Then water is added to the homogeneous mixture along with the fibers obtained from the waste bottles. Once the fibre-rich clay-cement paste is prepared, pour the paste into the mold and apply molding pressure. The density of blocks mainly depends on the molding pressure applied by means of hammer. It is said to develop a compaction pressure approximately equal to that of a single acting hammer strike. 2 MPa. After proper compaction the mold containing the clay-cement paste is left for a proper drying period, which was discussed earlier in the literature review. Then the sample is kept in water in wet jute bags for 28 days to get proper strength and the sample is sent for further testing.

Cylindrical sampling devices are:

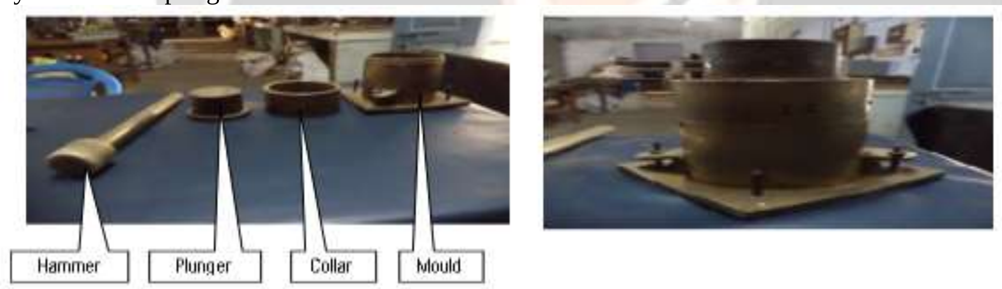

Figure 4.9: Test specimen preparation

The test specimens after moulding were allowed to dry for a period of 24 hours. The specimens were kept in curing tank and allowed to cure for a period of 28 days.

Figure 4.10: Curing of specimens in progress

1.9 Density

The dry density of samples (three samples for each composition) of different composition is determined after drying in an oven at a temperature of 105oC. The results are analyzed for the effect of molding pressure, cement content, fiber type, its length and quantity as described below.

1.9.1 Effect of Molding Pressure

Figure below shows the effect of molding pressure on dry density. Keeping the cement content constant, the dry density increases as the molding pressure increases. The significant increase in density observed in the modified samples may be due to the following factors

(i) Deprived of fill effect
(ii) Increase in homogeneity
(iii) Improvement in bonding also
(iv) Reduction in vacancies.

The measured density was found to be in the range of 1.847 to 1.959 g/cc. These values are in line with the desirable range for production of stabilized clay blocks, which is specified as 1.81 to 1.86 g/cc. Preliminary studies on clay blocks made using ASTRAM found the density to be 1.806 to 1.895 g/cc. In the present study, these values correspond to a molding pressure of 1.25 MPa. The density increases by about 6% to 7% when the molding pressure is increased from 1.25 to 7.5M Molding Pressure (MPa).

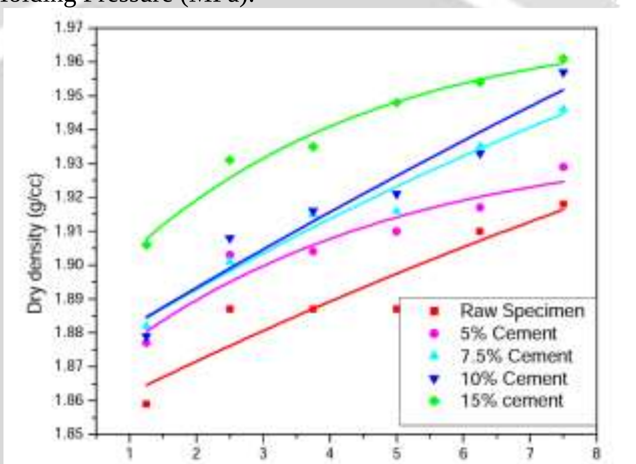

Figure 1.11: Effect of molding pressure and cement content on dry density

1.9.2 Effect of Cement Content

The effect of molding pressure and cement content on dry density for different fiber properties was calculated. The curves shown in Fig. 4.12(a) correspond to a low molding pressure of 1.25 MPa and to the kit fibre. Fig. 4.12(b) corresponds to the bottle fibre. Fibers do not contribute much to the improvement of density. The greater the length of the fiber or its content, the lower the value of the density. However this shortcoming is compensated by increasing the molding pressure. The rate of increase of density is apparent as the molding pressure is increased.

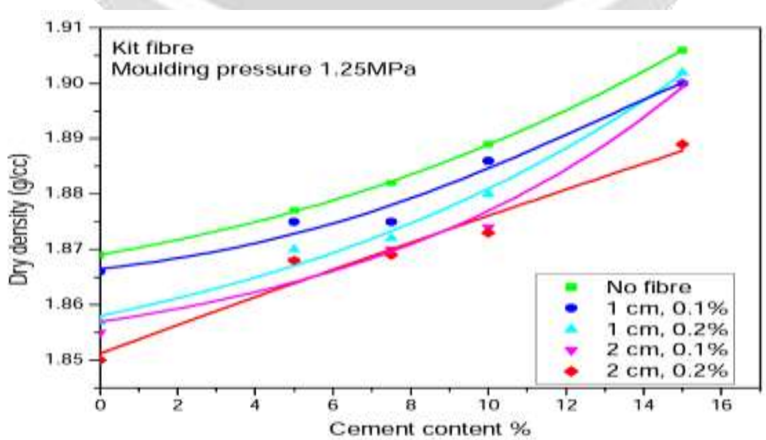

Figure 1.12: (a) Effect of cement content on dry density (molding pressure 1.25 MPa kit fiber)

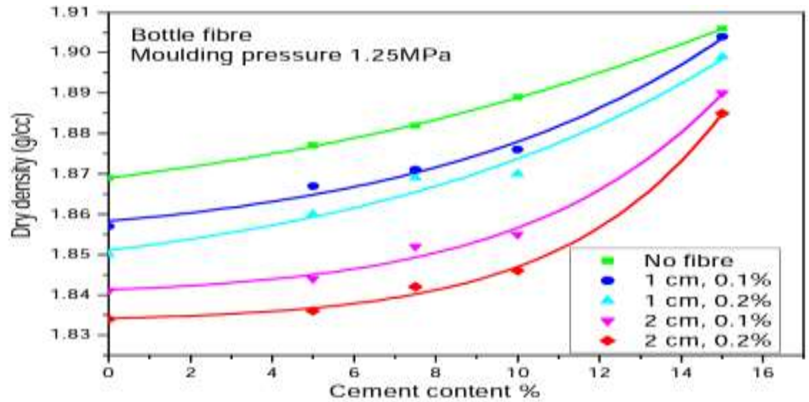

Figure 1.12: (b) Effect of cement content on dry density (molding pressure 1.25 MPa; bottle fiber)

Figure 1.12(c) shows the effect of molding pressure up to 7.5 MPa and the density of the Kit fiber properties. The effect of bottle fiber properties on density is shown in Fig. 1.12 (d). From these data, it is clear that an increase in cement content enables the fiber to regain density, but not as much as in the case of an increase in molding pressure. When the cement content was increased from 0 to 15%, the density increased from 2.2 to 3.7%. Chowdhary (2004) reported in a study that cement content has little effect on block density. The small increase observed in the study may be due to higher specific gravity and use of 43 grade cement.

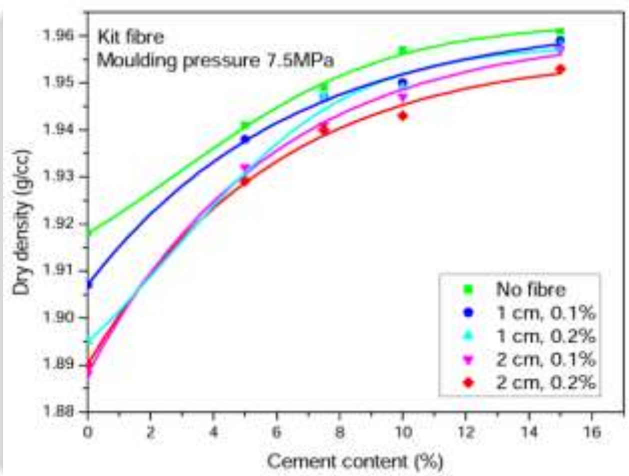

Figure 1.2 (c) Effect of cement and fiber content on dry density (molding pressure 17.5 MPa; Kit Fiber)

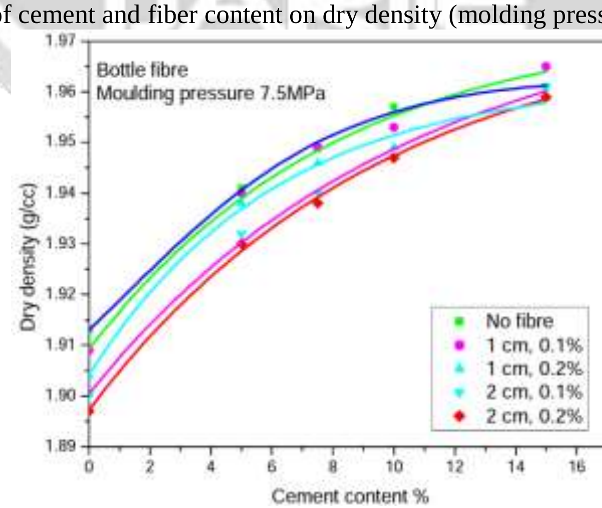

Figure 1.12 (d) Effect of cement and fiber content on dry density (molding pressure 7.5 MPa; bottle fiber)

1.9.3 Effect of fiber type, length and material

From Figure 1.12, it is clear that the density decreases with the addition of fibers and Table 1.11 shows the percentage reduction in density for different types, lengths and amounts of fibers. It is clear from the table that the effect of fiber content on the density of the samples was less pronounced. For a higher molding pressure of 7.5 MPa and a cement content of 15%, there was no decrease in density. The loose state of the fiber at low molding pressure and the low cement content may account for the reduction in density.

The low molding pressure leaves air space in the sample, causing the sample to become loose and less dense. The high condensation energy enables the particles to come closer to minimize vacancies. Thus the samples become denser. This will increase the bond between the fibers and the soil in the presence of cement.

Table 1.9: Percentage reduction in density for different fiber contents and lengths

Cement content (%)	Moulding pressure (MPa)	Type of fibre	Reduction in density (%) for fibre length			
			1 cm		2 cm	
			0.1%	0.2%	0.1%	0.2%
0	1.25	Kit	0.16	0.64	0.75	1.02
		Bottle	0.64	1.02	1.5	1.87
	7.5	Kit	0.47	0.73	0.94	1.09
		Bottle	0.57	0.94	1.56	1.46
15	1.25	Kit	0.31	0.21	0.31	0.89
		Bottle	0.14	0.31	0.89	1.1
	7.5	Kit	0.2	0.39	0	0.39
		Bottle	0.39	0.25	0.2	0.41

1.10 Compressive Strength

Cylindrical samples of 101.5 mm diameter and 117 mm height have been fabricated and tested. Tests were carried out on cylindrical specimens to correlate the values of compressive strength with the tensile strength. The sample will be a relevant replication on the engineering properties of soil, as the value of dry density and OMC has been found using Proctor mold for light compaction.

1.10.1 Effect of molding pressure

The effect of molding pressure on compressive strength is shown in Figure below.

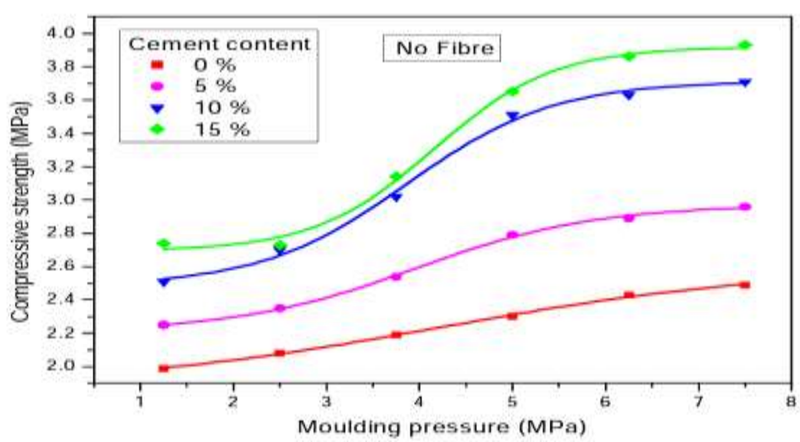

Figure 1.13: Effect of molding pressure on compressive strength

As seen, as the molding pressure increases, the compressive strength also increases. It is observed that the compressive strength increases by 20 - 50% when the molding pressure is increased from 1.25 to 7.5 MPa. It is observed that, by increasing the molding pressure and adding 10% additional cement, the compressive strength can be improved from 2.6 to 3.8MPa.

1.10.2 Effect of Cement Content

Figure below shows the variation of compressive strength of samples containing cementitious materials for different molding pressures. With an increase in cement content, for a given molding pressure, there was an increase in compressive strength. The addition of cement increases the compressive strength by 40 to 60%. For a given cement content, as the molding pressure increases, the compressive strength also increases. This increase in compressive strength is more significant for cement content up to 10% and for more than 10%, the effectiveness of adding cement was not sufficient for any molding pressure. This may be due to the low fiber cement ratio in the soil cement matrix. The ultimate strength of the samples appears to be more sensitive to changes in cement content than to molding pressure. The improvement in strength is due to the following factors:-

(i) Bad filler effect
(ii) Increase in homogeneity and
(iii) Better bonding.

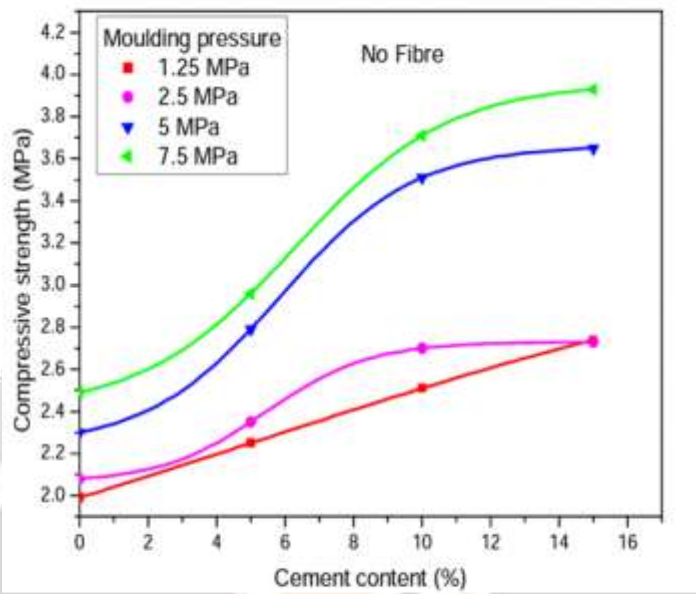

Fig. 1.14: Effect of cement content on compressive strength

Conclusion

The main findings of this research work are listed in this section. The study on the structure of blocks and block making mechanism of clay blocks is described here and it essentially comes under four steps.

(i) Density and strength of blocks
(ii) Study on Clay Block Masonry
(iii) Water absorption
(iv) Erosion study.
(v) Mixing ratio.

The findings from the experimental investigations are grouped under these sections, which apply to the characteristics of the materials used and the parameters investigated.

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