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Full Length Research Paper

Assessment of the Physical Properties of Bricks Made from Sand, Moorum and Quarry Dust with Molten Plastic as a Binding Agent

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Abstract

Plastics are multipurpose manmade materials used for various purposes. They are widely used because of their light weight, cost and ease of manufacturing. Despite their wide use, plastics are not biodegradable and cannot easily decompose when they are disposed as a waste. An alternative is to recycle these materials instead of disposing them to the environment. In this research work, we tried to assess the use of different fractions of molten plastic water bottles as a binding agent in the production of bricks. The materials used with the molten plastics were sand, moorum and quarry dust. The physical properties of the bricks were tested according to the ASTM specifications. The test results showed maximum compressive strengths with plastic fractions of 35% in all the three materials. The strengths increased up to 35% and showed reduction thereafter. At 35% plastic fraction, bricks from quarry dust exhibited the highest strength of 7.7 MPa while moorum bricks showed 7.15MPa. Brick weights decreased with increasing molten plastic fraction; the highest ranged from 2.85 – 3.0 kg while the minimum ranged from 2.1 – 2.5 kg. Moorum bricks had the least weight and quarry dust bricks had the highest. All of the bricks exhibited water absorption of less than 5.5% at 35% plastic fraction. Moorum had the highest absorption while sand bricks had the least water absorption. Qualitatively, the bricks from all the three materials fulfilled the ASTM specifications. Two tests that were not conducted in this research work and need more testing are the heat tolerance level of the bricks and the amount of volatile gases liberated to the atmosphere during the melting process of the shredded plastics.

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1. Introduction

Plastic is a very useful substance and its invention has contributed immensely to human development. It is light weight, water resistant, expandable, strong, durable and cheap (Parasnis, 2020; Sahani *et al.*, 2022). Plastics can be made in different forms and shapes (because of their plasticity) that are very attractive. They have very unique properties that enables them to mix with many kinds of materials (Arvind, 2018). Because of all these benefits, the application of plastic materials and their composites are growing rapidly.

Despite their benefits, plastics are hazardous materials since they also have adverse effects on the environment because of their non-biodegradable nature and since they are made up of toxic pollutants (Sahani *et al.*, 2022). They also put ocean health, food safety and quality, human health, coastal tourism and the climate at risk. When burned plastics release carbon dioxide into the atmosphere, and therefore have contribution to global warming (Sahani *et al.*, 2022). Besides carbon dioxide, the burning of plastics releases toxic gases and liberates hazardous halogens, which pollute the air. These gases are harmful to the central nervous system, are carcinogens, aggravate respiratory ailments such as asthma and emphysema and cause rashes, nausea or headaches. Plastic trashes degrade the aesthetic value of any site and therefore lowers tourism-related revenues. The cleanup and upkeep of such sites has also significant economic expenses (Schmaltz *et al.,* 2020).

Global estimation of plastic waste makes up about 13% of the total solid waste out of which roughly 25% is recycled and the rest is land filled. This has been intensified by rapid growth of population, urbanization, developmental activities and changes in life style of people. The current practice to minimize the problem of plastic waste accumulation is by employing the 5 R's (Reduce, Recycle, Reuse, Recover, and Residual Management), which is considered to be a base of waste management that needs to be strictly followed (Daftardar *et al*., 2017).

Many kinds of polyethylene (PE) are known, with most having the chemical formulae $(C_2H_4)_n$. PE is usually a mixture of similar polymers of ethylene with various values of polyethylene. Materials which contains one or more number of polymers having large molecular weight and solid in their finished state are known as plastics. Polypropylene (PP), also known as polypropene, is a thermoplastic polymer used in a wide variety of applications. They are polymers of natural materials such as cellulose, coal, natural gas, crude oil, salt, minerals and plants (Sahani *et al.,* 2022). They are produced via chain-growth polymerization from the monomer propylene. Polypropylene belongs to the group of polyolefins and is partially crystalline and non-polar and has a chemical formula of $(C_3H_6)_n$. They have low strength, hardness and rigidity but have high ductility. Polymers have a number of vital properties, when exploited alone or together, make a significant and expanding contribution to constructional needs. Plastics have specific gravity of 0.89 (Sahni et al., 2022).

In construction, materials account for 60 – 70% of the project cost (Ayoub *et al.,* 2023). Plastic if properly used can be one of the materials that can alleviate this cost. In construction field, plastic can partially replace the fine aggregates in powdered form or can totally replace cement as a binding agent when used in molten state. This is mainly done in the production of bricks and tiles. The materials that can be mixed with molten plastic can be sand, fly ash, quarry dust, or moorum. The bricks formed from plastic and these raw materials can replace other commonly known bricks like clay bricks/tiles, concrete bricks, and fly ash bricks. For structural engineering, one of the most essential things in design of load bearing members is material strength beside member forces. In the case of bricks, design strength is compressive strength which in turn affects the masonry strength built using bricks. Therefore, the question that needs to be answered is whether the bricks made from plastics can satisfy the standard specifications (e.g. compressive strengths, water absorption, weight, etc.) met by the already known bricks. Compressive strength is significant to structural engineer for calculating structural brickwork strengths in accordance with the recommendations of the Structural Masonry Codes of Practice.

In this regard, many researches have carried out tests on plastic bricks from sand and other fine aggregates. Moon *et al.* (2022) produced bricks from waste plastics and river sand using plastic sand ratios of 1:2, 1:3, and 1:4 and tested mainly compressive strengths and water absorption tests. Sahani *et al.* (2022) also did similar investigations with slightly different ratios of 1:2, 1:3, and 1:5 by weight. Surbhi and Chauhan (2023) also used sand with plastics with ratios ranging from 0 - 50%. Ayoub *et al.* (2023) used quarry dust in addition to sand with different ratios of plastics. All of these used melted plastics as a replacement for cement. The studies suggest the benefits of using plastic as an alternative resource for brick production. Yet, the studies gave conflicting results in the fraction of plastic that gives the highest compressive strength. Besides, they did not also compare the different materials used with the plastic.

The primary aim of this study is to reduce the non-biodegradable plastic waste bottles and to put these wastes to good use by producing bricks from the plastics and three different materials as fine aggregates. The materials used with the molten plastic were sand, moorum and quarry dust and the plastic were used in different ratios with the fine aggregates. Sand is one of the abundant resources but is limited to specific locations. Similarly, moorum is also an alternative to sand but scare in most areas. Quarry dust is generated from the stone crushing and is abundantly available in quarry sites. This dust is considered as a waste material but it can be put to good use if proper research is conducted. The objectives of this research are to select the best ratios of the plastic and the fine aggregates that gives the highest physical property standards of the bricks.

2. Materials and Methods

2.1. Materials used

The materials used for making plastic bricks were waste plastic bottles, sand, quarry dust, and moorum shown from Figures 1-4, respectively. The plastic bottles used were made from Polyethylene Terephthalate Ethylene (PETE) thermoplastic materials. These types of plastics are polymers with or without cross linking and branching. On application of heat with or without pressure, they melt and require cooling to be set to shape.

Figure 1: Partially shredded plastic bottles

Figure 2: river sand

Figure 3:quarry dust

Figure 4: moorum

The mold used to cast the bricks was made from wood of the standard dimension of length, width, and height of 190 mm x 90 mm x 90 mm, respectively (Figure 5).

Figure 5: Wooden mold used to cast the bricks

In this experiment, Wonji river sand was used. Quarry dust was obtained from stone crushing sites. Moorum is the product of decomposition and weathering of the pavement rocks of red color. Visually these are similar to gravel with presence of higher content of fineness. The moorum used in this research was obtained from Tulu Dimtu.

2.2. Procedure for plastic brick preparation

The following steps were followed for the preparation of the bricks. These were, collecting the plastic bottles, cleaning them to eliminate unwanted materials, partial shredding since there was no tool for complete shredding, melting the plastics, mixing with the raw materials to the right proportions, casting the bricks, and curing. The plastics were melted in empty container that was heated up by fire. After the container was heated up enough, dry shredded plastic bottles were added and the heating continued until the shredded bottles melted (Figure 7). The plastics melted at temperature ranging between 105 – 115ºC within a time of 2 minutes (Sahani *et al*., 2022). The melted plastics were then mixed with sand, quarry dust and moorum in proportions shown in Table 1. Mixing of materials was essential for the production of bricks of uniform strength. Generally, there are two types of mixing; hand mixing and machine mixing. In this project, hand mixing was adopted. The mix was poured into the mold and pressed down with a tamping rod. The bricks were removed from the mold after an hour even if it takes only 20 minutes for the bricks to settle and harden (Kamble and Kara, 2017). Thereafter the bricks were kept in curing tank and allowed to cure for a period of 7 days. Samples of the bricks prepared are shown in Figure 6.

Figure 7: Melted shredded plastic

Figure 6: samples of bricks made from molten plastic and the three materials.

2.3. Treatments considered

The treatments considered were based on the mix proportions of plastics by volume as shown in Table 1. For each treatment there were five replications making a total of 75 experimental units.

Table 1. Mix proportions of bricks made of various materials

Treatment	Plastic (%)	Various Materials (%)		
		Sand	Moorum	Quarry Dust
1.	25	75	75	75
2.	30	70	70	70
3.	35	65	65	65
4.	40	60	60	6o
5.	45	55	55	55

2.4. Testing procedures

The tests considered comprised of compressive strength, water absorption and weight comparisons. In addition, other tests were carried out according to the American Society for testing of materials (ASTM, 2020) standard specifications.

2.4.1. Quantitative tests

The compressive strengths were done following the procedure stated in IS 3495 (BIS, 1992) (Figure 8).

Figure 8:Compressive strength test

The bricks were also tested for water absorption in accordance with the techniques of IS code 3495 (part 2) (BIS, 1992). Before soaking the bricks in water, their dry weights were measured. Thereafter the bricks were soaked in water for 24 hours (Fig. 5) after which they were removed and wiped with clean cloth before the wet weight measurements were taken. The brick with water absorption of less than 7% provides better resistance to damage by freezing. The degree of compactness of brick was obtained by the pose in the bricks. According to BIS (1973), for the first-class bricks, the water absorption capacity should not be more than 15% by weight. Other tests extend this number to 20% (e.g. Clement *et al.*, 2019: Ayoub *et al.*, 2023).

Figure 9: Water absorption test

2.4.2. Qualitative tests

One of the tests conducted in this case is visual inspection. In this test, the shape of bricks was closely inspected for truly rectangular shape and sharp edges. The other is dimensional tolerance test based on the standard sizes. The standard size given in the IS Code are 19 cm, 9 cm and 9 cm for length, width, and height, respectively. In the third case, drop down tests were done by dropping the bricks from a height of 1 meter on firm surface (in this case, plain cement concrete surface). This test was necessary to test the bricks' resistance to impact. Finally, nail scratch tests were done on brick surfaces with the help of a finger nail. A brick with no impression on the surface satisfies the criteria of 1st class brick.

3 Results and Discussion

3.1. Brick weights

Consideration of brick weight is essential in relation to the dead weight of a building. Bricks with light weight eventually result in low dead weight of a building, which is considered good. Comparisons of the brick weights made from the three different materials in relation to the fraction of plastics are shown in Figure 10.

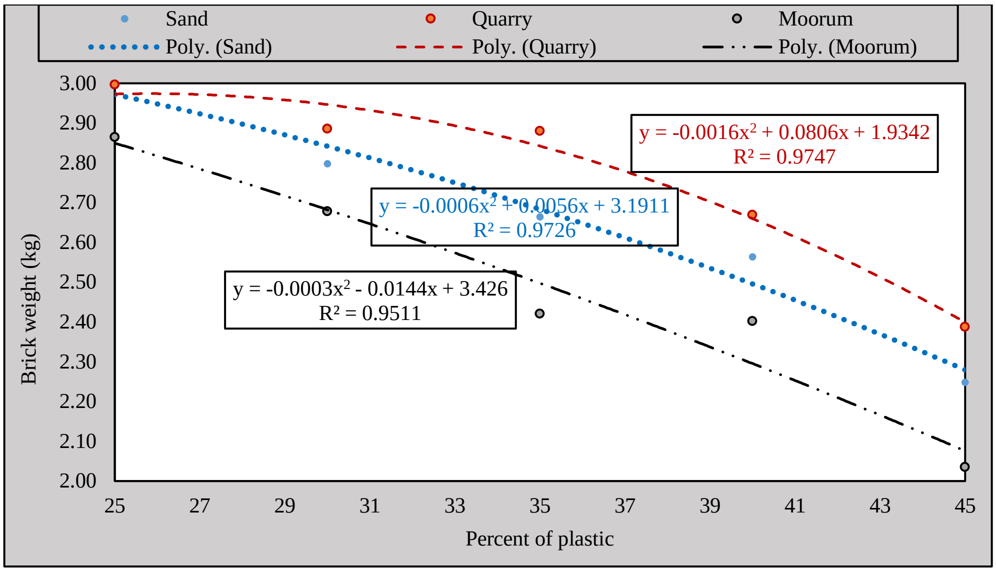

Figure 10: Change of weight of bricks with plastic content for the three different materials

As shown in the figure, all of the bricks showed weight reduction, which is of a quadratic nature as the plastic content increased. The reduction is faster for moorum and sand bricks than for quarry dust bricks. The weight reduction is considered as a positive side of using plastic melt as a binding agent in addition to its benefit in replacing cement. Out of the three materials, bricks made from moorum uniformly showed the lowest brick weight. This is because of the low weight of moorum compared to the other two raw materials used. At and above 35% plastic content, bricks made from this material exhibited weights less than 2.5 kg. The standard weight of red clay bricks is 2.27 kg (MyoAye *et al.*, 2020). Sand exhibited the highest weight, which is in excess of 2.4 kg regardless of the plastic fraction used.

The next step is to make statistical comparisons in order to find out whether there are significant differences among the materials used. The comparison is made using one-way ANOVA and the result is shown in Table 2.

Table 2. One-way ANOVA for comparison of brick weights made from the three materials

ANOVA Table

Source	SS	df	MS	F	Prob>F
Groups	0.26936	2	0.13468	1.42	0.2795
Error	1.13782	12	0.09482		
Total	1.40718	14			

For the analysis of ANOVA, the third treatment with plastic fraction of 35% was considered for all the three materials. The selection of the 35% becomes clear as more analysis is made on the compressive strength of bricks. The statistics does not show significant differences among the materials used as far as brick weights are concerned, at 35% plastic content. The three box plots are shown in Figure 11. Since there are no significant differences among the three materials, there is no need for pair comparisons.

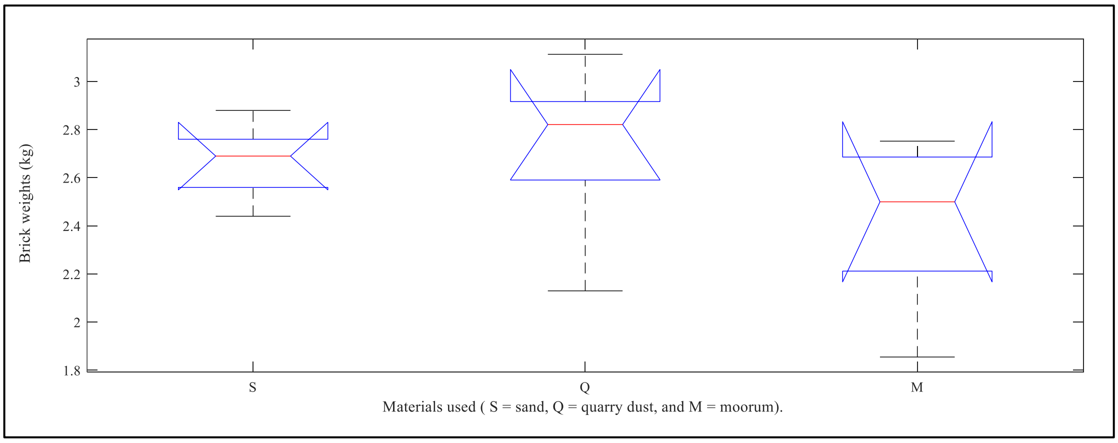

Figure 11: Box plots of the ANOVA results shown in Table 2

The box plots indicate the lowest variability among sand bricks made using 35% plastic fraction. This can be due to the uniformity of sand (lack of aggregates) compared to the other two materials. Despite the graphical result shown in Figure 10 that shows moorum bricks as low weight bricks, the statistical result did not corroborate this result. It means, there is no advantage gained by using one material over the other in terms of weight benefit. However, there is a benefit in reducing weight with addition of more fraction of plastic as shown in Figure 10.

The results obtained in this test are within the range of values obtained by other researchers. For instance, Kumar *et al.* (2020) obtained 2.2 kg for plastic bricks made with sand as fine aggregate though they did not mention the percentage of plastic. This corresponds to 45% plastic in this study. Moon *et al.* (2022) observed reduction in the weight of bricks as the plastic is added compared to pure sand bricks. Generally, a compromise is needed between weight and compressive strength that necessitates choosing the weight that corresponds to the percent of plastic that gives the highest compressive strength.

3.2. Compressive strengths

From among the qualities of bricks one of the most prominent is the compressive strength since it is indicative of its load bearing capability. It is defined as the ratio of maximum load at failure to average area of the two faces under compression (Clement *et al.*, 2019; Kumar *et al.*, 2020; MyoAye *et al.*, 2020). For a common brick the minimum value is 3.5 MPa, while for high quality brick it must be 14 MPa or higher (Clement *et al.*, 2019; MyoAye *et al.*, 2020). Normal strength of clay brick is 6.6 MPa (Clement *et al.*, 2019). In our tests, this parameter was influenced both by the percent of plastic in the brick and by the nature of the three materials used. Figure 8 indicates how this parameter changed with the percent of plastic in the three materials.

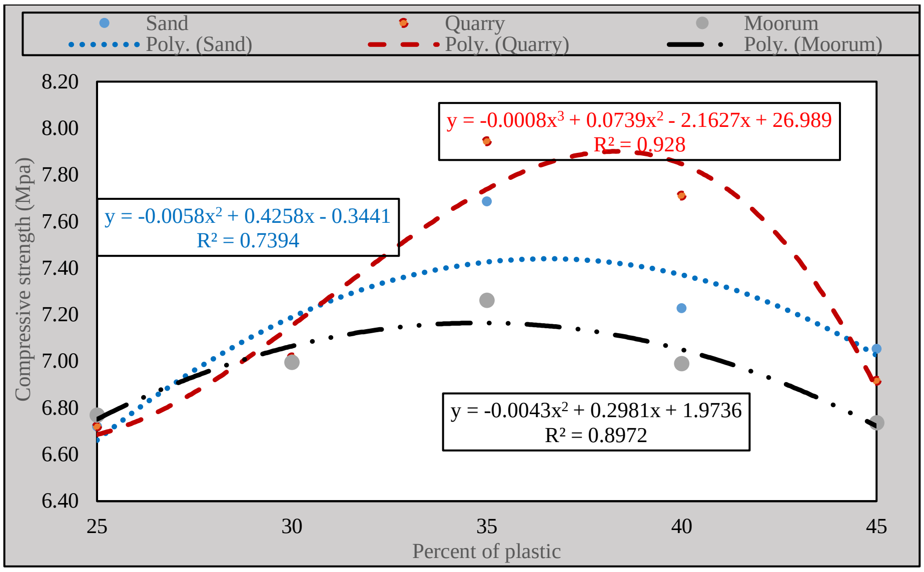

Figure 12: Compressive strengths of the bricks made from the three materials and different fractions of plastics

As seen in the figure, the optimum plastic fraction for bricks of good strength is around 35%. The plastic fraction did not show differences until the plastic fraction exceeded 30%. The materials did not exhibit the same strength at identical plastic fraction. Highest separation occurred between plastic fractions of 35 and 45 percent.

The plastic fraction at which maximum strengths occurred for each material were at the inflection points, which are obtained by taking the first derivative of each fitted equation and equating the result to zero. Calculated values for moorum gave 34.66%, which is also close to 0.35 plastic fraction as seen in the figure. For sand the result is 36.71% and for quarry dust, 37.6%. The shift may be linked with the density of the material. At 45% plastic fraction the strengths became almost similar again, for all the materials. The least (7.18 MPa) was exhibited by bricks made from moorum. Sand bricks exhibited intermediate values of about 7.45 MPa. Quarry dust could have revealed compressive strength of 7.9 MPa instead of 7.7 MPa if the fraction of molten plastic had been 37.6% instead of 35%. In all the three cases the compressive strengths were within the range of the normal clay brick, which is 6.6 MPa (Clement *et al.*, 2019). The unit of MPa is the same as N mm^{-2}.

3.2.1. Compressive strengths of sand bricks

The next thing is to check whether the differences are statistically different or not. This is done for each material separately. For sand the ANOVA is shown in Table 3.

Table 3. Compressive strength of bricks made from sand with different plastic fractions

ANOVA Table

Source	SS	df	MS	F	Prob>F
Groups	2.58284	4	0.64571	4.74	0.0075
Error	2.72576	20	0.13629		
Total	5.3086	24			

The ANOVA table shows significant differences among treatments at p = 0.05 level. In order to know which pairs are different it is necessary to do pair comparisons and this is shown in Figure 13.

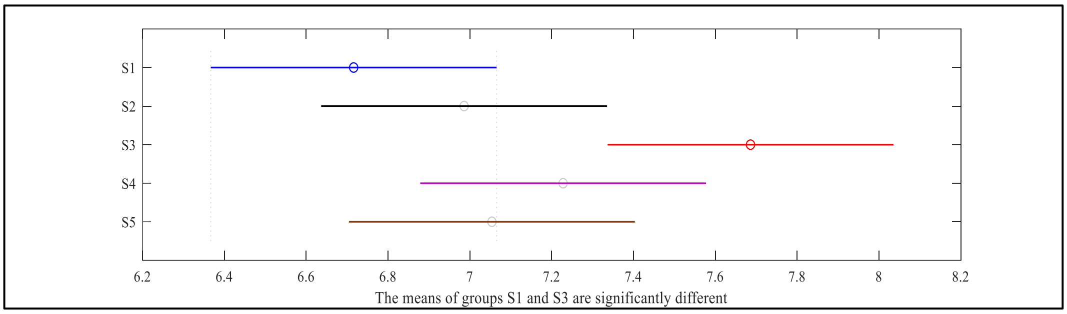

Figure 13: Pair comparisons of treatments for bricks made from sand with different plastic fractions

The pair comparisons show significant differences between treatment S1 that represents 25% plastic fraction and S3 that represents 35% plastic fraction. The rest of the treatments are not significantly different from each other. The box plot shown in Figure 14 shows how the brick with 35% plastic fraction differs from the rest.

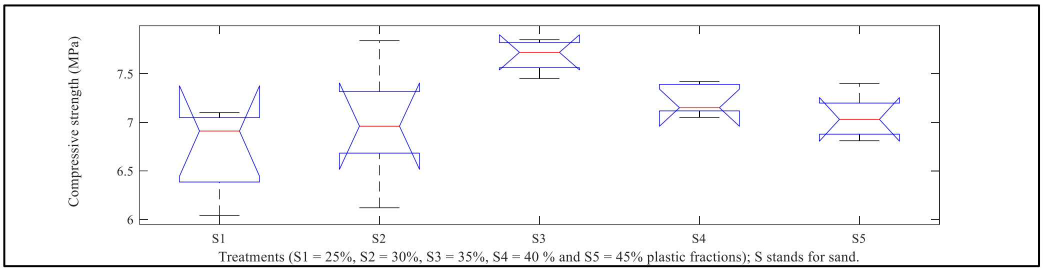

Figure 14: Box plots of treatments for bricks made from sand with different plastic fractions

For bricks made from sand at 35% plastic fraction, the variability is low for treatments S4 (40%) and S5, (45%) plastic fractions. This indicates better uniformity of bricks as the plastic fraction increases. Overall, for bricks made from sand, the 35% plastic fraction (as the amount of plastic mix ratio increases up to optimum values of 35% plastic waste bottles and 65% of sand) gives average compressive strength which is in excess of 7.5 MPa and it is therefore considered the best. According to ASTM, the obtained result satisfies the standard of quality bricks. Clay bricks may be classified into first class if the compression strength is 10 MPa, second class if 7 MPa, and third class if 3 MPa (MyoAye, *et al*., 2020). Thus the test results of our bricks are of the second class.

Sahani *et al.* (2022) in their studies with plastic-sand bricks obtained the highest compressive strength of 12.28 MPa for 1:4 ratio compared with 9.72 MPa at 1:3 ratio. Their results indicate reduction in compressive strength as plastic fraction increases. In this respect their results are different from the results of this study that yielded the strength at 35% plastic which is close to 1:3 ratio. Moon *et al.* (2022) obtained the highest compressive strength of 9.17 MPa for 1:2 ratio and 6.2 and 3.5 MPa for 1:3 and 1:4 ratios, respectively. Their results are different from this study and from the former result as well. On the other hand, the work of Surbhi and Chauban (2023) is roughly close to what is obtained in this study since they obtained 6.9 MPa for 30% plastic fraction and 5.2 for 40% plastic. Gupta and Gupta (2022) also obtained 8.1 MPa at plastic ratio of 1:3, which is close to what we obtained for sand (7.7 MPa) at plastic fraction of 35%. The inconsistencies may be rooted in the number of treatments they have considered. It may also be due to differences in the types of plastics they used, nature of mixing or compaction types. In the studies mentioned linear relationships were observed between plastic fraction and compressive strength, whereas in this study quadratic relations were obtained. Considering ratios of 25% and 45% there is hardly any difference between the two in terms of compressive strengths. For a person who considers ratios of 1:3 and 1:2, there is a declining trend, while from 1:5, 1:4 and 1:3 there is an increasing trend.

3.2.2. Compressive strengths of quarry dust

For bricks made from quarry dust with different fractions of plastics, the ANOVA Table is shown in Table 4.

Table 4. Compressive strength of bricks made from quarry dust with different plastic fractions

ANOVA Table

Source	SS	df	MS	F	Prob>F
Groups	7.24802	4	1.812	15.32	6.93427e-06
Error	2.36488	20	0.11824		
Total	9.6129	24			

As seen in the table, there are significant differences among treatments at 0.05 level for bricks made from this material. The pair comparisons are shown in Figure 15.

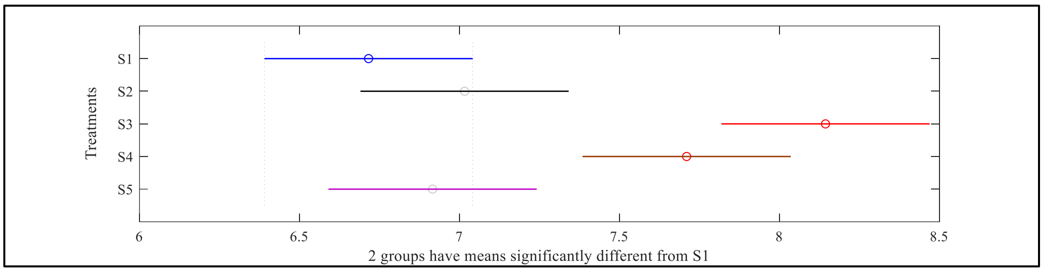

Figure 15: Pair comparisons of treatments for bricks made from quarry dust with different plastic fractions

As shown in the figure, S3 (35%) and S4 (40%) plastic fraction bricks are different from S1 (25%) and S2 (30%). Here again, S3 exhibited the highest mean compressive strength that exceeded 8 MPa. Box plots shown in Figure 16 exhibit the variability within replications.

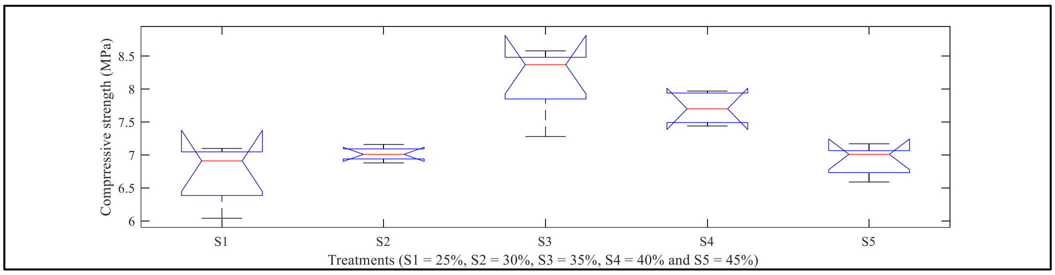

Figure 16: Box plots of treatments for bricks made from quarry dust with different plastic fractions

In the plot, for quarry dust bricks the lowest variability within treatments was observed for plastic fraction of 30%. The 35% plastic fraction bricks showed the highest variability within replications. Such high variability is indicative of inconsistency (presence of larger aggregates) in the strength of the bricks. Despite that, this group still manifested compressive strengths higher than all the rest. Asha et al. (2020) obtained compressive strength of 14.8 MPa for plastic-quarry dust bricks of 1:3 ratio. This value indicates the ability of quarry dust in enhancing compressive strength over the other two fine aggregates.

3.2.3. Compressive strengths of moorum bricks

For bricks made from moorum with different fractions of plastics the ANOVA Table is shown in Table 5.

As seen in the table, there are significant differences among treatments at 0.05 level for bricks made from this material. The pair comparisons are shown in Figure 17.

Table 5. Compressive strength of bricks made from moorum with different plastic fractions

ANOVA Table

Source	SS	df	MS	F	Prob>F
Groups	0.89626	4	0.22407	6.23	0.002
Error	0.71972	20	0.03599		
Total	1.61598	24			

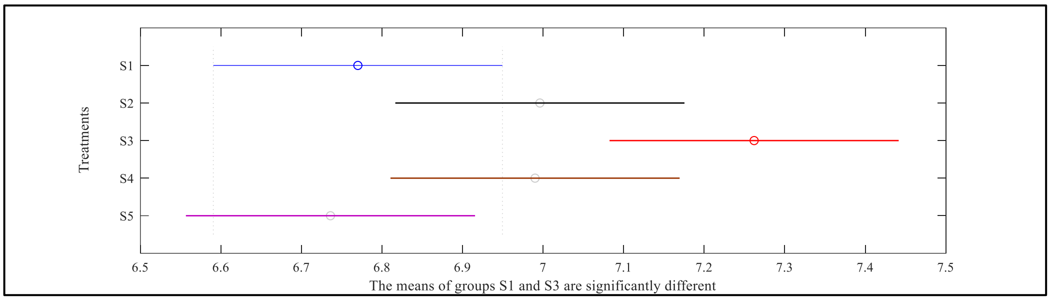

Figure 17: Pair comparisons of treatments for bricks made from moorum with different plastic fractions

The pair comparison shows that the bricks of 35% plastic fractions are significantly different from the 25% and the 45% plastic fractions. Even if the 30% and the 40% are not significantly different from the 35%, the latter still showed the highest compresssive strength in excees of 7 MPa and surpassed the other two materials. In order to look into the variability among replications, the box plots are shown in Fig. 14.

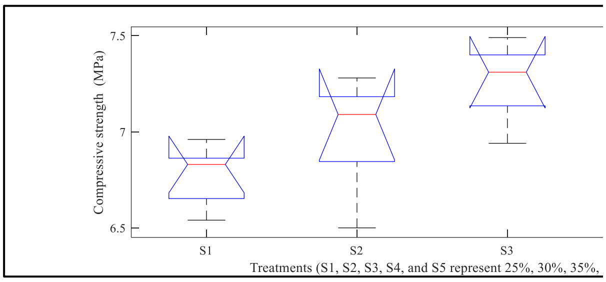

Figure 14. Box plots of treatments for bricks made from quarry dust with different plastic fractions.

As seen in the box plot, S5 showed the least variability among replications and shows high consistency. S2 has the highest variability, which means low consistency. S3 is somewhat in between.

3.2.4. Comparison of compressive strengths of bricks made from the three materials

The best compressive strengths were observed at plastic fractions of 35% for all the three materials. Therefore, the comparisons of compressive strengths of the three materials are done using compressive strengths at this percent fraction. The ANOVA for this comparison is shown in Table 6.

Table 6. ANOVA test of the three different materials at 35% plastic fraction

.

ANOVA Table

Source	SS	df	MS	F	Prob>F
Groups	1.94577	2	0.97289	8.51	0.005
Error	1.37212	12	0.11434		
Total	3.31789	14			

The ANOVA test shows significant differences among the three materials at 35% plastic fraction. The pair comparisons are shown in Figure 18.

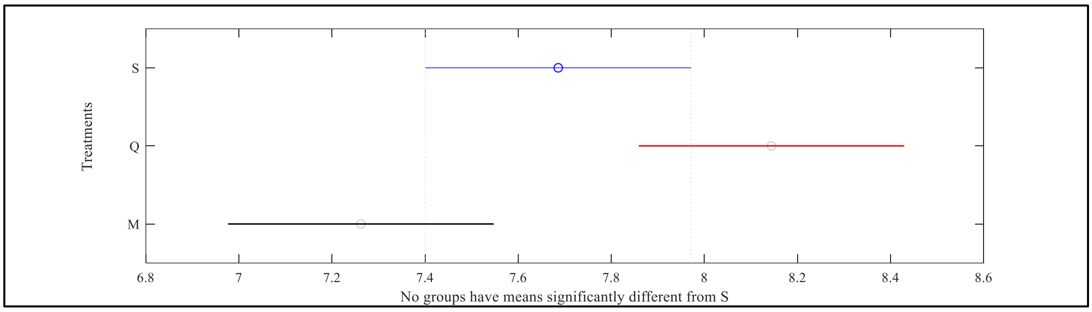

Figure 18: Pair comparisons of bricks made from the three different materials at 35% plastic fractions.

The pair comparisons show quarry dust bricks to be different from moorum bricks but not different from sand bricks, which means as far as compressive strength is concerned, bricks from sand and quarry dust are the same. Box plots reveal additional information as shown in Figure 19.

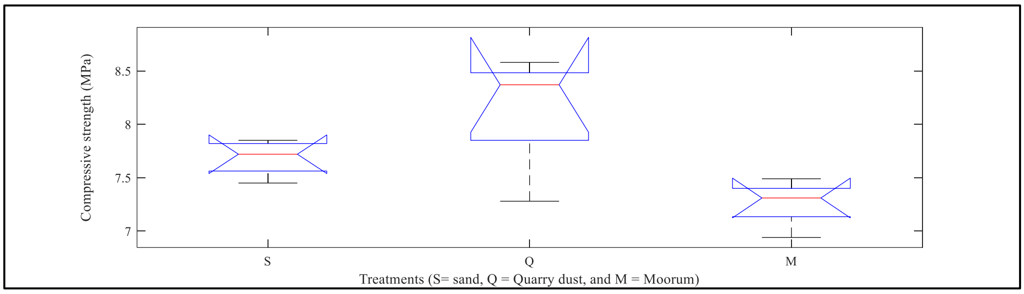

Figure 19: Box plots of treatments for bricks made from the three materials at 35% clay fractions

Even though quarry dust bricks showed slight edge over the other two bricks types in terms of compressive strength, there is high variability among replications. This may be due lack of proper mixing. Overall, if compressive strength between 7.5 and 8.0 MPa is tolerated, it is possible to use sand as a substitute for quarry dust since it is abundantly available at some locations compared to quarry dust.

3.3. Water Absorption Test

The water absorption tests were carried out according to IS 1077 1992 (Sahani *et al.*, 2022). In this test, bricks were measured in dry condition (w_d) after which they were soaked in fresh water for 24 hours. After the 24 hours they were taken out and wiped with clean cloth. Then the bricks were weighed in saturated condition (w_s). The difference between the two masses was taken as the mass of water absorbed from which the percentage of water (P_w) absorption was determined as follows.

$$P_w = \frac{w_s - w_d}{w_s} \; x\ 100\% \qquad (1)$$

The water absorption result is summarized in Figure 20

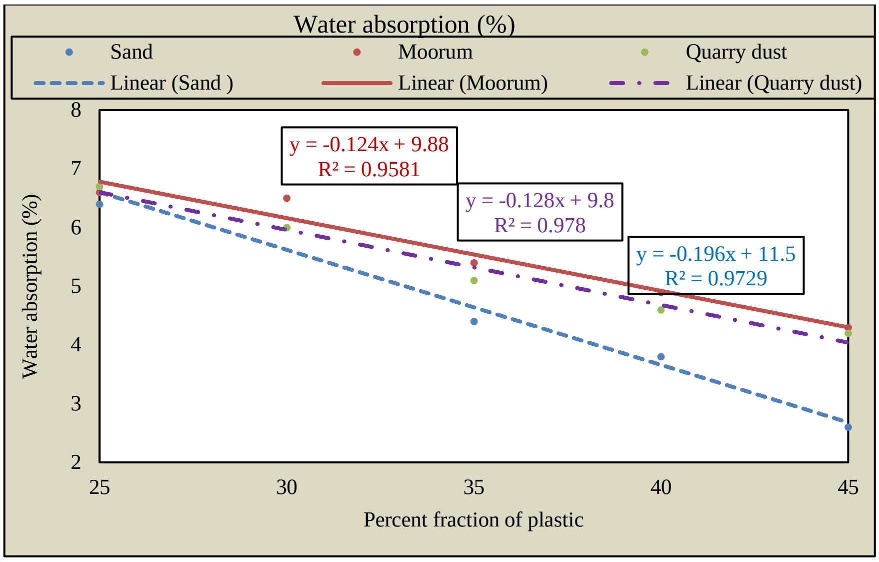

Figure 20: Water absorption for bricks made of plastic and various materials

As shown in the figure, in all cases water absorption linearly decreased with increase in plastic percentage. This is because the molten plastic fills most of the pore spaces between the particles of the fine aggregates. The low water absorption can also attribute to the hydrophobic nature of plastics (Kamble and Kara, 2017). At 35% plastic content, moorum exhibited the highest water absorption percentage of 5.4% followed by quarry dust (5.1%). Higher water absorption indicates higher porosity (void spaces) of the brick. This in turn is dependent on the porosity of the material used. The overall water absorption for all the sets of bricks were found to be less than 7%. According to Kamble and Kara (2017) good quality brick does not absorb more than 5% water. At the plastic fraction of 35%, the bricks from the three materials were within this limit. Therefore, the plastic bricks made from the three materials fulfilled the water absorption criteria for 1st class bricks, based on BIS (1973) recommendations.

At lowest plastic fraction of 25%, the bricks from all the materials exhibited nearly identical water absorption. The separation among the materials increased as the plastic fraction increased. Sand bricks showed the largest separation from the bricks of the other two materials. It also showed the fastest reduction in water absorption. Quarry dust and moorum showed nearly identical water absorption up to 45% plastic fraction. Surbhi and Chauhan (2023) claim that water absorption uniformly increase with increase in plastic fraction. They indicated water absorption increase from 4.2 – 9.2% as the plastic fraction increased from 0 – 50%. This is contrary to what other studies (e.g. Kumar et al., 2020: Ayoub *et al.*, 2023) including this one have observed. It also does not make sense since with increased plastic fraction more of the pore spaces are occupied by molten plastic and therefore less spaces are left for water molecules to occupy. Sahani *et al.* (2022) also obtained 0.0 water absorption for bricks at all plastic-sand ratios of 1:3, 1:4 and 1:5. This also appears unrealistic since the plastic does not fill all the pore spaces of the fine aggregates or at least there should have been distinctions in water absorption among the three plastic-fine aggregate ratios. Clay bricks may be classified into first class if water absorption is not be less than 15 %, and third class if water absorption is not less than 20% (MyoAye, *et al.*, 2020). The water absorption standard therefore indicates bricks of this study as first class bricks.

3.4. Visual Inspection

In this test, the shapes of the bricks were closely inspected. The bricks of good quality should have uniform and truly rectangular shape with sharp edges. In this test all of the bricks were found to be of uniform shape with sharp edges (mostly determined by the quality of the mold used and compaction during the brick preparation), thereby fulfilling the criteria of 1st class bricks.

3.5. Dimension Tolerance

The dimension of bricks was measured based on the procedure described in IS 3495 (BIS, 1992). The results were compared with the standard sizes. The standard sizes given in the IS code for length, width and height are 190 mm, 90 mm and 90 mm, respectively. The individual measurements of length, width and height were within the permissible 190±20, 90±10, and 90±10, respectively, limits of BIS (1992).

3.6. Nail Scratch Test

In this test, a scratch was made on brick surfaces with the help of a finger nail. No impression implies the quality 1st class brick (Shrestha, 2019) and all the bricks satisfied this condition.

3.7. Drop-Down Test

The last test done was a drop-down test. In this case the bricks were dropped down from a height of one meter on a plain concrete surface. According to Clement et al. (2019) a good brick should not break when dropped on a hard ground from 1 m height. Since none of the bricks broke when dropped from this height the test indicated that the bricks are strong enough to resist impact and satisfied the criteria of 1st class brick (Ghafoor *et al*., 2022).

4. Conclusion

In this work assessment was made to evaluate bricks made from molten plastic that served as a binding agent mixed with materials such as sand, moorum and quarry dust. The tests were made at five plastic fractions; namely, 25, 30, 35, 40, and 45 percents. The bricks were prepared and tested according to the ASTM specifications. The tests were done on the physical properties of the bricks (compressive strength, water absorption, weight, dimension tolerance, drop down and nail scratch tests). The tests were carried out after the bricks were cured for at least 7 days.

As far as the results are concerned, for all the materials maximum compressive strengths ranging from 7.15 to 7.7 were observed at plastic fractions of 35%. The brick that showed the maximum strength was the one made from quarry dust mix, while that of minimum strength was from moorum. For all the materials the weights of the bricks reduced from maximum of 2.85 – 3.0 kg observed at 25% plastic fraction to 2.1 – 2.5 kg at 45% plastic fraction. Of the three materials moorum bricks showed the least weight while quarry dust bricks showed the highest. All of the bricks exhibited water absorption of less than 5.5% with sand bricks showing the least value of 4.4 at 35% plastic fraction.

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