Innovative Formulations for Building Construction Bricks: Integration of Marble Dust and Lime as Alternatives to Clay for Improved Construction Brick Fabrication

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Abstract: This research offers a comprehensive examination of the production of bricks with leftover powdered marble and lime as eco-friendly materials. Different replacement percentages of leftover marble powder and lime (3%, 6%, 9%, and 12%) were applied to the soil to create bricks. Through a series of laboratory experiments, including compression tests, heat transfer tests, and scanning electron microscope (SEM) evaluations, the mechanical, thermal, and microstructural characteristics of the bricks produced were carefully evaluated. Bricks with increasing percentages of waste marble powder and lime replacement were found to have significantly changed physical, mechanical, and microstructural qualities. The findings offer valuable insights into the potential use of leftover marble powder and lime as environmentally friendly additives in brick manufacturing, with a focus on opportunities to enhance both sustainability and usability.

Keywords: Marble dust and lime, Thermal conductivity, Compressive strength, XRD, SEM.

1. INTRODUCTION

Demand for construction materials is growing day to day in housing sectors in both rural and urban areas [1]. The reduction in the sources of sand and the need to decrease the cost of construction projects has increased the need to classify different construction materials to sand as fine aggregates in construction projects [2]. Bricks are one of the conventional materials used for centuries [3]. In the world, Asia produced nearly 87% of bricks. India and China are the major patrons of bricks, so alternative and eco-friendly materials to overcome the problem [4]. The process of manufacturing bricks from clay is employed all over the world (especially in developing countries) in various projects and is very popular among contractors [5]. These bricks are commonly used due to their durability properties, economic value, availability, and ease of handling. They are used in the construction of all types of structures and their components, such as footings, main walls, partition walls, reinforced brick slabs, columns, and pavement [6-7]. The construction of residential buildings from brick masonry is a common practice in developing countries. The total consumption of bricks around the world is around 1.4 trillion annually [8-9]. The main ingredient used in the manufacturing of bricks is clay combined with sand and quartz. Structural clay products are ceramic-based materials that are manufactured by casting/molding, drying, and burning the clay mass in a kiln. Clay bricks exhibit a bulk-specific gravity ranging from 1.6 to 2.5. The higher the value for the bulk specific gravity, the higher will be the strength of the brick specimen [10-11]. The physical properties that play a major part in deciding the behavior of clay include plasticity, fusibility, texture, porosity, shrinkage, tensile strength, and color after burning. Sources of clay include naturally occurring alluvial deposits or excavation of shale, which is further broken down into small particles using grinders [12]. Clay can be made to have plastic characteristics after adding water and can be made as hard as stone by burning it. The annual consumption of clay required for the manufacturing of burnt bricks is 340 billion tons annually [13-15]. Various attempts have been made in the past to make the process of brick manufacturing cheaper. This can be mainly accomplished by replacing the clay as much as possible by adding substances or materials that are less costly. The addition of waste materials, such as rice husk ash, fly ash, bagasse ash, marble powder, and sawdust among others, to the bricks at a certain percentage is also being practiced [16]. The addition of these materials imparts different properties to the bricks related to their shape and color and may also lead to a decrease in the firing temperature required for adequate burning of bricks. It makes the brick manufacturing process more economical and environmentally friendly. If these bricks replace standard traditional clay bricks, it may have a significant effect on the environment. It will also lead to a decrease in the pollutants released in the air during the cycle of firing in the kiln. However, the waste materials need to possess certain chemical and physical properties to improve the properties of the brick [17-18].

Ecological administration in non-industrial nations is an unpredictable issue because natural issues are connected with social and monetary angles, which must be considered in the improvement of any ecological program or guideline [9]. The issue of waste amassing exists around the world, explicitly in thickly populated zones [10]. Scale, granulated slag, and steel chips are modern waste in the iron and steel industry and annoys both the well-being and climate when not appropriately discarded. Reusing or reuse of effluent and waste is financially or potentially environmentally significant [11].

Moreover, a boost in construction activities proves deficiency of conventional building materials and abundantly available industrial waste has endorsed the development of innovative building materials. So, to overcome these problems an economical alternative is to manufacture bricks by using fly ash as a raw material mixed with sand, lime, or cement. Due to the speedy upsurge in the capacity of thermal power generation in India, the production of a massive quantity of fly ash is almost 50 million tons per year. Fly ash is a fine-graded material obtained from the combustion of coal, transported by flue gases, and collected by electrostatic precipitators. It comprises of insignificant amount of un burnt carbon which is acidic. Its key ingredients are silica, aluminum oxide, and ferrous oxide. These bricks have many advantages like proper utilization of fly ash, good strength, less water absorption, and cheaper clay bricks. Marble waste and lime material have a bad effect on climate, human flourishing, and marine life correspondingly as it clarifications behind exhaustion of standard assets and because of the restricted extent of landfills; it is difficult to dump this waste material. Usage of waste marble powder in solid makes the air liberal. It will expand the strength of cement and make it strong and conservative [22-23].

A few attempts have been made to discover and diagram the potential consequences of utilizing waste marble powder and lime in mortars and cements and results about strength and handiness were separated and controlled preliminary of standard concrete. Marble powder and lime can be utilized as an admixture in cement, with the target that the strength of the solid can be expanded. Squander Marble powder and lime can be utilized to improve the mechanical and real properties of the standard cement. The work is made towards building up an unparalleled recognition of the strength credits of concrete utilizing marble powder and lime as a halfway substitution [24-25].

The following are the objectives of this examination.

- To increment the designing properties of the bricks.
- To maintain a strategic distance from the flowering of the bricks.
- To decline the porosity of the bricks.
- To clean the climate by using the marble residue and lime squander.
- To maintain a strategic distance from breaks and shrinkage

2. MATERIALS AND METHOD

This part will present the experimental program of all the exploration tests performed to achieve the objectives of its assessment. The soil was taken from Hayatabad Peshawar from a starter pit of 3x3ft, models were assembled from 4 primer pits, and all the models used in this assessment were framed in the lab as demonstrated by the available standard approach. For the lab testing program, marble waste and lime were considered as a contender stabilizer to treat/balance out soil. Following are the materials to be used as under.

Clay

Clay is a finely-grained typical stone or soil material that merges in any event one soil mineral with possible traces of quartz (SiO2), metal oxide (Al2O3, Mg, etc.), and characteristic issue. Geologic mud stores are commonly made out of phyllosilicate minerals containing variable proportions of water trapped in the mineral structure. Soils are plastic on account of atom size and estimation similar to water content and become hard, delicate, and non–plastic after drying or ending.

Clay is a remarkable kind of soil that is made by the crumbling breakdown of rock through the action of suffering [26].

Marble dust

Marble dust is a result framed during the creation of marble. A titanic proportion of powder is made during the cutting cycle. Marble dust, a strong waste material made from the marble managing can be utilized either as a filler material in concrete or aggregate while organizing concrete [27].

Lime

Limestone is a sedimentary stone made basically out of calcium carbonate (CaCO3) as the mineral calcite. It most routinely shapes in clear, warm, shallow marine waters. It is normally a trademark sedimentary stone that structures from the aggregation of shell, coral, algal, and fecal garbage [28].

Water

Water is an essential thing of brick as it is fundamentally used for the industrialization of brick since it helps with interfacing all the rough material for giving a genuine mix.

Additives

The additional substances used for the change and modification study are marble waste and lime. The soils were mixed in with added substances for which there were reasonable longings for improved planning properties. 3%, 6%, 9%, and 12% by weight of added substances was mixed in with the neighborhood soil.

3. RESULTS AND DATA ANALYSIS

Results from both customized specimens and standard (controlled) specimens created with varying proportions of marble dust and lime are included in this section. The following experiments were run: compressive strength, XRD, SEM, specific gravity, plastic limit, liquid limit, direct shear test, and thermal efficiency. Lime and marble dust are added in a variety of proportions: 0%, 3%, 6%, 9%, and 12%. Tests performed on the changed sample yielded positive findings.

Following are the results of experiments performed on the bricks manufactured.

Atterberg Limits

Following are the results of the Atterberg limits (Liquid limit and Plastic limit).

Table1: Liquid limit test result for virgin soil

Serial No.	Container Weight, W1(g)	Container Weight + Wet Soil, W2(g)	Container Weight + Dry Soil, W3(g)	Moisture Content	No. of Blows
1	25.64	111.55	89.32	22.23	32
2	25.64	125.43	100.08	25.35	24
3	25.64	134.67	106.55	28.12	19
Liquid limit			25.23		

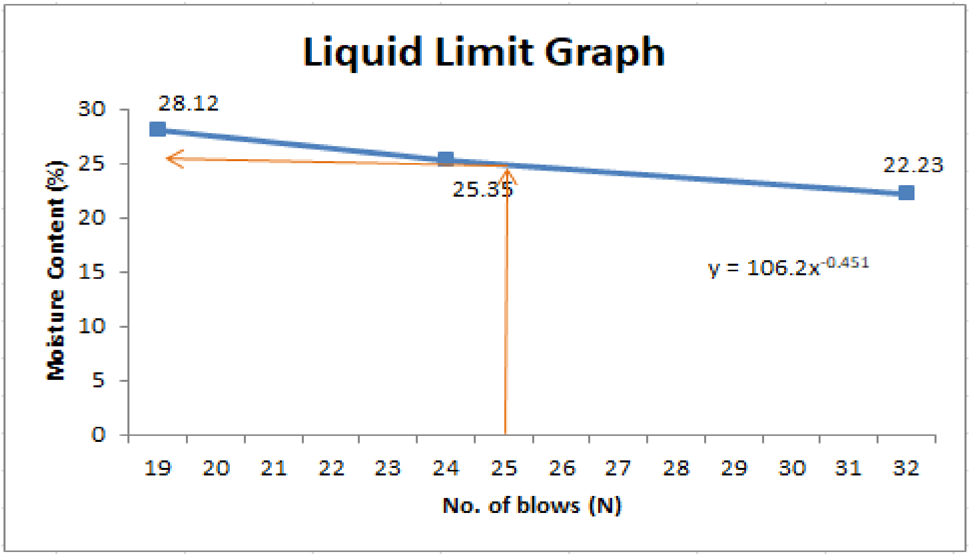

Figure 1: Plot of moisture content (%) vs number of blows for the liquid limit test.

Plastic limit (PL)

The following table and figure show the outcomes of the plastic limit test.

Table 2: Density of blast furnace bricks

Serial No.	Container weight, W1(g)	Container weight +Wet Soil, W2(g)	Container weight + dry Soil, W3(g)	Moisture Content
1	25.64	33.31	26.34	21.89
2	25.64	32.22	24.61	20.15
3	25.64	30.97	23.49	18.77
Plastic limit			20.27	

Plastic index (PI)

The difference between the liquid limit value and plastic limit value is known as the plasticity index written as PI and the results are given as follows.

Table 3: Plasticity Index (PI) value

Serial No.	Liquid limit	Plastic limit	Plasticity index (LL-PL)
1	25.23	20.27	4.96

Discussion

The clayey soil used to create bricks may be tested for plasticity and workability using the Atterberg Limit method.

The results of this test provide valuable insight into the properties of the soil and how well brick manufacturing operations function. The clayey soil is more moldable when the plasticity index is greater, which might result in bricks with smoother surfaces and stronger structural integrity. Conversely, excessive plasticity may lead to issues with drying and shaping. The Atterberg Limit test results offer a strong basis for educated decision-making in the brick business, guiding processes that ultimately impact the mechanical, aesthetic, and physical attributes of the finished product.

Specific gravity

The following table and figure show the outcomes of the specific gravity test.

Table 4: Specific gravity test for virgin soil sample (No additive)

S No.	Observation number	1	2	3
1	Weight of empty Pycnometer (gram)	200	200	200
2	Weight of Pycnometer + Soil sample(gram)	415	405	410
3	Weight of Pycnometer + Soil + Water(gram)	1545.1	1527.5	1536.7
4	Weight of Pycnometer + Water (gram)	1330.1	1322.5	1326.7
5	Weight of soil sample (gram)	215	205	210
6	Weight of equal volume of water (gram)	1130.1	1117.5	1116.7
7	Specific gravity	2.58	2.72	2.70
Average specific gravity at 20°c		2.66		

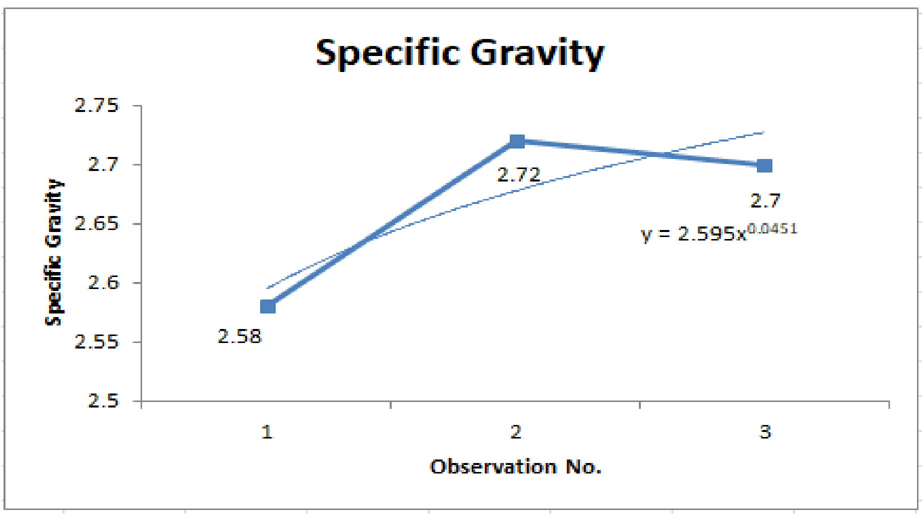

Figure 2: Plot of moisture content (%) vs number of blows for the liquid limit test.

DISCUSSION

With a firm understanding of the soil's specific gravity, brick producers may more accurately ascertain the clayey soil's particle packing properties, which in turn impact the bricks' strength, porosity, and thermal characteristics. By predicting specific gravity, brick makers can ensure the right balance between strength and weight while limiting deviations that might compromise structural integrity or increase production costs. This allows them to maximize material selection and blending operations.

Direct Shear Test

Following are the results of the direct shear test with additive mixed in different proportions shown in the tables and graphs.

Table 5: Direct shear test results of varieties of soil samples

Serial No.	Soil + Additive (%)	Cohesion C	Angle of internal Friction (φ)
1	100 + 0	0.057	28.22
2	97 + 3	0.061	26.88
3	94 + 6	0.043	29.55
4	91 + 9	0.019	24.78
5	88 + 12	0.010	20.12

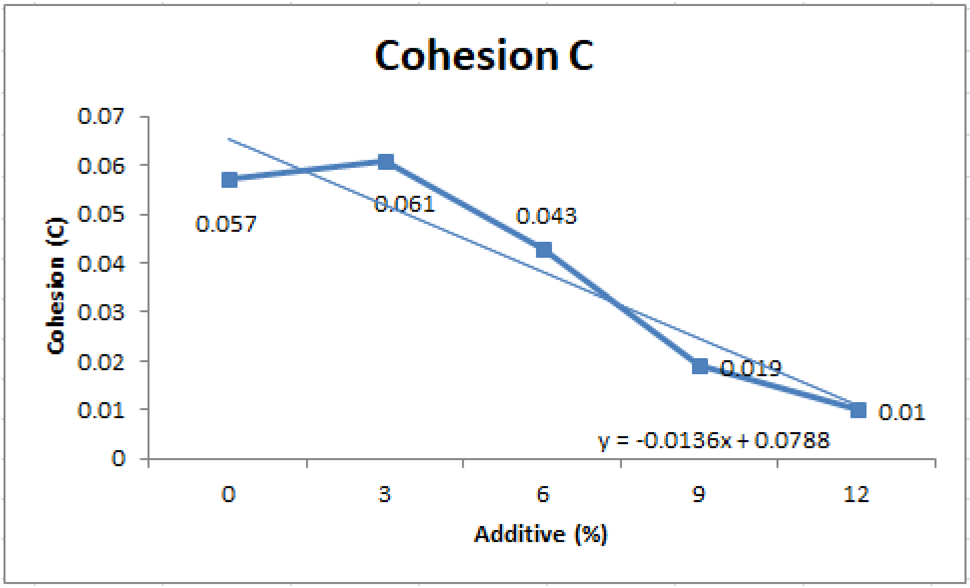

Figure 3: Cohesion in contradiction of the diverse specimens of soil represented graphically

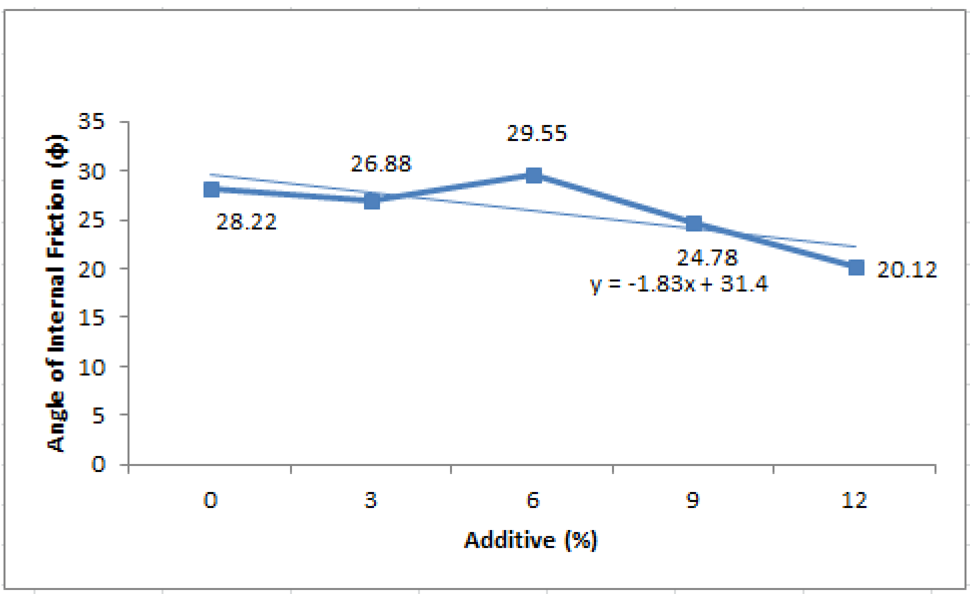

Figure 4: Angle of internal friction in contradiction of the dissimilar samples of soil represented graphically

Discussion

A substantial shift in the soil's shear strength characteristics is shown by the steady decrease in cohesiveness and angle of internal friction values as waste marble powder and lime replacement percentages rise. The findings also highlight the need to balance the potential trade-offs in mechanical properties against the benefits of using lime and leftover marble powder, such as improved workability and reduced environmental impact.

Compressive Strength

This test is done to check the compressive quality of the specimen under testing. The following table and graph will show the outcomes of the analysis done on multiple samples.

Table 6: Results of the compressive strength test

Serial No.	Soil + Additive (%)	Dimension of brick (inches)	Maximum load (KN)	Compressive strength (N/mm^2)
1	100 + 0	8.5x4x2.5	291.45	11.74
2	97 + 3	8.5x4x2.5	229.94	8.12
3	94 + 6	8.5x4x2.5	196.38	6.29
4	91 + 9	8.5x4x2.5	163.88	4.22
5	88 + 12	8.5x4x2.5	134.65	3.12

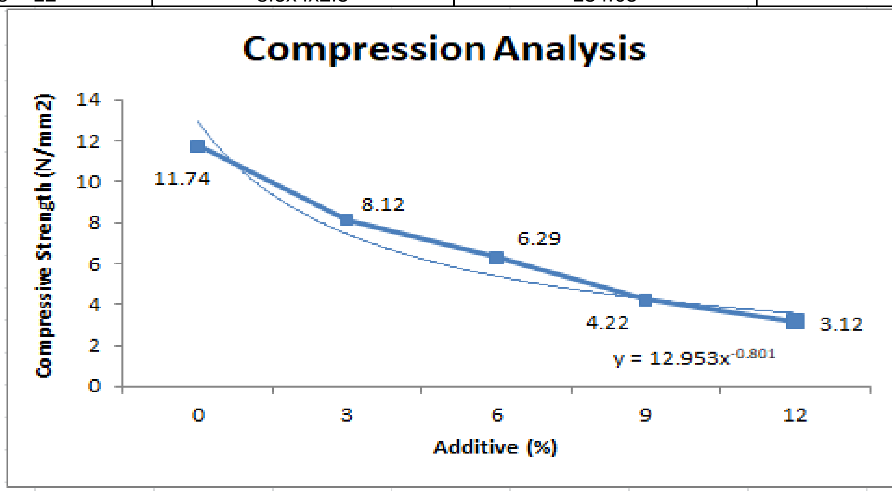

Figure 5: Compressive strength result explained graphically

Discussion

The addition of leftover marble powder and lime to the soil matrix alters the microstructure and bonding characteristics of the bricks, resulting in variations in the bricks' capacity to support weight and resistance to compressive stresses. By carefully modifying the proportions of waste marble powder and lime in soil mixes, it is imperative to combine mechanical robustness and environmental sustainability in brick making, as evidenced by the observed loss in compressive strength.

Water absorption

Following are the detailed outcomes of the water absorption test.

Table 7: Water absorption test results analysis

Serial No.	Soil + Additive (%)	Weight of wet brick, W2 (Kg)	Weight of dry brick, W1 (Kg)	Water absorption(%)
1	100 + 0	3.63	3.15	13.45
2	97 + 3	3.81	3.13	17.76
3	94 + 6	3.99	3.17	21.65
4	91 + 9	4.23	3.21	24.22
5	88 + 12	4.38	3.18	27.45

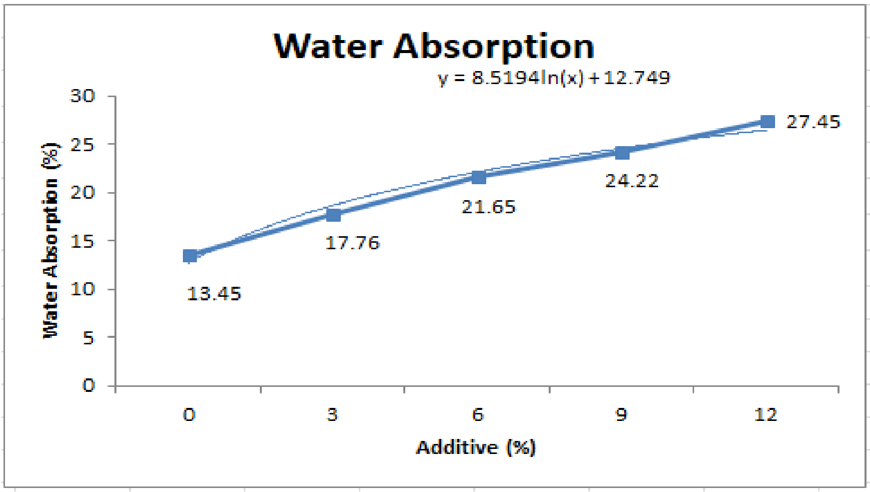

Figure 6: Graphical representations of the water absorption test

Discussion

The influence of waste marble powder and lime replacement on the porosity and permeability of the brick matrix is indicated by the steady rise in water absorption capacity observed in bricks with larger percentages of these additions. The pore structure and interstitial spaces inside the bricks are altered by the addition of leftover marble powder and lime, which increases their susceptibility to moisture penetration and increases their water retention.

Thermal Conductivity Analysis

The following table and figures explain the results of the thermal conductivity test.

Table 8: Thermal conductivity test outcomes

Serial No.	Soil + Additive (%)	Thermal conductivity ($Wm^{-1}k^{-1}$)	Increase of heat conductivity (%)
1	100 + 0	0.97	0
2	97 + 3	1.13	14.15
3	94 + 6	1.55	27.09
4	91 + 9	1.89	17.98
5	88 + 12	2.31	18.18
N/A			**Σ = 77.93 %**

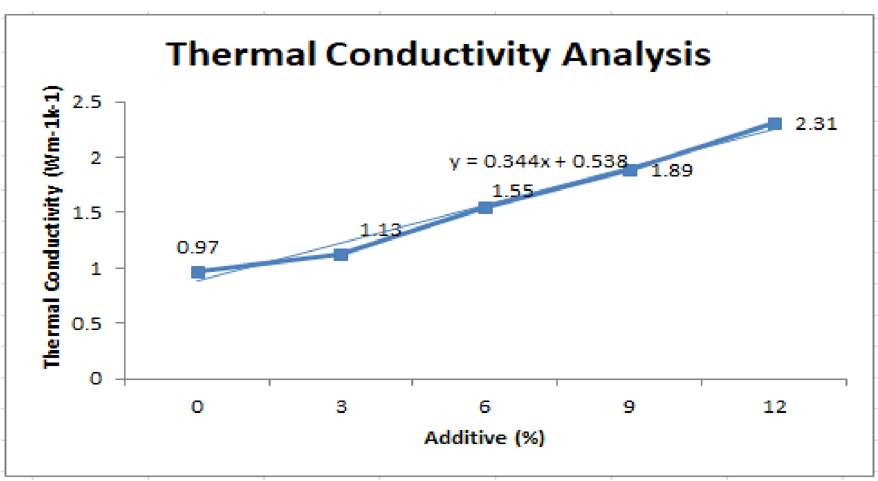

Figure 7: Thermal conductivity analysis outcomes with graphical representations

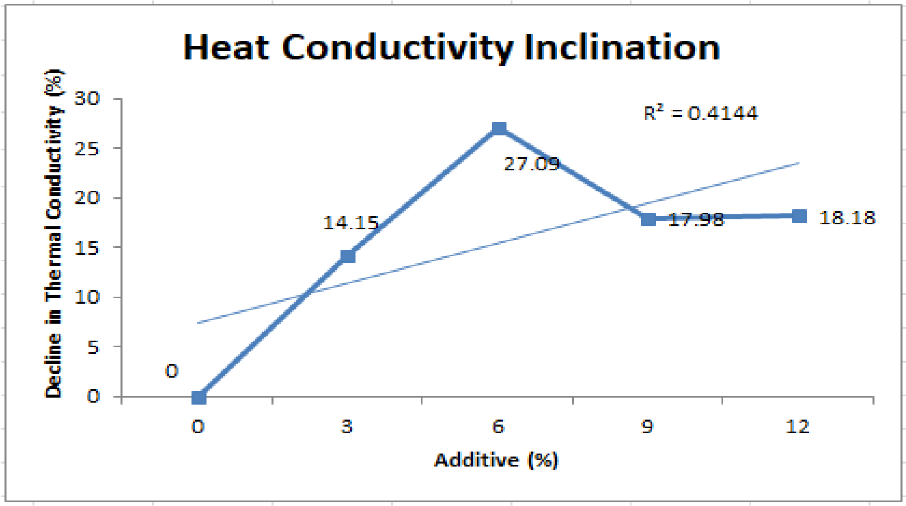

Figure 8: Increase of thermal conduction related to each additive content in percentage

Discussion

The bricks' improved thermal conductivity may affect their capacity to hold heat and offer thermal insulation. The remaining marble powder and lime were added to the soil mixture. Waste marble powder and lime additions have the potential to promote sustainable building practices by enhancing thermal efficiency and reducing energy consumption in construction applications. This is demonstrated by the boost in thermal conductivity observed in bricks containing these materials.

Scanning Electron Microscopy (SEM)

Scanning electron microscopy (SEM) is a microstructural investigation of different materials. The following figures will explain the SEM analysis outcomes.

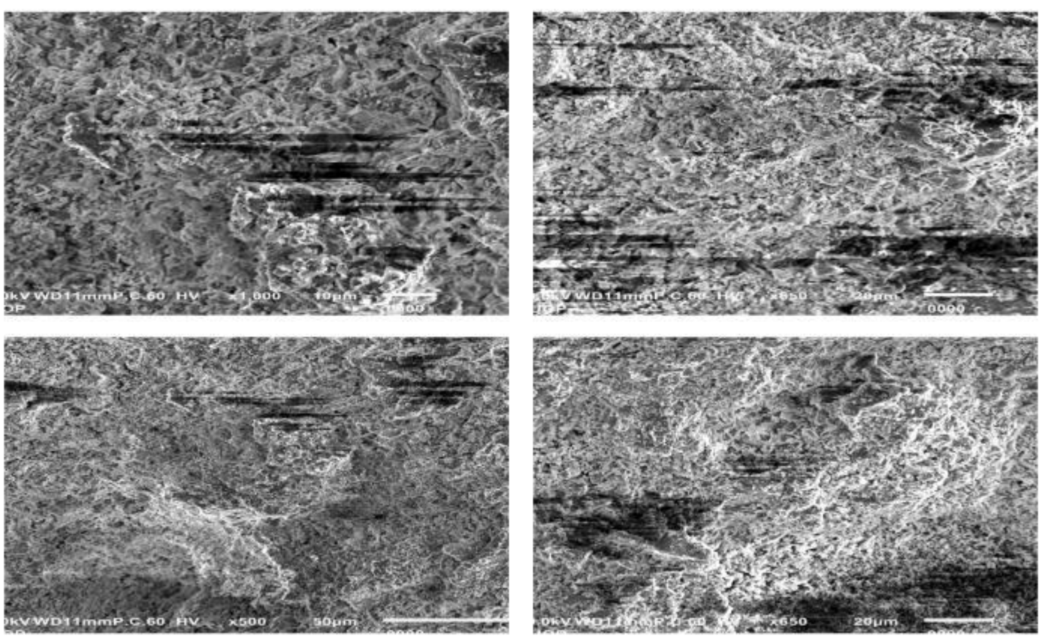

Figure 9: 0% additive Scanning electron microscopy (SEM) outcomes

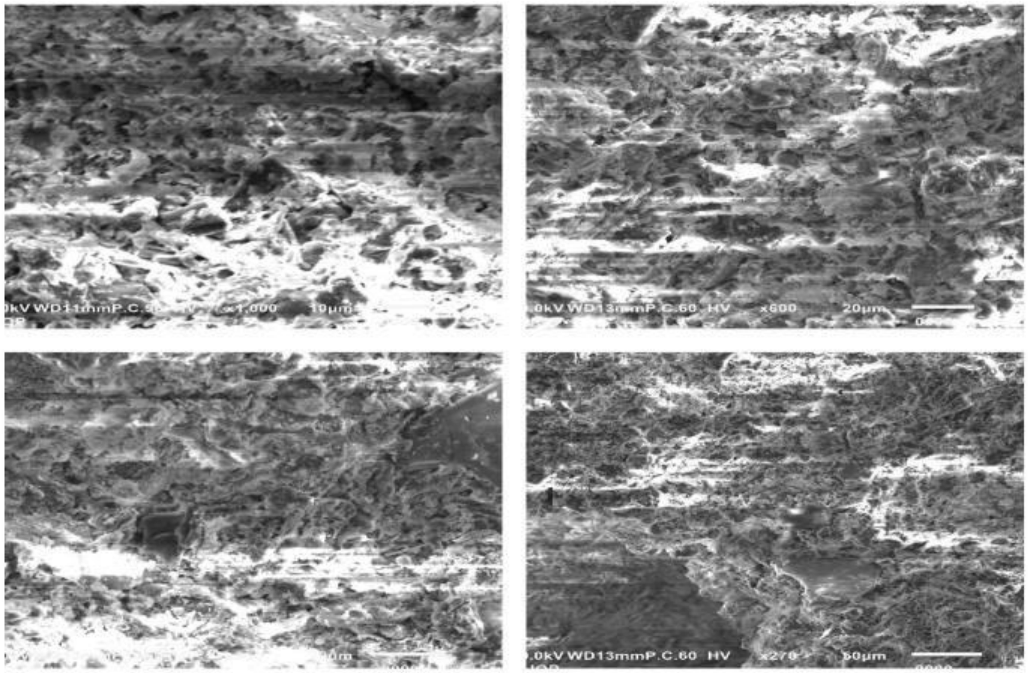

Figure 10: 3% additive Scanning electron microscopy (SEM) outcomes

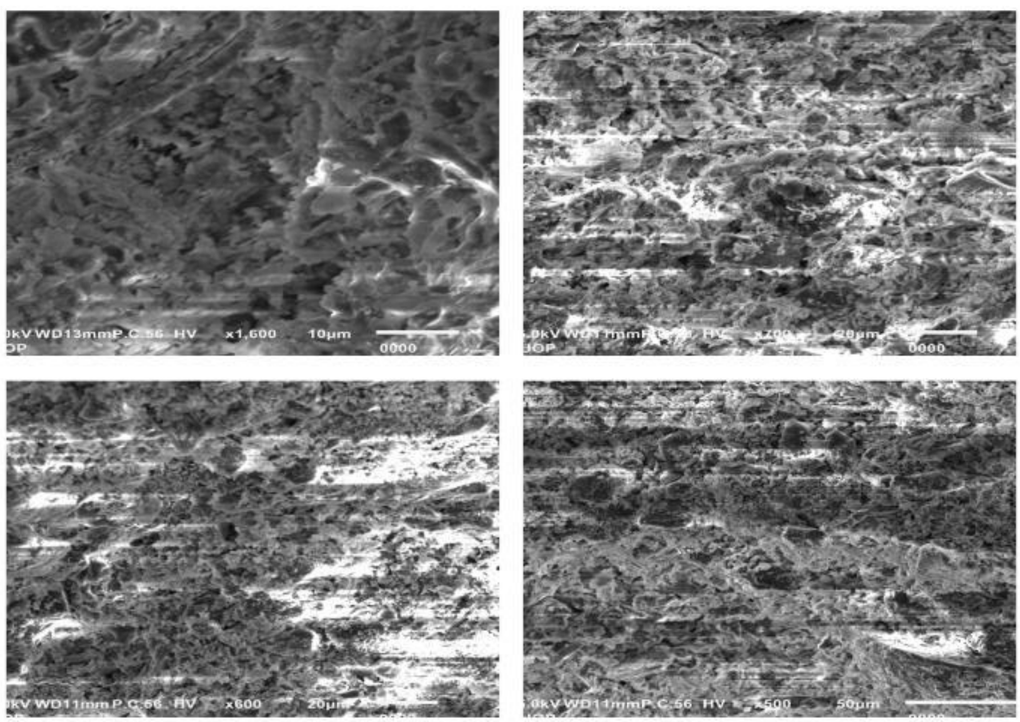

Figure 11: 6% additive Scanning electron microscopy (SEM) outcomes

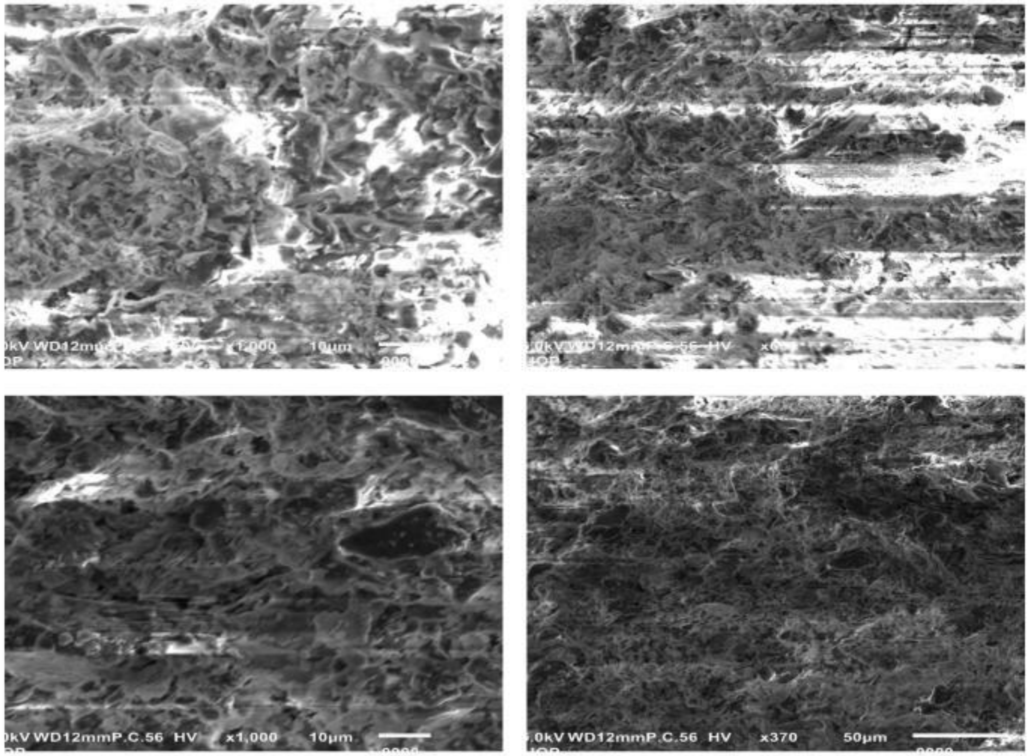

Figure 12: 9% additive Scanning electron microscopy (SEM) outcomes

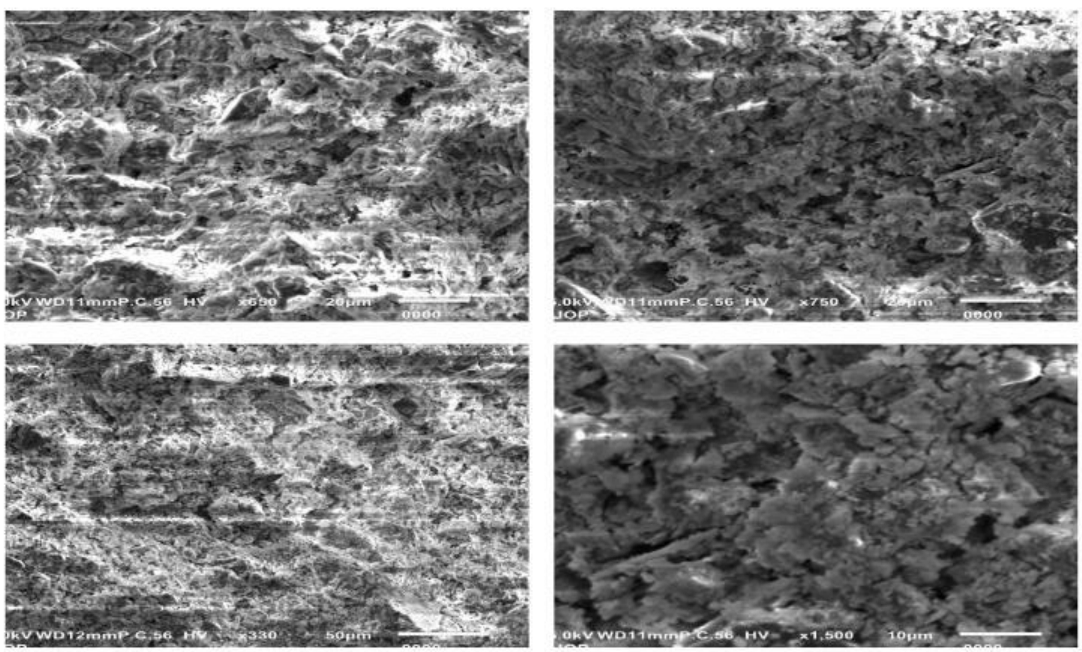

Figure 13: 12% additive Scanning electron microscopy (SEM) outcomes

Discussion

By allowing for an in-depth examination of the effects of waste marble powder and lime additions on the internal structure and surface morphology of bricks, SEM image studies provide an understanding of potential benefits or drawbacks of material properties. Using SEM micrographs, viewers could observe how the inclusion of lime and leftover marble powder altered the interfacial bonding and packing arrangement of the brick structure.

X-ray Diffraction (XRD)

Various percentages of the lime and waste marble powder content were being utilized in the brick manufacturing and tested by XRD and the following are the results in the graphical presentation.

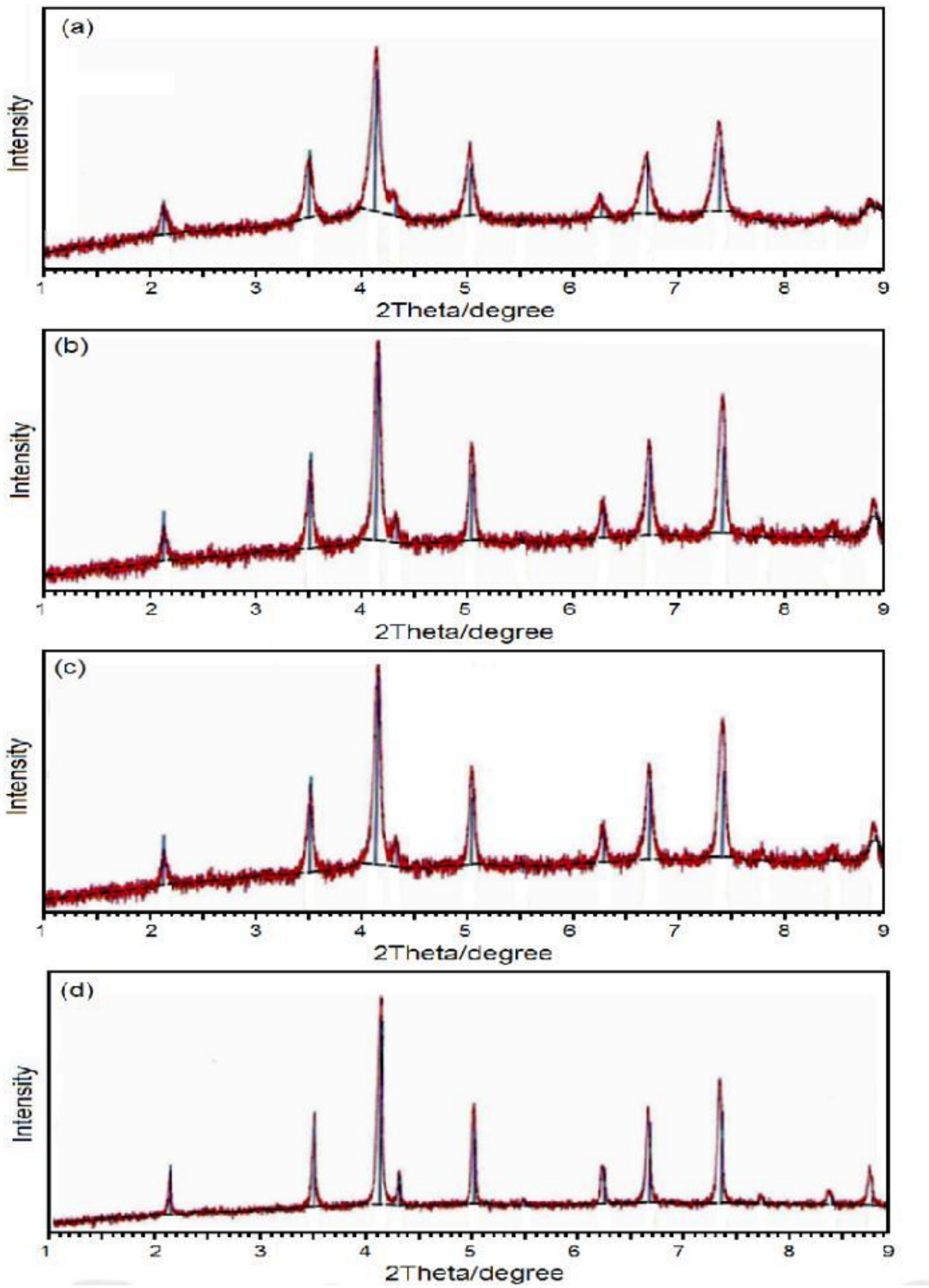

Figure 14: XRD graph of the bricks made with lime and waste marble powder in 3%, 6%, 9%, and 12% as a, b, c, and d respectively

Discussion

The existence of distinctive peaks belonging to certain crystalline stages is revealed by xrd pattern assessment, enabling the identification and quantification of mineral components within the brick structure.

CONCLUSION & RECOMMENDATION

Following are the conclusions and recommendations of the investigation.

CONCLUSION

- We infer that the marble dust and lime bricks help use the specific content of the additive in brick manufacturing. On the off chance that the added substance utilized around 6% additive for outlined structures in segment divider, for pathways, following ways, and so forth. On the off chance that we utilized over 6% additive then the strength of the brick declined majorly.

- Marble dust and lime bricks have a higher weight than typical brick.

- It is observed that marble dust and lime bricks have high water ingestion.

- Waste marble and lime which are accessible might be put to an effective use in brick making.

- Marble and lime bricks can assist with lessening the natural contamination accordingly making the climate spotless and sound.

Recommendations

There are few suggestions which are given below:

- Marble dust and lime bricks give us the trust and an approach to chip away at imaginative things identified with the marble dust and lime and to attempt to design some new polite materials that show some momentous reaction in future industry and change the contemplations of the specialists, clients, and ventures. For example, in going for marble dust and lime brick dividers in outlined structures as a parcel divider, marble dust, and lime brick tracks for running and running instead of concrete or stone tracks.

- Marble dust and lime could be utilized in the brick for what it's worth in compelling proportion to cleaning the climate.

- Marble dust and lime ought not to be utilized over 6%, as the compressive strength diminishes by more than a typical brick.

Acknowledgment

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