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4. An Optimized Partial Replacement of Crushed Concrete and Crushed Ceramic Waste in Concrete

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ABSTRACT

Nowadays, the count of building construction increases with more advancement due to the rapid population. Based on culture and environment, the construction material differed depending on strength and flexibility score. Several materials were utilized as an acceptable replacement for the concrete design. The material's performance was limited because of poor mix selection, leading to lower compressive strength. A novel Mimosa Pudica Mix Selection (MPMS) procedure was implemented to address this issue. Moreover, sea sand, crushed old concrete, and ceramic waste were acceptable replacements. Here, the sea sand is utilized as the fine aggregate; destroyed concrete and ceramic waste are regarded as coarse aggregate. The M-30 grade with IS: 10262, 1982, was considered for the proper mix selection. Then the five mixes were specified with different percentages of coarse aggregate, and the tests were performed to find the optimal mix. After seeing the optimal blend, the failure mode of the concrete is evaluated by applying different loads based on IS 516-1959. Moreover, it was tested in the MATLAB platform, and the testing outcomes were measured for 7 and 28 days of curing.

KEYWORDS:

Fine Aggregate, Coarse Aggregate, Ceramic Material, Split Tensile, Crushed Concrete, Compressive Strength.

1. Introduction:

In recent times, ceramic materials consumption has increased in daily life. Concrete production is processed with cement, coarse aggregate, fine aggregate and water [1]. Consequently, a typical concrete process is performed with cement to provide the finest aggregation process [2, 3]. The usage of cement bound together these aggregates. The cement concrete work must be done with aggregates that must be durable, hard and clean [4, 5]. The aggregates were prohibited from clay swellings, fine dust, and biological and herbal matter. The concrete strength would be minimized by aggregate adhesion [6].

Furthermore, the aggregate was categorized into several types, such as fine and coarse aggregate. The fine aggregate was considered the natural river sand and was less than 4.75 mm. The coarse aggregate was regarded as the crushed ceramic tile, and its size was said to be larger than 4.75 mm [7]. In this process, the concrete is produced by consuming a massive quantity of natural aggregates. Nowadays, the availability of natural aggregates is a complex issue [8, 9]. Therefore, alternative materials should be used instead of natural aggregates [10].

The trashed ceramic tiles and marble had specific functions in sustainable concrete production. Using waste products in concrete made it economical yet solved several disposal issues [11, 12]. In the ceramic industry, waste production is 30%; this ceramic waste is not recycled. The ceramic waste is rugged, durable, and highly resistant to biochemical, biological and physical deprivation. As the ceramic waste is loaded daily, there is pressure on ceramic industries to find a solution for the disposal process [13, 14]. The crumpled ceramic aggregate could be utilized to generate effective concrete. The crushed insulator bush scrap is used as coarse aggregate in concrete production. This kind of ceramic waste is increased from industries daily due to its brittle nature [15, 16]. The properties of substantial development were perceived by substituting the crinkled stone (crushed coarse aggregate) that provides the creased ceramic aggregate waste and fine aggregate as sand [17].

The ceramic trash was used to overcome the absence of aggregate problems in several building sites. Furthermore, the environmental issues could be reduced, which are related to the aggregate mining and disposal of waste [18]. Hence, most of the prevailing works used waste products such as salubrious ware and electronic insulator ceramics with massive data regarding the usage of ceramic materials [19]. Therefore, the essential way to use ceramic materials was to produce ceramic products at various high temperatures, which determined the microstructural form [20]. To overcome these issues, using a ceramic material, a new MPS technique is proposed to build concrete. The critical contribution of the present study is described as follows:

- Initially, the materials collected were ceramic tiles for the replacement process, and the crushing process was performed using the manual hammering system.
- Consequently, the mixes were specified based on the M-30 grade with IS: 10262, 1982 standard.
- Then, a novel MPMS was designed to select the optimal mix and measure the cracking mouth.
- At first, the compressive test was performed to find the optimal mix by satisfying the compressive strength condition.
- Once the optimal mix was selected, split tensile and flexural strength were measured for all mixes to justify the optimal mix.
- Finally, the reliability of the mixed material and the designed concrete is evaluated by measuring the cracking mouth based on IS 516-1959 standard.

The rest of this research was described as follows: Section 2 stated a literature review. Section 3 provided the system model and problem statement. A comprehensive process of the designed model was determined in Section 4. Section 5 presented the details of the experimental study. Section 6 concluded with future work or conclusions.

2. Related Works:

A few recent works of the literature review were described as follows:

Song et al. [21] proposed an Artificial Neural Network (ANN) model that was utilized to predict the Compressive Strength (CS) of the concrete. This technique consists of two modules. The first module depends upon the Ceramic Waste Powder (CWP) characterization related to the composition, material testing, and estimation of the properties of concrete in new and complex states.

The concrete mix was arranged to measure the CS by partially replacing the cement percentage with CWP of 10% and 20% via cement mass. Then, the second module depends upon the Decision Tree (DT) technique to forecast concrete CS. By the evaluation, it has reported less CS.

Lin et al. [22] discussed the Deep Transfer learning method that aimed to develop an effective technique for sorting Construction & Demolition (C&D). In this process, VGGNET-based knowledge transfer was used for classifying the different types of C&D waste. Then, a better global learning rate was identified by adopting the cyclical learning rate. Also, the training time was shortened with the help of knowledge transfer. However, replacing the construction waste in the concrete reported less split tensile.

Barnat-Hunek et al. [23] proposed the Machine Learning approach to determine the texture image features of the Lightweight Cement Composites (LCC) with modified hydrophobic coated with Nano-type cellulose and to assess the material's durability. Initially, the texture features were selected from the image attained from the scanned microscope.

The 16 parts were chosen by the support vector machine system with the sequential forward selection process. This system was used to find the contact angle ranges related to the resistance degree of analyzing material with an accurate outcome of 82%. However, lightweight concrete reported high cracking rate than standard concrete.

Recycling Aggregates (RA) was attained by crushed inert demolition and construction rubbish. The variable was reportedly composed and occurred through time-consuming manual sorting. So, Hoong et al. [24] suggested a Convolution Neural Network (CNN) for selecting the partial replacement range of the RA. For the partial RA replacement, the CNN has reached the best accuracy rate of 97% to organize the grains images after the trained phenomena. But, the RA's flexural strength was deficient.

Ku et al. [25] proposed Region-based Convolution Neural Network (RCNN) was used for sorting vast quantities of things before mixed and crushed states. Initially, the height image via three-dimensional cameras was taken as the input for this process, indicating the correspondent grasping parameters through acquisitive rectangles on the feature.

The DL method was used to adopt the Auto-Encoder (AE) and RCNN with the optimum grasping rectangle output. Here, the curing days were maximized. Hence, it is only supported for long-term construction works.

3. Material and Mix Proportions:

Materials considered for the present work are cement, sea sand as fine aggregate, crushed concrete and ceramic waste material as coarse aggregate. The cement mix ratio is obtained using the IS: 12269, 1987 standard. Here, the crushed concrete was attained by the jaw crusher. Also, the ceramic waste is prepared by the jet Mill.

Table 1: Properties of coarse aggregate

Coarse aggregate specification			
Property	**The ceramic coarse aggregate value**	**Cement**	**The crushed concrete coarse aggregate value**
Specific gravity	2.63	3.1	2.62
Consistency (%)	-	30	-
Impact strength	18.5%	-	17%
Compressive strength	-	54.2N/mm^2	-
Crushing strength	22.7	-	20.5
Fineness	7	4%	6.5

Here, the concrete M30 grade mix was taken to prepare and selected within the principle of IS: 10262, 1982. Hence, the properties of the mix materials are described in Table1, and the mix proportion range of M-30 grade is detailed in Table 2.

Table 2: M-30 grade mix selection

Mix selection							
Grade	**Mix. no**	**Mix (%)**	**Water (kg/m^3)**	**Sand (kg/m^3)**	**Crushed concrete (kg)**	**Cement (kg)**	**Ceramic waste material aggregate (kg)**
M30	L-1	0% Crushed concrete 0% ceramic waste	216	45	608	50	0
	L-2	10% Crushed concrete 10% ceramic waste	208	40	710	45	260.8

Mix selection							
Grade	**Mix. no**	**Mix (%)**	**Water (kg/m^3)**	**Sand (kg/m^3)**	**Crushed concrete (kg)**	**Cement (kg)**	**Ceramic waste material aggregate (kg)**
	L-3	20% Crushed concrete 20% ceramic waste	185	33	686	43	321.6
	L-4	30% Crushed concrete 30% ceramic waste	178	36	687	35	382.4
	L-5	40% Crushed concrete 40% ceramic waste	165	30	683	30	475

First, sea sand, crushed concrete and ceramic wastes were blended in the dry form to acquire a consistent color. Then, the quantity of water determined from the functionality testing was incorporated, and the entire batch of pavement was stirred for five minutes.

In the meantime, the molds are securely fastened together to prevent leakage, and oil is put on to coat the interior area of the molds; the using rod for tamping is packed into molds in three stages after mixing the mortar.

Subsequently, within 24 hours, the molded prototypes were extracted from their molds and submerged in a freshwater compartment. Afterwards, the prepared specimen is cured for 28 days. After curing, the prepared samples were taken from the water compartment and kept dry under the sun shade. The dimension of the designed concrete cube is 3*150mm for the M30 grade.

4. Proposed MPMS for Optimal Mix Selection:

Based on the specific IS, the mixes were prepared then the tests were carried out for fresh and hardened properties. This study mainly intends to reduce the cracking rate when applied load. A novel Mimosa Pudica Mix selection (MPMS) procedure was implemented. The appropriate mix was selected based on the optimal compressive and split tensile strength. The proposed design is exposed in Fig. 1.

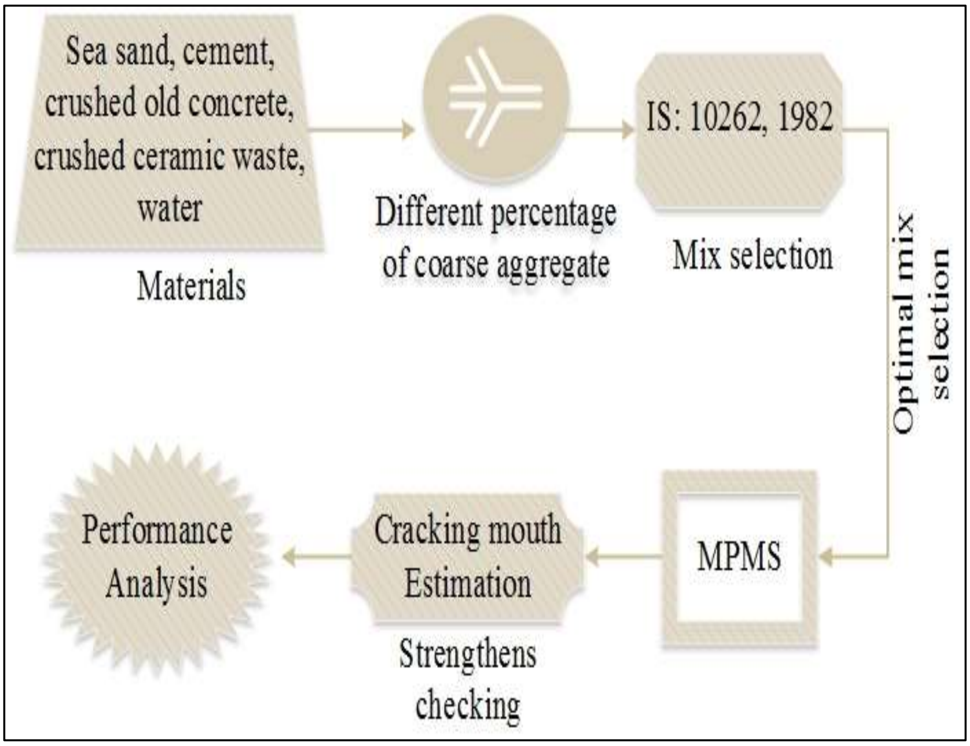


Figure 1: The block diagram of the proposed MPS architecture

Here, sea sand is utilized as the fine aggregate, and crushed old concrete and ceramic waste are taken as coarse aggregate. Moreover, the mix proportion range for the M-30 grade is based on the IS: 10262, 1982. The optimal mix was selected using the mimosa pudica fitness solution.

4.1 Process of MPMS:

The optimal model is designed based on the mimosa pudica plant. Usually, the plant's fitness is closing the leaf if any sensation occurs. These processes were adopted to trace the optimal compressive and tensile strength. Primary, the acceptable replacement performance parameters were initialized using the mimosa pudica plant initialization process, which is exposed in Eqn. (1).

$$R_o = C, S_t, C^m, F \tag{1}$$

Here, R_o denoting the training function, compressive strength is exposed as C split tensile is mentioned S_t and the flexural strength is explained as F .

$$O_c = \begin{cases} if\,(C > 55) & optimal \\ \quad else & non\_optimal \end{cases} \tag{2}$$

Here, the optimal compressive strength is represented as O_c and C denotes the compressive strength. Moreover, the optimal compressive strength range fixing is exposed in Eqn. (2). This optimal function is repeated continuously till the condition is met. Hence, the finest compressive strength is attained for all testing cases. Moreover, this suggested novel MPMS is tested in the MATLAB environment.

$$Cracking \quad rate = \frac{crack \quad portion}{Total \quad Specimen \quad size} * C^m distance \tag{3}$$

In addition, the cracking rate of the fabricated concrete is analyzed by applying the load based on the IS 516-1959. Hence, the cracking mouth estimation is preceded by Eqn. (3). Here, C^m determines the cracking mouth.

Algorithm 1: MPMS
Start *{* $int\, C, S_t, C^m, F;$ *//Evaluation parameters were initiated*   ***Mix selection ()***   ***{*** $if(C > 55)$ *{*   *Optimal mix*   *// each specimen mix, compressive strength was calculated; if the optimal condition is satisfied, then it is considered as an optimal mix*   *}*   *}*   ***Cracking range estimation ()***   *{*   *Load= IS 516-1959*   *//To check the compressive strength, the load was applied based on the IS 516-1959* $failure \quad mode \rightarrow cracking \quad portion$ *// cracking rate is determined as the failure mode of the implemented research*   *}* *}* *Stop*

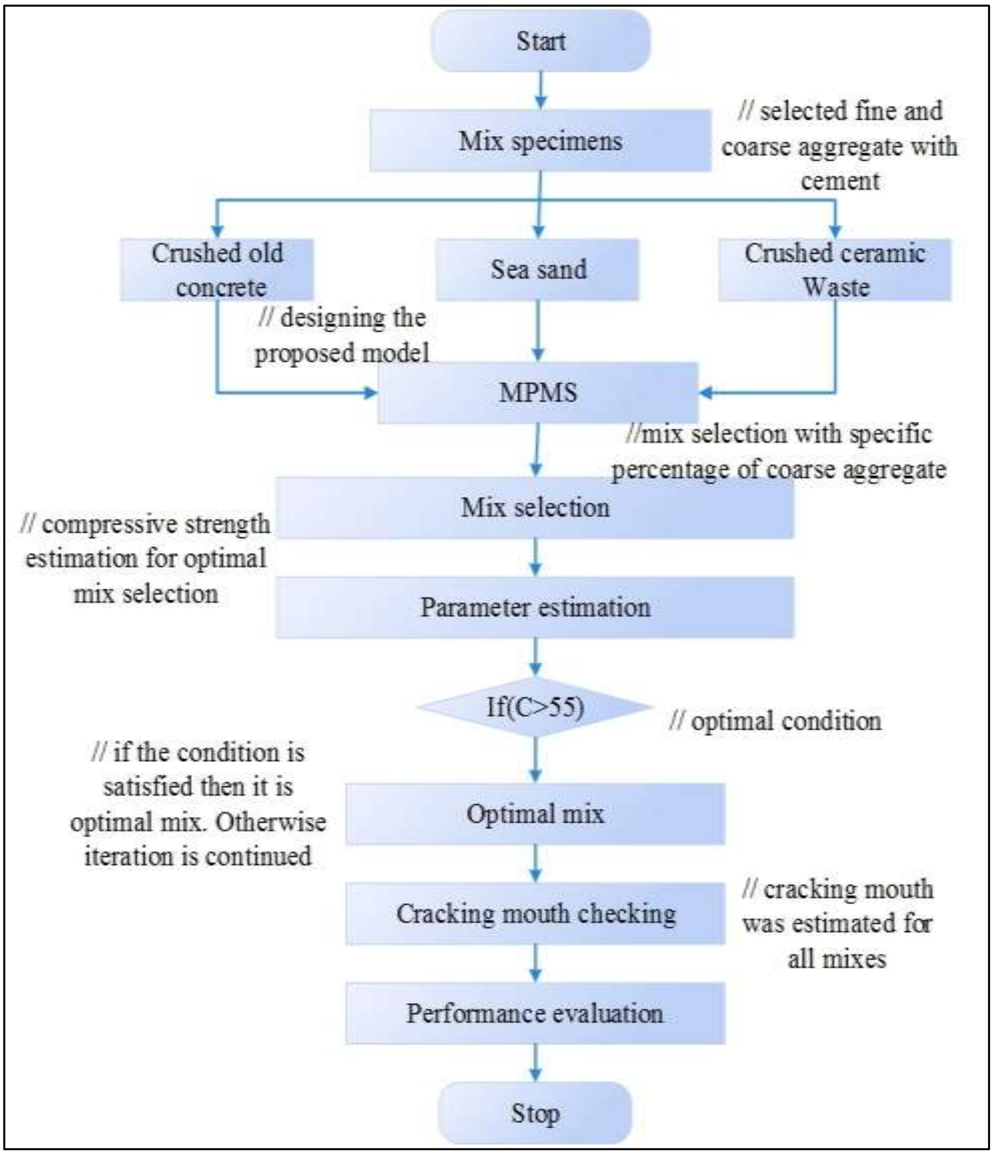


Figure 2: Flowchart of MPS model

Fig. 2 and Algorithm one clearly illustrates the steps for the developed system. The Python code was executed, and the outcomes were verified using the processing steps. In the Pseudocode format, the algorithm was written by incorporating entire parameters of the mathematical function.

5. Result Analysis:

The proposed mechanism was implemented in the MATLAB platform. The implementation process was processed on the Windows 10 platform. This work was to implement the replacement process of ceramic waste into concrete. Moreover, the strengths and weaknesses of the modeled concrete are analyzed by applying the specific load standard.

5.1 Case Study:

This research developed a novel technique for the Mimosa Pudica optimizer replacement process. Initially, the material was collected using the proposed MPS model for the concrete production phenomena. Here, the performance graph indicates that the performance rate was higher. It verified that the proposed design could use ceramic material in concrete production.

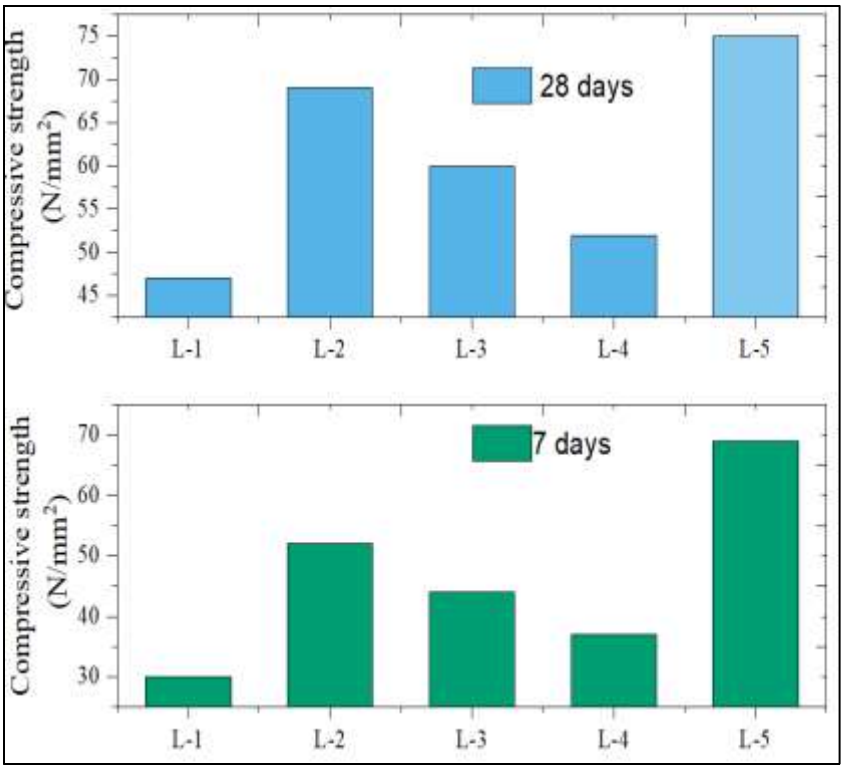


Figure 3: Compressive strength of 7 days cured samples

Here, the compressive strength was valued based on the IS 516-1959 standard. Moreover, the testing outcomes were measured for 7 and 28 days. The L-5 mix has reported good compressive strength for 7 and 28 days. In addition, the compressive strength after 28 days is higher than the 7 days cured compressive strength. The L-5 reported 69 N/mm^2 compressive strength for 7 days of fixed specimens, and 75 N/mm^2 compressive strength was recorded for 28 days of selected samples. These details are graphically represented in Fig. 3.

The split tensile parameter is evaluated to measure the modelled concrete's tensile strength. The highest split tensile recorded for the 7 days cured sample is 6 N/mm^2 which is gained for the L-5 mix. Also, the lowest tensile recorded for the 7 days is 3 N/mm^2, achieved for the L-1 mix. Moreover, the highest split tensile of the 28 days cured sample is 7.2 N/mm^2, attained for the L-5 mix. The test outcome of split tensile is exposed in Fig. 4, and the overall compressive and tensile test results are disclosed in Table 3.

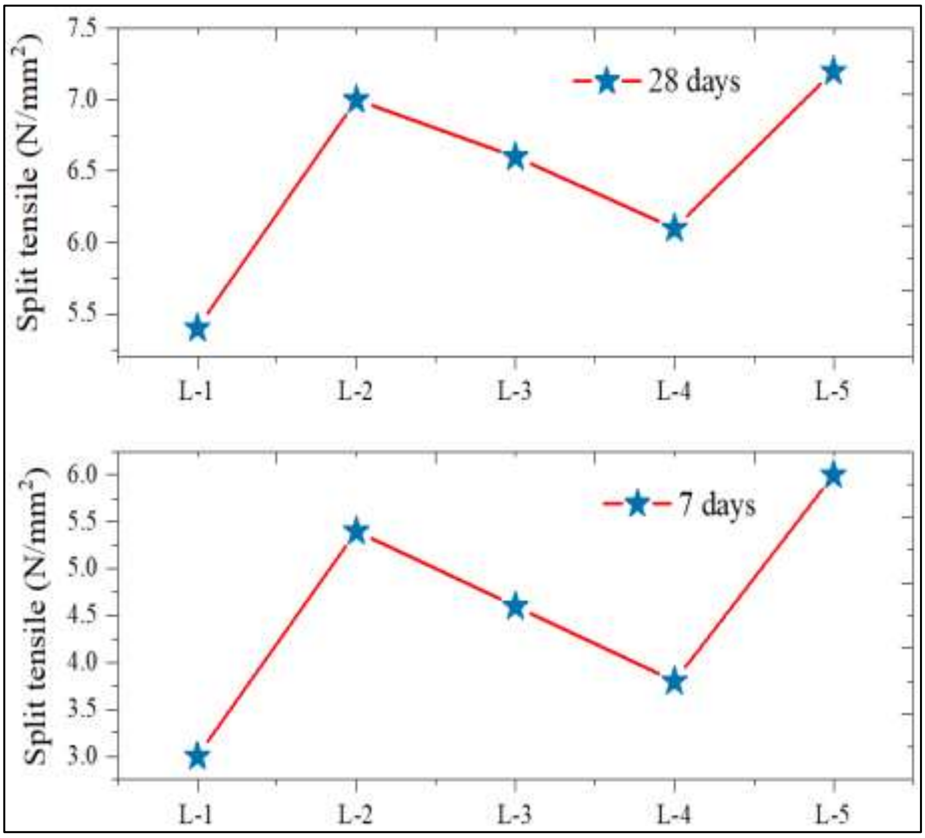
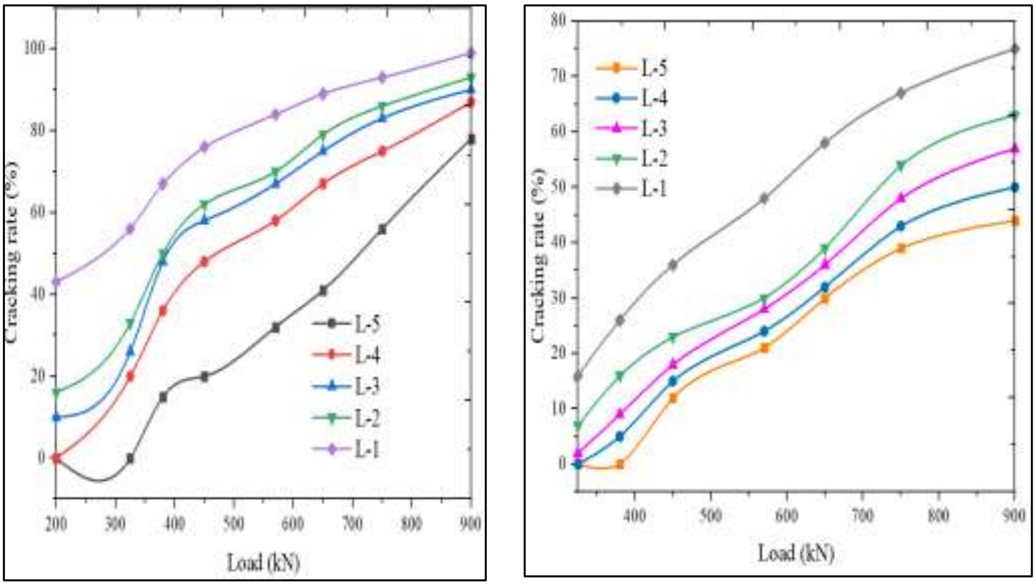


Figure 4: Split tensile test

The cracking rate parameter was measured to measure the moulded concrete's reliability. By the concrete strength test, the L-5 mix is described as the optimal mix. Then the strength of the concrete is evaluated for all mixes by applying the specific loads. Here, the L-5 mix has defined the less craking outcome than other mixes. It has been verified that attaining good compressive and split tensile strength has diminished the cracking range. For the 7 days cured samples, the first crack recorded for the L-5 mix is 400kN load which is 15% of the crack.

Table 3: Performance assessment

	Compressive strength (N/mm^2)		Split tensile (N/mm^2)	
	7 days	**28 days**	**7 days**	**28 days**
L-1	30	47	3	5.4
L-2	52	69	5.4	7
L-3	44	60	4.6	6.6
L-4	37	52	3.8	6.1
L-5	69	75	6	7.2



i) j)

Figure 5: Cracking rate: i) 7 days, j) 28 days

After 28 days of curing, the L-5 mix recorded the highest cracking rate at 44% for a 900kN load. Also, the first crack appeared at 450kN load, and the crack percentage is 12%. Moreover, the maximum cracking rate of 75% is attained for the L-1 mix at 900kN load, as defined in Fig. 5. By the validation; the concrete strength depends on the optimal combination and full days of curing.

Table 4: Validation outcome

Testing results			
Mixes	**Compressive strength**	**Flexural strength**	**Split tensile**
L-1	65	6.4	5.4
L-2	34.8	4.6	2.3
L-3	63.1	7.7	4.5
L-4	46.8	3.2	3.9
L-5	75	8.2	7.2

In addition, to justify the optimal mix, some tests were carried out: compressive strength, tensile and flexural. Those outcomes are exposed in Table 4.

5.2 Comparative Analysis:

In the proposed MPS, the accurate performance of replacing the material in concrete production was provided with various performance metrics such as compressive strength, Density and water absorption. Moreover, the proposed mechanism was compared with several prevailing methods such as Recycled sand from the crushed Brick System (RBS)

[26], Clay Ceramic waste method (CCW) [27], Granulated Blast Furnace Slag technique (GBFS) [28], Thermo Gravimetric Analysis (TGA) [29].

5.2.1 Density:

The material's Density represents the denseness of an object in a particular area. It is also determined as the mass for each unit volume. The parameter was essential to measure how the material was packed tightly together. It was the exclusive physical property of the specific material. High-density concrete was one type provided with higher Density than standard concrete. The weight of the concrete mix was added to obtain the increased Density. The added weight is derived from the materials and commonly adds heavy aggregate.

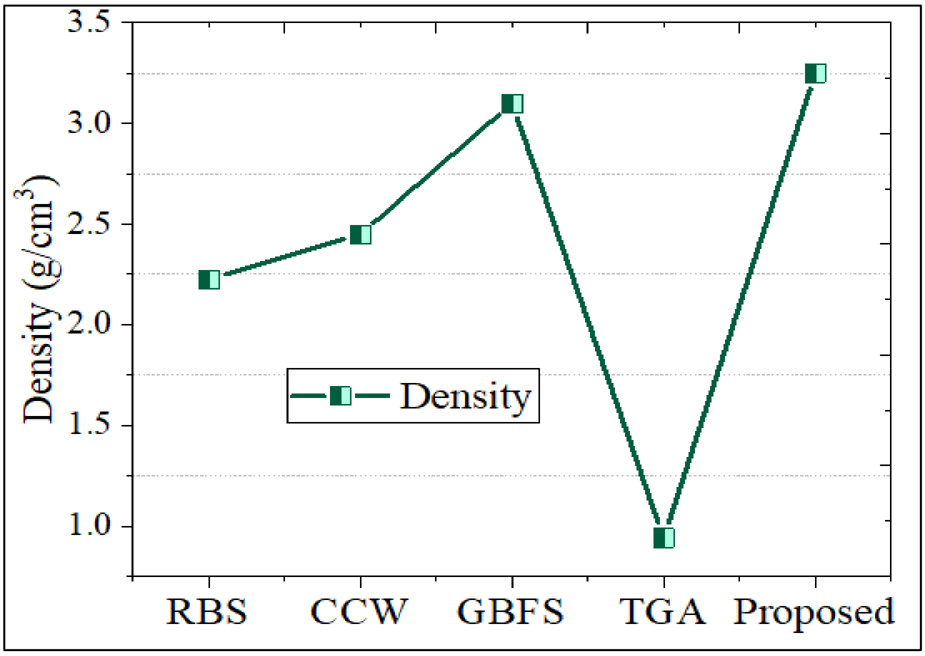


Figure 6: Comparison of Density

Different currently used models, like RBS, had a density of 2.225 g/cm^3, CCW had 2.45 g/cm^3, GBFS had 3.10 g/cm^3, and TGA had 0.94 g/cm^3. In this instance, the suggested MPS model gained 3.25 g/cm^3, which offered a high-density value compared to the current models and presented the density comparison in Fig. 6.

5.2.2 Water Absorption:

The proportion of the aggregate weight to the volume of water was said to be specific gravity, and the measurement of weather resistance was defined as water absorption. Water absorption was used to determine the total water absorbed under precise conditions.

The factors that affect the water absorption were condiments used, high temperature and length of exposure—the data outhouses light on the material performance in water or humid environments. An absorption test was utilized to define the water tightness of concrete. The amount of water infiltrates into concrete samples when submerged.

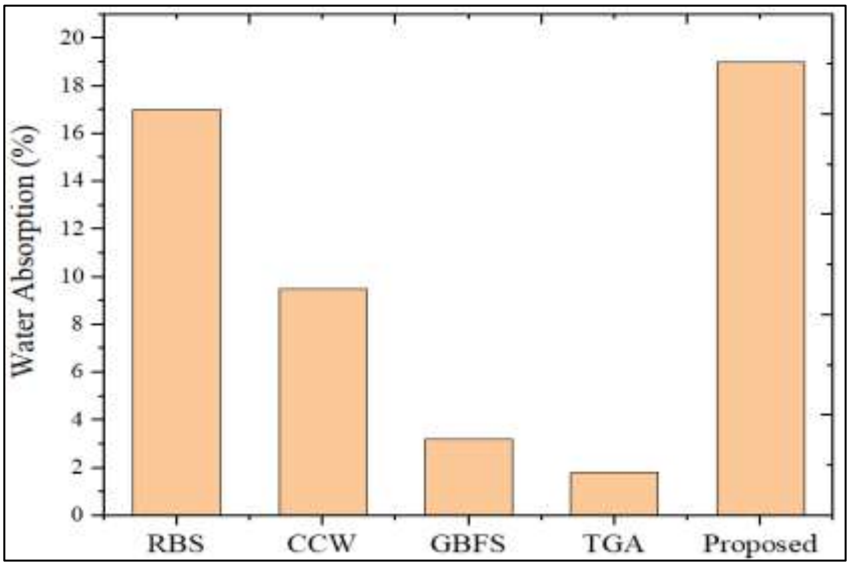


Figure 7: Comparison of Water Absorption

The Water Absorption of the current mechanisms, such as RBS, CCW, GBFS, and TGA, was 17%, 9.5%, 3.2%, and 1.8%, respectively. In this case, the developed model outperformed the current approaches regarding Water Absorption by 19%. The comparison of the Water Absorption is shown in Fig. 7. Hence, mix L-5 reported a superior outcome in testing assessment than other mixes. It indicates the correct optimal mix selection by the implemented novel solution. Also, this study raises awareness about using concrete and ceramic wastes as applicable.

6. Conclusion:

Ceramic products were the most critical construction materials used in several building structures. Typical manufacturing ceramic materials include wall and floor tiles, household ceramics, salubrious ware and technical ceramic. In this study, the optimal mix selection is carried out by a novel MPMS. Here, the optimal mix is selected based on the finest compressive strength. The compressive strength test is executed for every mix; once the maximum fixed compressive strength is obtained, the process is stopped, and that mix is selected as the optimal one. Compared to the existing models, the water absorption rate is maximized by 2%, and the Density is improved by 0.2%. Besides, the maximum compressive strength recorded by the selected optimal mix is 75N/mm^2. Finally, to continue the work further, the failure mode of the proposed methods was tested by applying different loads. The designed concrete has a 44% cracking rate after 28 days of curing. Hence, to find the optimal cracking rate, the curing days must be increased further in future work to evaluate the designed concrete's reliability.

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