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Investigating and Optimizing the Mechanical Properties of Glass Powder and Marble Dust Modified Cementations Concrete

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Abstract: The cement industry not only depletes natural resources but also is a source of environmental threat by releasing CO_2 content into the atmosphere, which promotes global warming. Subsequently, the whole or partial substitution of cement with supplementary cementitious materials (SCMs) is a feasible and cost-effective approach to enhancing concrete`s adaptability while also utilizing agro-industrial wastes. The research comprises two phases, in the first phase the main variables of interest in cementations mix design selection were sand, cement, and water results based on the primary mechanical property (compressive strength). In the second phase of research, a sequential and systematic optimization technique was applied to develop a modified cementations concrete using marble dust and glass powder. The concerned properties were workability (slump flow) and mechanical properties (compressive and tensile strength). Finally, the optimum finding of marble dust and glass powder were 2.9 and 90 respectively by using the multi-objective optimization technique of RSM. The experimental findings for the slump flow, compressive strength, and tensile strength were 126 mm, 30.73 MPa, and 2.6 MPa, respectively, which were quite near to the expected response values, with the difference between them being less than 5%.

Keywords: Glass Powder, Marble Dust, Modified Cementations Concrete, Mechanical Properties

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1. Introduction

The cement's alkali content will rise as a result of the addition of waste glass. Additionally, it aids in the production of bricks and ceramics, protects raw resources, and reduces energy use and the amount of garbage disposed of in landfills. Glass powder and other suitable recycled materials are mostly utilized in civil engineering-related fields. It is particularly advantageous to utilize trash in place of clinker because, in addition to conserving energy and reducing CO_2, additives can enhance the characteristics of concrete by making it more compact and altering its microstructure. Their recycling rate is around 100%, and they can be employed in concrete without compromising the longevity of the concrete. To lessen environmental issues, glass powder has recently been employed as a construction material. Glass powder can reduce the alkali-silica reaction (ASR), which can be caused by both coarse and fine glass aggregates in concrete. This effect is comparable to that of supplemental cementing materials (SCMs). As a result, glass is employed to substitute other cementation materials.

Marbles are a common building material today. The processes of sawing, grinding, and polishing produce a lot of debris. As a result, the amount of waste marble, which represents 20% of all marble quarried, has increased to millions of tonnes. However, there are concerns about the alkali-silica reaction. Ordinary Portland cements the principal binder in concretes, is produced using roughly 3% of the world's energy, and accounts for nearly 8% of all anthropogenic carbon emissions. The greatest consumer of both natural aggregate and fresh water is the concrete industry. Increased concrete production for future use will significantly deplete these natural resources and pollute the environment. Therefore, it's required to substitute another material for natural sand in concrete, either partially or entirely, without sacrificing the substance's quality. One such resource that can be used in place of sand as fine aggregate is leftover marble dust. The goal of the current project is to use waste marble powder in place of natural sand as a fine aggregate in concrete. Since the beginning of time, marble has been one of the most significant building materials, particularly for decorative purposes. About 25% of the processed marble is converted into marble powder at processing facilities during the sawing and polishing of marble blocks.

It has been accepted that high amounts of energy consumption and carbon dioxide emissions are major sustainability issues related to the production of cement. In general, the global cement industryapproximately consumes 12-15% of the gross production of energy. Additionally, for the production of one ton of cement, approximately 0.73 to 0.99 tons of carbon dioxide emits into the atmosphere. It is noted that the cement industry alone contributes about 10% of the total anthropogenic carbon dioxide emission. To overcome the major issues, it is indispensable to limit the utilization of cement for concrete production and promote the industrial waste materials as replacement of cement. However, the complete exclusion of cement and the use of sustainable eco-friendly binder material is regarded as the most desired approach for accomplishing the full set of green material manufacturing objectives.

2. Literature Review

Chu [1] discovered that ultra-high performance Fiber reinforced concrete (UHPFRC) is a concrete that has a high content of cement requires a large amount of quartz sand has problems in becoming widely utilized in the future and becoming carbon neutral. If it is employed as an aggregate replacement or replacement for aggregates, recycled materials (such as glass that is used) can affect its performance. Ultra-high-performance fiber reinforced concrete (UHPFRC) which contains a significant amount of cement and uses a large amount of quartz sand, is having problems in becoming widely used and also becoming carbon neutral. When it is used as an aggregate or cement replacement or as a replacement for aggregates, recycled materials (such as glass that has been used) can affect the effectiveness of UHPFRC. It was found that the proper amount of WGP can significantly enhance UHPFRC's compressive strength, workability as well as bending strength and microstructure. The strength was noticeably increased by more than 150 Maps, and the cement content decreased by 18.8 percent to 365 kg/m^3. While investigating the mechanism, we found that the wet method was used to determine the density of the paste's packing and Slurry Film Thickness (SFT) mathematical models were employed.

Jing [2] studied the issue and established whether the blend of rice husk and met kaolin-based geopolymer GP was stable thermally. The materials were evaluated for compression strength as well as volume shrinkage at temperatures of high (T is 300 degrees Celsius to 500 degrees C and 700 degrees C and at 900 degrees Celsius). After calcination, they were heated to high temperatures to test how stable the material was thermally. Fourier Transform, X-ray Diffraction the phase was studied by using the scanning electron microscope (SEM) as well as the infrared spectrum remoter (FT-IR). Before and following high-temperature calculations, the polymer microstructure and composition were compared. Ash made of rice husk is the most effective chemical activity achieved in the case of the substance being heated at 550 degrees Celsius for 4 hours. A building material that is responsible for CO_2 emissions and greenhouse gas emissions is cement. Geopolymer has received lots of attention as a replacement for cement as a green building material. A large amount of active silica can be found within both glasses powder (GP) and rice husk and ash (RHA) even though they were made in different fields, and their microstructures differ.

Khan [3] studied the effect of substituting waste PET and silica-based fumes for normal Portland cement (OPC) on the characteristics of the initial and final forms of grouts made from cementations materials. The results revealed the fact that when OPC was substituted for regular PET, a decrease in both flexural and compressive strengths was observed. However, certain strengths were restored through the incorporation of irradiation PET. Comparatively to the control samples, there was a small decrease in drying shrinkage after both regular PET as well as irradiation PET was added. The results of the microstructural study were that the addition of Irradiation PET to cement grout causes the creation of new substances that help in the densification as well as the amplification of the structure of the microscopic. Bayraktar [4] examined the use of industrial wastes to create concrete has played a significant role in the creation of environmentally green building materials. In this study basalt fibers (BF) strengthened foamed concrete made of the waste marble dust (WMP) along with crushed granulated blast furnace wastewas examined for its physical-mechanical, durable as well as thermal characteristics (GGBFS). A foaming agent based on protein was employed to make foamed concrete with levels of 50 kg/m^3 and 100 kg/m^3 using a 0.75 water to binder (w/b) percentage. The results showed that the use ofWMP and BF in combination resulted in substantial compressive and flexural strength enhancements that were 179.49%, 141.79%, and 139.91%, 93.18% at 7 and 28 days. The combination of the 30% GGBFS together with one percent BF resulted in 50 kg/m^3 of foam with the strongest compressive strength, 32.57 MP, and the lowest porosity of 14.8 percent.

Mistry as well as Roy [5] examined the possibility of using it in addition to conventional lime-hydrated filler The current study examined the efficiency of bituminous mixture and mastic containing rice husk and ash (RHA) and fly ash of class F (FA-F) in various amounts. AFM testing and an altered Lott man test, a variety of freeze-thaw cycles Marshall mix design and indirect tensile strength, and various other methods were employed to test this. The results of the test

Indicated that mixes that had RHA and FA-F additions achieved extraordinary results even at lower OBC. (OBC). In addition, RHA displayed the maximum adhesive force and demonstrated a homogeneous dispersion of the bee-like structures within the mastic. This can be explained by its thin and porous structure. Gencel [4] studied the study of the micro-structural mechanical, thermal, and endurance characteristics of foam concrete that is supplemented using flax fibers (HFs) as well as fly ash (FA) using the Taguchi optimization method discussed in the paper. With levels of foam at 50 75, 100, and 50 kg/m^3, three different kinds of concrete mix-ups made of foam were made. A H F and FA-free reference mixture is also available. In the end, FA is foundin the mixtures at levels of 0%, 10 percent 20-20 30, 40 percent, and 50 percent to alternative to cement. The HFs were added to the mixtures with concentrations of 0.75 percent, 1.5%, and 3.3%by the weight of cement. The length of the fibers of HFs varied. Reliability was measured by using the slump test. By using the Taguchi optimization method, the results were scrutinized to show that using HFs leads to significant improvements in flexural and compressive strength. The application of FA increases the resistance to high temperatures in foam concretes, while reducing the shrinkage in drying as well as thermal conductivity.

Saridemir and colleagues [6] have examined in this research study, the micro and mechanical structural properties of high-strength mortars (HSMs) modified with diatomite-based powder (CDP) at both low and high temperatures are studied. The performance of residuals in HSMs modified by CDP was observed to be superior to that of the reference HSM (R-HSM) which was constructed using zero CDP. The HSM modified using 15 percent CDP (15CDP-HSM) was identified to have the greatest mechanical properties at high and low temperatures Based on the test results. Li [7] identified the filler method of using GD to concrete to make use of waste materials and reduce carbon footprint. To test a variety of mortar mixes with different quantities of GD used as a replacement for cement and/or as filler for gaps were made. Regarding waste disposal and reduction in cement content, the results showed that filler technology is far superior to the alternative of cement replacement. Additionally, this technique could enhance the strength and microstructure of the mortar. Shankaramurthy [8] proved that the most significant and frequently used cementations ingredient in the creation of concrete is thecement. A lot of materials are mixed with cement, in the form of other powders. To enhance the quality and flexibility of the concrete that is produced cementations components such as fillers, cementations ingredients, or any other materials can be utilized. While additive manufacturing has grown rapidly over the last 20 years, significant quantities of remaining metal powder that was produced from additive manufacturing were also produced. Metal flakes can be expensive and recycling this metal powder poses dangers to the environment and stress. The results found to be that the right quantity of SS micro powder to add to cement paste (by volume of the mix) enhanced the durability and strength of the mix, however, the addition of between 2 and 8 percent SS causedadverse consequences. It is suggested that more research is conducted on its use in higher doses for use as a cement substitute.

Marchon and others [9] explored the role of admixtures in the creation of concrete manufacturing systems that can be used to achieve digital fabrication, and at the same time, encourage research in the crucial areas of study. With the aid of concrete with no formwork manufacturing infrastructure components can be constructed in an additive manner. The demands that were fulfilled by the formwork can now be applied to concrete, which is an enormous advantage but creates engineering problems for the materials. This study was discussed as the using admixtures to create the rheological characteristics and hydration needed for printed concrete. Lu et al. [9] studied the huge amount of waste marble in the stone-processing industrythat needs to be properly removed to prevent health hazards or environmental harm. In this study, artificial stoneware was made by recycling waste marble through the modification of surfaces and low-temperature sintering. The mechanical properties of stoneware sintering were improved through reinforcements made from boehmite platelets as well as mullet fibers. The results indicated Stoneware became stronger and denser due to the higher compaction pressure that powder compacts experience. Stoneware's toughness was affected by the effect of the synergy effects produced by composite reinforcements comprised of platelets and fibers. Stoneware with reinforcements far outperformed natural marble and unreinforced stoneware based on their mechanical characteristics. In addition, the strengthening mechanism included the reduction of fault size, improvement in adhesiveness to the surface, and enhancing the durability of stoneware. The mechanisms for toughening included crack deflection as well as fracture bridges. Galetakis as well as Soultana [10] explored the potential use of the mentioned by-products to make aggregates or substitutes in the production of cement-based construction products has been the focus of research projects that are discussed in this article. The study's components and preparationmethods, as well as their quantifiable properties, and possible uses, were all investigated. The marble sludge and quarry dust were mostly used for fine aggregates and cement substitutes when

Making concrete. The production on a large scale of quarry dust and sludge from quarries, aggregate industries, as well as ornamental stone factories poses a significant risk to the environment. These materials can positively impact the environment and economy if used for building.

Google [11] examined the recycling or disposal of waste materials as among the major environmental problems. The study found that millions of tons of waste dust in the form of powder are generated each year from limestone quarries and marble processing plants. They can be used as fillers for self-compacting concretes as they possess a higher level of quality as compared to cement (SCCs). To achieve this, an experiment was conducted to find out whether marble powder (M) and limestone filler (LF) could be used for the creation of SCCs without or with fly ash. The results indicated that the high replacement rate of filler had little effect on SCCs their fresh properties. The inclusion of fly ash helped to reduce the effects of these problems. Furthermore, marble powder and limestone filler were added to improve the transport and mechanical qualities. Ergun [12] examined methods and findings from an in-laboratory evaluation of the mechanical properties of concrete specimens that contain diatomite and WMP to provide partial substitutes for cement in concrete is described in this article. Analyzing the waste and raw material preparation for concrete specimens using diatomite as well as WPM at various weight ratios to replace cement as a super plasticizing admixture to lower water demand compressive and flexural tests on the specimens constitute most of the laboratory work. The highest compressive and flexural strength was discovered in concrete samples that contained 10 percent diatomite and 5 percent WPM as well as 5 percent WPM plus diatomite substituted at 10 percent by the weight of cement as per the results of tests. It was also observed that substituting diatomite for WMP and diatomite for cement in conjunction with a super plasticizing mix could increase the mechanical characteristics of standard concrete mixtures.

3. Research Methodology

In this research methodology, to attain the above-listed purposes, this study will be supported in three phases. In the first phase, mixed designs will be selected based on the central composite design(CCD) method. CCD is a statistical method to select appropriate mix designs within a given range of variables (marble dust and glass powder. The second phase of the research will deal with the investigation of slump flow, setting time, density, compressive strength, and tensile strength of Each mix design. In the third phase, the multi-objective optimization technique of

Response Surface Methodology (RSM) will be utilized to optimize mixed ingredients for achieving maximum levels of mechanical properties. However, slump flow will be kept in the allowable range. Lastly, an optimized mix provided by the RSM technique will be experimentally validated.

3.1 Collection of Materials

An experimental program was created to accomplish all the goals, and choosing the right materials is always a difficult task. For the cementations mortar, glass powder and marble dust are among the ingredients. The characteristics and attributes of all the primary materials used to make cementations materials are covered in this section.

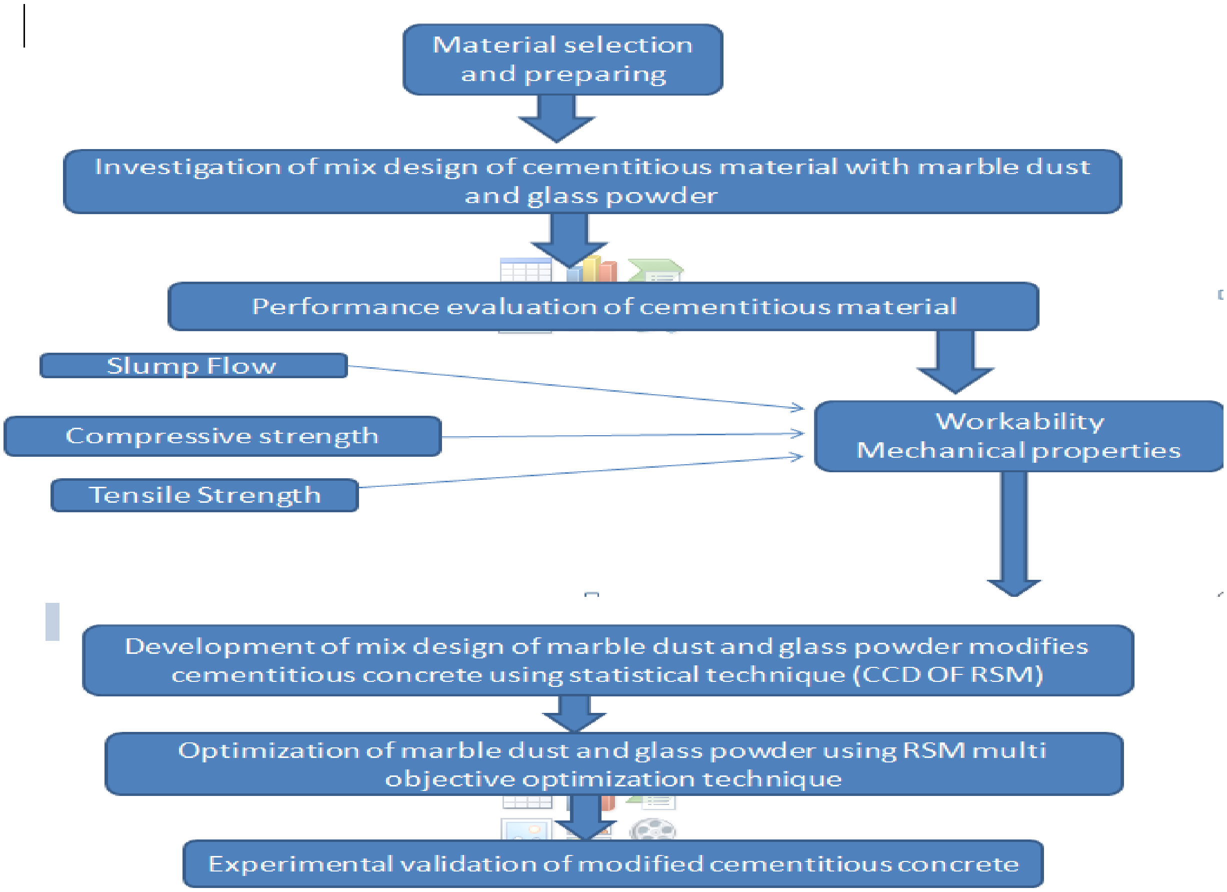

Figure 1 Flow chart of research methodology

3.2 Cementations chemistry

Since regular Portland cement (OPC) is the main binder used in the construction of mixes that allow concrete to be digitally fabricated we have decided to solely examine OPC hydration within this segment. But other binders can be substituted and other cementations materials are discussed later we will discuss additional materials. Three types of phases make the bulk of Portland cement silicates, which comprise impure tricalcium silicate and tricalcium silicate (C_2S and delete) and the aluminates that include tricalcium aluminate (C_3A) and the tetra calcium aluminum aluminoferrite (C_4AF) as well as the Sulphates, which are generally the gypsum component that dehydrates depending upon the location from which it originates It could also be present in the form of anhydrite. This diagram shows the main chemical processes that take in the initial hydration process of the model cement.

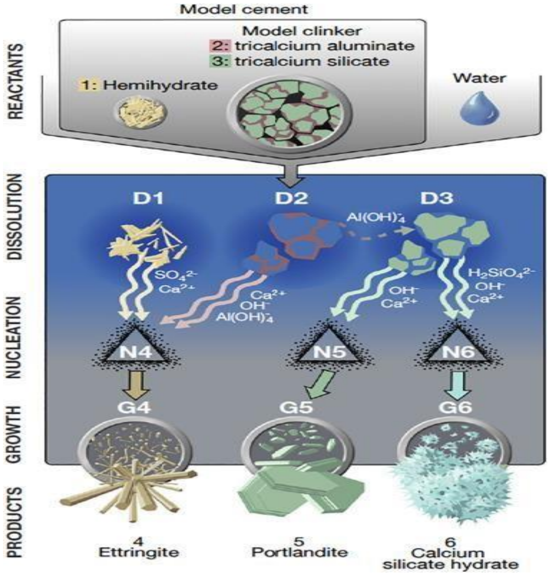

Figure 2 Model Cement

The first anhydrous phases break down, and then the nucleation of hydrates when their supersaturation levels have been reached as well as their subsequent development. The two main phases at the beginning of the process of hydration are C_3S. This creates calcium silicate hydroxide (C-S- H) and the crystallized phase called portlandite. C_3A that results in the formation of ettringite andcalcium sulfurates.

3.3 Cement

The cementations material that was used in this study complies with ASTM C-150 (ASTM 2017). Grade 53 Ordinary Portland Cement (OPC), a type-1 cement that is readily available locally, is used to make masonry mortars. Also, Maple Leaf Pvt. Ltd. produced the cement. Table 3.4.1 lists cement's chemical makeup by (ASTM 2004). Table 3.2 also includes physical properties given by (Designation 2002, ASTM 2009, and ASTM 2013).

Parameterof cement	L.O.I	SIO_2	AL_2O_3	FeO_3	CaO	MgO	SO_3	K_2O	Na_2O	CL-
Results	1.92	21.73	3.60	1.50	63.20	3.20	2.50	0.27	0.96	0.03

3.4 Glass powder

Glass powder, also known as "glass frit" or "glass flux," is glass that has been ground into incredibly minute particles, typically with a median grain size ranging from 30 micrometers to as thin as 0.1 micrometers. Additionally conceivable are specialized distributions or sizes. The characteristics of glass powder depend on the type of glass used, as well as on particle size and morphology. Specialty glass powders can satisfy a wide range of requirements depending on their composition. The characteristics of glass powder depend on the type of glass used, as well as on particle size and morphology. Specialty glass powders can satisfy a wide range of requirements depending on their composition.

Figure 3 Glass Powder

Components	CL-	SIO_2	AL_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	L.O.I
Glass powder	0.04	71.40	2.54	0.37	11.2	1.60	0.16	0.36	12.25	0.82

3.5 Marble dust

A metamorphic rock called marble dust powder is made up of recrystallized carbonate minerals, most frequently calcite or dolomite. Felsic marble is possible. Stonemasons use the term "marble" more generally to refer to un-metamorphosed limestone, whereas geologists only use it to describe metamorphosed limestone. Meanwhile earliest times, marble has been employed extensively as a building substantial. As a result, marble dust is a very important substance and needs to be properly disposed of in the environment. Furthermore, recycling waste improperly might lead to environmental issues that are worse than the waste itself. Marble dust powder, specifically from Mohmand Agency in Khyber Pakhtunkhwa, Pakistan was needed for the research project. The technique includes site visits, sample collection, and lab testing on samples.

Components	TiO_2	SIO_2	AL_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	L.O.I
Marble dust	0.04	2.42	2.07	0	55.65	1.60	0.16	0.01	0.36	43.232

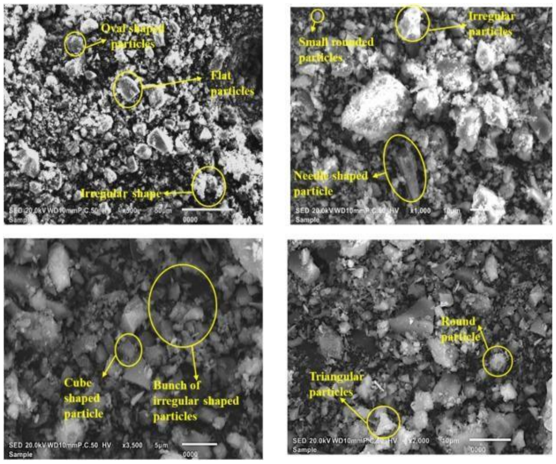

Figure 4 Scanning Electron microscopic images show various shapes of glass powder.

3.6 Sand

Natural quartzite sand was used as the fine aggregate in the construction of all test specimens. According to ASTM C 136, a study of the aggregate sieve was conducted. Table 3.7.1 displays the sand's physical characteristics.

Bulk Density (kg/m^3)	1503 kg/m^3(ASTMC29/C29M-09)
Specific Gravity	2.68(ASTM C128-15)
Water Absorption	1.12% (ASTM C128-15)
Fineness Modulus	2.22

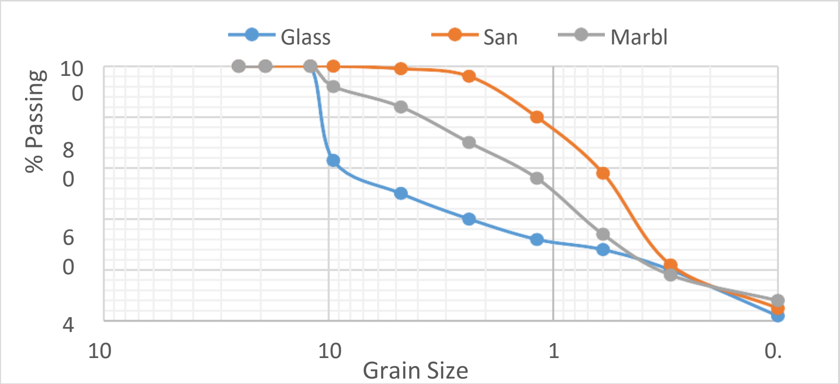

Figure 5 Sieve analysis of sand, glass powder, and marble dust

3.7 Mix Design of CM

A systematic and sequential optimization technique was employed to produce the cementations Mixture with the maximum strength. The three stages of the optimization process required altering the mixture's sand, cement, glass powder, and marble dust contents. It was done to optimize sequentially. Included in this are the three stages of glass powder and marble dust ratio optimization for the best mechanical properties of cementations cement mortar mix design.

Mix Designation	Marble%	Glass%	W/C	Cement	Sand	Water	Marble (Gram)	Glass (Gram)
M0	0	0	0.6	479	1598	278	0	0
M1	0	12.5	0.6	419	1598	278	0	60
M2	0	25	0.6	359	1598	278	0	120
M3	10	0	0.6	431	1598	278	48	0
M4	10	12.5	0.6	371	1598	278	48	60
M5	10	25	0.6	311	1598	278	48	120
M6	20	0	0.6	383	1598	278	96	0
M7	20	12.5	0.6	323	1598	278	96	60
M8	20	25	0.6	263	1598	278	96	120

3.8 Design of experiments (DOE) by statistical response surface method (RSM)

A statistical method for establishing and assessing the relationship between dependent and independent variables as responses and factors is known as the response surface method (RSM). The entire process entails four steps: design of experiments (DOE), trial-based assembly of responses, establishment of the RSM numerical model, and optimization and authentication of the model that has been created. Central composite design is the most feasible and often used test design strategy in the RSM methodology (CCD). CCD is a two-stage factorial design with data points that include star points with extreme + and square corner points for all +1 and -1 design points. To estimate the responses (compressive and tensile strength), quadratic models arecreated using the 2nd-degree polynomial.

$$y = \quad + \sum \beta_i M_i + \sum \beta_{ii} M_i^2 + \sum \beta_{ij} M_i N_j$$

Where "y" is the predicted reaction, which might be a mechanical property of cementations mortar. Furthermore, the constant coefficient, linear coefficient, quadratic coefficient, and interaction coefficient are represented by o, i, ii, and ij respectively. Furthermore, M i and N j stand for independent variables.

3.9 Central Composite Design (CCD) Module

The ranges of independent variables were selected using trial mix designs and literature research. Additionally, the curing temperature was maintained at room temperature while the cementations mortar range was changed. The experimental plan was made using the commercially available Design expert® software. To optimize cementations mortar, nine mix designations were used. According to the central composite design configurations with three variables and five centerpoints shown in the illustration, nine mixes of the proposed cementations mortar composite are selected at random.

3.10 Mixing and Casting of Cementations Mortar

To examine the effects of marble dust, glass powder, cement, and water dosage on the mechanical strength of cementations mortar, various mixed proportions of these ingredients were used to make cementations mortar. To manufacture cementations mortar, water was combined with a total of 479g, 1598g, and 278g, respectively. The entire mixing process, using the Hobart mixture, took five minutes. Dry mixing took around 30 seconds at a slower rate after the cementations mortar mixture was gradually added. When the mixing process was finished, the mortar mixture was placed into standardized molds and left in the lab to set. Samples were demoded and wrapped in plastic folds to reduce excessive water loss during curing. The temperatures of each sample were kept constant.Samples are tested on days 7, 14, and 28 after casting.

Mix Designation	Marble%	Glass%	W/C	Cement	Sand	Water	Marble (Gram)	Glass (Gram)
M0	0	0	0.6	479	1598	278	0	0
M1	0	12.5	0.6	419	1598	278	0	60
M2	0	25	0.6	359	1598	278	0	120
M3	10	0	0.6	431	1598	278	48	0
M4	10	12.5	0.6	371	1598	278	48	60
M5	10	25	0.6	311	1598	278	48	120
M6	20	0	0.6	383	1598	278	96	0
M7	20	12.5	0.6	323	1598	278	96	60
M8	20	25	0.6	263	1598	278	96	120

Figure 6 Casting of cementations mortar samples

4. Testing

The details of the experiments performed in this study are elaborated in the following subsections.

4.1 Mini Slump Flow Test

The workability of the fresh cementations mortar mix design nation was assessed by performing a mini-slump flow (MSF) test by ASTM C1437.

Figure 7 Mini Slump Flow Test (ASTM- C1437)

4.2 Compressive Strength

One important mechanical attribute is compressive strength; typically, variations in compressive strength evaluation are connected with all other mechanical qualities. As described in the section on "Mixing and Casting of Cementations Mortar," three 50 mm x 50 mm cubes were cast against each mortar mixture. Compressive strength testing was carried out in accordance with ASTM-C 109/C 109M as soon as the required curing time was reached. 3.0 kN/s of load was added to the sample gradually until it ultimately failed.

Figure 8 Compressive Strength Test (ASTM –C 109/ C 109M).

$$\boldsymbol{f_{ck} = \frac{P}{A}}$$

where, f_{ck} = Compression strength (MPa); P = Maximum applied force (N), A = Bearing area of cube (mm^2)

4.3 Tensile Strength

In the present study, the split tensile test, by ASTM C 496/C 496M, was used to assess the tensile strength of mortar specimens. A constant rate of 0.94 kN/sec was used to equallydistribute the load on the cylinder along two lines that were at right angles to one another.

Figure 9 Split Tensile Strength Test (ASTM C 496/ C 496M)

The specimen was placed precisely beneath the center line of the spherical block of the testing machine thanks to the alignment jig's ability to prevent the specimen from rolling during the test setup. Twostrips were put at the top and bottom of the sample before the load was applied in order to distribute the weight evenly along the cylinder. At 7-, 14-, and 28 days following casting, three cylindrical specimens were tested against each combination.

5. Results and Discussion

The outcomes of the experimental program that was carried out to meet the objectives were included in this part. The basic mechanical attribute (compressive strength) of the cementations matrix in mix design was first investigated. The most important influencing variables were cement, sand, and dose of water solution. In the current study programmed, they have been chosen because they provide superior compressive strength. Workability (slump flow) and mechanical characteristics were the problematic properties (compressive and tensile strength). The main factors that affect the qualities of CM after choosing a suitable cementations mortar mixture are the percentages of glass powder and marble dust. Glass powder (GP) and marble dust (MD) impact on cementations mortar (CM) qualities was evaluated using central design composite (CCD) of response surface methodology (RSM).

Mix Designation	**Marble %**	**Glass%**	**W/C**	**Cement**	**Sand**	**Water**	**Marble (Gram)**	**Glass (Gram)**	**Compressive strength**		
									7 days	**14 days**	**28 days**
M0	0	0	0.6	479	1598	278	0	0	14	21	40
M1	0	12.5	0.6	419	1598	278	0	60	12	16	35
M2	0	25	0.6	359	1598	278	0	120	8	13	28
M3	10	0	0.6	431	1598	278	48	0	9	14	24
M4	10	12.5	0.6	371	1598	278	48	60	7	20	22
M5	10	25	0.6	311	1598	278	48	120	8	11	18
M6	20	0	0.6	383	1598	278	96	0	10	15	23
M7	20	12.5	0.6	323	1598	278	96	60	9	11	22
M8	20	25	0.6	263	1598	278	96	120	8	10	19

5.1 Effect of Glass Powder and Marble Dust on Compressive Strength

Hence mix design from M0 to M8 has shown higher compressive strength; therefore, the same was selected for the next phase of the research work.

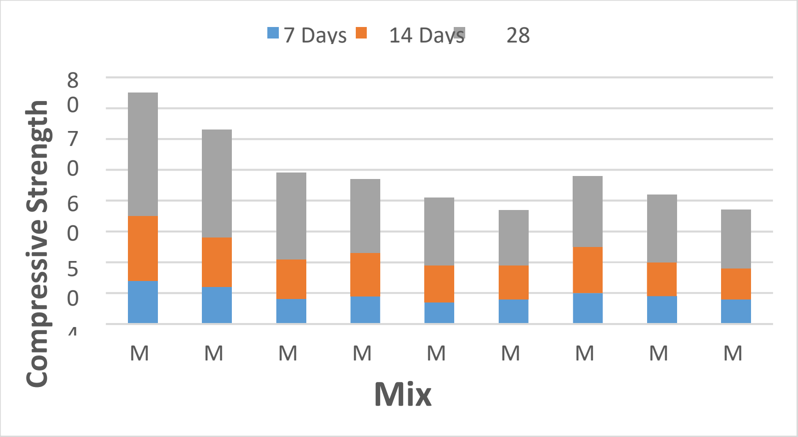

Figure 10 Effect of GP&MD on compressive strength

5.2 Workability

Workability refers to how simple or difficult it is to position, handle, and condense a combination. The slump flow of the mixture is commonly used as a quantitative indicator of workability. A 3D response surface graph is used to figure out the influence of marble dust (MD) and glass powder (GP) on the slump flow of cementitious mortar. The impact of MD and GPin phases of slump flow of cementitious mortar.

Mix Designation	Marble%	Glass%	W/C	Cement	Sand	Water	Marble (Gram)	Glass (Gram)	Slump flow (%)
M0	0	0	0.6	479	1598	278	0	0	135
M1	0	12.5	0.6	419	1598	278	0	60	114
M2	0	25	0.6	359	1598	278	0	120	119
M3	10	0	0.6	431	1598	278	48	0	126
M4	10	12.5	0.6	371	1598	278	48	60	122
M5	10	25	0.6	311	1598	278	48	120	117
M6	20	0	0.6	383	1598	278	96	0	120
M7	20	12.5	0.6	323	1598	278	96	60	124
M8	20	25	0.6	263	1598	278	96	120	128

When cementations was synthesized with 20 percent Marble dust and 25 percent. Glass power, a maximum slump flow of 128 percent was recorded. Furthermore, the Marble dust of 0 percent and glass power of 12.5 percent had the least amount of slump flow (114 percent). The contour graph shows the composite flow intervals, which may be used to anticipate the values of Marble dust andglass power for the specified slump flow value. However, slump flow can be predicted by the ANOVAequation.

$$Slumpflow\ (\%) = 134.50 + 0.23333\ A1 - 2.200\ B1$$

Where, A1 andB1 Represents Marble dust and glass powder respectively.

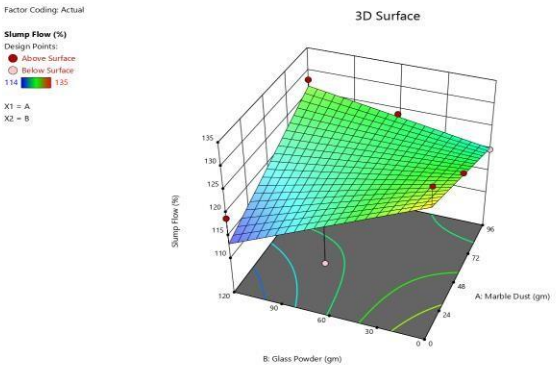

Figure 11 D Response Surface of Slump flow

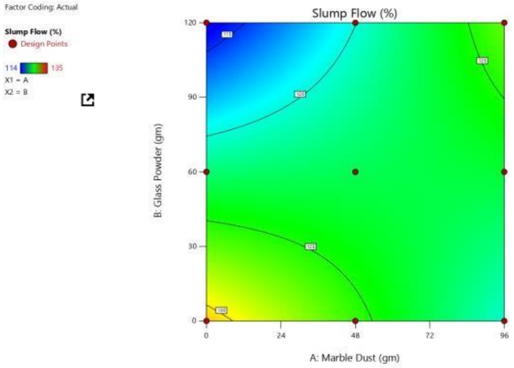

Figure 12 Contour Diagram of Slump Flow

5.3 Compressive Strength

The compressive strength of CM mortar decreases with the increase in marble dust (MD) ratio whereas enhanced with the increase in the percentage of Glass powder (GP) The impact of marble dust and Glass powder on compressive strength is shown in Figure. However, compressive strength can be predicted by the ANOVA equation.

Compressive strength = $22-6.50A-3.67B+2AB+6.50A^2-1B^2$

Where A; MARBLE DUST, B; GLASS POWDER

Mix Designation	Marble%	Glass%	W/C	Cement	Sand	Water	Marble (Gram)	Glass (Gram)	Compressive strength (MPA)
M0	0	0	0.6	479	1598	278	0	0	40
M1	0	12.5	0.6	419	1598	278	0	60	35
M2	0	25	0.6	359	1598	278	0	120	28
M3	10	0	0.6	431	1598	278	48	0	24
M4	10	12.5	0.6	371	1598	278	48	60	22
M5	10	25	0.6	311	1598	278	48	120	18
M6	20	0	0.6	383	1598	278	96	0	23
M7	20	12.5	0.6	323	1598	278	96	60	22
M8	20	25	0.6	263	1598	278	96	120	19

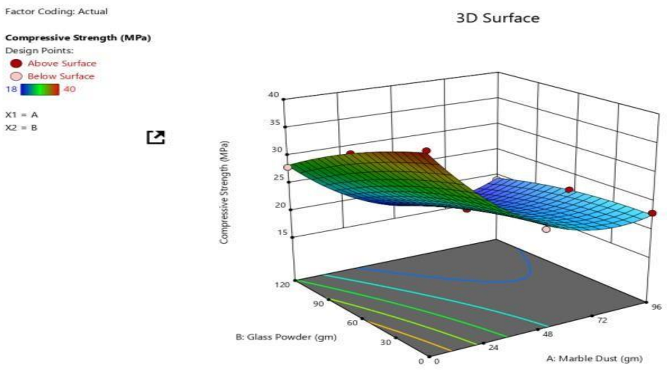

Figure 13 Response Surface of Compressive Strength

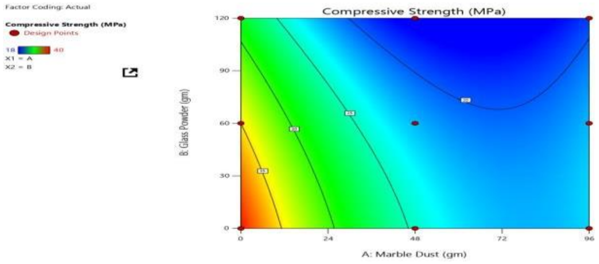

Figure 14 Contour Diagram of Compressive Strength

5.4 Tensile Strength

The split tensile strength cementations mortar enhanced with the percentage of Marble dust (MD) whereas the density of glass powder decreased due to its lightweight and at 12.5%, marble dust showed the best optimum percentage to be replaced with cementations-based mortar, as the percentage of glass powder increased the tensile strength decreased. This occurs due to the lightweight of Marble dust. The Impact of Marble dust and glass powder on split tensile strength is shown figure and table. However compressive strength can be predicted by ANOVA.

Tensile Strength = 2.34-0.0667A-0.1667B

Where, A = Marble dust, B = glass powder

Mix Designation	Marble%	Glass%	W/C	Cement	Sand	Water	Marble (Gram)	Glass (Gram)	Tensile strength (MPA)
M0	0	0	0.6	479	1598	278	0	0	2.7
M1	0	12.5	0.6	419	1598	278	0	60	2.1
M2	0	25	0.6	359	1598	278	0	120	2.5
M3	10	0	0.6	431	1598	278	48	0	2.4
M4	10	12.5	0.6	371	1598	278	48	60	2.2
M5	10	25	0.6	311	1598	278	48	120	2.3
M6	20	0	0.6	383	1598	278	96	0	2.6
M7	20	12.5	0.6	323	1598	278	96	60	2.4
M8	20	25	0.6	263	1598	278	96	120	1.9

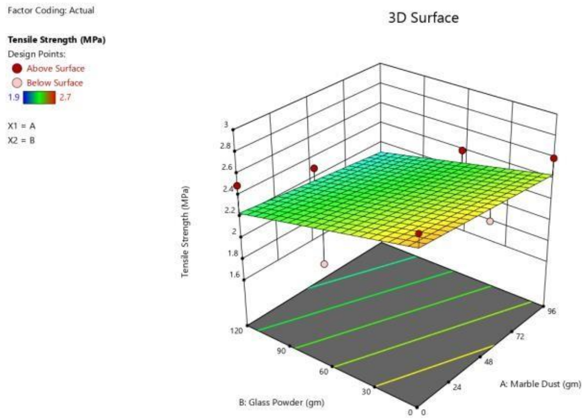

Figure 15 D Response Surface of tensile Strength

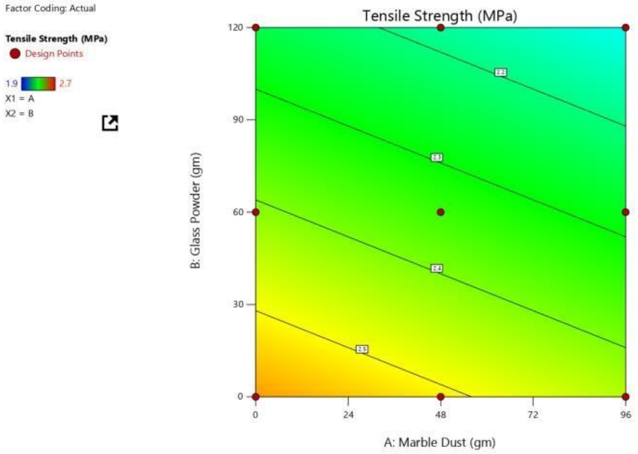

Figure 16 Contour Diagram of Split Tensile Strength

5.5 Optimization of Marble Dust (MD) Glass powder (GP) for The Development of Maximum Strength Cementations Mortar (CM)

Within the same region, obtaining the optimal value of all individual responses is challenging. Asa result, multi-objective optimization is regarded as the best approach for obtaining the optimal solution that simultaneously meets the needs of all respondents. To discover the best feasible responses, a multi-objective optimization approach was used after creating and testing ANOVA models for all of the responses. The equation gives the global desirability function utilized in RSM optimization.

$$D = (d_1^{r1} * d_2^{r2} * d_3^{r3} * \dots * d_n^{rn})^{1/\Sigma r_i} = [\int_{i=1}^{n} d_i^{ri}]^{1/\Sigma r_i} \quad (4.4)$$

The number of independent variables (factors) and dependent variables (responses) incorporated in the optimization process is denoted by n. Two independent variables, marble dust and glass powder were employed in this study, as well as three responses: slump flow, compressive strength, and tensile strength, all of these were optimized at the same time. Where ri reflects the importance of each of the factors or responses, the importance is graded on a scale of 1 to 5, with 1 indicating the least important and 5 indicating the most important. The individual desirability functions di varied from 0 (undesired) to 1 (desired). The desirability of the best solution is calculated as the geometric mean of the individual desirability of all variables (factors and responses). When the targeted value is close to one, the finest choice is very near to achieving the intended objective. The RSM multi-objective optimization practice was performed to accomplish the finest solution that meets the aims of all responses at the same time. The study's primary goal was to optimize the

Responses, which included compressive and tensile strength. All of the responses were determined to be optimum at 2.96 and 90.61, marble dust and glass powder respectively.

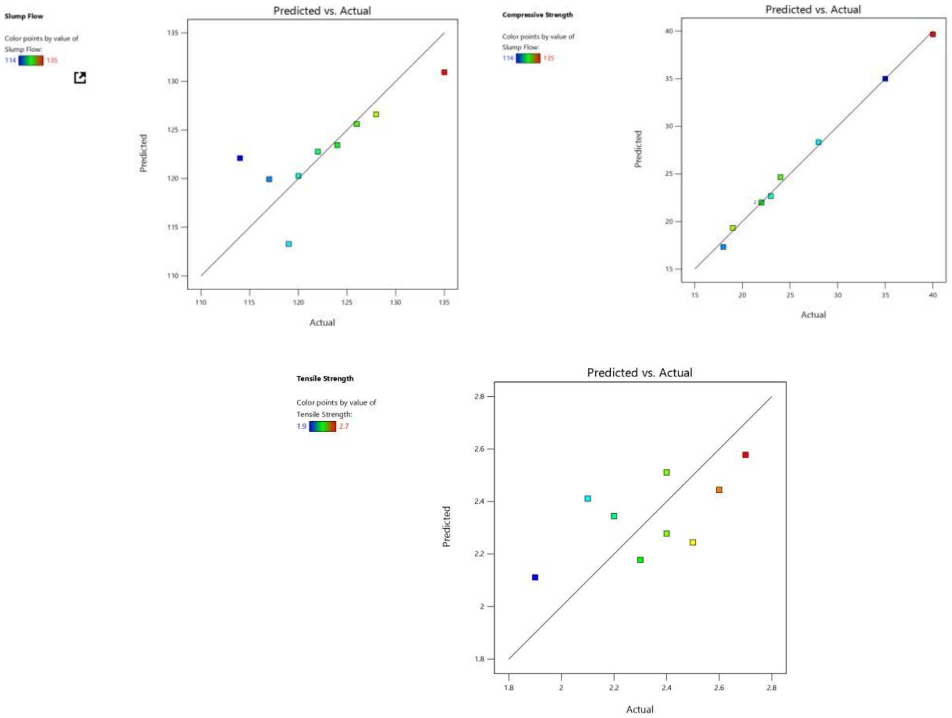

Figure 17 Normal plot of Residuals for Slump flow, Compressive strength, and TensileStrength

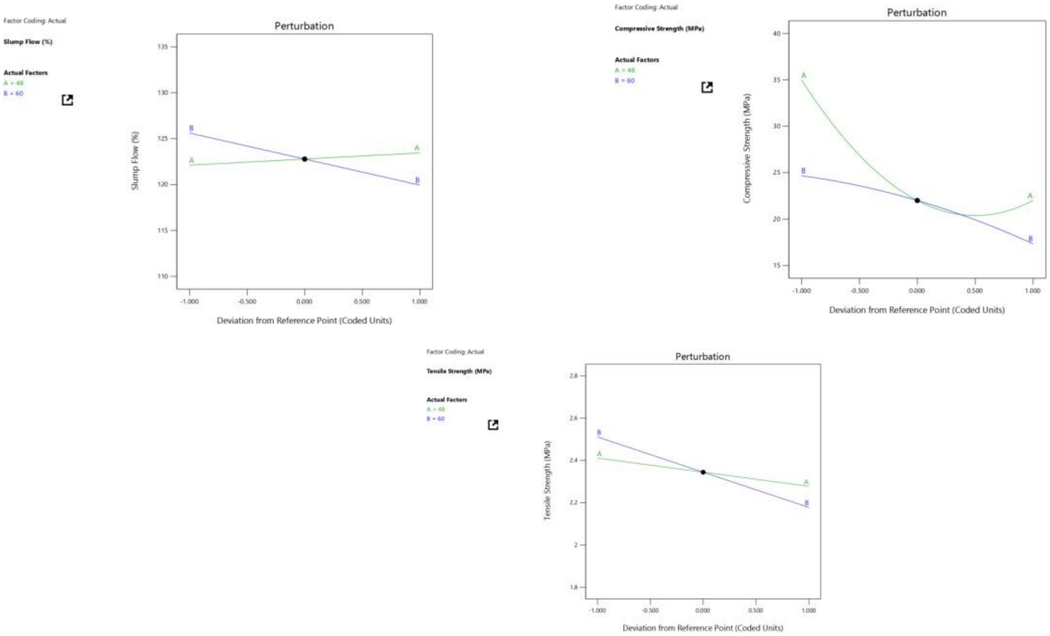

Figure 18 Perturbation Curves for Slump Flow, Compressive Strength, and Tensile Strength

5.6 Experimental Validation study

For the improved mix design, an experimental program was designed. The samples were mixed, cast, and cured according to the process outlined. The experimental findings were quite nearto the expected response values, with the difference between them being less than 5%

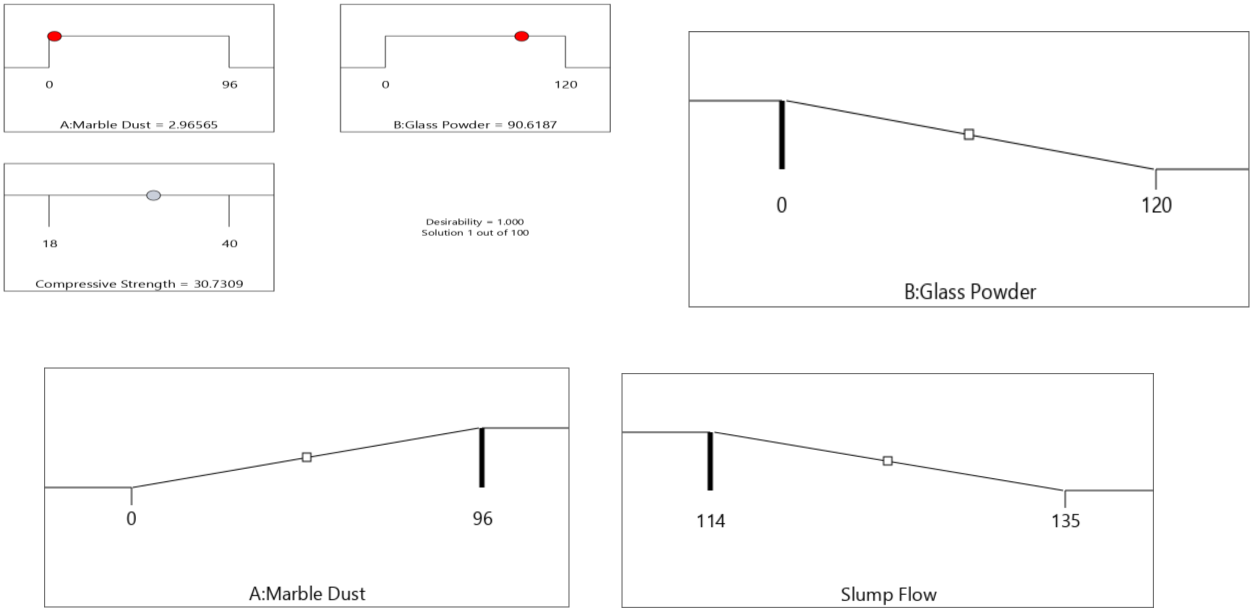

Figure 19 Ramps of the Optimized CM Mortar

Response	**Predicted**	**Experimental**	**Error (%)**
Slump flow	126.03 %	122%	4.03
Compressive strength	30.7309 MPa	24 MPa	6.7309
Tensile strength	2.6 MPa	2.2 MPa	0.4

6. Conclusion

This paper summarizes the research's major results, which were discussed in the results and discussions. The findings were to the objectives of the research work. The conclusions are given as under. Primary conclusions from the experimental work are given below:

1. Using 3D surface diagrams, the interaction of major cementations factors with cementations properties (workability and mechanical properties) has been effectively observed. The contour

Diagrams provide efficient predictions of variable ranges for desired properties based on the intervals of varied responses.

2. For the cementations matrix, RSM-ANOVA statistical models for the determination of compressive and split tensile strength were established and statistically authenticated.
3. The RSM might be utilized to create a cementations mix with any goal response value from any mutable combination of factors such as various ratios, the mix proportioning of CM having a compressive strength of about 80 MPa can be determined.
4. In stages, a technique for designing optimum cementations mixes was created. The goal was to increase cementations strength to its maximum level. A progressive optimization of the cementations is necessary to reach the goal. First, a mix design was created for the selection of Marble Dust and Glass Powder percentages that produce superior mechanical qualities. This mix design was used to develop a ratio that gives comparatively better compressive strength development. The marble dust and glass powder mix has been designed utilizing RSM's multi-objective optimization technique employing the chosen mix design. The main polymeric variables were then tuned. The RSM optimization approach shortens the design cycle, enhances the functionality of existing processes and products, and boosts the robustness and reliability of those same goods and processes.

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