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Review on Metal Concrete Composite Structure

Kathiresan Karuppanan*

School of Civil Engineering and Architecture, Adama Science and Technology University, Adama, Ethiopia.

Chimdi Gadafa Benti

School of Civil Engineering and Architecture, Adama Science and Technology University, Adama, Ethiopia

Abdi Mohammed

School of Civil Engineering and Architecture, Adama Science and Technology University, Adama, Ethiopia

Sissay Dechasa

School of Civil Engineering and Architecture, Adama Science and Technology University, Adama, Ethiopia

Kefale Fufa Goboto

School of Civil Engineering and Architecture, Adama Science and Technology University, Adama, Ethiopia

Dharm Singh

Civil Engineering Department, Samrat Ashok Technological Institute, Vidisha-MP, India

Abstract - The focus of this literature review is to look at the benefits and drawbacks of composite construction. Considering each of the two components, structural steel and concrete, can be used to its full potential, composite constructions have shown to be cost- effective in the long run. The idea behind combining steel and concrete systems is that each kind of construction has a natural advantage that, when combined, results in a more efficient system. In a composite structure subjected to service load, the time-dependent effects of creep and shrinkage in concrete can cause gradual cracking towards the beam ends, resulting in significant moment redistribution and increased deflections of composite beams, in addition to instantaneous cracking. In the present article, a comprehensive review of analysis and behaviour of composite construction with alternate shear connections are examined. Application of neural networks in composite construction has also been discussed in this article.

Keywords: *Construction, composite, Steel concrete composite (SCC), Slim-floor beams (SFBs), RCC*

INTRODUCTION

In comparison to traditional composites, the usage of steel-concrete composites (SCCs) is quickly increasing in the construction sector because to their enhanced constructability, lower labour costs, improved bind to reinforcing steel, greater structural integrity, and faster project deadlines. These structural composites are always at risk of fire. As a result, the impact of fire on SCC behaviour must be assessed and factored into design considerations. SFBs (slim-floor beams) are low-cost technologies that allow for a significant reduction in the thickness of industrial and commercial building floors. The current paper examines recent developments and the history of SCCs, as well as recent investigations on SFB fire performance. The development of SCC systems is first described briefly. The principal structural members' fire resistance and particular thermal definitions are then offered. Finally, experimental data as well as analytical and computational approaches for forecasting fire resistance are provided. The primary goal of this research is to evaluate the performance of SFBs as a fire-resistant flooring solution. Further research is needed to strengthen Eurocode 4 standards so that the rapidly developing construction sector may benefit from the advantages of composite building technologies while keeping safety in mind. Several research have been undertaken in order to improve the design quality of these systems, and some of them will be reviewed in this article.

Figure 1: RCC column construction

In the building industry, composite structures are becoming increasingly common. Because of the confinement effect of steel with concrete and design adaptability, composite columns such as concrete filled steel tubes have high performance. In comparison to RCC and steel frame structures, composite structures have additional advantages. The primary requirement is for research on the behaviour and properties of composites in comparison to RCC and steel. Concrete is a prominent building material in India, particularly for medium and low- rise structures. In high-rise structures, steel is commonly employed, while composite construction is less common, yet composite construction may be more useful in medium and high-rise buildings. To maximise the benefits of steel and concrete while producing efficient and cost-effective structures, steel concrete composite construction can be used in place of RCC constructions. The contractor or owner must decide whatever sort of qualities they require in the field, and then the type of material may be chosen based on those properties. This study compares many features of building construction for steel, RCC, and composite structures, taking into account numerous investigations on the subject.

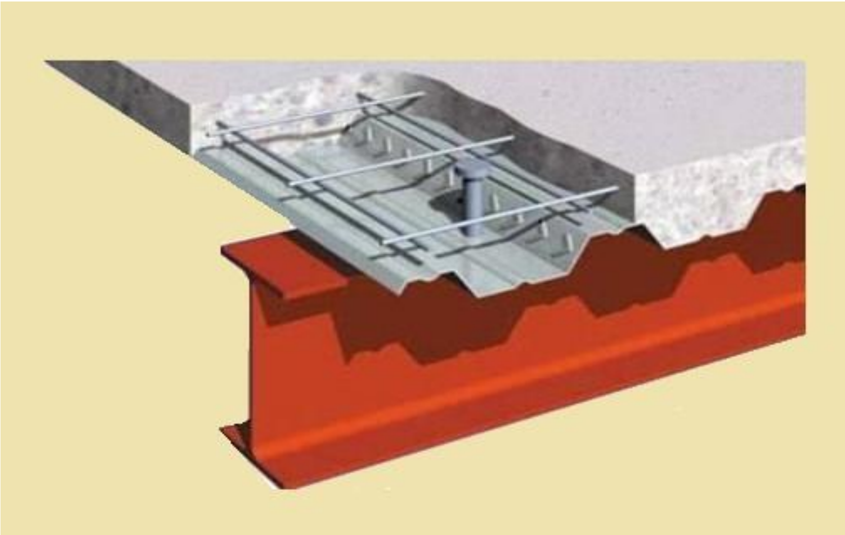

Figure 2: Steel Concrete

Steel concrete composite beams are made out of a steel beam and a reinforced concrete slab with shear connections cast on top of it. Concrete slabs are simply rested over steel beams

and supported by them in traditional composite construction. Since there is no connection between both the concrete slabs and the steel beam, these two components behave independently under stress. When a shear connector is installed between the concrete slab and the steel beams, the slip is minimised, and the steel beam and concrete slab operate as a composite beam. A composite beam behaves in the same way as a Tee beam.

The basic notion of a composite beam is that concrete is stronger in compression than steel (which is prone to buckling in compression), and steel is stronger in tension than concrete. The benefits of both materials are fully leveraged by exploiting the composite action of these two. In India's non-residential multi-story building industry, composite construction is quickly gaining traction. Its success is largely due to the strength and rigidity it achieves while using the fewest materials possible. Simply said, concrete is good in compression and steel is good in tension, which is why composite construction is regarded so good. When these two materials are combined structurally, their strengths are amplified, which may be used to build a highly efficient and lightweight design.

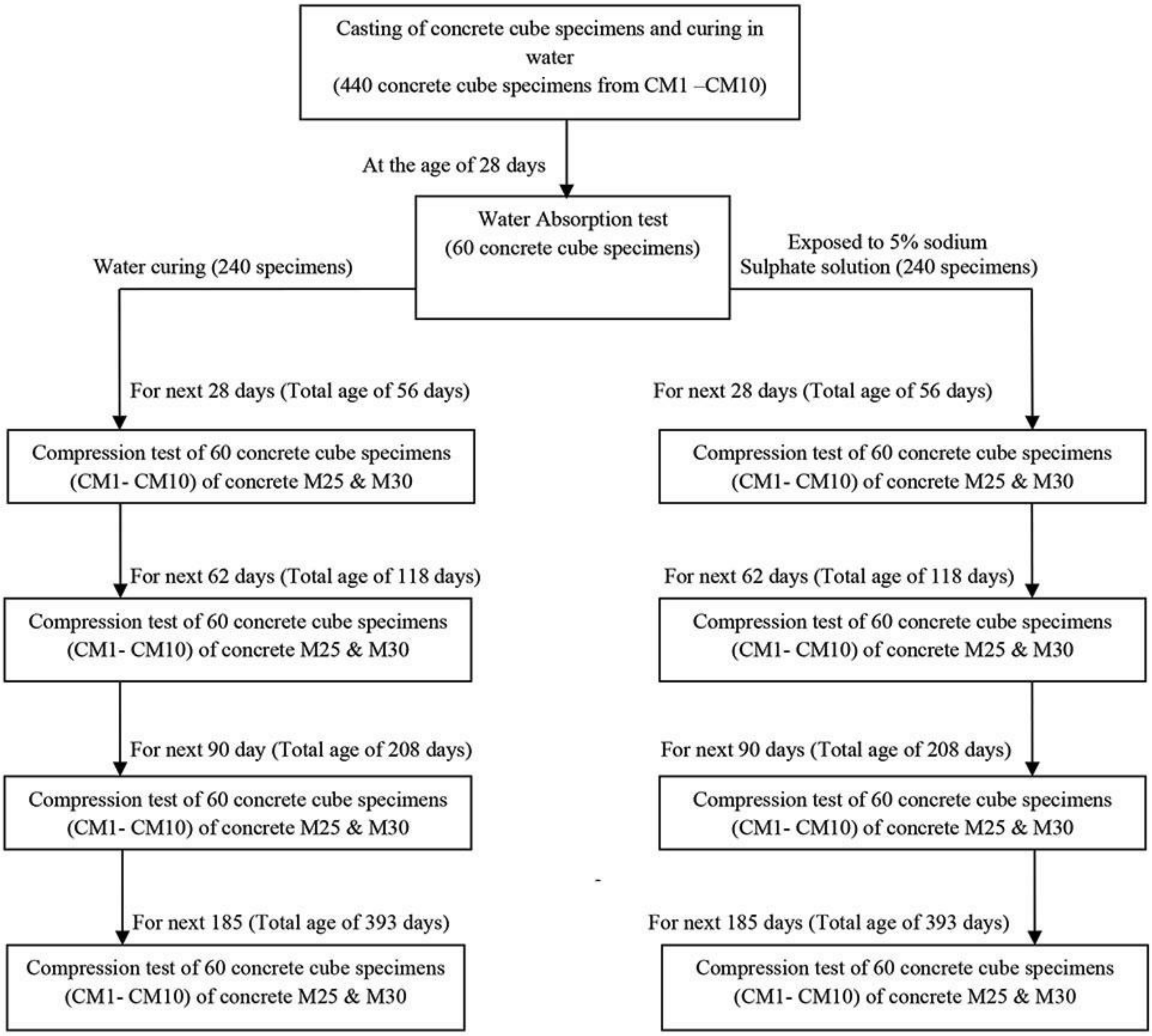

Figure 3: Experimental program of proposed work

The lighter weight of the composite parts reduces the forces acting on the elements that support them, such as the foundations. In terms of building speed, composite systems are also advantageous. Floor depth reductions made possible by composite construction can save money on services and improve the building envelope.

Concrete is made up of cement, sand, gravel, water, and admixtures, and is one of the most widely used building materials. The civil engineering and building business is one of the most likely users of mineral resources, resulting in a large volume of solid waste as a by- product. In the preparation of mortar and concrete, numerous minerals additives such as granulated blast furnace slag, fly ash, and silica fume have been employed. Marble dust can also be used as a filler, a partial replacement for cement, and a partial or full replacement for fine aggregate in mortar and concrete. As a result, different studies have been conducted to see if such a waste product can be used to preserve or improve the durability and strength of concrete.

LITERATURE REVIEW:

Singh G. and Madan S.K. investigated the compressive strength and workability of concrete using marble dust as a partial replacement for cement in an experiment. The authors demonstrated that up to 10% marble dust may be utilised as a cement substitute with a 21.22% improvement in concrete strength [1]. According to Hanifi Binici et al., the durability of the marble and GBFS concrete was found to be superior to that of Portland cement concrete. There was a much greater bonding between additives and concrete in the marble, granite, and GBFS specimens. Compressive and flexural strength were investigated, and improved results were discovered [2]. The findings of a research conducted by M. Shahul Hameed and A. S. S. Sekar, in which marble sludge powder was employed as a filler in concrete and was shown to be a 100 % substitute for natural sand. The concrete's salt resistance was considerably improved [3, 6]. Bahar Demirel investigated the effects of using waste marble dust as a fine material on the mechanical characteristics of the solid in his study, and found that using waste marble dust to substitute fine material passing through a 0.25 mm filter at certain proportions improved compressive strength [4].

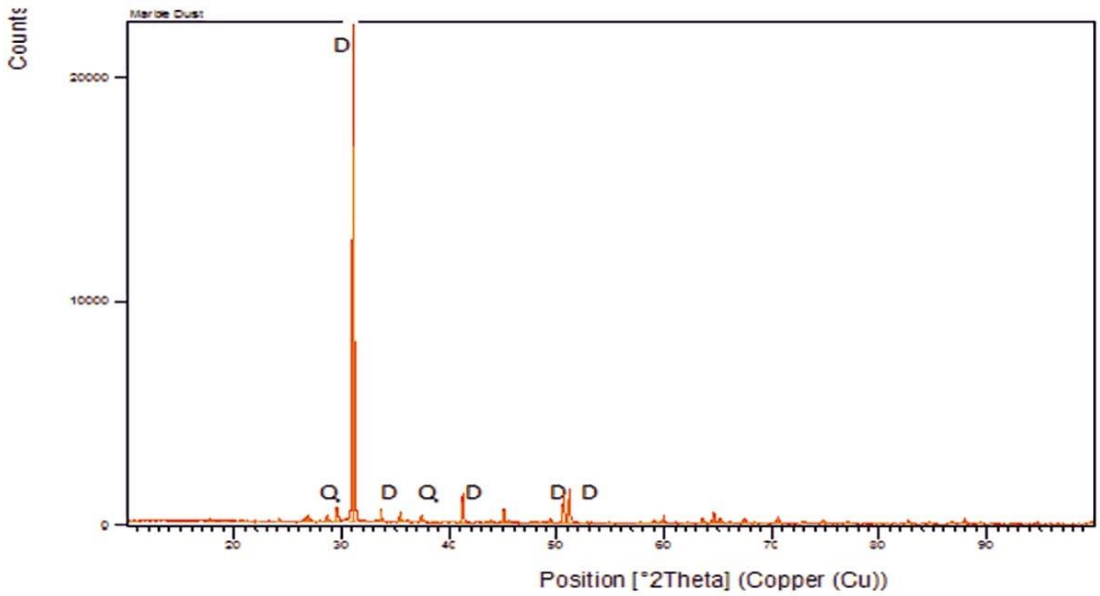

Figure 4: X-Ray diffraction spectrum of marble dust

According to certain test findings, replacing natural sand with granite powder waste up to

15% of any formulation was beneficial for concrete production without compromising strength and durability criteria [6]. According to the findings, marble powder is suitable for the definition of high-performance concrete (HPC), and its qualities are fundamentally superior to those of the reference concrete [7]. At 9 % metakaolin and 10% marble powder, the optimal strength value of concrete was attained for both compressive and split tensile strength [8]. Authors studied the partial substitution of cement and sand by waste marble powder in seven different concrete compositions and found good results [9].

The technical and sustainability issues that the concrete industry faces, rather than the business challenges, are the emphasis of this study. It's hard to believe that substantial technical hurdles still exist for a material that has been used effectively for thousands of years, but they do. Concrete, being the most widely used building material, is utilised in large amounts. There are no credible statistics on global concrete output, however data on global cement production exists. Cement was manufactured at a rate of around 4.6 billion metric tonnes in 2016, with China accounting for half of it. Converting this amount to cubic metres of concrete is not accurate due to the several applications of cement. Assume that concrete contains 75% cement and that the cement composition of concrete is normally 300 kg/m3. Concrete would require around 72 billion metric tonnes of aggregates on this basis. The industry's first problem is ensuring the long-term viability of concrete construction. Concrete solutions are frequently the most environmentally friendly and have the potential for a very long service life; yet, because concrete is used in such large amounts, it has a worldwide influence.

With the growing range of cement types, additives, and aggregates, the usage of maximum w/c ratio and minimum cement content as the primary way of ensuring acceptable durability is becoming more controversial, and specifiers are turning to performance-based durability specifications. Another difficulty facing the concrete industry is developing a technically sound, cost-effective approach for defining durability by performance.

Indian cement output is expected to increase by 12% year on year to 332Mmt in 2022, according to rating agency ICRA. The increase would be driven by pent-up pre-Covid-19 lockdown demand, rural housing need, and an uptick in infrastructure development, according to the report. ICRA anticipated that demand will increase by 8% year over year to 358Mmt. Domestic production increased by 44% year on year to 142Mt in the first quarter of the 2022 fiscal year, and by 2% year on year to 142Mt in the first quarter of the 2020 fiscal year. The top 12 Indian cement makers, according to ICRA, would achieve their highest-ever average operating profit per tonne of cementitious material in the fiscal year 2022. It said that this is likely to occur due to an increase in net sales realisation and cost optimisation measures [figure 5].

This review paper will address two challenges that are not new, nor do they need new technical research, but they are issues that continue to blight the concrete sector. These are:

A rigorous cost analysis study was also conducted to justify the usage of marble powder in concrete, which yielded promising strength and quality results [10]. Ground granulated blast

furnace slag, metakaolin, and silica fume were used in place of cement. The adequacy of mineral admixtures was evaluated using durability tests such as resistance to sulphate attack, water absorption, and sorptivity. Self-compacting concrete might be made using added cementitious elements without sacrificing durability, according to the authors [11].

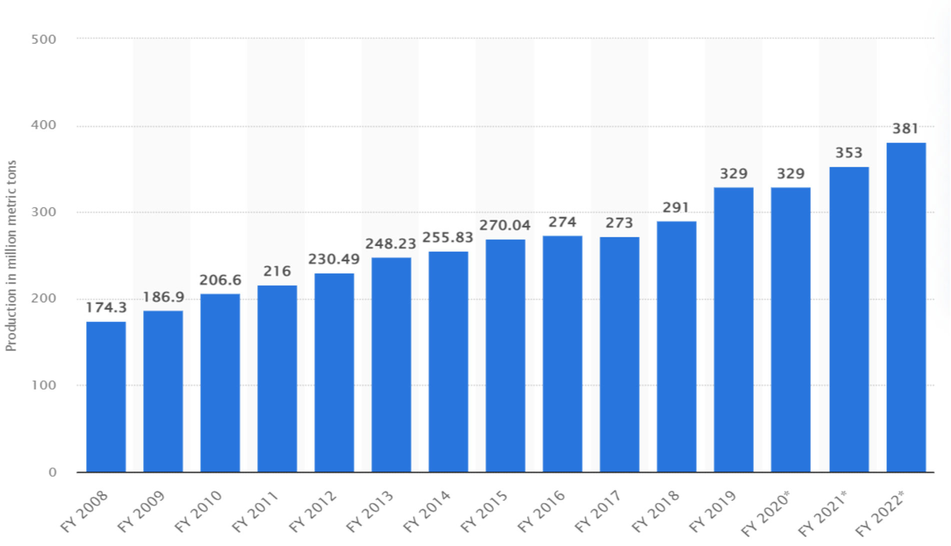

Figure 5: Production of cement

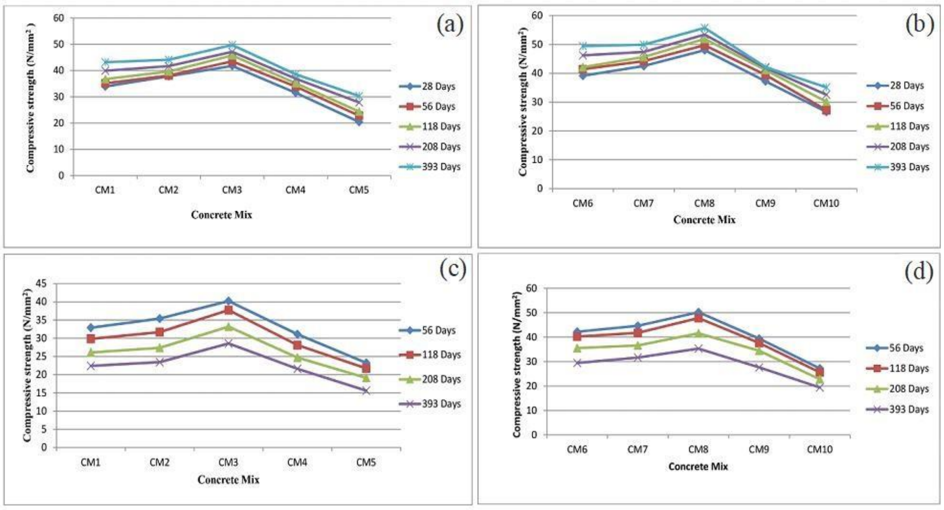

Figure 6: Compressive strength of concrete (a) M25 (N/mm2) cured in fresh water, (b) M30 (N/mm2) cured in fresh water, (c) M25 (N/mm2) immersed in sulphate solution after 28 days of water curing. (d) M30 (N/mm2) immersed in sulphate solution after 28 days of water curing.

The pozzolanic reaction and the formation of the microstructure of concrete through the use of waste elements, according to the authors, are substantially responsible for improvements in concrete durability [12]. Priyatham et al. showed that marble dust could be used to replace both cement and fine aggregate, and that substituting sand with quarry dust and 10% marble powder increased the compressive strength of concrete by 30% [13].

According to Ali Khodabakhshian et al., the mechanical properties of concrete using marble waste powder decline at replacement ratios more than 10%, while satisfactory results may be obtained below that level [14]. Ahmed O. Mashaly et al. determined the physico-mechanical properties of three types of mixes, including cement paste composites, mortar and concrete mixes, and the durability performance of hardened mortar and concrete mixes at 28 days and 90 days, showing that mortar and concrete mixes modified with granite sludge up to 20% cement replacement exhibited negligible declines in physical and mechanical properties [15]. Shashank Dixit et al. discovered that concrete containing marble dust at a concentration of 0 to 15% had the highest compressive and split tensile strengths [16]. Using granite dust as a paste substitute might significantly increase carbonation and water resistance, decrease final shrinkage strain and shrinkage rate, and reduce cement amount by up to 25% [17, 18].

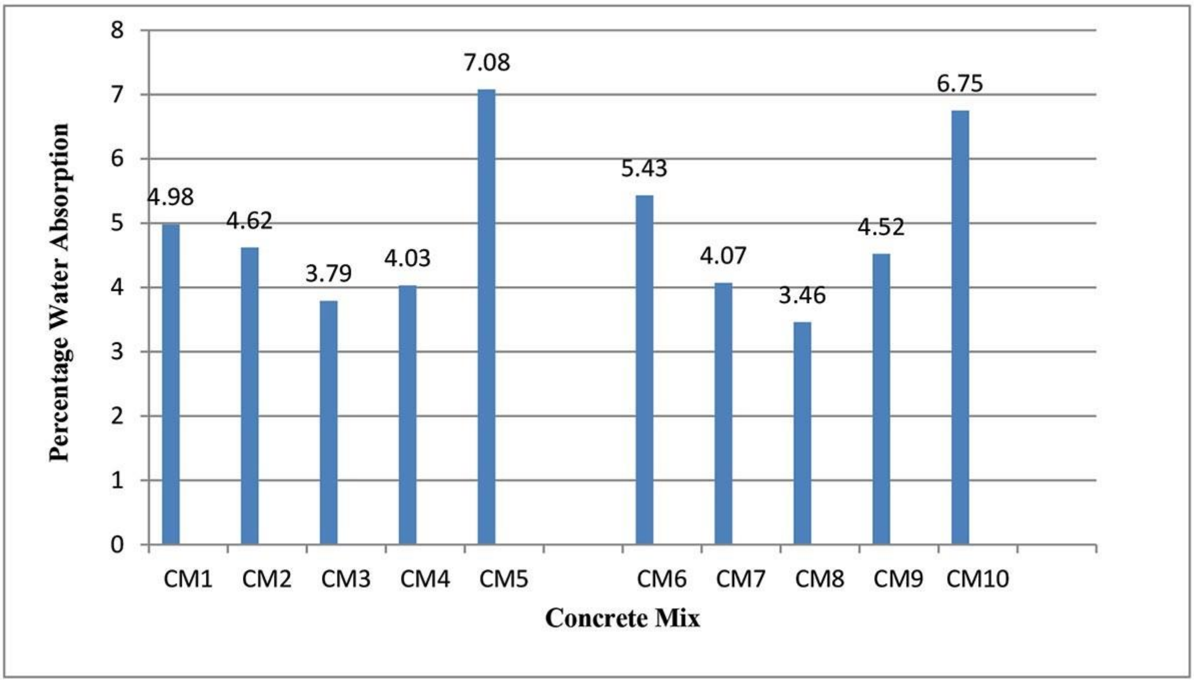

Figure 7: Percenage water absorption of concrete of grade M25 and M30 of concrete cube specimens (size 150 mm), namely, CM1, CM2, CM3, CM4 & CM5 stand for 0%, 5%, 10%, 15% and 20% replacement of cement with marble dust in concrete and CM6, CM7, CM8, CM9 & CM10 stand for 0%, 5%, 10%, 15% and 20% replacement of cement with marble dust in concrete M25 & M30 were cast respectively. The experimental program of proposed work is depicted.

The impact of integrating marble powder as an additional cementation material on the rheological and mechanical characteristics of self-compacting concrete was investigated by Boukhelkhal A. et al. The authors discovered that employing marble powder in self-

compacting concrete improves their fresh qualities but decreasing their mechanical strengths when hardened. The scientists also discovered that self-compacting concrete containing waste marble powder that had been exposed to magnesium sulphate had a lower expansion and a stronger resilience to sulphate attacks. [19-20]. Haris H. et al. investigated the strength qualities of concrete, such as compressive strength, split tensile strength, flexural strength, and shear strength, as well as the influence of sulphate attack on the strength of concrete. According to their findings, basalt fibre boosted concrete strength even when subjected to sulphate assault over time when compared to standard concrete [21].

PROPORTIONS OF MATERIALS AND MIXTURES

Marble dust was collected from the Alwar marble processing sector in Rajasthan, India. Table 1 displays the chemical makeup of marble dust. The mineralogical composition of marble dust is determined using the XRD method, as illustrated in Figure 2. The principal crystalline minerals contained in marble dust, according to the XRD spectrum, are magnesium calcium bi(carbonate) ($MgCa(CO_3)_2$) and calcium magnesium aluminium catena-alum silicate.

Table 1: Compressive strength of concrete M30 (N/mm2) immersed in sulphate solution after (28 days of water curing).

Oxides compound	Percentage
CaO	42.45
Al_2O_3	0.520
SiO_2	26.35
Fe_2O_3	9.40
MgO	1.52

Table 2. Physical testing of cement			
Sr. no.	Test	Result	IS Requirement 8112-2013
1	Fineness of cement	2.5%	(Max 10%)
2	Consistency of cement	30 %	
3	Initial setting time	72 min	(Min 30 mint)
4	Final setting time	195 min	(Max 600 mint)
5	Compressive strength of cement at: 3 days 7 days 28 days	27.33 N/mm2 36.25 N/mm2 47.75 N/mm2	23 N/mm2 33 N/mm2 43 N/mm2

1. Cement:

In this job, ordinary Portland cement 43 grade according to IS 8112 -2013 is used. Table 2 shows the results of the cement test.

2. Compressive Strength Testing of Specimens

With the use of a mixer, marble dust was blended with cement in a dry state. For each combination of M25 and M30, control cubes of 150 mm x 150 mm x 150 mm were cast in five different %ages of marble dust. Tables 7 and 8 provide more information. The whole cubes were compacted using a table vibrator, and the curing was completed in a curing tank at a temperature of 27 2 for 28 days. After weighing the hardened cubes, they were tested for compressive strength. The cubes were positioned in the centre of the compression testing machine, which delivered a consistent stress vertically at a rate of 5250 N/Sec. At 28+28 days, 90+28 days, 180+28 days, and 365+28 days, the cubes were put to the test.

Table 3. Sieve Analysis of 20mm coarse aggregate				
IS Sieve size	Weight Retained (gm)	Cumulative weight retained(gm)	Cumulative % weight retained	Passing %
40mm	0	0	0	100
20mm	253.5	253.5	8.45	91.55
12.5mm	91.55	639.1	21.3	88.70
10mm	2085	2724.1	90.80	9.20
4.75	275.9	3000	100	0
Sum	3000.0		∑C=220.55	
Fineness modulus of coarse aggregate 20mm = (∑C+ 500)/100 = 7.2				

Table 4. Sieve Analysis of 10mm coarse aggregate				
IS Sieve size	Weight Retained (gm)	Cumulative weight retained(gm)	Cumulative % weight retained	Passing %
20mm	0	0	0	100
16mm	25	25	0.83	99.17
12.5mm	250.6	275.6	9.18	90.82
10mm	500.4	776	25.86	74.14
4.75mm	2224	3000	100	0
Sum	3000.0		∑C=135.87	
Fineness modulus of coarse aggregate 10mm = (∑C+ 500)/100 = 6.3				

3. Water absorption

Concrete cube specimens were used to conduct water absorption testing. Table 11, Table 12, and Figure 5 show the findings of the marble dust-containing mixtures. At the age of 28 days, the concrete cube specimens were dried in an oven at 110oC and then submerged in water, with weights examined and %ages of water absorption computed. Water absorption may occur in pores that are emptied while dry and refilled when submerged.

4. Oven dry mass

The mass of the concrete cube specimens was first calculated, and then they were dried in an oven for at least 24 hours at a temperature of 110°C. The mass of the concrete cube specimens was estimated after they were removed from the oven and allowed to cool in dry air at a temperature of 27 2 °C. It was deemed dry if the concrete cube specimen was somewhat dry when its mass was first estimated, and the second mass nearly agreed with the first. If the concrete cube specimen was wet when the mass was originally calculated, it was placed in the oven for a second drying treatment of 24 hours before the mass was calculated again. The specimen was declared dry if the third value equalled the second. If the difference between two subsequent mass values is greater than 0.5 % of the lower value, return the specimen to the oven for another 24 hours of drying and repeat the procedure until the difference between any two successive values is less than 0.5 % of the lowest value obtained. A was assigned to the last value.

Table 5. Sieve Analysis of coarse sand (Fine aggregate)

IS Sieve size	Weight Retained (gm)	Cumulative weight retained(gm)	Cumulative % weight retained	Passing %
4.75mm	104	104	10.4	89.6
2.36mm	150	254	25.4	74.6
1.18mm	113	367	36.7	63.3
600 micron	136	503	50.3	49.7
300 micron	157	660	66.0	34.0
150micron	170	830	83.0	17.0
75micron	170	1000	100	
Sum	1000		∑F=371.8	
Fineness modulus of coarse aggregate 10mm = (∑F)/100 = 3.71				

Table 6. Mix Proportions for M25 & M30 grade concrete.

Mix constituents	For 1 m3 of M25 concrete (kg)	1 bag of cement (kg) for M25	For 1 m3 of M30 concrete (kg)	1 bag kg of Cement (kg) for M30
Cement	415	50	425	50
Water	195	23.5	187	22
Sand	610	73.50	550	65
Coarse aggregates	1165(583+582)	140(70+70)	1160(580+580)	136(68+68)
Water cement ratio	0.47	0.47	0.44	0.44

5. Saturated Mass after Immersion

The specimen was submerged in water at about 27 2°C for not less than 2 days after final drying, chilling, and mass determination, and until two successive mass measurements of the surface dried sample at intervals of 1 day revealed an increase in mass of less than 0.5 % of the bigger value. The mass of the specimens was estimated after they were surface dried by eliminating surface moisture using a towel. After immersion, the final surface dried mass was classified as B.

Table 7: Concrete mix of M25 and M30 with percentage replacement of cement

S. No.	Concrete mix M25 with percentage replacement of cement					Concrete mix M30 with percentage replacement of cement				
Concret e mix	CM1	CM2	CM3	CM4	CM5	CM6	CM7	CM8	CM9	CM10
Cement (kg)	12.610	11.979	11.3485	10.717	10.089	12.6596 8	12.02684	11.39305	10.76116	10.12832
Marble dust as replace ment of cement (kg)/(%age)	0.0000/(0)	0.6304/(5)	1.261/(10)	1.8916/(15)	2.522/(20)	0/(0)	0.63284/(5)	1.26568/(10)	1.89852/(15)	2.53231/(20)
Sand (kg)	18.50	18.50	18.50	18.50	18.50	16.71	16.71	16.71	16.71	16.71
Coarse Agg (kg)	35.393	35.393	35.393	35.393	35.393	35.2354 7	35.23547	35.23547	35.23547	35.23547
Water (Litre)	5.913	5.913	5.913	5.913	5.913	5.68421 1	5.684211	5.684211	5.684211	5.684211

6. Calculation of water absorption

Water absorption = B-A

Water absorption %= [(B-A)/A] 100

7. Sulphate attack

When concrete cube specimens were submerged in a 5 % Na2SO4 solution, their sulphate resistance was measured in terms of strength loss. In portable water appropriate for drinking, each litre of solution contained 50.0 g of Na2SO4. The solution was prepared the day before and kept at 27 2°C, covered. After 28+28 days, 28+90 days, 28+180 days, and 28+365 days, concrete cube specimens were removed from the sulphate solution. The compressive strength of normal concrete cube specimens was measured at 56 days, 118 days, 208 days, and 393 days and compared to 28+28 days, 90+28 days, 180+28 days, and 365+28 days.

8. **Case Study 1: Prestige Trade Towers**:

This project is located in Bangalore's core business centre, between the state assembly and the main route that connects the city to the airport and northern Bangalore. Because of the high volume and frequency of VIP traffic, access to concrete trucks during normal working hours is severely limited. The existence of high-end flats and houses, as well as a prominent school in the area, added to the challenges of employing traditional building methods.

9. **Site constraints for design of basements**:

The Towers have a total height of 117 metres and two deep basements with five levels of stacked automobile parking, three levels of retail floors, and twenty-one levels of office floors. Pit parking in the lower basement, as well as 2-level stack parking above, were required for the office tower's enormous number of parking spaces. A 2-level stack parking was also included in the top basement. As a consequence, the excavation depth to the raft's bottom was around 11 metres. The presence of ground water at a depth of 6 metres made it much more difficult to maintain the excavation dry for building.

The shoring operations included a large shore piling system with whaler beams and struts, as well as sacrificial piles. The volume of ground water encountered necessitated the installation of both deep well and vacuum dewatering techniques.

10. The structural system's design is as follows:

For the following reasons, it was agreed from the start, with the support of the building owners and other stakeholders, that composite construction would be the best option for the superstructure

- Large concrete pours would be less problematic.
- Lighter construction resulting to lighter foundations considering subsurface conditions
- Construction timetables might be shortened, allowing early access to the offices
- During the execution of the works, there was construction activity on numerous levels.

11. **Structural design**:

The design team agreed that the structural system should be built with a strong reinforced concrete core to withstand all lateral stresses caused by seismic activity and wind, and gravity loads should be carried principally by a composite structure of steel columns and beams.

The lift banks, bathrooms, and stairwell shafts all worked out perfectly for this concrete core. The architectural requirement for a minimum 3.0m floor to ceiling clearance after including all services necessitated the use of a flat slab-like solution.

Figure 8: Floor structural design

For the composite structure, two methods were examined; the first was significantly more complicated, consisting of:

- Concrete-filled hollow tubes for the columns
- Concrete-filled hollow tubes for the columns
- Steel columns with welded Steel plates encased in concrete
- 3-plate beam sections welded using submerged arc welding process
- 1.0 mm thick decking sheets 80mm high at the crest lying on top of the floor beams with a structural concrete topping for both fire protection and composite action

After much thought, consideration of pricing, availability of materials, and other factors, it was decided to go with the second alternative.

12. Construction:

The lateral core would be built first, at least 4 to 6 stories ahead of the structural steel framework, according to the building sequence. The following would be the order of the works:

- Raise structural steel columns two floors by applying self-climbing shuttering in the RCC core
- Install primary and secondary beams; • install decking sheets and concrete; enclose columns in concrete; and • apply a cementitious fireproof coating to exposed beams.

Despite the severe limitations on site, composite construction was a success, and the finished edifice is today regarded as one of the city's most distinctive structures.

13. Case Study 2: Bagmane Lynx

This renowned office skyscraper, located on Bangalore's Outer Ring Road in the heart of the IT belt, is a microcosm of the many structural systems that have been successfully combined

to generate iconic office structures. The building has two basements with parking and MEP equipment, a four-level arrival space, and fourteen levels of office floors.

Figure 9: Skyscraper building

14. Design - V columns:

Basements and office areas are often constructed using traditional flat slab systems with perimeter beams. The building's lateral stability is provided by a strong central core of elevator and stair shafts. The distinctive design characteristic of this construction is a special architectural necessity of giving an unexpected arrival area using V columns.

The V columns are concrete-filled tubes that emerge from a pedestal atop the podium and basement columns. The V columns are then connected to a massive structural steel transfer beam that supports seven floors of office space above.

The structural system was designed and built utilising cutting-edge software, resulting in shorter cutting lengths and less waste. Quality control was accomplished by a thorough testing and quality assurance approach.

Figure 10: V column construction

15. Construction:

The use of couplers to connect the reinforced steel bars, as well as the extension of steel tubes made in 6m lengths and carried to the job site, posed a problem.

The project was completed successfully and within the stipulated time frame thanks to a coordinated effort between the expert vendor and the design team. To allow for the expansion of the columns, temporary towers had to be built. Finally, a normal concrete deck slab was laid on the fifth floor to connect it to the reinforced concrete flat slab system.

Figure 11: Carbonation Problem

One of the most serious durability issues is reinforcement corrosion, which reduces the design life of reinforced concrete. Protective measures of reinforced bars in concrete buildings have become highly significant due to a rising need for extended service lifetimes of infrastructure (usually 100–120 years) and the expensive expense of creating and maintaining it.

Figure 12: Spalling Concrete

Corrosion prevention and protection strategies include the use of corrosion inhibitors, alternative reinforcement, steel and concrete coatings, and electrochemical procedures, which are all accessible and approved by various agencies. Concrete structure durability difficulties are among the most serious challenges confronting the civil engineering community across the world.

Corrosion of steel reinforcement is one of the most serious durability challenges, since it causes rusting, cracking, spalling, delamination, and structural damage. Bridges, commercial buildings, flyovers, residential buildings, and other infrastructure are all thought to be affected by this. The performance and aesthetics of concrete structures can be affected by

atmospheric corrosion, galvanic corrosion, and stress corrosion cracking. As a result, research is being conducted all over the world to create ways or materials that will prevent steel from corroding in concrete.

16. Corrosion of Steel in Concrete

Surface loss happens when metals and alloys react chemically, biochemically, or electrochemically with their surroundings, and they change to oxides, hydroxides, or carbonates, which are more thermodynamically stable. Corrosion is the word for this process. When there is a difference in electrical potential along the surface of an embedded steel bar, the concrete serves as an electrochemical cell, with anodic and cathodic areas on the steel and pore water in the hardened cement paste functioning as an electrolyte. This causes current to flow through the system, producing an assault on the metal with the lower electrode potential (i.e. the anode), while the cathode stays unharmed. As a result, rebar corrosion begins.

17. Mechanism of Corrosion of Steel in Concrete

Steel in concrete produces a protective passive coating on its surface as soon as the cement hydrates, consisting of Fe_2O_3 sticking securely to the steel with a thickness in the range of 103 to 101 m. This layer prevents ions from moving between the steel and the surrounding concrete, lowering the rate of corrosion. Steel is protected by the presence of this oxide layer. Only at high pH, i.e. 12–14, is it stable. This layer must be broken down for corrosion to occur. This happens in the presence of carbonation or chloride ions, as well as poor-quality concrete, and corrosion occurs in the presence of water and oxygen.

18. Chloride-Induced Corrosion

When steel is embedded in a sound concrete layer, it remains in a passive state, free of corrosion; nevertheless, when the concrete surrounding it deteriorates, it switches to an active state (corrosion begins). Chloride ions may enter the reinforcing system from the environment or be combined internally.

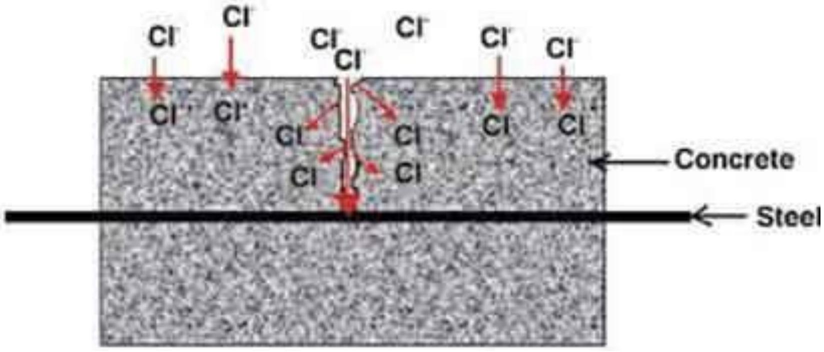

Figure 13: Chloride Induced Corrosion

Sulphate-resistant durability of concrete built with marble dust as a partial replacement for cement.

The possibility of producing more durable concrete with marble dust as a partial replacement for cement by 5 %, 10%, 15%, and 20% by weight is presented in this experimental investigation. For two grades of concrete, M25 and M30, standard concrete cube specimens of size 150mm150mm150mm were cast with OPC and 0% marble dust. The compressive strength and water absorption of concrete were investigated after 28 days of fresh water curing, and then concrete cube specimens were put for both water curing and sulphate solution exposure for the next 28 days, 90 days, 180 days, and 365 days.

Figure 14: Chloride induced corrosion effect

Following the examination, it was discovered that a 10% substitution of marble dust with cement worked well in both circumstances. When compared to conventional concrete cube specimens, compressive strength increased by 24.85% and 23.27 % in the event of water curing for M25 and M30 concrete, respectively. As subjected to sulphate solution, the compressive strength of M25 and M30 concretes increased by 27.13 % and 19.90 %, respectively, when compared to conventional concrete cube specimens. It was also discovered that when 10% of the cement was replaced with marble dust, water absorption decreased from 4.98 % to 3.79 % and from 5.43 % to 3.46 %, respectively, when compared to conventional concrete cube specimens for M25 and M30 concretes.

RESULTS AND DISCUSSIONS

The aggregates, hydrated cement paste containing marble dust, and the transition zone between the paste and the aggregates make up the concrete structure. Partially replacing cement with marble dust by 0%, 5%, 10%, 15%, and 20% for two classes of concrete, M25 and M30, was investigated. The following is a report on the compressive strength of concrete cube specimens (CM1-CM10):

Figures 3 and 4 demonstrate the compressive strength of concrete cube specimens cured in fresh water with varying %ages of marble dust as substitute for cement at ages of 28 days, 56 days, 118 days, 208 days, and 393 days, respectively. Tables 9 and 10 show that when cement is replaced with marble dust by 5% and 10%, the compressive strength of concrete specimens rises at 28 days, 56 days, 118 days, 208 days, and 393 days, respectively, when compared to ordinary concrete cube examples. For M25 grade concrete, replacement of cement with marble dust by 5% and 10% results in increases of 11.44 % and 23.13 % at 28 days, 8.45 % and 23.85 % at 56 days, 7.9 % and 24.61 % at 118 days, 4.43 % and 18.09 % at 208 days, and 2.2 % and 15.20 % at 393 days. Similarly, for replacement of cement with marble dust by 5 % and 10%, the increases are 8.64 % and 22.69 % at 28 days, 6.76 % and

20.10 % at 56 days, 8.38 % and 23.27 % at 118 days, 2.58 % and 15.58 % at 208 days, and

1.01 % and 12.77 % at 393 days. In the instance of M25, CM2 and CM3 have stronger compressive strength than CM1. Similarly, in the case of M30, CM7 and CM8 have better compressive strength than CM6.

Table 8: Compressive strength of concrete M25 and M30 cured in fresh water

N/mm^2 at the age of following days)	Compressive strength of concrete M25 cured in fresh water					Compressive strength of concrete M30 cured in fresh water				
	CM1	CM2	CM3	CM4	CM5	CM6	CM7	CM8	CM9	CM10
28 Days	33.93	37.81	41.78	31.54	20.45	39.14	42.52	48.02	37.24	26.62
56 Days	35.13	38.10	43.51	33.91	22.80	41.40	44.20	49.72	39.40	39.40
118 Days	36.73	39.63	45.77	35.18	24.39	42.11	45.64	51.91	41.14	30.12
208 Days	39.92	41.69	47.14	36.92	27.85	46.21	47.40	53.41	41.90	32.56
393 Days	43.17	44.12	49.73	38.57	30.30	49.40	49.90	49.90	42.14	35.11

There are additional losses in compressive strength at 28 days, 56 days, 118 days, 208 days, and 393 days when 15 % and 20 % of the cement is replaced with marble dust. Replacement of cement with marble dust by 15 % and 20 % results in reductions of 7.04 % and 39.73 % at 28 days, 3.47 % and 35.10 % at 56 days, 4.22 % and 33.60 % at 118 days, 7.52 % and 30.24

% at 208 days, and 10.66 % and 29.81 % at 393 days for M25 grade concrete. For M30 grade concrete, the reductions are 4.85 % and 31.99 % at 28 days, 4.83 % and 34.33 % at 56 days, 2.30 % and 28.47 % at 118 days, 9.33 % and 29.54 % at 208 days, and 14.70 % and 28.93 % at 393 days for marble dust by 15% and 20% respectively. In the instance of M25, CM4 and CM5 have lower compressive strength than CM1. Similarly, in the case of M30, CM9 and CM10 have lower compressive strength than CM6.

It may be determined that when 10% of the cement is replaced with marble dust, the compressive strength reaches its maximum value. There is no gain in compressive strength when more than 10% of cement is replaced with marble dust.

Table 9: Percentage water absorption of concrete M25 and M30.

S.No.	Percentage water absorption of concrete M25					Percentage water absorption of concrete M30				
Mix	CM1	CM2	CM3	CM4	CM5	CM6	CM7	CM8	CM9	CM10
Marble dust %	0	5	10	15	20	0	5	10	15	20
Weight of dry sample (kg)	8.43	8.44	8.44	8.42	8.33	8.65	8.64	8.66	8.40	8.30
Weight of Saturated sample (kg)	8.85	8.83	8.76	8.76	8.92	9.12	9.06	8.96	8.78	8.86
%	4.98	4.62	3.79	4.03	7.08	5.43	4.86	3.46	4.52	6.75
Absorption										

19. Water absorption-

Concrete isn't the only material that may be harmed by water's physical and chemical breakdown processes. As a result, it is necessary to evaluate the features of water that make it the primary agent of material degradation. Figure 5 depicts the quantity of water absorbed by concrete mixes M25 and M30. Tables 11 and 12 show that replacing cement with marble dust by 5%, 10%, and 15% reduces the %age of water absorption of concrete cube specimens as compared to conventional concrete cube specimens. At 28 days, the reductions in M25 grade concrete are 7.23 %, 23.90 %, and 19.08 %. Similarly, for M30 grade of concrete the decrease are 10.50 %, 36.28 % and 16.76 % at 28 days.

It was also discovered that by substituting 20% marble dust for cement, the %age of water absorption of concrete cube specimens increased as compared to conventional concrete cube specimens. At 28 days, the rise in M25 grade concrete is 42.17 %. Similarly, after 28 days, the rise in M30 grade concrete is 24.31 %. For both the grade M25 and M30, concrete cube specimens prepared by 10% substitution of cement with marble dust in concrete have the lowest %age of water absorption when compared to ordinary concrete cube specimens.

20. Effect of Sulphate Attack

In hardened concrete, a chemical reaction results in the development of an expanding product, which might have hazardous consequences. Expansion may occur without causing harm to the concrete at first, but as internal stresses build up, they express themselves in the form of closure of the expansion joint, deformations and displacement in various parts of the structure, cracking, spalling, and pop-outs. Concrete degradation is known to take two unique forms as a result of a chemical interaction between hydrated Portland cement and sulphate ion from an external source. Concrete expansion can occur as a result of sulphate attack. When concrete fractures, its permeability rises, allowing aggressive water to infiltrate more readily into the interior, hastening the degradation process. Sulphate attack can also manifest itself as a gradual loss of strength and bulk when the cohesion of cement hydration products deteriorates.

Table 10: Compressive strength of concrete M25 and M30 immersed in sulphate solution after 28 days of water curing

N/mm^2 at the age of following (days)	Compressive strength of concrete M25 immersed in sulphate solution after 28 days of water curing.					Compressive strength of concrete M30 immersed in sulphate solution after 28 days of water curing				
	CM1	CM2	CM3	CM4	CM5	CM6	CM7	CM8	CM9	CM10
56 Days	32.9	35.4	40.22	31.11	23.24	42.22	44.65	50.2	39.4	27.2
118 Days	29.83	31.68	37.73	28.12	21.73	40.25	41.76	47.82	37.64	25.63
208 Days	26.1	27.37	33.18	24.69	19.12	35.54	36.61	41.59	34.44	22.79
393 Days	22.41	23.44	28.57	21.61	15.62	29.45	31.67	35.31	27.63	19.41

21. Compressive Strength

Figures 6 and 7 illustrate the compressive strength of concrete cube specimens with varying

%ages of marble dust as a cement substitute at 56 days, 118 days, 208 days, and 393 days, respectively. Tables 13 and 14 show that when cement is replaced with marble dust by 5% and 10%, the strength of concrete cube specimens rises at 56 days, 118 days, 208 days, and 393 days, respectively, when compared to regular concrete cube specimens. Replacement of cement with marble dust by 5 % and 10% enhances the strength of M25 grade concrete by 7.6% and 22.25 % at 56 days, 6.2 % and 26.48 % at 118 days, 4.87 % and 27.13 % at 208 days, and 4.6 % and 27.49 % at 393 days. Similarly, replacing cement with marble dust by 5% and 10% enhances the strength of M30 grade concrete by 5.76 % and 18.9 % at 56 days, 3.75 % and 17.32 % at 118 days, 3.01 % and 17.02 % at 208 days, and 7.54 % and 19.90 % at 393 days. When it comes to M25, CM2 and CM3 have more compressive strength than CM1. Similarly, in the case of M30, CM7 and CM8 have greater compressive strength than CM6.

There are additional losses in strength at 56 days, 118 days, 208 days, and 393 days when 15 % and 20 % of the cement is replaced with marble dust. For M25 grade concrete, the reductions are 5.44 % and 29.36 % at 56 days, 5.73 % and 27.15 % at 118 days, 5.4 % and 26.74 % at 208 days, and 3.57 % and 30.30 % at 393 days, respectively, when cement is replaced with marble dust. Similarly, replacing cement with marble dust by 15 % and 20 % enhances the strength of M30 grade concrete by 6.68 % and 35.58 % at 56 days, 6.49 % and 36.32 % at 118 days, 3.1 % and 35.88 % at 208 days, and 6.18 % and 34.09 % at 393 days. In the instance of M25, CM4 and CM5 have lower compressive strength than CM1. Similarly, in the case of M30, CM9 and CM10 have lower compressive strength than CM6. It may be determined that when 10% of the cement is replaced with marble dust, the compressive strength reaches its maximum value.

CONCLUSIONS

From the current investigation, the following findings may be drawn:

1. The use of marble dust instead of cement has no negative impact on the compressive strength, water absorption, or durability of concrete.
2. The experimental results for M25 concrete show that 10% marble dust replacement in concrete can be used, with compressive strength increases of 23.13 %, 23.85 %, 24.61%, 18.09 %, and 15.2 % for 28 days, 56 days, 118 days, 208 days, and 393 days, respectively, whereas compressive strength increases of 22.25 %, 26.48 %, 27.13 %, and 27.49 % for 28 days, 56 days, 118 days, 208 days,
3. The experimental results for M30 concrete show that 10% marble dust replacement in concrete can be used, with compressive strength increases of 22.69 %, 20.10 %, 23.27%, 15.58 %, and 12.77 % for 28 days, 56 days, 118 days, 208 days, and 393 days, respectively, whereas compressive strength increases of 18.19 %, 17.32 %, 17.02 %, and 19.90 % for 56 days, 56 days, 118 days, 208 days, and 393 days
4. The test findings demonstrate that using marble dust as a partial replacement for cement improves concrete's resistance to sulphate attack.

5. For both M25 and M30 grades, a 10% substitution of cement with marble dust results in more durable concrete in terms of water absorption. Water absorption is reduced by 25% in M25 concrete and 36% in M30 concrete.
6. The findings support a strong recommendation for the use of marble dust as a cement substitute in concrete, reducing dust pollution in the environment.

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