

Impact of Composite Materials by Silica Fume and Fly Ash in Cement and Partial Substitution of Fine Aggregate Using Quarry Dust in Steel Fibre Concrete

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Abstract

Mineral admixtures can be added to concrete to replace some of the cement, increasing its overall strength. Fly ash (FA) and silica fume (SF) are two often used mineral admixtures. A series of experiments were conducted to investigate the effect of adding varied amounts of fly ash and a consistent amount of silica fume on concrete strength by using the same amount of substitute for cement and the same water-binder ratio. The results show that fly ash has a certain influence on improving the fluidity of concrete, and the influence on the strength of concrete is mainly in the later period. The influence of silica fume on the fluidity and strength of concrete is better than that of fly ash, and the main influence of silica fume is becoming very strong. The strength of concrete combined with fly ash and silica fume increases initially before decreasing with the addition of mineral admixtures. All of the industrial waste used in this study as fine aggregate proved to be an effective filler material, filling the internal vacuum of the concrete and increasing the strength attributes of normal strength concrete. The present paper focusses on to study the mechanical properties of normal concrete with composites concrete with various amount of fly ash and quarry dust as a particle characterization and the impact of adding SF to concrete.

Keywords: Fly ash, Silica fume, Steel fibre, Mechanical properties, Quarry dust

INTRODUCTION

Cement that hardens over time is used to bind aggregate together, resulting in concrete, a composite material. Concrete is the most often utilized building material in the world, coming in second only to water. For thousands of years, people have used sand and gravel to create dwellings and roads. Sand is extracted directly from floodplains, overbank areas, and/or lively river systems [1]. On the scale of human life, it is a finite reserve. With the exception of size grading, little preparation is required for its abstraction from rivers. Though, it is now commonly understood that reckless and persistent sand excavating can have an adverse impact on the ecology, particularly if the river being dug erodes. Sand mining in or near channels always changes the deposit budget and has the potential to drastically alter waterway hydraulics [2]. It also has a detrimental consequence neighboring agricultural productivity, river bank stability, engineering structures, and river ecology. The river under mining erodes. Sand mining in or next to channels always changes the sediment budget and can have a big impact on the hydraulics of the channel. It also has a negative effect on the ecosystem, engineering structures, river bank stability, and agricultural productivity of the nearby areas [3].

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Two waste products of industrial development are fly ash and silica fume. They are haphazardly released into the environment, posing a health risk. Nonetheless, they work well as concrete admixtures to increase the material's strength. Numerous scientists have investigated this in-depth and discovered that adding industrial waste to concrete, for example fly powder and silica smog, affects a number of performance metrics, including concrete strength. The strength and permanence of concrete have been effectively replaced up to 30% by mass with Fly ash is a byproduct of thermal power plants, without experiencing any negative effects. In certain instances, a significant amount of fly ash (>40%) is added to concrete to provide the required qualities and reduce production costs [4]. With a comprehensive approach, the fly ash concrete system can help us meet the growing demand for concrete, improve its durability at little to no additional cost (or even lower in some cases), and dispose of Coal-fired power stations generate huge amounts of solid waste in an environmentally friendly manner. Concrete incorporating fly ash has been found to have outstanding mechanical and durability qualities in several laboratory and field experiments [5]. A by-product of the smelting of silicon is silica fume. Quartz is reduced in an electric arc to create silicon steel and ferrosilicon mixtures. Silica emission is recognized by its small, spherical particles, large surface area, and high silicon dioxide (SiO₂) concentration in the glassy phase. The microstructure of the hydrated blended cement with silica fume revealed that it is a very active Pozzolana that strengthens cement paste resistance to sulfate attack [6]. Utilized in two separate ways as an addition to enhance the qualities of concrete (in both its fresh and hardened phases) and as a substitute for cement to lower the cement content Silica fume is recognized for producing high-strength concrete. Consequently, using fly ash and silica fume combined offers an intriguing substitute. A mixture of the two by-products has been used in several recent studies. It is still unclear how much each of fly ash and silica fume pays to the strength and water perviousness of concrete [7]. Although there appears to be a wealth of literature on silica fume and fly ash studies, the majority of serious research projects are focused and targeted towards compressive strength.

The purpose of the fine aggregate is to help the mixture become more homogeneous and workable. The supreme prevalent cause of fine aggregate is found in river bonds. Natural river sand contains grown more expensive and scarcer in recent years. As a result, we must consider other materials. River sand may be partially replaced by quarry dust. An extra benefit of using quarry dust in concrete has been suggested as a substitute to using river sand [8]. Concrete constructed with comparable amounts of river sand is known to be less strong than concrete created using quarry dust. The compressive strength of quarry dust-based concrete improves with age, regardless of the proportion of dust used. The application of fine aggregate made from quarry dust. Quarry dust presents a disposal issue, but it can be made into a profitable resource by using it as fine aggregate. Utilization will also lessen the demand on the natural fine aggregate supply, lowering the price of concrete as a result [9].

The main materials used as fibers in cement-based composites include steel, glass, and polymer, or they might be produced from natural sources. Fibers tend to be closer together than traditional steel bars for reinforcement, which makes them a more effective crack-controlling material. It is vital to highlight that the fiber used as concrete reinforcement does not replace standard steel bars. In the context of modern concrete technology, steel bars and fibers serve distinct purposes, and both should be employed in a variety of settings. Steel fiber (SF) is the most frequent type of fiber used for reinforcement in concrete. SFs stood first employed to stop or manage drying and plastic shrinkage in concrete [10]. Subsequent investigation and development showed that adding SFs to concrete greatly enhances the material's ductility before the ultimate failure, energy absorption capacity, flexural toughness, reduced cracking, and durability. Many large projects employ this kind of concrete because it is safe, long-lasting, and reasonably priced. However, creating high-performance concrete with long-lasting durability is a difficult task because fly ash and silica fume dosage limits are crucial, and numerous studies have shown that adding more or less of these admixtures will not increase the strength or durability of the concrete [11].

Through, this study will examine the effects and consistency of various fly powder and silica fume dosages on the compressive strength of concrete and offer benchmarks for concrete configuration. This

study investigates the mechanical properties and applications of SF reinforced concrete (SFRC), as well as the effects of incorporating SFs into concrete [12]. There aren't many noteworthy scientific studies or technical data on tensile strength. Investigating all of the strength characteristics of concrete, such as its compressive strength, split tensile strength, and flexural tensile strength, at various dosages (percentages as replacement of cement) is therefore essential. The knowledge contained in this investigation aims to improve understanding of the role that fly ash and silica fume play when steel fibre is added on the concrete's tensile strength and to ascertain the ideal amount to maximize tensile strengths [13].

Research Significance

Limiting the quantity of cement obligatory in the manufacturing of concrete is the main objective of the current exploration. This helps to lessen the amount of ozone-depleting compounds that enter the atmosphere. The usage of these materials also keeps a safe distance from landfill problems and their removal, which could result in major environmental problems. Mainly important to maintaining ability is the use of these elements as a decision to set in a dynamic way. As a result, the current investigation is focused on using contemporary wastes (SF,FA and QD) to create concrete.

OBJECTIVES AND METHODOLOGY

The major objective of the current study is to add steel fiber, SF, FA, and QD in order to achieve the optimum ternary significant blend. In order to fulfill the review's objective, an exploratory program was unquestionably developed. This study aims to is to determine the ideal ratio of SF to FA, which can partially replace concrete. Steel fiber (1.5%) will be used to increase strength, along with various combinations of cement alternatives by SF (5%) and FA by various percentage (5% to 25%) and as well as fine aggregate by QD (5% to 25%). Every ternary concrete blended mix's mechanical characteristics were compared and set up, and the normal composite in with yields the best mixture for substantial blend ternary mixture.

EXPERIMENTAL PROGRAM

Materials

The assessment of this investigation task and the real properties of the significant endeavored by Indian principles technique states to the requirements of IS 10262-2009 using a 53-grade kind of regular Portland concrete. A finely divided secondary effect material called silica rage is created when silicon or ferrosilicon blends accumulate in an electric curve radiator. It is a pozzolanic substance with a spherical form and regular particles less than 0.1 μm . In Portland concrete, Class F low calcium fly debris is mostly replaced to act as a restricting particle and reduce the chloride vulnerability in the concrete; for this reason, alternative confining materials are more reasonable in building improvement endeavors [14]. Locally accessible stream sand that is mixed in different ways as demonstrated by IS 383-1997, and test an impetus for explicit gravity of sand is 2.45, corresponding to Zone II. Quarry stone residue is best described as a buildup that results from the elimination of further, non-volatile waste material after the rocks are advanced to encase fine particles smaller than 4.75 mm. In accordance with IS-383-1970, the fundamental tests on quarry powder were conducted. 20 mm coarse totals that were locally open and acclimated to IS: 383-1970 were employed. Conventional water that was virtually free of harmful substances was utilized, kept at pH 7, and had its chloride content removed for different combinations. The test findings and oxide composition of the used fly ash, quarry dust, silica fume, and OPC. In this review, are accounted in Tables 1 and 2, respectively.

Table 1. Specific Gravity of CE, FA, CA and QD.

S.N.	Properties	Cement	F. A	C.A	QD
1	Fineness	8.5	3.18	6.86	2.90
2	Specific gravity	3.15	2.45	2.67	2.50
3	Bulking	-	5.26%	3.6%	5.33%
4	Dry Loose Bulk Density	-	1460 Kg/m ³	1530 Kg/m ³	1800 Kg/m ³
5	Water Absorption	-	1.6%	0.6%	0.5%

Table 2. Oxides Composition of OPC, Silica fume, Fly ash and Quarry dust

Oxides	OPC (%)	S.F. (%)	F.A (%)	Q.D. (%)
SO ₃	3.55	1.37	0.051	0.12
Al ₂ O ₃	4.25	1.82	14.30	10.54
Fe ₂ O ₃	1.5	3.15	5.32	16.06
CaO	68.64	2.49	2.46	11.17
MgO	1.45	2.39	0.39	4.42
Cl	0.2	0.075	0.048	0.055
Loss of Ignition	1.4	3.07	0.63	2.91

Concrete Mix Design

The British method of mix design was used, by a combination consisting of crushed coarse aggregate, fine aggregate and ordinary Portland cement, for a typical concrete strength of 30 MPa. To achieve a slump of 30–60 mm, a w/c ratio of 0.5 was selected. Quarry dust was used to moderately substitute the fine aggregate. The replacement percentages ranged from 0% to 25%, and they were mixed in several batches in Table 3. To make it easier to see changes in workability, the water content of each mix was maintained constant. To distinguish the unique impact of the non-reactive industrial waste on the properties of both fresh and hardened concrete. 1.5 percent of the cement's weight was added to steel fiber to make it noticeably stronger in tension. The evaluation of silica fume and other contemporary materials was crucial in determining the detailed result of the novel material on the qualities that are toughened and green.

Table 3. Mix Ratio of M 30 Concrete.

S.N.	Items	Volume for 1 m ³	Ratio
1	CE	0.121	1
2	Water	0.192	0.5
3	FA	0.274	1.75
4	C A	0.412	2.87

Production of Test Specimens

Concrete was manufactured in drum mixer. All around twelve 15 cm cubes were anticipated for every mix to choose for the compressive strength. Cylinder of 10 cm in dia. and beam of dimension 10cm × 10 cm × 50 cm were cast to choose the split rigidity and flexural strength analysis at four test ages, for instance 7,14,21 and 28 days in Table 4. Every sample were projected in two coat and compressed until air rises appearing on a shallow level ended. The samples were kept between 25 and 27 degrees Celsius in reasonably moist air and in a vibration-free environment throughout the curing period. The mold was removed after two days, labeled with a sign for future identification, and then allowed to cure in fresh, clean water.

Table 4. Mix Proportion for 1 Cubic meter of Concrete in Kg.

Mixes	Cement	Steel Fibre	Silica Fume	Fly ash	Fine Aggregate	Quarry Dust	Coarse Aggregate	Water
M1	383.2	-	-	-	673.26	-	1100.57	191.6
M2	344.88	5.17	19.16	19.16	639.6	33.66	1100.57	191.6
M3	325.72	4.88	19.16	38.32	605.94	67.32	1100.57	191.6
M4	306.56	4.59	19.16	57.48	572.28	100.98	1100.57	191.6
M5	287.4	4.31	19.16	76.64	538.61	134.65	1100.57	191.6
M6	268.24	4.02	19.16	95.8	504.95	168.31	1100.57	191.6

Where: M1, M2, M3, M4, M5 and M6 are the mixes having 0% and 5% silica fume and 0%,5%,10%,15%,20% and 25% of fly ash as a substitute of cement and 0%,5%,10%,15%,20% and 25% of quarry dust as a substitute of sand.

TEST RESULTS AND DISCUSSIONS

Slump Value

To look at the properties of adding fly ash and silica smoke to concrete materials, as well as substituting quarry dust for fine aggregates in various mixes (M1, M2, M3, M4, M5, and M6). Using a constant w/c ratio of 0.50, the slump test results for various mixes were 105,127,160,178,180 and 183 mm respectively. The numbers is presented as a slump value in Figure 1. It was demonstrated that the OPC-fly ash cement was more useful than the OPC control mixture. This is a result of the blinder's size in fly ash increasing. OPC-fly ash concrete combinations with constant silica smoke concentration had lower slump values than blends with a comparable fly ash % but no silica smoke [15]. This is due to the fact that more water is needed the larger the surface region of the silica smoke units.

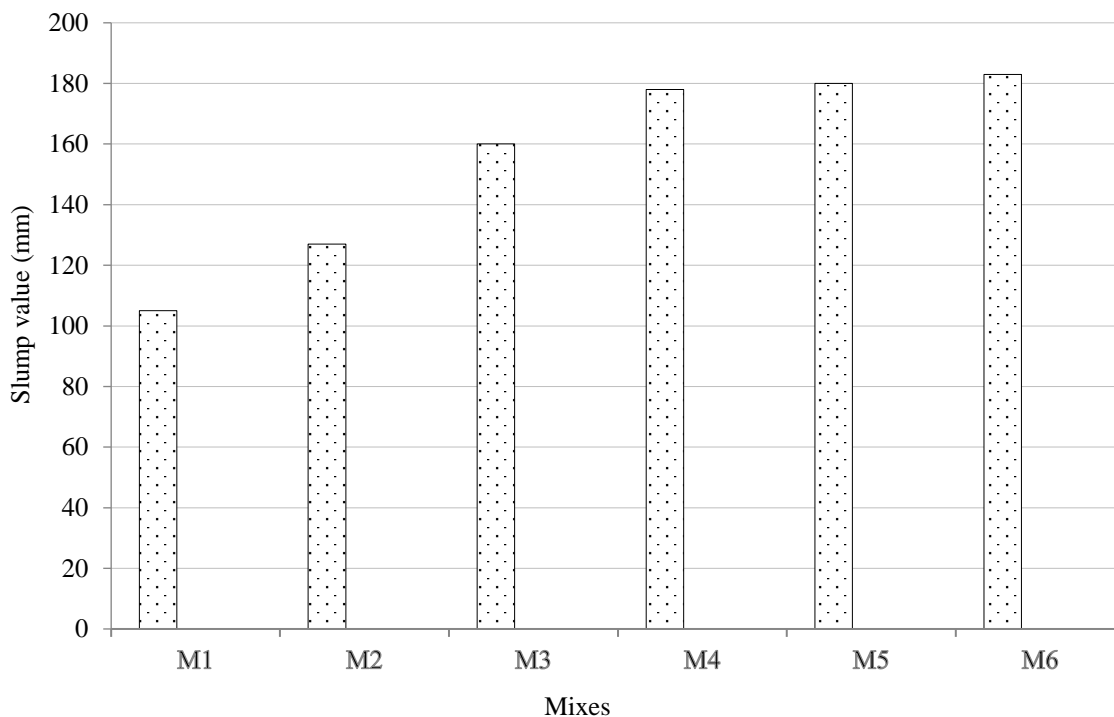


Figure 1. Slump Value.

Compaction Factor

Workability is evaluated in terms of the compaction aspect when the w/c ratio (0.5) is fixed. As seen in Figure 2, the values obtained for the different combinations (M1, M2, M3, M4, M5, and M6) are 0.73,0.75,0.79,0.82,0.87 and 0.90.

Compressive Strength

The compressive strength of the concrete was tested with silica smoke, quarry dust, and Portland fly residue. Figure 3 displays the compressive strength plus relative quality afterwards 7, 14, 21, and 28 days of submerging the mixtures in water. After seven days, the pressure of substantial combinations with and without fly residue and silica smoke concentration was found to be 18.2 MPa for mix M1 and 30.4 MPa for mix M5. After 14 days of soaking, the blends M5 and M1 had the lowest compressive strength (33.5 MPa) and the highest compressive strength (21.7 MPa). The compressive strength at day 21 of Portland silica smoke with varied levels of fly residue is commonly proven to be higher than that of set cement [16]. Furthermore, the 28-day restoring strength and improved compressive strength of the fly residue blends were found to be greater than that of the Portland concrete mix. Anyway, it was demonstrated to have more strength in all SF blends than fly ash blends when compared to cured cement. These conclusions unambiguously demonstrate that silica smolder and fly ash can be mixed to create ternary mix concrete with enlarged compressive strength [17].

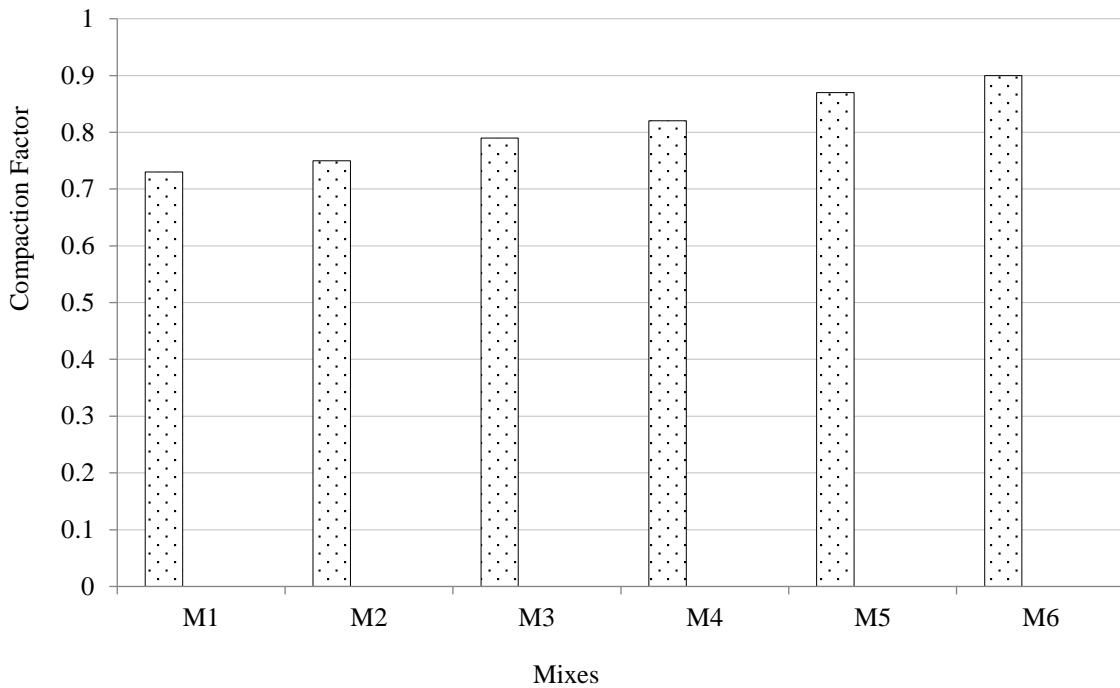


Figure 2. Compaction Factor.

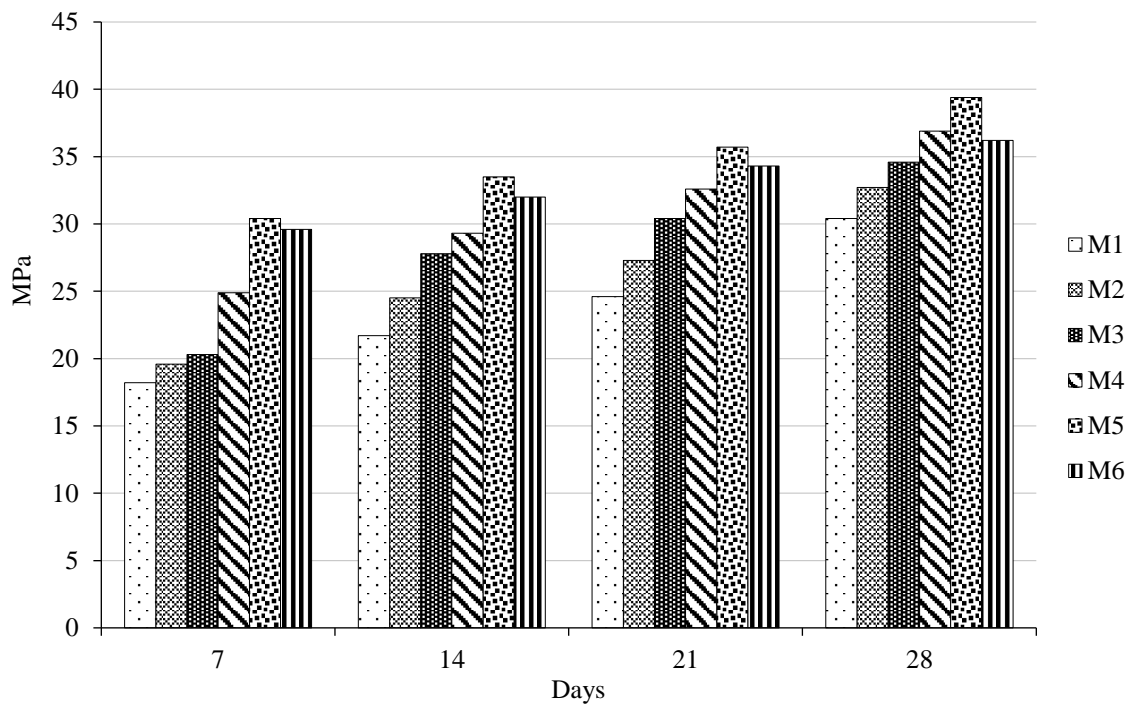


Figure 3. Compressive Strength of Concrete.

Split Tensile Strength

The calculation $f_{ct} = 2P/\pi ld$ was utilized to calculate the split rigidity. P stands for the maximum compressive weight applied along the cylinder's length, and D represents the diameter. Together with different mixtures from the initial exploratory results, Figure 4 visually depicts the split rigidity of concrete [18]. It is evident that the combination of steel fiber and fly ash and silica fume has significantly improved. It was observed that the mix (M5) split rigidity increased with curing time and that the mix's split tensile strength was 5.9 MPa after 28 days [19].

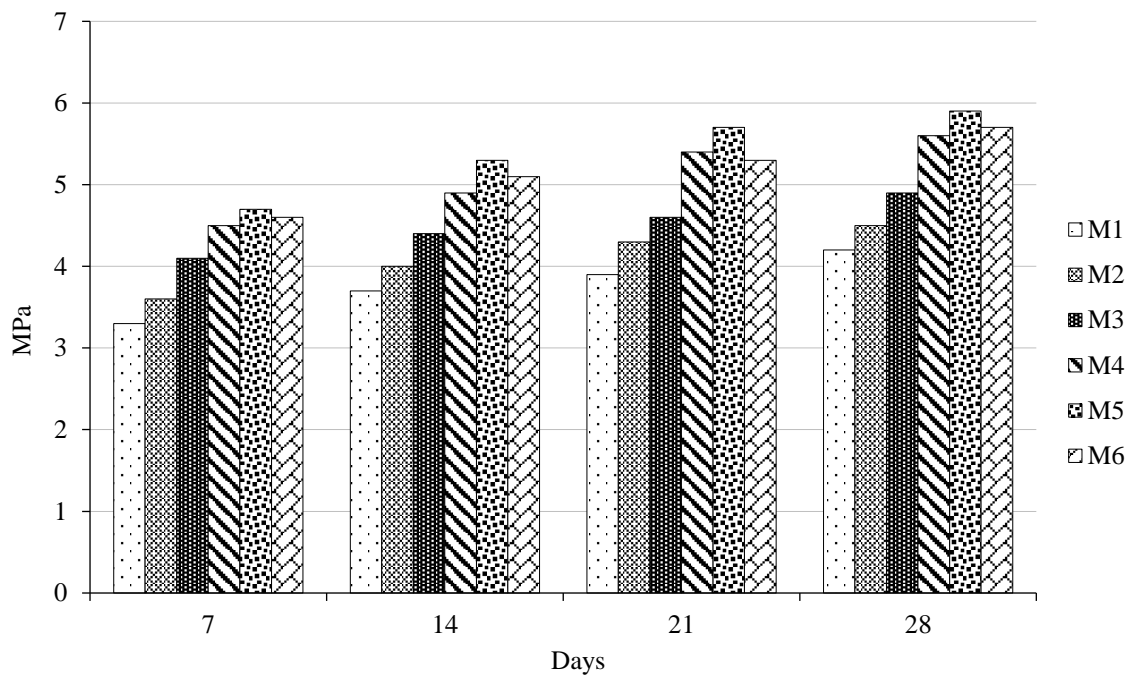


Figure 4. Split Tensile Strength of Concrete.

Flexure Strength

Figure 5 depicts the results of the lab test for the 28-day flexural stiffness of concrete. The results show that flexural stiffness was supposed to grow at a rate of around 20% in tandem with the expansion of fly ash replacement [20]. The pressing impact of contemporary materials used as fine total substitution could explain the increase in flexural stiffness generated by the expansion of modern waste as a fractional additional of fine total. The utilization of modern waste resources boosted the holding power of the concrete glue by filling the openings and dipping the microscopic spaces in the significant inner design [21].

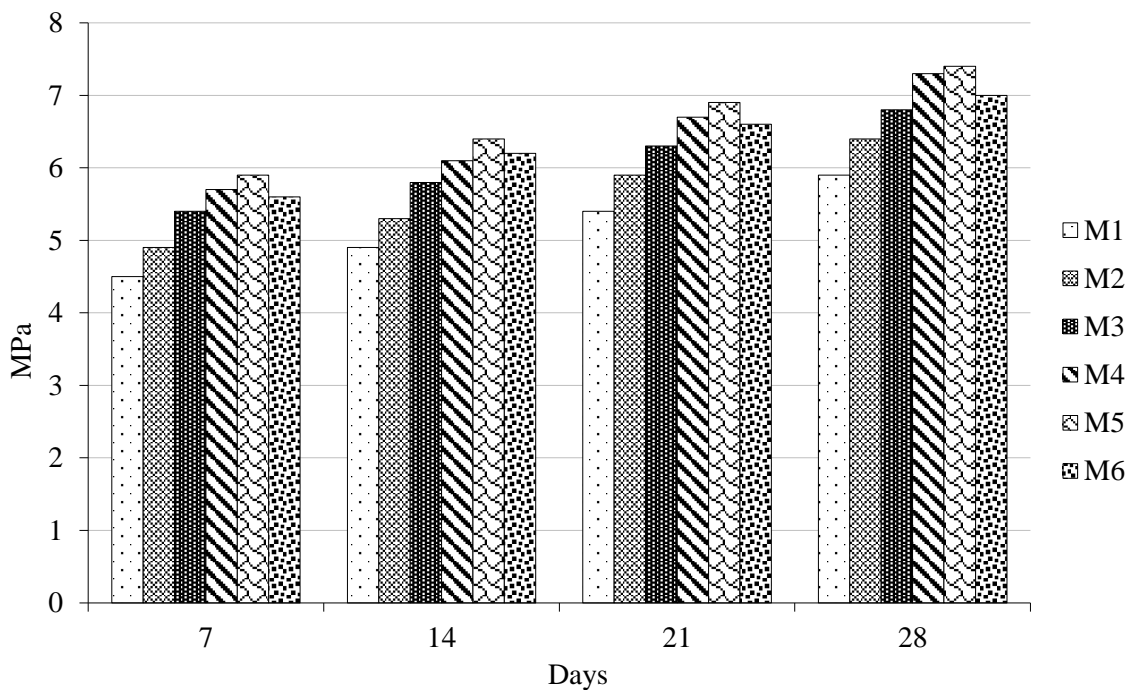


Figure 5. Flexure Strength of Concrete.

Conclusion

The important objective of this investigation was stated based on the discussion of the many experimental results and a few completions of this investigation work:

1. The early age compressive rigidity of cement was further developed by the expansion of silica fume, fly residue quarry powder, the compressive strength was likewise enlarged by the expansion of steel fiber.
2. The consumption of fly ash and quarry dust in place of concrete and fine aggregates in concrete blends has allowed for a substantial increase in strength that exceeds the mean strength.
3. The complete set of concrete strength properties decreased when fly ash and quarry dust were used in place of cement as a fine aggregate, with a content of up to 25%.
4. The split tensile strength of M5 is somewhat higher than that of all the other mixes, indicating that partial replacement of concrete with silica fume (5%), fly ash (20%), and quarry dust (up to 20%) is possible.
5. After 28 days, the mix's (M5) flexure strength is 21.73% greater than that of the green cement.

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