International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Review Paper on Effects of Fly Ash and Quarry Dust on Partial Replacement of Cement and Fine Aggregate

Mayank Srivastav [1], Pushpendra Kumar Kushwaha[2], Mithun Kumar Rana[3]

[1]*M. Tech. Research Scholar, Civil Department, RKDF College of Engineering, Bhopal (M. P.),402026 India*
[2]*Assistant Professor, Civil Department, RKDF College of Engineering, Bhopal (M. P.), 402026, India*
[3]*Assistant Professor, Civil Department, RKDF College of Engineering, Bhopal (M. P.), 402026 India*

ABTRACT

The need for the mechanical properties of building materials has increased over the past few decades, leading to a rise in the use of high strength concrete (HSC). Energy-intensive raw materials that are bad for the environment are used in its production. Because the production of aggregate and cement has an effect on the environment, resource preservation and environmental protection are urgently needed. The mechanical properties of HSC mixed with industrial wastes were assessed in this study to see if it would be possible to do so. Instead of using cement and fine aggregate in the concrete, different proportions of fly ash and quarry dust have been included. In addition to durability attributes like porosity, density, acid mass loss, and strength loss, the concrete's workability, compressive strength, and flexural strength were also assessed and documented. The results indicate that the mechanical performance of the high strength concrete was enhanced by the addition of up to 30% of fly ash and quarry dust, respectively.

Keyword - Fly ash, quarry dust, flexural strengths, fine aggregate, cement, strength

1. Introduction

Concrete is a composite material made of cement and both coarse and fine aggregate. Portland cement is the most often used component in the production of concrete. The demand for building materials is growing, which is causing the price of cement and other raw materials to rise daily. The use of alternative building materials in construction areas is strongly advised and favoured to address these concerns.

Fly ash

Coal-fired power and steam generating plants release fly ash into the environment. Typically, coal is ground and air is forced into the combustion chamber of the boiler where it ignites instantly, producing heat and a molten mineral residue. The flue gas is cooled by the heat extracted from the boiler by the boiler tubes, which also causes the molten mineral residue to solidify into ash. The lighter, finer ash particles, known as fly ash, stay suspended in the flue gas while the heavier, coarser ash particles, known as bottom ash or slag, sink to the bottom of the combustion chamber. Fly ash is collected by particulate emission control equipment, such as electrostatic precipitators or filter cloth baghouses, before the flue gas is exhausted.

Fly ash

Crushed rock aggregate is more suitable for the production of high strength concrete compared to natural gravel and sand. For this research, quarry dust is collected from Megala contractors at Bhopal .

Quarry dust

2. Literature Review

Byung Hwan et al. (1992) studied the flexural behaviour of reinforced concrete beams including steel fibres. Nine reinforced concrete beams have undergone testing, comprising one series of double-reinforced concrete beams and two series of single-reinforced concrete beams. The volumetric fibre concentrations of the reinforced beams in each series were 0%, 1%, and 2%. The load was applied according to the four-point flexural loading condition. The crack widths and crack spacing at each loading step were recorded during the loading process. These findings showed that crack widths rose almost linearly with steel stress, but that crack widths at the same loading stages drastically decreased with an increase in steel fibre content.

(2004) Song and Hwang investigated the mechanical properties of high-strength steel fiber-reinforced concrete. Among the properties were rupture modulus, splitting and compressive tensile strengths, and toughness index. Steel fibres were added at volume fractions of 0.5%, 1.0%, 1.5%, and 2.0%. The fiber-reinforced concrete's compressive strength peaked at 1.5% volume fraction, a 15.3% gain over the HSC. At 2.0% volume percent, the splitting tensile strength and rupture modulus of the fiber-reinforced concrete reached values of 126.6% and 98.3%, respectively, as the volume fraction climbed. The fiber-reinforced concrete's toughness index rose in proportion to the rise in response.

Ganesan et al. conducted an experimental study in 2007 on ten external beam-column junctions composed of steel fibre reinforced high-performance concrete (SFRHPC). The M60 grade concrete was designed using a modified ACI methodology. The volume fraction of the fibres used in this experiment ranged from 0 to 1% with a 0.25% increment. Joints were tested under positive cyclic loading, and the results were assessed for stiffness deterioration, ductility, and strength. Test results indicate that SFRHPC is a viable alternative technique for reducing transverse reinforcement congestion in beam-column joints while enhancing stiffness, ductility, and strength. According to testing, using fibres could improve the dimensional stability and integrity of the joints.

Gencoglu (2010) states that cementitious materials are brittle, notch sensitive, and tension-weak due to their limited strain tolerance. Recently, there has been a notable improvement in the strength and ductility of textile fabrics, a new class of cement-based materials. The present research investigates the possible application of pultruded cement textiles as a reinforcing technology for enhancing the flexural capacity of concrete that has undergone flexural loading. Basic concrete beams with a measurement of 100100460 mm were made. The samples were reinforced using polyethene (PE) fabrics impregnated with cement paste and alkali-resistant (AR) glass. Two levels of strengthening—consisting of four and eight layers of fabric—were applied to five replica specimens in each category.

The behaviour of pre-stressed concrete beams with carbon fiber-reinforced polymer (CFRP) rods under high cycle fatigue at low temperature was examined by Reza Saiedi et al. (2011). We looked at seven precast T-beams; two had regular steel strands and five had CFRP rods that were prestressed to different degrees. Every beam had a history of constant loading. Some beams were directly loaded monotonically to failure as control specimens. Other beams experienced three million cycles of flexural loading, either at room temperature or at 28°C, prior to being monotonically loaded to failure at the same temperature. While all CFRP-pre stressed beams survived the three million cycles, the steel-pre stressed beam did not. However, it was shown that

When used as a fine aggregate, quarry dust completely replaces natural river sand, lowering the cost of making concrete (Sivakumar et al., 2011). This is because concrete made with quarry dust has hardened and durable properties. This paper describes an experimental study that looked at the consequences of totally replacing sand with quarry dust. Several ratios of quarry dust (CM 1:3, CM 1:2, and CM 1:1) were employed when examining the cement mortar cube. The results of the experiment showed that adding quarry dust increased the fine to coarse aggregate ratio to 0.6, which enhanced the properties of the elastic and compressive moduli.

Arivalagan (2011) states that in order to understand the cyclic behaviour of polypropylene fibre reinforced concrete, a study utilising plain concrete beams with and without reinforcement was conducted. Each beam was tested with two point loads on the same dimensions. Under positive cyclic loading, the tested beams' strength, ductility, energy absorption capacity, energy absorption, and stiffness degradation were evaluated. Test results show that adding polypropylene fibre to a beam increases its stiffness, strength, ductility, and energy-absorbing capacity. The results also showed that polypropylene fibres were effective in reducing the width and propagation of cracks. The results also showed that although polypropylene fibres had very little effect on the beam's rigidity, when combined with reinforcement, they improved the behaviour of reinforced concrete beams and changed the way they failed.

Research by Ndihokubwayo (2013) found that the 28-day high-performance fly ash concrete withstood flexural loading forces of 5.1 MPa, 4.0 MPa, and 3.9 MPa while withstanding compressive loading forces of 30.9 MPa, 29.7 MPa, and 26.2 MPa, respectively. The researcher had varied the proportions of fly ash in cementitious materials by 30, 40, and 50%. The testing findings showed that utilising a super plasticizer product with a water-to-cementitious ratio of 0.39 and a gravel-to-sand ratio of 2.12, the fly ash concrete was able to reach high-performance compressive strengths after 28 days.

In a comparative study, Marthong and Agrawal (2012) examined the impact on concrete's properties when fly ash was used to partially replace OPC of various grades. Variations in fly ash dose of 10%, 20%, 30%, and 40% are the main variable being studied in this work. The main areas of investigation were shrinkage, durability, and compressive strength of concrete. Test results show that in all OPC classes, adding fly ash to concrete generally improves its properties to a certain replacement level. Normal consistency increases with higher fly ash and cement grades. Soundness and setting time decrease as cement grade rises. The workability of concrete increases with the addition of fly ash and decreases with the cement grade.

Devi et al. (2012) investigated the strength and corrosion resistance of concrete that included triethylamine, an organic inhibitor, at dosages of 1%, 2%, 3%, and 4% by weight of cement together with quarry dust as fine aggregate. Test findings for durability, strength, and water absorption were contrasted with those of concrete built with natural sand. Corrosion resistance of the concrete is evaluated based on the weight loss measurement and impressed voltage method's capacity to withstand chloride ion penetration. The results show that adding quarry dust instead of sand to concrete strengthens it and increases its overall properties. When an inhibitor is applied, the concrete becomes even more resistant to corrosion and offers excellent protection against chemical attacks. Concrete with plasticizer and well-graded quarry dust for fine aggregate may be beneficial to the construction industry.

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Subramanian and Kannan (2013) investigated the feasibility of using different quarry dusts by looking at the physical and chemical properties, workability of the quarry dust concrete, and behaviour of the quarry dust mortar and reinforced cement concrete beams in different ratios of 100:0, 80:20, 70:30, 60:40, and 0:100 (quarry dust to sand) for M20 grade of concrete. Using IS mix design, the varying ratios of four distinct quarry dusts to river sand were combined. Tests on cubes and cylinders were conducted to find the compressive and tensile strengths of concrete produced of different ratios of quarry dust with river sand. These experiments' outcomes were contrasted with those that were achieved with natural sand.

Sudhir, Kapgate et al. (2013) assessed the design mix of M25 grade concrete for the laboratory analysis, substituting 0%, 20%, 25%, 30%, and 35% of the quarry dust, arranged as M1, M2, M3, M4, and M5, in that order. Tests for slump, compaction factor, compressive strength, split tensile strength, and flexural strength have been conducted on hardened concrete. In the current investigation, the hardened properties of concrete created using quarry dust were investigated. More water must be added to the mixture for higher surface area aggregates in order to completely wet the particle surfaces and preserve their unique workability.

In one experiment, quarry dust was substituted for sand in 10% increments from 0% to 100%, resulting in varying concrete strengths (Balamurugan and Perumal, 2013). M20 and M25 grades of concrete with a consistent 60mm slump are chosen for the inquiry. The compressive strength of concrete cubes is evaluated at room temperature at the ages of 7 and 28. The split tensile strength and flexural strength of concrete are found at 28 days of age. The test findings show that only with 50% replacement are the maximum compressive, tensile, and flexural strengths reached.

Syed Afzal Basha et al. (2014) conducted experiments to assess the compressive strength of cement concrete that contained fly ash. Fly ash is added to concrete mixes M25 and M30 in the following proportions: 0%, 10%, 20%, 30%, and 40%, under the Indian Standard Code (IS-10262-82). Concrete cubes are cast for each mix type, and after seven, fourteen, twenty-one, and eighteen days of curing, their compressive strengths are measured and compared to ordinary concrete.

The compressive, split tensile, and flexural strengths of concrete reinforced with steel fibres were determined by Tarun Sama et al. (2014) in their investigation of the behaviour of M-40 grade concrete with a mix ratio of 1:1.62:2.83 and a water/cement ratio of 0.45. 50 steel fibres with an aspect ratio were used in four different percentages: 0, 1, 5, and 2 percent. In lieu of cement, two percentages of Class F fly ash were utilised: 40% and 60%. The outcomes were compared and evaluated with respect to the control material. The use of steel fibre makes concrete stronger overall, particularly in the split tensile and flexural zones. It was discovered that the amounts of steel and flash fibres that showed the most increases in tensile and flexural strength were 2% and 40%, respectively. The flexural and split tensile strength of concrete reinforced with steel fibres is noticeably higher than that of ordinary concrete. The ratio of 2% steel fibres to 0% fly ash yields the highest compressive stress. Furthermore, the 40% fly ash and 2% steel fibre tension is almost exactly the desired tension.

Comparing two steel fibres with 40% fly ash to two steel fibres with 0% fly ash, the split tensile stress is almost the same. The optimal stress was discovered at 40% fly ash and 2% steel fibre addition; flexural tension increased as the percentage of steel fibres increased. The created cement concrete is both cost-effective and environmentally friendly because flyash was used in its production. However, the tensile strength of the concrete was not greatly enhanced. Because concrete is replaced by flash, the prepared concrete is both cost-effective and environmentally friendly. The workability of concrete is greatly improved by the addition of flyash. Concrete's ductility is greatly increased by steel fibres and flyash. The ratio of tensile strength to compressive strength can be increased by lowering flyash and steel fibres.

Fly ash is a more crucial component of concrete than cement, according to Abdun Nur (1961), which produces concrete of greater quality. Mehta (2006) highlighted the necessity of substituting cement with high volume fly ash, citing the product's high cost, longevity, and environmental concerns as reasons for the recommendation. Concrete mixes containing thirty percent by weight of fly ash (ASTM Class F) can be proportioned to achieve the required workability, early one-day strength, and elastic modulus for structural purposes, according to Swamy et al. (1983). The doses of admixtures or super plasticizers were adjusted to obtain cohesiveness and workability with slumps greater than 4 inches (100mm) for ease of insertion in structural components with steel reinforcement.

Approximately half of the fly ash produced is used in current operations, according to Chatterjee (2011). Additionally, he asserted that fly ash may replace cement up to 70% of the time when combined with sulphonated naphthalene formaldehyde superplasticizer, high strength cement, and fly ash with exceptionally high reactivity. He asserted that grinding could result in fly ash particles with enhanced submicrocrystalline characteristics. Studies on Indian fly ashes by Bhanumathidas and Kalidas suggest that a 13% increase in strength might be obtained from a 52% increase in ground fineness. Nonetheless, it was stated that a 64% increase in native fineness translated into a 77% increase in strength. It was proposed that grinding coarse fly ash would not greatly increase reactivity in light of the findings. Furthermore,

Poon, Lam, and Wong (1999) concluded that the use of fly ash in place of cement reduces the porosity of concrete and plain cement mortars based on their experimental results. It has been shown in the literature under review that the workability and durability of concrete are enhanced when part of the cement is replaced with fly ash. On the other hand, it was demonstrated that concrete that contained fly ash instead of cement had a weaker 28-day strength than concrete that did not. The literature analysis shows that fly ash grinding is not as effective. This could be as a result of the destruction of fly ash's spherical shape, which enhances workability and reduces voids. The cost of grinding somewhat offsets fly ash's comparative economic advantage over cement. The low reactivity of low lime Indian fly ashes in comparison to high lime fly ashes limits the usage of larger quantities of fly ashes for cement substitution. Because fly ash is less reactive than cement, a system must be developed to replace cement in increasing amounts with fly ash without activating or grinding the ash. Hwang, Noguchi, and Tomosawa (2004) concluded that the inclusion of fly ash as a replacement for sand causes the pores in concrete to decrease based on their experimental findings about the development of compressive strength in concrete containing fly ash. In an experimental investigation, (Siddique, 2003) evaluated the mechanical properties of concrete mixtures in which class F fly ash was utilised to partially replace fine aggregate (sand). Class F fly ash was replaced with five different weight-based substitutes for fine aggregate: 10%, 20%, 30%, 40%, and 50%. The test findings showed that at all ages, fly ash concrete mixes with fly ash replacing 10% to 50% of the fine aggregate exhibited compressive strengths higher than control mixes. Furthermore, the compressive strength of concrete mixes rose as the proportion of fly ash increased. This increase in strength that came from replacing fine aggregate with fly ash was attributed to the pozzolanic activity of fly ash. The splitting tensile strength increased as the quantity of fly ash used to replace fine aggregate increased. Additionally, flexural strength and elastic modulus test results were superior to those of the control concrete. Namagg & Atadero (2009) provided details on the early stages of a study to investigate the usage of considerable volumes of high lime fly ash in concrete. The writers used fly ash in place of some of the cement and fine aggregates. They looked into replacement percentages that ranged from 0% to 50% in their investigation. They stated that using concrete with 25% to 35% fly ash produced the greatest results in terms of compressive strength. They concluded that the pozzolanic activity of high lime fly ash was the cause. A comprehensive lab-based investigation investigating the use of untreated low-lime fly ash as a sand substitute in foamed concrete was carried out by (Jones & McCarthy, 2005). For a given plastic density, the spread seen in fly ash concretes was up to 2.5 times more than that in sand mixtures. The early age strengths of fly ash and sand concrete were found to be comparable, while the 28-day values changed significantly with density. The strength of fly ash concrete was more than three times that of sand concrete. Furthermore, whereas the strength of sand mixtures were mostly unchanged after 28 days, the strength of fly ash foamed concrete after 56 and 180 days was up to 1.7 to 2.5 times greater than 28 days values. Fly ash has been studied as a potential replacement for sand in polymer concrete (Rebeiz, Serhal, and Craft, 2004). Fly ash was added to the weight mix design in place of 15% of the sand. The compressive strength increased by around thirty percent by substituting fly ash for fifteen percent of the sand. The stress-strain curve also showed improvement. They also noticed that the addition of fly ash, which has an eye-catching black colour and lowers permeability, resulted in a good surface finish. The flexural strength of beams composed of steel-reinforced polymer concrete has been increased by 15%. After 80 thermal cycles, polymer concrete containing fly ash exhibited a 7% increase in thermal cycling resistance in comparison to polymer concrete without fly ash. (Rao, 2004) stated that approximately 650 kg/cu.m of fine material must be used in the production of self-compacting concrete. Additionally, fine aggregates must comprise more than 50% of the aggregate in order for the coarse aggregate to float in the fine material. This need for fine materials can be easily met by using fly ash.

HVFA, which uses concrete and replaces 50% of the cement by mass with flyash, has been studied by P. Kumar Mehta. He discussed how adding a significant quantity of flyash improved workability, durability, water need, reduced sulphate attack, and decreased cracking. He said there's no doubt this technology will help developing countries like China and India.

Chao-Shun Chang, Chung-ho-huang, How-ji Chen, and Shu-ken Lin[2] suggested a design mix technique that included 20 to 80% flyash instead of cement. They used two distinct types of class F flyash, one having an ignition loss of 4.6% and the other with a loss of 7.8%. After then, experiments were conducted to ascertain the properties of the concrete. Test results clearly showed that adding flyash to concrete causes it to take longer to set, slowing the strength-building process by 91 to 365 days. He established the link between flexural and compressive strength for all grades of HVFA. It was claimed that the flyash with ignition loss had superior mechanical properties. Ultimately, he found that by using a sensible mixed proportion, concrete may be used to replace 80% of class F flyash.

.L.K. Two HVFA mixtures, one utilising class C flyash and the other class F flyash, were studied by Crouch, Ryan Hewitt, and Ben Byard. The results were compared to TDOTA widely used mixtures that employed flyash of the same class in less quantity. He discovered that employing HVFA increases durability, decreases void content, and lowers absorption when compared to TDOTA combinations. The setting time was increased by two hours to 22 degrees Celsius, the standard temperature. They claim that because of its better compressive strength and comparable pricing, employing HVFA will be suitable in warm climates.

Yash Srivastava and Ketan Bajaj [4] tested the stabilising power of flyash by substituting it with other soil for 10% to 60% of the investigation. Additionally, utilising prisms and cubes with flyash replacement levels of 35%, 50%, and 75%, all of the hardened properties of HVFAC are examined in his paper, including compressive strength and flexural strength. According to their research, replacement of up to 50% might be achieved for a 12% increase in total cost. Muhammad Shahzada, Tufail, Khan, Bora Genturk, and Jianqiang Wei explored the mechanical characteristics of quartzite, limestone, and concrete. For two hours, the materials were heated to temperatures ranging from 25 to 650 degrees. We evaluated the elastic modulus, tensile strength, and compressive strength of the material. They arrived to the conclusion that concrete's mechanical qualities are greatly impacted by temperature changes. As the temperature climbed, the ultimate train grew, but the elastic modulus, tensile strength, and compressive strength all decreased.

H.W. Regarding Hwang and P.S. Song claims that the low strain capacity and tensile strength of high strength concrete can be eliminated by using steel fibres. At volume fractions of 0.15, 1%, 1.5, and 2%, steel fibres were added. As the percentage rose, the hardness index rose as well, peaking at 0.15%.

Because expanded polystyrene is lightweight and an excellent energy absorber—it can even split during casting—Bing Chen and Juanyu Liu developed EPS concrete by employing a method similar to sand wrapping. Based on the results, EPS beads with a density of 800-1800 kg/m3 and a compressive strength of 10-15 MPa can be used instead of coarse and fine aggregate. 8. The effects of steel and polypropylene fibres on lightweight, high-strength concrete were investigated by Kayali O., M.N. Haque, and B. Zhu . Fines were replaced with flyash, and indirect rupture and indirect tensile strength were enhanced by 20% and 90%, respectively, by using polypropylene at a volume ratio of 0.56%.

The goal of the study by Neelesh Kumar Singh, Prerit Saxena, Rohit Kumar Shakya, and Rishabh Sharma[9] was to replace cement with fly ash in percentages of 5%, 10%, 15%, and 20%. Their research revealed that, in comparison to other ratios, 10% fly ash content offers more strength without the need for admixtures. When the fly ash content rises, less strength and more water are required.

P. Nath and P. Sarker claims that fly ash was used in the study to replace between 30 and 40 percent of the cement. As a result, compressive strengths increased to 85 MPa after 56 days of curing and 60 MPa after 28 days. Strength increased with a 30% replacement as opposed to a 40% replacement. The researchers also assessed the chloride ion permeability, finding that it had reduced by 35 to 45% or more after 28 days. Fly ash reduced the concrete's sorptivity as well as its drying shrinkage.

Snehal Afiniwala, Nirav Patel, and Dr. Indrajit Patel looked into how fly ash affected self-compacting concrete (SCC). In the M20 and M25 combinations, class F fly ash was used in place of cement to the tune of 50%, 55%, and 60%, respectively. Tests were conducted to determine the rheological properties of concrete. It was determined that each property satisfies the 50% and 55% replacement standards. Fly ash levels kept rising although the flow of concrete decreased. Therefore, one may claim that fly ash can be utilised to make SCC for a very cheap price.

3. Conclusion

Viable natural sand resources are becoming scarce in many parts of the world, whether as a result of river sterility or extinction, high extraction or transportation costs, a lack of water for processing in some places, or environmental issues. The following aspects are a summary of the current situation of the concrete industry dealing with the shortage of fine aggregate and the use of quarry dust as an alternative:

Excessive river sand mining has almost reached the point of total depletion, making further mining completely impractical. Therefore, it is essential to cease all future river sand extraction and start looking for alternatives right away. As alternatives to river sand for use as fine aggregate in concrete, studies on concrete have been done on the use of near shore marine sand, dune sand, land-based sand, offshore sand, quarry dust produced sand, and bottom ash. But it is advised that more research be done on quarry dust for practicality and feasibility. The results of the laboratory tests have demonstrated that quarry dust can substitute sand entirely or partially. harmful compounds, such as particles that are less than 75 m Because quarry dust causes different grading, increased surface area consumes more water, and lessens durability characteristics, it is said to be hazardous to concrete.

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