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Development of Cement Concrete Using Granite Dust and Fly Ash as Partial Substitutes

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Abstract: In this scenario, we observe how the strength of the concrete changes when the standard cement is switched out for granite powder and fly ash as the fine aggregate. In this particular investigation, the researchers employed anything from zero to fifty percent fine aggregate and whatever quantity of cement they deemed appropriate. Concretes of grade M25 and M60 are used since there is a need to take into account either low and high strengths. At room temperature, compressive testing was carried out on cubes of fly ash-added concrete that had been aged 7, 14, 28, and 90 days respectively. After 14 and 28 days after being mixed, cylinders of fly ash-added concrete were split and evaluated for their tensile strength. During a cure period of 28 days submerged in water, the flexural strengths of the concrete beams were measured. We were able to evaluate the chemical solution resistance of concrete made with fly ash and quarry dust by curing samples of concrete in a variety of chemical solutions and then determining the amount of strength and weight that was lost as a result. The high performance concrete mix that was created was made using the M60 grade of concrete. The major focus of this investigation is on the characteristics and performance of concrete in which the cement and fine aggregate have been partly substituted by large volume fly ash (HFA) and quarry dust (QD). The strength, stiffness, and residual strength of high-performance reinforced concrete beams were investigated and tested to see how they would perform under cyclic loading circumstances in terms of the deterioration of these properties. In this investigation, the researchers used a sophisticated chloride penetration technique to concrete that was produced using a combination of fly ash and quarry dust (RCPT). Last but not least, research was conducted on the compressive, split tensile, and flexural strengths, in addition to the chloride permeability, of concrete mixes that included varied amounts of fly ash and quarry dust. The findings demonstrate that reducing waste by recycling stone dust to pavement is a feasible alternative.

Keywords: High volume fly ash, quarry dust, RCPT, high – performance beam,cyclic loading

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Introduction

Combining coarse and fine aggregates with cement results in the production of composite material known as concrete. Portland cement is the component that is used in the production of concrete at the highest frequency. As a direct result of this, the cost of cement and other raw materials is going up in order to keep up with the rising demand for these goods, which can be observed in the building and construction sector [1-3]. The use of alternative building materials is strongly suggested as a potential solution to these problems in the construction

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industry. In the construction industry, fly ash is an alternative that is well-known and often utilized to the more conventional material, concrete. Fly ash is produced when fine particles from the boiler contact with the fuel gases used to burn coal. Several other materials may serve as a suitable replacement for Portland cement. Quarry dust, which is produced when rocks are finely crushed, is comparable to fly ash in that it may be utilized in the building of concrete structures, brickworks, wall constructions, and so on. Quarry dust is made when rocks are carefully crushed. It is possible to incorporate it into concrete by using it as a fine aggregate. Fly ash and quarry dust may, to a limited extent, be used in lieu of some of the more traditional elements in concrete [4], but only up to a particular amount. Recent studies have shown that the strength of concrete may be improved by using fly ash and quarry dust to replace as much as fifty percent of the concrete's components. This substitution can raise the concrete's overall density. This may help minimize some of the issues that have been brought on by a paucity of raw materials in the building industry. As a direct consequence of this, we looked at two possible alternatives to cement and fine aggregate: fly ash (class F), and quarry dust. The purpose of this research is to investigate the outcomes that occur when cement is replaced by fly ash (30%), quarry dust (40%), and fine aggregate (50%) respectively. After allowing the hardened concrete to cure for a period of 28 days, several structural properties of the concrete were evaluated, including its compressive, split tensile, and flexural strengths, and compared to those of controlled concrete made with the appropriate design mix. By curing concrete specimens with fly ash and quarry dust in a variety of chemical solutions, we were able to assess the durability of the samples as well as the percentage of attribute loss.

Beams made of high-strength reinforced concrete were put through a series of tests in which they were subjected to cyclic loading conditions. The results of these tests revealed the residual strength and stiffness degradation characteristics of RC beams. The specimens were made with fly ash and quarry dust. After that, we extrapolated the necessary binder from our data, which increased the durability and structural rigidity of the concrete while still complying with every one of the fresh and hard cement specifications specified by the IS...

Fly ash

Coal is used in most of the world's major manufacturing processes. Electricity generation, steel production, and the operation of a select few automobiles have all historically relied on coal as a fuel source. Fly ash is the term for the tiny black particles created when coal is burned. This fly ash is expelled together with the flue gases from boilers. Pulverized flue ash is another name for this substance because of the small size of the particles it contains. Electrostatic precipitators, which have walls that are electrically charged in the opposite direction of the particles being captured, work swiftly to collect small particulate matter of ash that has been forced out of hot boilers. Fly ash disposal has been a problem for many sectors for a long time. They previously dumped it at a landfill remote from the manufacturing sector. Lightweight ash particles mixed with the surrounding atmosphere, creating dust or air pollution, which in turn harmed the ecosystem. Moreover, landfill disposal results in soil contamination, which makes the soil stagnant and unusable. Even if it doesn't reach the surface water, it may still contaminate the water supply by seeping into the soil. As a result, the fly ash became a major challenge to eliminate or repurpose.[5]

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Current utilization of fly ash.

Fly ash is a resource item put to use in a wide variety of every day tasks. Fly ash's pozzolanic properties make it a prime ingredient in cement production. Fly ash's engineering qualities allow for a wide variety of geo-technical uses. Fly ash is often employed as a filler because of its inherent interstitial character. Fly ash's morphological features allow it to be used in the manufacturing of various ceramics[6-8]. Fly ash's physical and chemical qualities make it a useful additive to agricultural soil. Reclaiming farmland that contains fly ash may be quite beneficial. Soil made from fly ash is as nutrient-dense as possible. Fly ash's micronutrient content is beneficial to plant development since many kinds of plants need micronutrients to thrive. In 2012, the rate of fly ash production in India reached up to 170 million tons per year, and its usage rate is predicted to exceed the aim of 100%. Around 89% of India's annual fly ash production was used in cement production or as a substitute for another commodity used in cement production[9]. Ten percent of fly ash is utilized for filling in low-lying areas and is rammed in. Fly ash is being used to fill up the various intermixing low-lying areas. Brick manufacturers only utilize a small fraction of the fly ash they produce. The use of fly ash for brick manufacturing is mandated by a government notice from 2003 concerning the exploitation of fly ash within the region of thermal power plants. Just a tiny fraction of fly ash produced is actually put to good use in farms. Road and embankment building, building components or industrial usage of buildings, hydraulic structure building, agricultural research and application, and mine filling operations using fly ash are the primary foci of fly ash use.

Literature Review

Adrian Chajec *et al.*,(2021Use of granite powder and fly ash as supplementary cementitious material substitutes in concrete may reduce cement production's environmental impact. This paper's goal is to assess the viability of producing air-cured cementitious mortars using either granite powder or fly ash. The first step was to examine the similarities and differences between cement and these additives on the levels of morphology, chemistry, and granulometry. Afterwards, after using granite powder and fly ash, a wide variety of mortars were created. Both the cured composites and the uncured mixes were tested for their mechanical properties. Finally, a cost-benefit analysis was conducted to see whether it was beneficial to modify cementitious composites using granite powder or fly ash. With this information, we can evaluate the relative merits of using granite powder and fly ash in cement. Finally, it's important to note that all of these components may be used in the production of durable air-cured cement if done so correctly. This result has significant implications for achieving environmental benefits via reduced cement production. Possible reductions in carbon dioxide emissions might result from using greener processes in the manufacturing of cement products. Utilizing granite powder in concrete mixture mortar production might significantly reduce landfill trash.

Tatiane Santos *et al.*, (2020) The effects of using granular marble scraps instead of CP V Cement concrete were investigated. The raw materials and pastes' physical-chemical properties were described using XRD, XRF, TG/DTA, SEM, and grain - size analyses. The

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axial loading toughness, perceived density, capillary capacity, and total capacity of water absorption of pastes aged for 28, 14, and 28 days were measured. Replaced elements ranged from 0% to 30% in the various pastes. The results demonstrated that the marble waste may be utilized as a cement replacement, with the additional advantages of improved packing and a little bit of filling activity. It was estimated that yearly CO2 emissions may be reduced by 0.28 million tons if 10% of CP V Portland cement was replaced with the marble residue. The results show that this is a practical way to reduce CO2 emissions from the cement industry and put to good use marble scraps that otherwise would have been thrown away improperly.

Abhishek Jain *et al.,* (2020), We are investigating the possibility of using granite waste aggregate (GWA) instead of fine aggregates (NFA) in fly black ternary mix self-compacting cement (SCC). As a control, one of the SCC combinations was made with just portland cement (OPC), whereas the other eight SCC mixes comprised binary blends of industrial waste and GWA with varying percentages of each. The control SCC combination was made with only OPC. A battery of tests, such as slump, T500, V-funnel, J-ring, L-box, U-box, segregation resistance, bleeding, fresh density, and slump stream loss, were used to assess the unique features of the materials (with time). In the hardened stage, compression strength as well as void % were measured and analyzed. All of the SCC combinations could be safely passed, flowed, and not segregate when put under these conditions. Binary blend SCC mixes had improved residual slump (up to 50% of GWA), fresh density (and bleeding), as compared to OPC-based control SCC mixtures in all three categories. When binary mix SCC compositions containing up to 40% GWA were compared to those without, the latter demonstrated larger gains in compressive strength. The findings of this study provide support to the hypothesis that quaternary blended SCC mixes with adequate workability attributes may be created using GWA as a replacement for NFA.

Devi *et al.,* (2017) Concrete was made by replacing some of the cement with metakaolin and utilizing coarse aggregates as the fine aggregate. Tests on the durability of concrete made from a mixture of quarry dust and metakaolin show that the concrete's strength improves with age. With a replacement rate of 15%, concrete matures stronger and more corrosion-resistant than unreinforced concrete of the same age. Metakaolin is a cementing chemical that, when coupled with calcium hydroxide, reinforces the pore structure of concrete. The additional pozzolanic 34 reaction significantly improves its concrete's density and impermeability, as well as its resistance to corrosion. The addition of metakaolin to quarry dust concrete facilitates the finalization process. Quarry dust concrete with 15% metakaolin added has passed strength and durability tests, therefore it may be used for construction.

Methodology

The following flow chart describes the methodology used in the research work.

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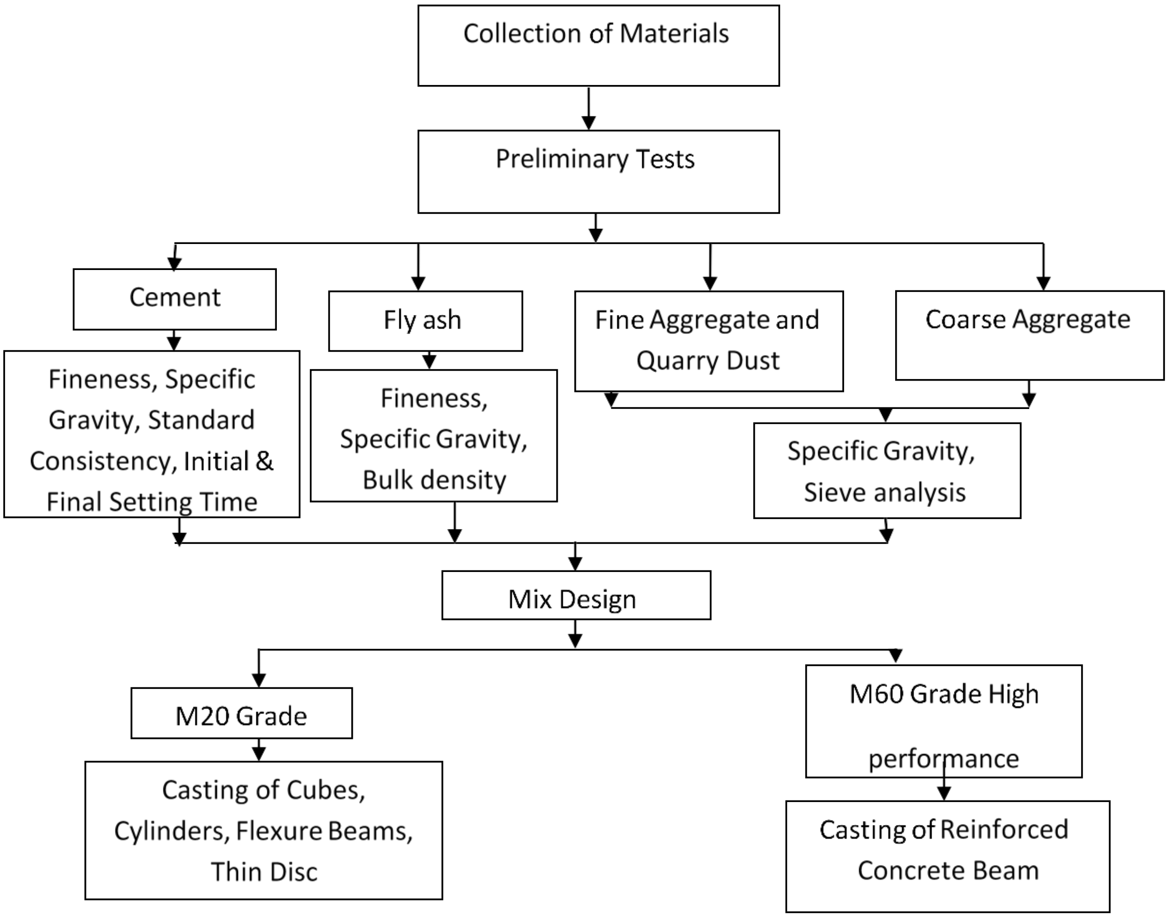

Figure 1. Flow chart for methodology

Cement

The binding material used for the concrete is Ordinary Portland cement confirming to Indian Standards IS 12269-1987 of 53 grades The properties of cement used is given in Table 1

Table. 1: Properties of cement

S.NO	PROPERTY	EXPERIMENTAL RESULTS
1	Compressive strength	53.67 N/mm^2
2	Specific Gravity	3.15
3	Initial setting time	34 Minutes
4	Final setting time	620 Minutes
5	Standard consistency	31%

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Table. 2: Properties of fly ash

PHYSICAL PROPERTIES	OBSERVATIONS	PERMISSIBLE VALUE AS PER IS 3812-1981
Specific gravity	2.07	-
Fineness	$534m^2/kg$	Shall not be less than $320m^2/kg$
Bulk Density	$1187kg/m^3$	-

Characterization of fly ash

Laboratory analysis has been used to determine fly ash's composition. In the lab, we tested the fly ash for things like its pH, electrical conductivity, moisture content, settling time, and water holding capacity. The chemical properties of fly ash were analyzed; this included the presence of oxides of elements such silicates, aluminates, iron oxide, calcium oxide, magnesium oxide, titanium oxide, etc.

Physical characteristics of fly ash

The scanning electron microscope was used to examine the size and shape of fly ash particles for the physical characteristics of fly ash. The specific dimensions were enlarged and converted to meters. SEM images revealing variations in morphology and pore size were analyzed. Secondary electron microscopy using a JEOL JSM 6360 SEM was used to investigate the nanostructures of fly ash and characterize their morphological characteristics. Several varieties of fly ash were tested using standard procedures to assess its physical properties such pH, electrical conductivity, moisture content, settling time, and water holding capacity[12-14]

pH

A digital pH meter was used to determine the pH of the fly ash leachate (Model LI 120, Elico Ltd, India). Ten grams of oven-dried fly ash was combined with one hundred milliliters of distilled water to make the sample. After continually stirring for half an hour, the pH of this solution was measured.

Moisture content

Fly ash samples were weighed to calculate their relative water content, or moisture. The value is reported as a percentage. Fifty grams of the collected fly ash were weighed in order to calculate the moisture content. This sample was kept in a dry, cool place at room temperature. Taking the fly ash samples' starting weight (Ww). After spending the night in a 90°C oven, we measured the weight (Wd) of the samples. The difference between Ww and Wd was used

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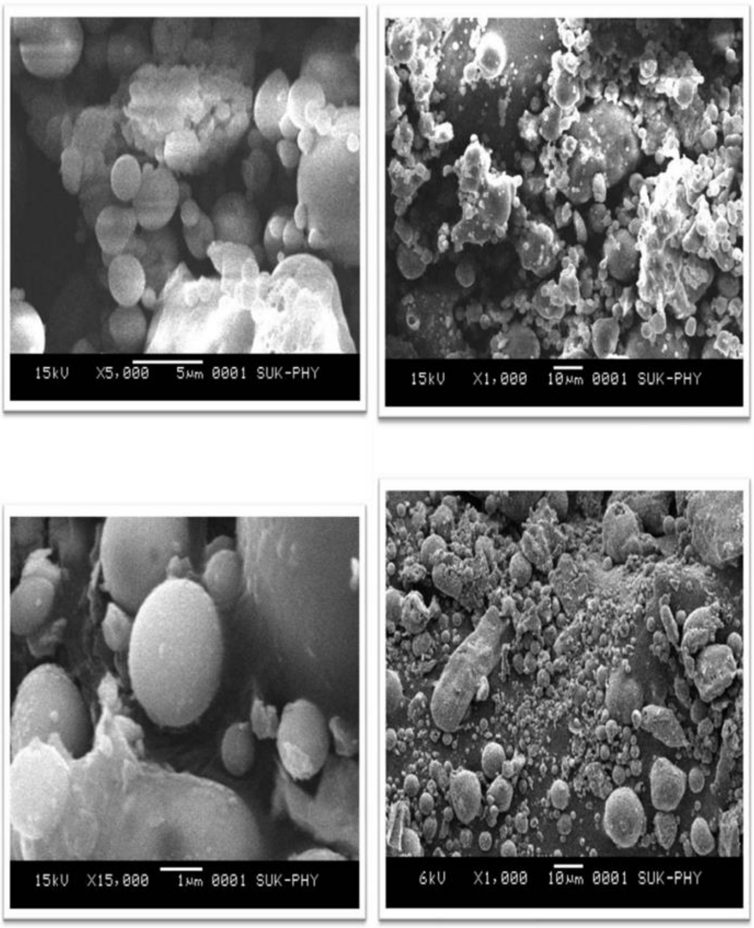
to calculate the amount of water/moisture lost due to evaporation. Percentages of moisture content were given. Fly ash samples' moisture content was determined using the following formula.

Moisture Content (%) = (Ww - Wd)/Ww x 100

The fly ash samples were collected from Parli thermal power station. The different types of ash samples such as fly ash, bottom ash and slurry or pond disposed ash were collected from the sampling site. The bottom ash was collected from the boilers and fly ash was collected from electrostatic precipitator (hoppers). The pond ash, which is dumped in ash pond in the form of slurry, was collected to study its characteristics. The samples of fly ash were stored in laboratory for the analysis and its characteristics study.

The samples were subjected to proximate analysis using X-ray diffraction (XRD) and scanning electron microscopy with energy dispersive X-ray micro analysis (SEM) for studying their shape, size and the physical appearance of ash samples. The Figure. 2 & 3 shows the details of test results of SEM for fly ash at 15v & 6kv on 10µm and 15v on 5 µm & 1µm. The different size, shapes and texture of the fly ash was observed under electron microscope[15].

Fig. 1: (SEM–Fly ash–15v & 6kv on 10µm)   Fig. 2: (SEM–Fly ash–15v on 5 µm & 1µm)



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For the study of different components present in the fly ash, the samples were subjected to XRD analysis. From the peaks the presence of different elements andtheir quantities were determined by comparing with observed standard XRD JCPDS data for known component. The X-ray diffraction graph of representative fly ash samples is given in Fig. 3.

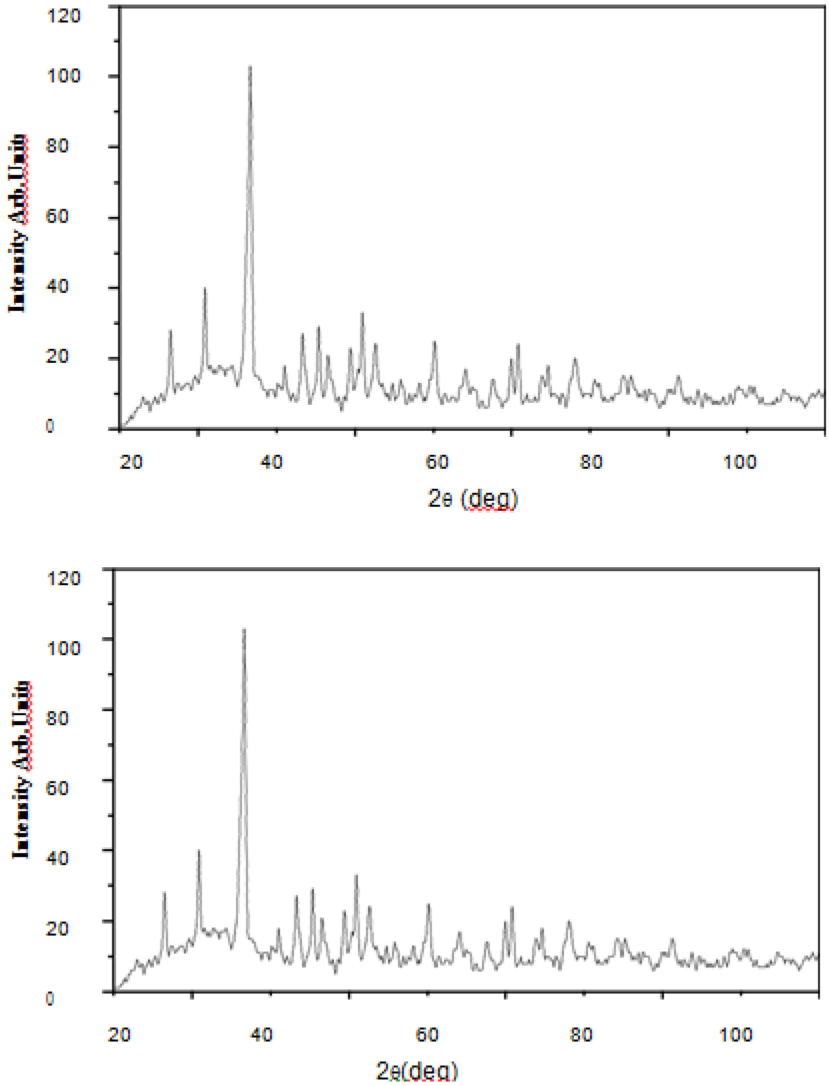

Fig. 3. XRD graphs of fly ash samples collected from thermal power plant

Chemical characteristics of fly ash

Particle size distribution, chemical make-up, and mineralogical make-up of the sample were all analyzed. Fly ash contains a variety of metals and metal oxides, some of which are poisonous or harmful and have an adverse effect on the environment. Fly ash management is improved by increased reusability and recycling thanks to improved characterisation. (Table 2)

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Table 2: Chemical components of fly ash collected from different sampling points of thermal power plant

Content	Type of fly ash		
	Bottom ash	**ESP fly ash**	**Pond ash**
SiO_2 (%)	47.2	58.3	57.7
Al_2O_3 (%)	24.9	27.4	26.4
Fe_2O_3 (%)	16.8	7.6	7.3
CaO (%)	5.3	0.9	2.4
MgO (%)	1.6	1.1	1
TiO_2 (%)	0.9	0.7	0.8
LiO (%)	1.2	1.4	1.3
K_2O (%)	1.7	2.2	2.1
Na_2O (%)	0.4	0.4	0.3
MnO (%)	0.09	0.7	0.6
P_2O_5 (%)	0.2	0.2	0.2

Flexural strength

Table 2 displays the results of two-point load tests performed on a beam made of fly ash concrete, including the loads applied and the resulting beam deflection. With 30% fly ash and quarry dust substitution, the failure load of a beam made of fly ash concrete was measured at 6.4 MPa. Flexural strength significantly deteriorated when about 30% fly ash and quarry dust were substituted in concrete.

The flexural strength, $f_b = pl/bd^2$Where,

p - load (force) at the fracture point L - length of the support (outer) spanb - width

d –thickness

Flexural strength = $11x\ 500/\ 100 \times 100^2$

= 5.5Mpa

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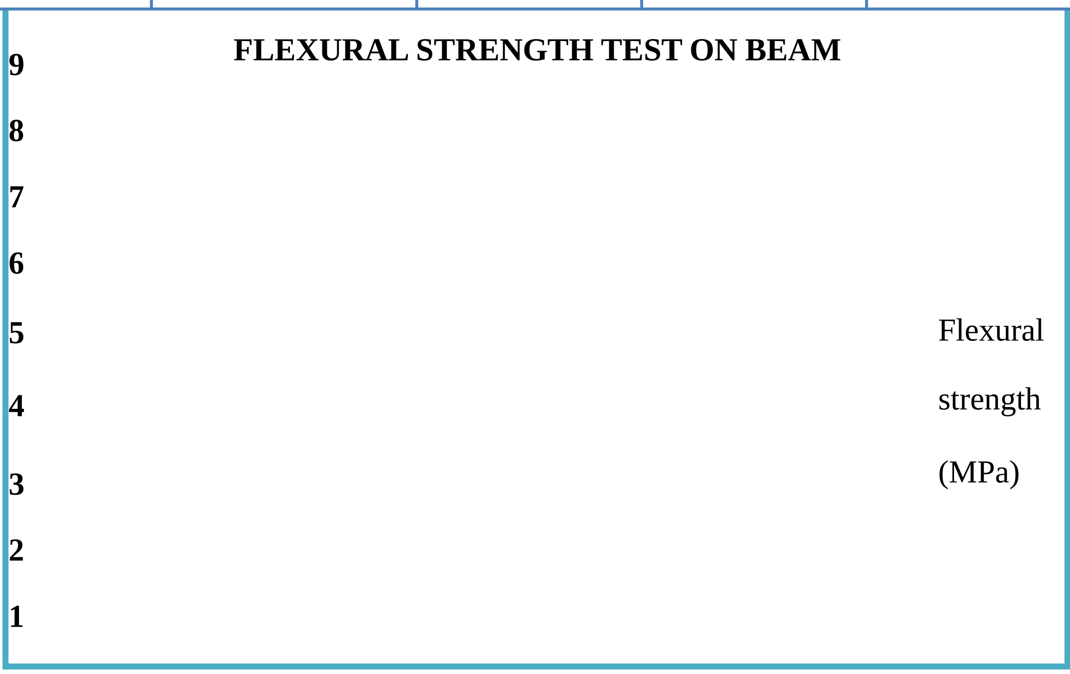
Fig. 4 Testing of fly ash & quarry dust concrete beam

Table 3: Flexural strength of fly ash & quarry dust concrete beam

FA & QD %	**Load (kN)**			**Flexural strength (MPa)**
	Trial 1	**Trial 2**	**Average**	
0	12	10	11	5.5
20	16	12	14	7.0
30	15	17	16	8.0
40	13	16	14.5	7.2
50	14	17	15.5	7.75



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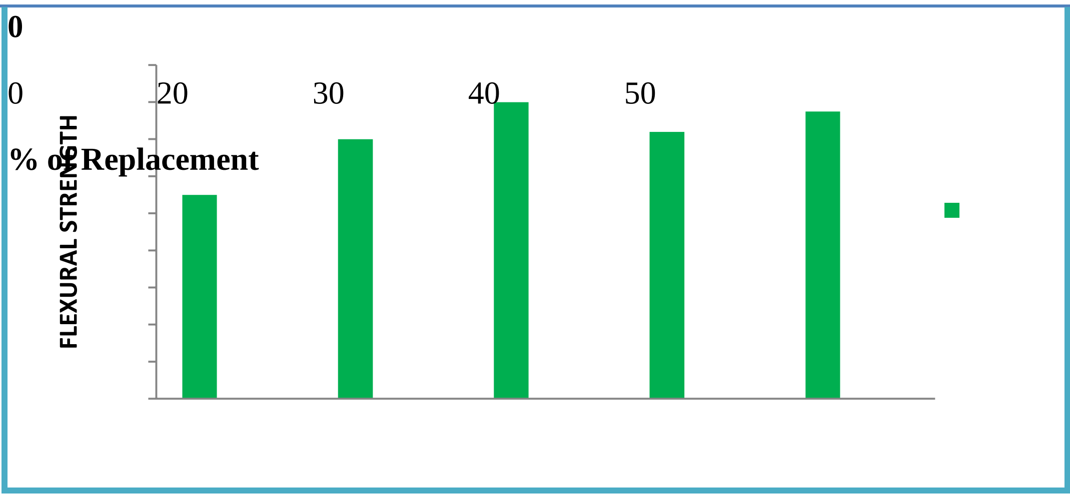

Fig.6: Flexural strength of fly ash & quarry dust concrete beam

Conclusion

Extensive testing was done for this study, and the findings were compared and reviewed critically with those found in the existing literature. Compressive strength, split tensile strength, flexural strength, and load versus deflection findings of a high-performance concrete (HPC) beam subjected to cyclic loading are among the primary attributes of concrete for which conclusions are drawn from the study.

• By comparing the XRD peaks to standard XRD JCPDS data for known components, we were able to estimate the existence and abundance of individual elements. Using JCPDS data, the existence of certain chemicals was verified by comparing the peak to the standard known component peak value..

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