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EXPERIMENTAL STUDY ON STRENTGH PROPERTIES OF CONCRETE BY FRACTIONAL REPLACEMENT OF CEMENT WITH FLY ASH & SAND WITH STONE DUST

SUBMITTED BY
NIRAJ SUBEDI
(2021255409)
UNDER THE SUPERVISION OF
Er. RAVI KUMAR
(ASSISTANT PROFESSOR)
DEPARTMENT OF CIVIL ENGINEERING
SWAMI DEVI DYAL INSTITUTE OF ENGINEERING AND TECHNOLOGYBARWALA, PANCHKULA, INDIA (134118)
KURUKSHETRA UNIVERSITY, KURUKSHETRA (2021-2023)

ABSTRACT- High-Performance Concrete (HPC) stands out in the global construction industry for its exceptional strength and durability, achieved through a precise combination of normal andspecial materials. This project centers on scrutinizing the strength properties comprising compressive strength, split tensile strength, and flexural strength of M40 grade HPC mixes. Investigation spans various replacement levels: 25%, 30%, 35%, and 40% of cement by fly ash, and 60%, 65%, 70%, 75%, and 100% of stone dust with sand. The water-binder ratio is fixed at 0.35, with a superplasticizer (BASF) enhancing workability.

The HPC mix adheresto IS: 10262-1982 and IS: 456-2000 standards, undergoing meticulous examination of mechanical characteristics like Compressive strength, Split-tensile strength, Flexural strengthwere examined. Results reveal the impact of different replacements on the mix's strength properties, emphasizing the superior characteristics attained through the replacement of 100% stone dust and 25% fly ash with 1.2% superplasticizer. This comprehensive report details the methodology, experimental setup, materials, and testing procedures, contributing valuable insights to sustainable and high-performance concrete construction by showcasing the advantages of fly ash and stone dust incorporation in specific proportions.

Key Words: High Performance Concrete, Fly Ash, M-Sand, Compressive Strength, Split Tensile, Flexural Strength, super plasticizer

1. INTRODUCTION

High-performance concrete (HPC) represents a specialized category of concrete that fulfills distinct performance and uniformity criteria beyond the capabilities of conventional constituents, mixing methods, and construction practices. Achieving HPC often requires incorporating chemical and mineral admixtures alongside standard ingredients used in regular concrete. Ongoing research endeavors focus on enhancing concrete properties, emphasizing strength, durability, and overall performance as a structural material. Various materials, such as ash, furnace slag, stone dust, and silica fume, are under scrutiny for their potential contributions to high-strength and high-performance concrete. Stone dust has emerged as a novel construction material, offering heightened strength and performance for specialized structures. The exploration of ash and stone dust gained traction initially as a pollution control measure, redirecting ash from atmospheric release. Subsequent investigations revealed their utility in concrete, presenting ash and stone dust as valuable materials for construction. In India, the utilization of improved stone dust and ash is increasingly prevalent, signifying a positive trend in sustainable construction practices.

1.1 Concrete

The large-scale manufacture of cement inevitably raises a number of environmental difficulties, and on the other, it unrestrictedly depletes natural resources. This threat to our ecology has a junction rectified to several investigations within the usage of commercial by- merchandise as supplementary cementation material in creating concrete. Another drawback in this quick-growing world is to comprehend the sturdiness and the strength of the concrete structures. High-performance concrete (HPC) has been developed over the last 20 years and was primarily introduced through personal sector study style and construction like high rises and parking garages. By mistreatment by merchandise like ash and stone dirt with superplasticizers, we can attain high-performance concrete, that possesses high workability, high strength, high modulus of snap, high density, high dimensional stability, low piousness, and resistance to chemical attack.

1.2 Objectives of this Project

This experimental study aims to assess the impact of varying degrees of replacement in concrete composition. Specifically, it focuses on substituting 25%, 30%, 35%, and 40% of cement with ash, and 60%, 65%, 70%, 75%, and 100% of sand with stone dust. The primary objective is to scrutinize the effects of these substitutions on critical strength characteristics, including compressive strength, flexural strength, and split strength. Motivated by the need to understand how changes in concrete composition, especially the use of ash and stone dust, influence its mechanical properties, the study systematically examines a range of replacement levels. The ultimate goal is to provide valuable insights into optimizing concrete formulations for enhanced strength, offering practical guidance for sustainable construction practices.

1.3 General Fly Ash

The disposal of general fly ash presents significant environmental challenges that demand urgent attention. Given its fine powder nature, fly ash can easily disperse in the air, posing threats to both air and water quality, as well as potential respiratory issues for those exposed. The prevalent practice of suspending fly ash in ash ponds near thermal plants raises long-term concerns. Firstly, the construction of these ash ponds requires extensive land, leading to a gradual reduction in available agricultural space. The continual need for new ash ponds exacerbates the loss of agricultural land, incurring substantial costs in the process. Furthermore, the conventional method of converting fly ash into suspension involves large water quantities, contributing to the risk of groundwater contamination, particularly during rainy seasons. To address these challenges, it is crucial to leverage the ample supply of fly ash for civil engineering construction, with a specific focus on pavement construction. This strategic approach not only mitigates the environmental impact associated with traditional disposal methods but also maximizes the beneficial use of fly ash in various infrastructure projects.

Fly ash, characterized by its fine powder consistency, poses environmental risks when not properly managed. The propensity of fly ash to disperse in the air raises concerns of contamination in both air and water, potentially leading to respiratory issues when inhaled. Additionally, when fly ash settles on leaves and crops in the vicinity of the power station, it can negatively impact agricultural yields. The common practice for disposing of both fly ash and bottom ash involves converting them into a suspension for containment in ash ponds near thermal plants. However, this technique gives rise to long-term issues and severe challenges, including:

The development of ash ponds necessitates vast land tracts, gradually depleting available land for agriculture over time.

Upon the filling of one ash pond, the construction of another becomes necessary, incurring substantial costs and resulting in further loss of agricultural land.

The substantial water requirements for converting ash into suspension pose a risk of leaching salts and metallic content to groundwater during rainfall, emphasizing the imperative to utilize the abundantly available fly ash for civil engineering construction, particularly in pavement construction, as a solution to mitigate the challenges associated with fly ash disposal.

1.4 Fly Ash Production and its Nature

The combustion of pulverized coal in thermal power plants results in the production of fly ash, wherein the heat transforms clay minerals in the coal powder into finely united particles, predominantly comprising aluminum silicate. This fly ash exhibits both ceramic and pozzolanic properties. Following coal combustion for heat generation, the residual ash consists of 80% fly ash and 20% bottom ash. The ash is captured by flue gas collected at economizer, air pre-heater, and clairvoyance hoppers, with clinker-type ash accumulating in the water-impounded hopper beneath the boilers, termed as bottom ash. The World Bank has warned India that by 2015, the disposal of coal ash could necessitate a thousand square kilometers or one square meter of land per person (Parisara ENVIS newsletter, 2007).

India has regarding seventy thermal power plants and coal presently accounts for seventy per cent of power production within the country. The method of coal combustion leads to fly ash. the matter with fly ash lies within the undeniable fact that not solely will its disposal need massive quantities of land, water, and energy, its fine particles, if not managed well, by virtue of their lightness, will become mobile. Currently, Brobdingnagian quantity of fly ash is being generated annually in Bharat, with sixty-five acres of land being occupied by ash ponds. Such an enormous amount will cause difficult issues, within the type of land usage, health hazards, and setting dangers. Each in disposal, similarly as in utilization, utmost care should be taken, to safeguard the interest of human life, wildlife, and environment.

The physical, geotechnical and chemical parameters to characterize fly ash area unit an equivalent as those for natural soils, e.g., relative density, grain size, Atterberg limits, compaction characteristics, permeableness constant, shear strength parameters and consolidation parameters. The properties of ash area unit a perform of many variables equivalent to coal supply, degree of pulverization, style of boiler unit, loading and firing conditions, handling and storage strategies. A modification in any of the higher than factors may end up in detectable changes within the properties of the ash made. The procedures for determination of those parameters are kind of like those for soils.

Various Indian collieries provide the coal, that is thought to own a awfully high ash content of just about forty to forty five per cent. India's thermal power plants turn out a calculable a hundred million tons of fly ash once a year. This ash has to be disposed of each day. Primarily, the fly ash is disposed of mistreatment either dry or wet disposal theme. In dry disposal, the fly ash is transported by truck, chute or conveyor at the positioning and disposed of by constructing a dry hill (dyke). In wet disposal, the fly ash is

transported as suspension through pipe and disposed of in poundage referred to as "ash pond". Most of the ability plants in Bharat use wet disposal system, and once the lagoons area unit full, four basic choices area unit available:

i. constructing new lagoons mistreatment standard construction material,
ii. truck age of fly ash from the present lagoons to a different disposal web site,
iii. raising the present dyke mistreatment standard constructional material, and
iv. Raising the dyke mistreatment fly ash excavated from the lagoon (’ash dyke’).

The option of raising the present dyke is extremely price effective as a result of any fly ash used for constructing dyke would, additionally to saving the world filling price, enhance disposal capability of the lagoon. A very important side of style of ash dykes is the internal system. The oozing discharge from internal surfaces should be controlled with filters that allow water to flee freely and additionally to carry particles in situ and therefore the piezo metric surface on the downstream of the dyke. The inner system consists of construction of rock toe, a 0.5m thick sand blanket and a sand chimney. Once the completion of the ultimate section together with earth cowl the turfing is developed from sod/grass on the downstream slope.

Several factors have obstructed fly ash utilization in Bharat, whereas it's being extensively used globally. Coal-based thermal power stations are operational for over fifty years, however the idea of developing friendly solutions for fly ash utilization is merely regarding fifteen years previously. Overall fly ash utilization in Bharat stands at a reasonably low level of regarding fifteen per cent of the number generated. Varied prospects for its use area unit underneath analysis. Among varied factors that account for the low level of utilization, the chief factors are:

i. Poor understanding of the chemistry of fly ash and its derivatives for correct finish applications
ii. Absence of standards and specifications for fly ash products
iii. Lack of reliable quality assurance for fly ash products,
iv. Poor public awareness regarding the product and their performance,
v. Non-availability of dry fly ash assortment facilities,
vi. Straightforward accessibility of land with prime soil at low-cost rates, for producing standard bricks, and
vii. Lack of correct coordination between thermal plants and ash users.

The designing, style and construction of ash disposal facility need the combination of geotechnical, environmental, hydrological engineering and different governing factors though the works of diverse researchers within the past have helped in rising understanding of the useful use of ash in cement concrete, brick producing and different applications, however a comprehensive plan regarding geotechnical aspects of ash –gravelly sand mixtures for varied engineering applications particularly for pavement construction haven't nonetheless understood.

In this study, a shot is being created within the laboratory to grasp the behavior of fly ash gravelly sand mixtures to utilize fly ash within the pavement construction. The strength, lightweight and changed compaction, cosmic background radiation tests were conducted on the fly ash gravelly sand mixtures. The fly ash proportions adopted within the study area unit 5%, 10%, 15%, two hundredth and twenty fifth by dry weight of soil. Researchers have disbursed studies towards utilization of fly ash for varied engineering applications for 3 decades. A number of the studies conferred within the type of articles in conferences, journals, and within the type of reports within the recent past area unit reviewed recognize to grasp and know the extent of analysis work disbursed regarding utilization of fly ash.

1.5 Quarry Stone Dust

Concretely from natural stone mining and processing industries generate huge amounts of waste that continuously accumulate in open landfills and create unresolved environmental problems. The global natural stone industry provides an annual output of 68 million tons of processed products (dust or slurry). In 2006, the European Union alone accounted for 39.2% of the total amount, ranking first in this sector, followed by Asia with a sizable share of 37% belonging to China and India.

Quarry dust is an industrial byproduct. It is formed by screening the products of secondary and subsequent crushing of igneous rocks, sedimentary rocks, or gravels. It can be classified according to particle size from 0 to 4.75 mm. Currently, a large amount of quarry dust is generated in natural stone processing factories.

Quarry stone dust is inexpensive and widely available worldwide. It is formed from waste crushed stone (gravel) products in crushing plants. Mine dust generated in industrial plants is reused as a component of concrete mixtures without prior treatment. Stone dust generated from crushing plants is cheap and widely available. It is made up of fine waste of crushed products from stone (gravel) quarries.

1.6 Advantages of the Fiber Reinforced Concrete

Granular deposits are increasingly depleted, especially in high-demand areas such as urban areas. Therefore, it is necessary to find other synthetic sources. One source is hard rock, which is mined and crushed. Coarse and fine aggregates can be produced from hard rock quarries. Stone crushing methods and techniques as well as the nature of the stone determine the quality and properties of the product. In particular, particle shape can be positively or negatively affected by crushing, which is even more important for crushed sand because they strongly influence the plastic properties of concrete. The shape can often be reduced through the use of appropriate pressing techniques.

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At the time of chip grinding, fine particles are removed in aggregate mills through the use of feed circuits, corrugated grinding surfaces, and low reduction speeds. However, in impact crushers, well-shaped aggregates can be produced even at high reduction rates. Types of crushing equipment are jaw crushers, roller crushers, disc or gyratory crushers, cone crushers, bar crushers, and impact crushers such as horizontal impactors (e.g. hammer mills) or vertical mills. Modern equipment such as gyratory mills, cone mills, and rod mills tend to produce better particle shapes. Washing and scrubbing may also be necessary for crushed aggregates.

2. LITERATURE REVIEW

Miller, et al. (1980)[1] investigated the utilization of Cement Kiln Dust (CKD) and fly ash as key constituents in developing pozzolanic bases, aiming to achieve comparable properties to those of a stabilized base. The study recognized the potential of these materials in enhancing the strength and durability of the bases. However, it emphasized the necessity for a thorough evaluation of specific CKD-fly ash combinations, underscoring the importance of analyzing chemical and strength test data to ascertain the optimum properties for an appropriate mix design. This insight highlights the nuanced approach required for utilizing CKD and fly ash effectively in the development of pozzolanic bases, emphasizing the need for tailored material assessments to achieve optimal outcomes.

Rajamane et al. (2008) [2] demonstrated that the incorporation of fly ash enhances compressive strength while improving durability. The pozzolanic reaction between fly ash and calcium hydroxide contributes to the formation of additional cementitious compounds, positively impacting concrete properties.

Gupta et al. (2013) [3] have addressed the economic and environmental aspects of using fly ash and stone dust in concrete. The research explored the cost-effectiveness and environmental benefits,considering the reduction in cement consumption and waste utilization.

Pan et al. (2016)[4] Their study delved into aspects such as setting time and early-age strength development, providing a comprehensive understanding of the behavior of these materials in the initial stages of concrete formation.

Li et al. (2019) [5] investigated the impact of superplasticizers on strength characteristics. Their study revealed that the use of superplasticizers, such as BASF, improved workability and ultimately enhanced the compressive, split-tensile, and flexural strengths of concrete mixes.

Collins et al. (1983) [6] conducted a study highlighting the efficacy of substituting Cement Kiln Dust (CKD) for lime in various lime-fly ash-sand combination systems for molding construction. The research demonstrated that the majority of the CKD-treated fly ash and combination mixtures yielded materials with properties comparable to those of traditional lime-fly ash-aggregate mixtures. These properties encompass strength, durability, dimensional stability, and other engineering characteristics. The findings underscore the potential of CKD as a viable alternative to lime in developing construction materials, particularly in combination with fly ash and sand. This study contributes valuable insights to the broader literature on using industrial by-products in construction, emphasizing the importance of evaluating alternative materials for their engineering properties and performance in specific applications.

Barnes et al. (1997) [7] conducted studies on the influence of metallic element activators on cosmic background radiation and unconfined compressive strength of hydrous fly ash and conditioned fly ash. A matter of ten raw fly ash was shown to extend cosmic background radiation values up to one hundred and tenth, and a 2.5% lime addition made cosmic background radiation values over two hundredths. check results show that unconfined compressive strengths for HFA and CFA materials area units are usually between fifty and a hundred psi once seven days, and step-by-step increase at fifty-six days because of pozzolanic reactions (Barnes 1997). HFA and CFA mixtures with ten raw fly ash and a pair of.5% lime has shown compressive strength that will increase the maximum amount to three hundredths and 700% bigger than those of untreated material, severally.

Tahir et al. (2017) [8] emphasize the utilization of stone dust as a substitute for fine aggregate in concrete production. Their research underscored the potential of stone dust as an eco-friendly alternative to sand, contributing to sustainable concrete manufacturing practices. The findings revealed that the incorporation of stone dust instead of sand positively impacted the compressive and flexural strengths of the resulting concrete. This implies that the replacement of fine aggregate with stone dust could be a viable strategy for enhancing the mechanical properties of concrete, aligning with the broader goals of sustainable and environmentally conscious construction. The study contributes valuable insights to the literature on alternative materials in concrete production, providing a foundation for further exploration and application of stone dust in construction practices.

Paige-Green et al. (1998) [9] reported that usually, a minimum of three to five percent of lime stabilizer is critical to achieve a major increase within the compressive strength. Though the utilization of lime stabilization is widespread, the reportable performance of the technique is usually variable.

Babu et al. (1997) [10] have tested a series of three various fine aggregate substitutes quarry stone dust, and beach sand. From his study, the basic compressive stresses were arrived at by prism tests, for a mortar proportion of 1:6. His results do not agree with the code provision to some extent.

Narasimhan et al. (1999)[11] have reported that concrete mixtures could be designed by using quarry rock dust as fine aggregate, targeting strengths above 5 MPa greater than specified characteristic strengths.

Sahu et al. (2003)[12] have found that there is a significant increase in compressive strength, modulus of rupture, and split tensile strength for both concrete mixtures when sand is partially replaced by quarry rock dust. The workability of the concrete mixtures decreased with an increase in the percentage of quarry rock dust as a partial replacement of sand.

Prakash Rao et al. (2004)[13] reviewed the concrete cubes/prisms with crusher dust concrete which indicates 17 percent higher strength in compression, 7 percent more in split tensile strength, and 20 percent more flexural strength (Modules of rupture) than the concrete cubes/prisms with river sand as fine aggregates. The differences in strength are possible due to the sharp edges of stone dust providing a stronger bond with cement compared to the rounded shape of river sand.

Nagaraj et al. (1996)[14] have reported that due to its higher surface area quarry stone dust consumes more cement when it is compared with sand. Quarry stone dust and sand mixture reflect the same concrete strength in the hardened state. Thus enhancing the utilization of quarry rock dust will be more effective.

Nisnevich et al. (2003)[15] have reported that in lightweight concrete replacements of bottom ash with quarry rock dust close to 50 percent were achieved with increased strength and reduction in the activity of concentrations of radionuclides. And also shows that quarry rock dust indicates a high volume of voids: i.e., 42.4 to 50.0% (in standard natural sand it is varied in the range of 36-40%). The volume of voids is 6 to 8 % higher for quarry stone dust.

3. EXPERIMENTAL INVESTIGATIONS

3.1 General

Concrete is a fundamental material in construction which is integral to modern infrastructure but poses significant environmental challenges due to its high greenhouse gas emissions from cement production and the ecological disruption caused by excessive sand extraction. This study addresses these issues by exploring the partial replacement of cement with fly ash—a by-product of coal combustion—and the substitution of natural sand with stone dust, a by-product of stone crushing. By leveraging these industrial by-products, the research aims to create eco-friendly, durable concrete with enhanced mechanical properties. Methodology involves preparing concrete mixes with varied replacement levels, conducting comprehensive tests (workability, compressive strength, split tensile strength, flexural strength), and evaluating durability to ensure long-term performance. The findings promote sustainable construction practices, resource efficiency, and cost-effectiveness, highlighting the potential for widespread adoption of green concrete technologies.The materials used and therefore the tests conducted on the materials area unit conferred within the following sections.

3.2 Materials

3.2.1 Cement

Ordinary Portland Cement (OPC) is the primary binding material used in this study, recognized for its high compressive strength and durability. It is produced by heating a mixture of limestone and clay to create clinker, which is then ground with gypsum. OPC comes in different grades, with the most common being OPC 33, OPC 43, and OPC 53, classified according to their 28-day compressive strength. In concrete, OPC serves as the main binder, initiating hydration reactions when mixed with water. This process leads to the formation of calcium silicate hydrate, which provides strength and durability to the concrete. Furthermore, OPC is compatible with various admixtures and supplementary cementitious materials, such as fly ash, enhancing the overall performance and sustainability of concrete. The varied basic property of cement is conferred within Table 3.1.

Table. 3.1 Basic Physical Properties of cement employed in the Study

Property	Description	Typical Value
Specific Gravity	Ratio of cement density to the density of water	3.15
Density	Mass per unit volume	1440 kg/m³
Fineness	Measure of particle size (surface area per unit weight)	225-325 m²/kg
Consistency	Amount of water required to form a standard paste	26-33% by weight of cement
Setting Time	Time required for the cement paste to start and finish setting	Initial: ≥ 30 minutes; Final: ≤ 600 minutes
Soundness	Ability to retain volume after setting	Determined by Le Chatelier test
Heat of Hydration	Heat generated during the hydration process	85-100 J/g after 7 days
Compressive Strength	Ability to withstand axial loads	3days: ~23MPa. 7days: ~33MPa. 28days: ~43MPa (OPC 43)
Bulk Density	Mass per unit volume including air between particles	830-1650 kg/m³ depending on compaction

3.2.2 Coarse Aggregate

Coarse aggregates are essential components in concrete that provide bulk, strength, and stability to the mixture. In this research, crushed granite or similar types of coarse aggregates are used. These aggregates are sourced from natural rock deposits and are processed to meet specific size and quality requirements. Typically ranging from 10 mm to 20 mm in diameter, coarse aggregates should ideally be angular to provide better interlocking and load-bearing capacity. High-density aggregates contribute significantly to the overall strength and durability of the concrete and must be resistant to weathering, chemical attack, and wear. They provide the primary structural framework for concrete, helping to bear loads and distribute stress, while also occupying a significant portion of

the concrete volume to reduce shrinkage and potential cracking. High-quality coarse aggregates improve compressive, tensile, and flexural strength and, although they do not significantly affect the workability of fresh concrete, their size and shape can influence the ease of mixing and placement.

3.2.3 Fine aggregate

Fine aggregates, including natural river sand and stone dust, enhance workability and improve the mechanical properties of the concrete. Natural river sand, sourced from riverbeds, offers smooth, rounded particles that contribute to the cohesion and stability of the mix. At the same time, stone dust, a by-product of stone crushing, provides a finer texture that enhances density and strength, reducing environmental impact using industrial by-products. This study aims to develop eco-friendly, durable concrete by integrating these aggregates, promoting sustainability in construction while meeting structural requirements through optimal mechanical properties. Stone dust replaces a portion of fine aggregate, improving packing density and reducing voids.

3.2.4 Quarry Dust

Quarry dust, a by-product of crushing rocks, is utilized in this research as a fine aggregate to partially or fully replace natural river sand. It is sourced from the crushing process and consists of fine, angular particles that enhance the interlocking capability within the concrete mix, providing bulk, strength, and stability. The physical properties of quarry dust, including particle size distribution, specific gravity, bulk density, fineness modulus, and moisture content, are confirmed to meet the standards in IS 2386-3 (1963). These properties ensure the production of high-quality, high-strength concrete by improving workability, compressive strength, and durability. By adhering to these standards, quarry dust not only enhances the mechanical properties of concrete but also promotes sustainability through the utilization of industrial by-products, thereby reducing environmental impact. This alternative fine aggregate plays a crucial role in developing eco-friendly, durable concrete that meets structural requirements.

$$\text{Sand Replacement percentage} = \frac{\text{Weight of stone dust}}{\text{Weight of sand+weight of stone dust}} * 100$$

Table. 3.2: Physical properties of quarry dust

Physical Properties	Observations
Specific Gravity	2.60
Absorptions	1.3%
Bulk Density	1750 Kg/m3
Sieve Analysis	Zone II

3.2.5 Super Plasticizer

Conplast SP 430 is a high-range water-reducing admixture used concretely to achieve the desired slump and workability with a lower water-cement ratio. This type of admixture allows concrete to maintain its fluidity and ease of placement without compromising strength and durability. By reducing the amount of water needed, Conplast SP 430 enhances the overall quality of the concrete, leading to improved compaction, reduced porosity, and higher strength. It complies with international standards, specifically BS 5075 Part 3 and ASTM C494 as Type A (water-reducing) and Type F (high-range water-reducing), ensuring its effectiveness and reliability in various construction applications. This makes it an essential component in producing high-performance concrete mixes that are both workable and durable.

Table. 3.3: Physical properties of super plasticizer

Properties	Observations
Appearance	Brown liquid
Specific Gravity	Typically, 1.20 at 20ºC
Chloride Content	Nil to BS 5075
Air entrainment	Typically, <2% additional air is entrained at normal dosages
Alkali content	Typically, < 72.0 g. Na2O equivalent/liter of admixture

3.2.6 Water

In concrete mix design, water plays a critical role in determining both the workability and strength of the concrete. Water is essential for the hydration process of cement, which is the chemical reaction that enables the cement to bind with the aggregates and harden. The amount of water used in the mix affects the concrete's workability; too little water can make the mix stiff and difficult to work with, while too much water can weaken the concrete and reduce its durability. The water-cement ratio (w/c) is a key parameter that balances these aspects, typically ranging from 0.4 to 0.6 for most concrete mixes. For high-performance concrete, a lower w/c ratio is often desired to achieve higher strength, and admixtures like superplasticizers are used to maintain workability with minimal water content. Proper water management ensures that the concrete achieves the desired mechanical properties and longevity.

3.2.7 Fly Ash Used

Fly ash is a pozzolanic material that reacts with calcium hydroxide in cement to produce additional calcium silicate hydrate (C-S-H), which enhances strength and durability. The fly ash sample collected was held on within the air-tight containers. The fly ash proportions adopted within the study, by dry weight of cement, are 5%, 10%, 15%, 20%, and 25%. These proportions were selected to evaluate the impact of fly ash on the concrete's mechanical properties and durability. The varied properties of the fly ash obtained from the VTPS area unit are conferred within Tables 3.4 and 3.5.

The partial replacement is expressed as:

$$\text{Cement Replacement Percentage}=\frac{\text{weight of Fly ash}}{\text{weight of cement+weight of fly ash}} * 100$$

Table. 3.4: Physical properties of Fly Ash

Physical properties	Observations	Permissible values as per IS 3812-1981
Specific Gravity	2.07	-
Fineness	534m2/kg	Shall not be less then 320m2/kg
Bulk Density	1187kg/m3	-

Table 3.5. Chemical Properties of Fly ash employed in the Study

Content of the Component	Value
% SiO2	60.5
% Al2O3	30.8
% Fe2O3	3.6
% CaO	1.4
% MgO	0.91
% SO3	0.14
% K2O+Na2O	1.1
Loss of ignition (LOI)	0.8
Specific surface area, m2/kg	338
Lime reactivity, N/mm2	6.2

3.3 Concrete Mix Proportion

The high-performance concrete was designed for the casting of specimens. The method proposed in guidelines ACI 211.4R is used for the mix design to ensure it meets the high standards required for structural applications. The mix proportions were tabulated in Table 3.6.

Table 3.6. Mix Proportion

Mix	Cement (kg)	Fine aggregate (kg)	Coarse aggregate (kg)	Water (kg)	Super plasticizer (l)
M60	493	576	1170	158	4.93
M40	400	620	1120	160	4
M20	361.50	595	1176	191.60	-

3.4 Casting of Specimen

Concrete specimens were cast for various percentage replacements, to perform the compressive strength test. 100 cubes were cast with dimensions 150 X 150 X 150 mm. To perform a split tensile strength test, 70 cylinders were cast with a diameter of 150mm and a height of 300mm. To perform the flexural strength test, 20 beams were cast with dimensions 100 X 100 X 500 mm. To test HPC beams under cyclic loading, nine numbers of R.C.C beams were cast with dimensions 1800 X 225 X 150 mm.

Table 3.7. Description of specimens

Test Detail	Detail of specimens
Compressive Strength	Cube:150*150*150mm
Flexural Strength	Beam: 100*100*500
RC beam Under Cyclic Loading	Beam:1800*225*150mm

3.5 Curing of specimens

The prepared specimens were subjected to a curing period of 28 days before undergoing testing. Cube, cylinder, and small beam specimens were immersed in a curing tank for the entire duration. R.C.C. beams were kept moist for 28 days by wrapping them with jute bags to maintain adequate hydration.

3.6 Tests Conducted

The following tests were performed to obtain the properties of hardened concrete:

i. Strength test on concrete
ii. Durability tests on concrete
iii. NDT tests on concrete
iv. Cycling loading test on high performance concrete beam

3.6.1 Strength Test on Concrete

(a) Compressive Strength Test

A total of 100 cube specimens, each measuring 150 mm × 150 mm × 150 mm, were cast for concrete mixes with replacement levels of 0%, 20%, 30%, 40%, and 50%. These specimens were cured and tested for compressive strength by IS: 1343-1980. Compressive strength test is performed using a Universal Testing Machine (UTM). The compressive strength of each specimen was determined using the formula:

$$\text{Compressive Strength} = \frac{\text{Load}}{\text{Area of cube}}$$

(b) Split Tensile Strength Test

The split tensile strength test is performed to measure the tensile capacity of concrete. Cylindrical specimens are placed horizontally in a compression testing machine, and a load is applied along the diameter until the specimen splits. This test, conducted as per IS 5816:1999, helps determine concrete tensile properties, which are essential for resisting cracking under tension.

(c) Flexural strength test

The flexural strength test evaluates the ability of concrete to withstand bending or flexural loads, simulating the behavior of beams and slabs in structures. Typically sized 100 mm × 100 mm × 500 mm, Beam specimens are subjected to two-point loading in a flexural testing machine until failure occurs. The flexural strength is calculated based on the load at failure, as defined by IS 516 (Part 1):2021. Together, these strength tests provide comprehensive data to ensure concrete meets the required safe and efficient construction standards.

3.6.2 Durability Tests on Concrete

(a) Chemical Exposure to Hydrochloric Acid

Chloride attack significantly impacts the durability of concrete, with around 40% of corrosion failures in reinforced concrete attributed to chloride-induced damage, primarily affecting steel reinforcement through accelerated corrosion. The Bureau of Indian Standards (BIS) permits a maximum chloride content of 0.05% in cement, recently revised to 0.1%. To evaluate durability, concrete cubes with fly ash and quarry dust were cured in water for 28 days, then immersed in 5% sulfuric acid (H_2SO_4) and 5% hydrochloric acid (HCl) solutions for 90 days. After this exposure, the cubes were weighed, and the percentage weight loss was calculated, providing insights into the resistance of the modified concrete to chemical attacks.

(b) Chemical Exposure Sulphate Solutions

A sulphate attack occurs when sulphates in a solution react with the hydration products of cement, causing an expansion in the cement paste and leading to gradual deterioration of the concrete. This reaction can result in a volume increase of up to 227%. In this investigation, fly ash concrete cubes were cured in potable water for 28 days. After curing, the specimens were immersed in a 10% sodium sulphate solution for 90 days. Following this exposure period, the specimens were removed, and durability factors were assessed to determine the impact of sulphate attack on the concrete's performance.

(c) Chemical exposure sulphuric acid solution

The presence of sulphate ions contributes to the corrosion of steel reinforcement in concrete, with the severity depending on the alkalinity of the cement. In this study, fly ash concrete cubes were initially cured in potable water for 28 days. After this, the specimens were immersed in a 3% sulfuric acid (H_2SO_4) solution for 90 days, with the solution's pH level carefully maintained at 3 throughout the curing period. Upon completion of the chemical exposure, the specimens were weighed, and the percentage loss in weight was calculated to evaluate the impact of sulphate-induced deterioration. This analysis provides insights into the concrete's resistance to acidic environments, highlighting its potential durability in aggressive conditions.

(d) Chemical Exposure NaCl solution

Salt attacks are a significant factor leading to the deterioration of concrete, primarily due to the presence of salts in water. In this study, fly ash concrete cubes were initially cured in water for 28 days. Following this curing period, the specimens were submerged in a 5% sodium chloride (NaCl) solution for 90 days to simulate exposure to salt. After the chemical curing period was complete, the weight and strength of the concrete specimens were measured. The extent of concrete degradation was then calculated as a percentage, providing insights into the material's resistance to damage caused by salt.

3.6.3 NDT Test on Concrete

Non-Destructive Testing (NDT) is an essential method used to evaluate the properties of concrete structures without causing damage or altering their usability. These techniques are particularly valuable for assessing the condition of existing structures, monitoring construction quality, and ensuring compliance with design specifications. NDT methods provide critical information about the strength, durability, and internal condition of concrete, enabling timely maintenance and extending the service life of structures. Common NDT method for concrete are as follows.

(a) Rebound Hammer Test (Schmidt Hammer Test)

The Rebound Hammer Test, also known as the Schmidt Hammer Test, is a non-destructive method used to assess the surface hardness of concrete and estimate its compressive strength. In this test, a spring-controlled hammer strikes the concrete surface, and the rebound distance, known as the rebound index, is measured. Higher rebound values indicate greater surface hardness and higher compressive strength. The compressive strength (fc) is calculated using the formula fc=k×rebound index, where k is a correlation factor obtained from calibration against concrete specimens of known strength. This test is quick, economical, and widely used for quality control and in-situ evaluation of concrete without causing damage to the structure. To ensure accuracy, measurements are taken at multiple points, and the test is conducted on clean, dry surfaces.

(b) Ultrasonic Pulse Velocity (UPV)

Ultrasonic Pulse Velocity (UPV) is a non-destructive testing technique that measures the velocity of ultrasonic waves passing through concrete, helping to assess its uniformity, integrity, and internal quality. By sending high-frequency sound waves through the concrete and measuring the time it takes for them to travel, UPV can detect internal defects such as cracks, voids, or delamination's. The speed of the waves is influenced by the concrete's density and elasticity, which are linked to its overall strength. This method is useful for evaluating the homogeneity of concrete and indirectly estimating its compressive strength, making it valuable for quality control and structural assessment.

(c) Penetration Resistance Test

The Penetration Resistance Test is a non-destructive method that evaluates the resistance of concrete to penetration by a probe, which indicates the concrete's compressive strength. The test involves driving a probe into the surface of the concrete, and the depth of penetration is directly related to the concrete's strength—greater resistance to penetration indicates higher strength. This method is particularly useful for assessing surface hardness and identifying variations in concrete quality at different depths, which can be crucial for detecting issues such as surface deterioration or weak zones in the concrete. Additionally, it is a quick, cost-effective method often used in field applications to evaluate the quality of concrete without causing damage.

(d) Resistivity Test

The Resistivity Test measures the electrical resistivity of concrete, which is a key indicator of its durability, especially regarding the likelihood of corrosion in reinforced concrete. Concrete's resistivity is influenced by factors such as moisture content, porosity, and the presence of soluble ions, particularly chlorides, which contribute to corrosion. Higher resistivity indicates better resistance to corrosion. This test is essential for assessing the chloride resistance of concrete and predicting the potential for reinforcement corrosion, which is a significant concern for the longevity and safety of reinforced concrete structures. It is a non-destructive, cost-effective method widely used for evaluating the long-term durability of concrete, particularly in environments exposed to aggressive conditions like marine or de-icing salt exposure.

(e) Impact Echo Test

The Impact Echo Test is a non-destructive testing method that uses stress waves generated by a brief impact to detect internal flaws in concrete, such as cracks, voids, or delamination. When the stress waves encounter any irregularities within the material, they are reflected to the surface, and the time taken for the waves to return is analyzed to detect these defects. The test can be used to measure the thickness of concrete structures. This method is particularly effective for assessing internal defects and evaluating the quality of concrete in thicker sections, providing valuable insights into the structural integrity of the concrete without causing any damage.

4. EXPERIMENTAL RESULTS & DISCUSSIONS

4.1 General

The primary aim of this research is to investigate the effects of partially replacing cement with fly ash and natural river sand with stone dust on the strength properties of concrete. By substituting these sustainable materials, the study explores potential improvements in mechanical properties such as compressive, tensile, and flexural strengths while promoting eco-friendly and cost-effective construction practices. Various concrete mixes with different proportions of fly ash and stone dust are prepared, with superplasticizers used to maintain workability despite lower water-cement ratios. The research includes comprehensive testing, such as compressive strength tests, split tensile strength tests, and flexural strength tests. Results indicate significant enhancements in strength and durability, supporting the use of fly ash and stone dust as viable alternatives to traditional materials, contributing to more sustainable and economical concrete production. This study highlights the importance of using industrial by-products to reduce environmental impact while achieving high-performance concrete for construction applications.

4.2 Mix Design of M40 Mix Concrete by IS Method

Table 4.1 Design stipulations:

Characteristic compressive strength required in the field at 28 days.	40 MPa
Maximum size of aggregate	20 mm (angular)
Degree of quality control	Good

Type of Exposure	Mild

Table 4.2 Test data for Materials:

Specific gravity of cement	3.15
Compressive strength of cement at 7 days	Satisfies the requirement of IS: 269 – 1989
1. Specific gravity of coarse aggregates	2.60
2. Specific gravity of fine aggregates	2.60
Water absorption:	
1. Coarse aggregate	1.0%
2. Fine aggregate	1.0%
Free (surface) moisture:	
1. Coarse aggregate	Nil
2. Fine aggregate	2.0%

Actual quantities required for the mix per bag of cement:
The mix is 0.40: 1: 1.14: 2.49.
For 50 kg of cement, the quantities of materials are worked out as below:
Cement = 50 kg
Sand = 57 kg
Coarse aggregate = 124.5 kg
Water:
for w/c ratio of 0.40, quantity = 20 litres of water
Extra quantity of water to be added for absorption in case of CA, at
0.5 per cent mass = 0.62 litres
Quantity of water to be deducted for moisture present in sand, at 2 per cent by mass = 1.14 litres.
d) Actual quantity of water required to be added = 20 + 0.62 – 1.14
= 19.48 litres
Actual quantity of sand required after allowing for mass of free moisture = 57 + 1.14
= 58.14 kg
Therefore, the actual quantities of different constituents required for one bag mix are: Water : 19.48 litres
Cement : 50.00 kg
Sand : 58.14 kg Coarse Aggregates: 124.5 kg

4.3 Casting and Testing of Concrete Cubes for Compressive Strength

Cubes of concrete should be cast for every shift of concreting work to estimate the strength of concrete. Concrete for filling the cubes should be taken from the middle discharge of concrete mixer. Concrete from beginning or at the end of discharge should be avoided. Cubes should be filled in 3 equal layers. Each layer should be uniformly tamped at least 35 times with a16mm blunt rod. The tamping should be done so that the rod penetrates through the layer up to the lower layer. Cubes should be properly levelled and finished using hand trowel. Cubes should be kept in shadow and properly covered with wet gunny bags. Cubes should be de-moulded after 24 hours and immersed in water for curing. It is important to keep the cubes away from the shocks or vibrations, especially for the initial 3 days of casting. We recommend that a minimum of 6 cubes should be taken every day and the batch of 3 cubes be tested for 7 days, 28 days, 56 days and 90 days respectively. As per IS 456 -2000, the minimum frequency of sampling is as follows: -

Vol of concrete Number of samples

75 cube specimens and some more cubes are required additional for each specimen of 50m3volume. Three test specimens shall be made for each sample for testing at 7days, 14 days, 28 days, 56 days, 90days. If 3 and 7day strengths are required, additional samples should be taken, over and above mentioned in the frequency of sampling.



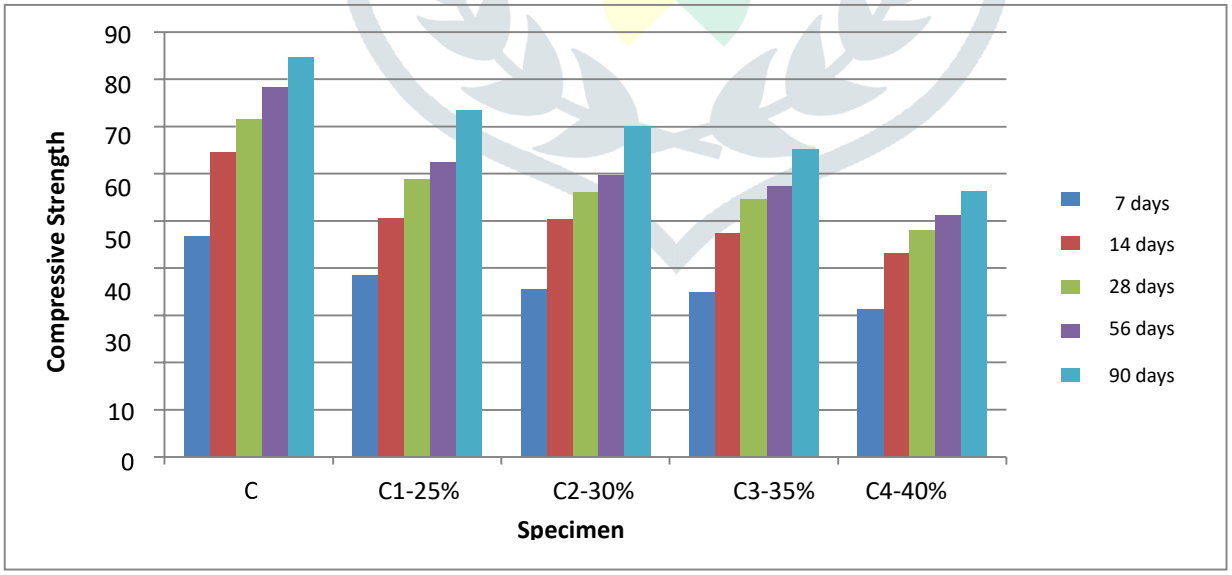
Fig 4.1 Casting of Cubes

4.4 Compression Strength Test

After 7 days, 14 days, 28 days, 56 days and 90 days of curing, three 150mm cubes of a concrete mixture were tested using the compression machine. These cubes were loaded on their sides during compression testing such that the load was exerted perpendicularly to the direction of casting. The average value of the three cubes was taken as the compressive strength.

Table 4.3 Compressive strength (N/mm2) values with different replacement levels of fly ash

S.N.	Specimen	7 Days	14 Days	28 Days	56 Days	90 Days
1	C	46.76	64.66	71.48	78.23	84.51
2	C1-25%	38.45	50.59	58.80	62.36	73.54
3	C2-30%	35.54	50.32	56.0	59.78	69.96
4	C3-35%	34.79	47.44	54.71	57.36	65.19
5	C4-40%	31.2	43.2	48.00	51.23	56.32



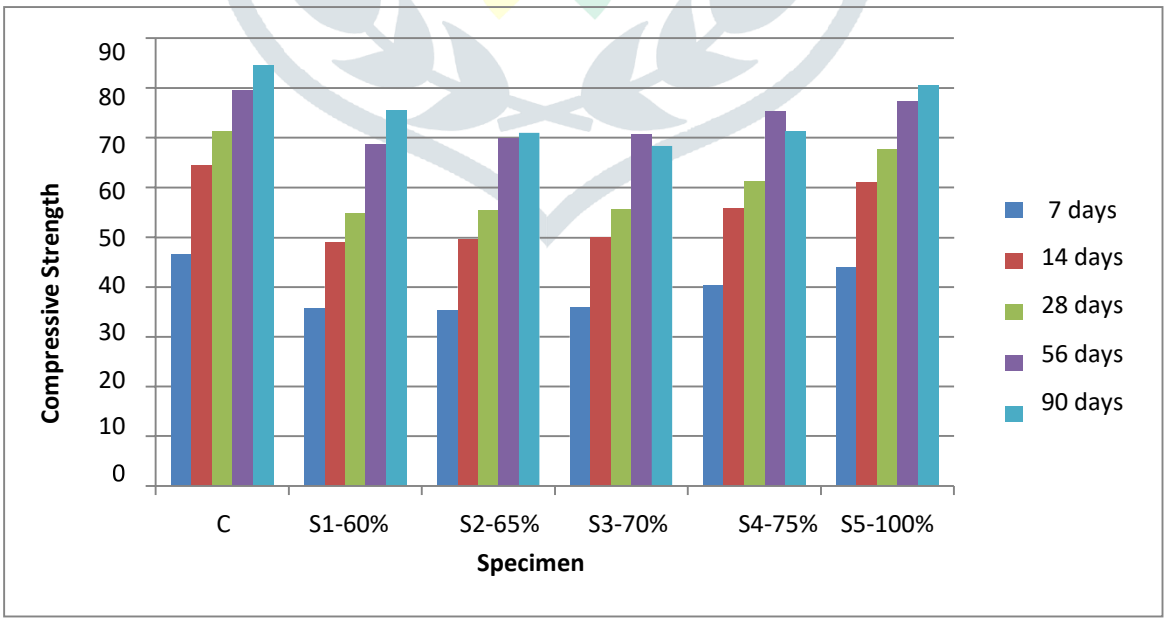
Bar Chart-1.0: Compressive strength (N/mm2) values with different replacement levels of fly ash



Fig 4.2 Compression Test with fly ash

Table 4.4 Compressive strength (N/mm2) values with different replacement levels of stone dust

S. N.	Specimen	7 Days	14 Days	28 Days	56 Days	90 Days
1	C	46.46	64.46	71.38	79.56	84.61
2	S1-60%	35.68	49.01	54.76	68.62	75.49
3	S2-65%	35.32	49.63	55.38	69.79	70.95
4	S3-70%	35.89	49.87	55.68	70.63	68.32
5	S4-75%	40.37	55.82	61.28	75.36	71.34
6	S5-100%	44.0	60.99	67.72	77.21	80.59



Bar Chart-2.0: Compressive strength (N/mm2) values with different replacement levels of stone dust



Fig 4.3 Compression Test with Stone dust

4.5 Split Tensile Strength Test

This test method consists of applying a diametral compressive force along the length of a cylindrical concrete specimen at a rate that is within a prescribed range until failure occurs. This loading induces tensile stress on the plane containing the applied load and relatively high compressive stress in the area immediately around the applied load. Tensile failure occurs rather than compressive failure because the areas of load application are in a state of triaxial compression, thereby allowing them to withstand much higher compressive stress than would be indicated by a uniaxial compressive strength test result. Thin, plywood bearing strips are used to distribute the load applied along the length of the cylinder. The maximum load sustained by the specimen is divided by appropriate geometrical factors to obtain the splitting tensile strength.

Significance and Use Splitting tensile strength is generally greater than direct tensile strength and lower than flexural strength (modulus of rupture). Splitting tensile strength is used in the design of structural lightweight concrete members to evaluate the shear resistance provided by concrete and to determine the development length of reinforcement.

As per IS456, split tensile strength of concrete. = 0.7Fck

The splitting tensile strength is calculated using the formula Tsp = 2P/ pi DL

Where P = applied load

D = diameter of the specimen L = length of the specimen

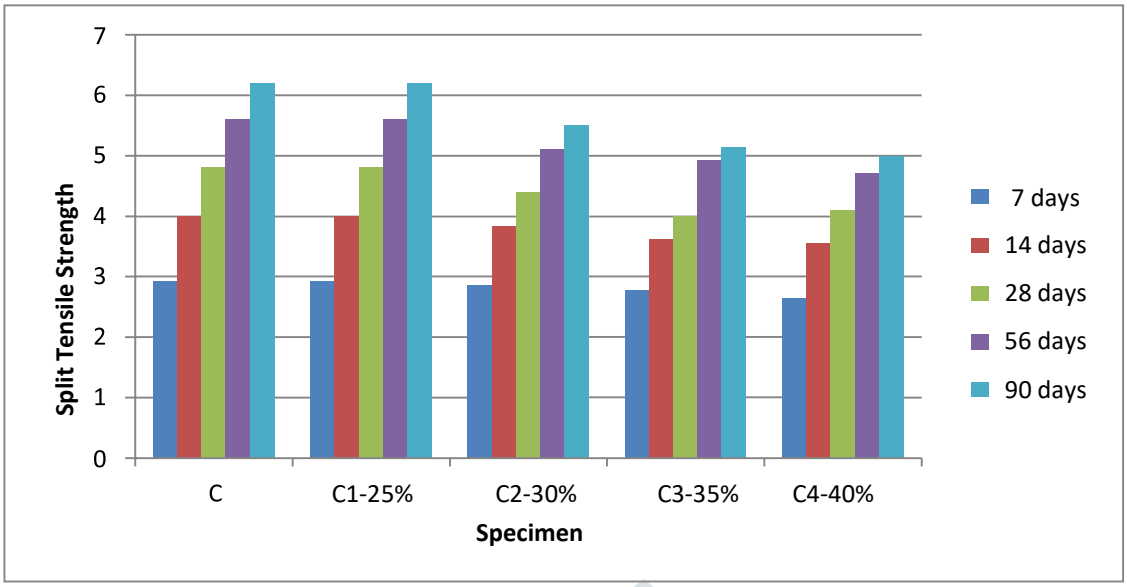
Therefore P = Tsp x pi DL/2 Split Tensile Strength

T = 2P/ pi DL

The test was carried out by placing the cylindrical specimen horizontally between the loading surfaces of a compression testing machine and load is applied until the initial crack of the specimen occurs, along the diameter.

Table 4.5 Split tensile strength (n/mm2) with different replacement levels of fly ash

S.No	Specimen	7 Days	14 Days	28 Days	56 Days	90 Days
1	C	2.92	4.0	4.8	5.6	6.2
2	C1-25%	2.92	4.0	4.8	5.6	6.2
3	C2-30%	2.86	3.83	4.4	5.1	5.5
4	C3-35%	2.77	3.62	4.0	4.93	5.14
5	C4-40%	2.64	3.54	4.1	4.71	4.98



Bar Chart-3.0 Split tensile strength (N/mm2) with different replacement levels of fly ash



Fig 4.4 Split Tensile Test

Table 4.6 Split Tensile Strength (N/mm2) values with different replacement levels of stone dust

S.N	Specimen	7 Days	14 Days	28 Days	56 Days	90 Days
1	C	2.9	4.0	4.8	5.12	5.67
2	S1-60%	2.67	3.52	3.93	4.91	5.28
3	S2-65%	2.58	3.63	3.96	4.85	5.20
4	S3-70%	2.67	3.39	3.86	4.79	4.97
5	S4-75%	2.82	3.83	4.34	4.37	4.85
6	S5-100%	3.30	4.35	4.83	5.26	5.61

Flexural Strength Test

The take a look at was administrated on 100mm X100mm X500mm size prism. The take a look at was administrated on a universal testing machine of 400kN capability, adopting 2 purpose loading. The bearing surfaces of the supporting and loading rollers area unit cleaned, and any loose sand or different material far away from the surfaces of the specimen. The specimen was placed within the UTM which the load was applied to the topmost surface as forged within the mould, on 2 lines spaced 20cm apart. The load was redoubled till the specimen fails, and also the most load applied to the specimen throughout the take a look at was recorded and look of the broken faces of concrete was noted Experimental Investigation on High Performance Concrete with Partial Replacement of Cement by ash and absolutely Replacement of Sand by Stone dirt The Flexural Strength or modulus of rupture (fb) is given by:

fb = pl/bd2 (when a > 20.0cm for 15.0cm specimen or > 13.0cm for 10cm specimen) or

fb = 3pa/bd2 (when a < 20.0cm but > 17.0 for 15.0cm specimen or < 13.3 cm but > 11.0cm for 10.0cm specimen.)

Where,

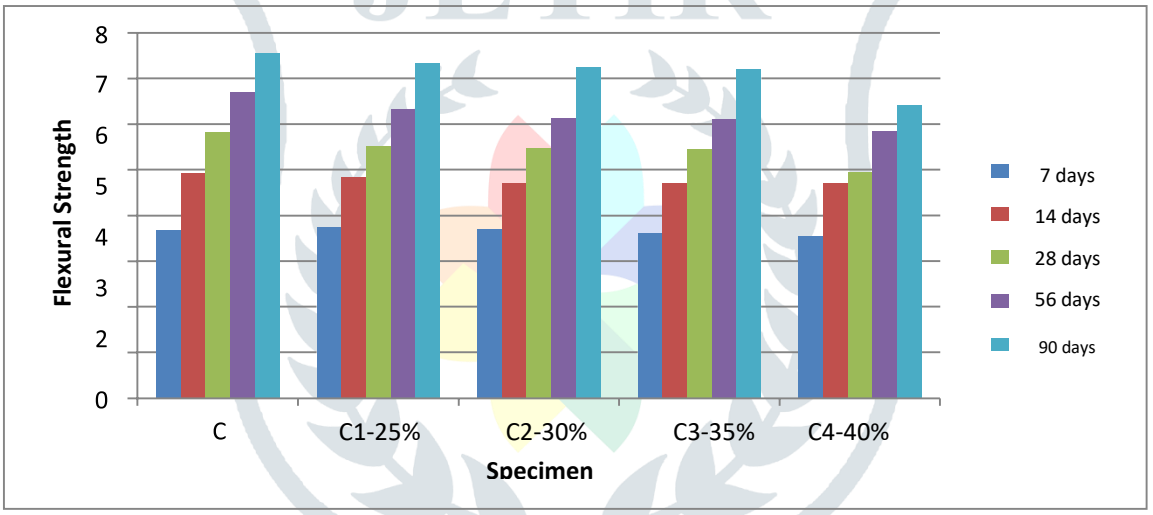
a = the distance between the line of fracture and the nearer support, measured on the center line of the tensile side of the specimen

b = width of specimen (cm) d = failure point depth (cm) l = supported length (cm)

p = max. Load (kg)

Table 4.7 Flexural strength (N/mm2) with different replacement levels of fly ash

S.No	Specimen	7 Days	14 Days	28 Days	56 Days	90 Days
1	C	3.68	4.93	5.83	6.69	7.56
2	C1-25%	3.74	4.85	5.52	6.32	7.33
3	C2-30%	3.71	4.72	5.46	6.14	7.24
4	C3-35%	3.61	4.71	5.45	6.12	7.21
5	C4-40%	3.55	4.72	4.95	5.85	6.42



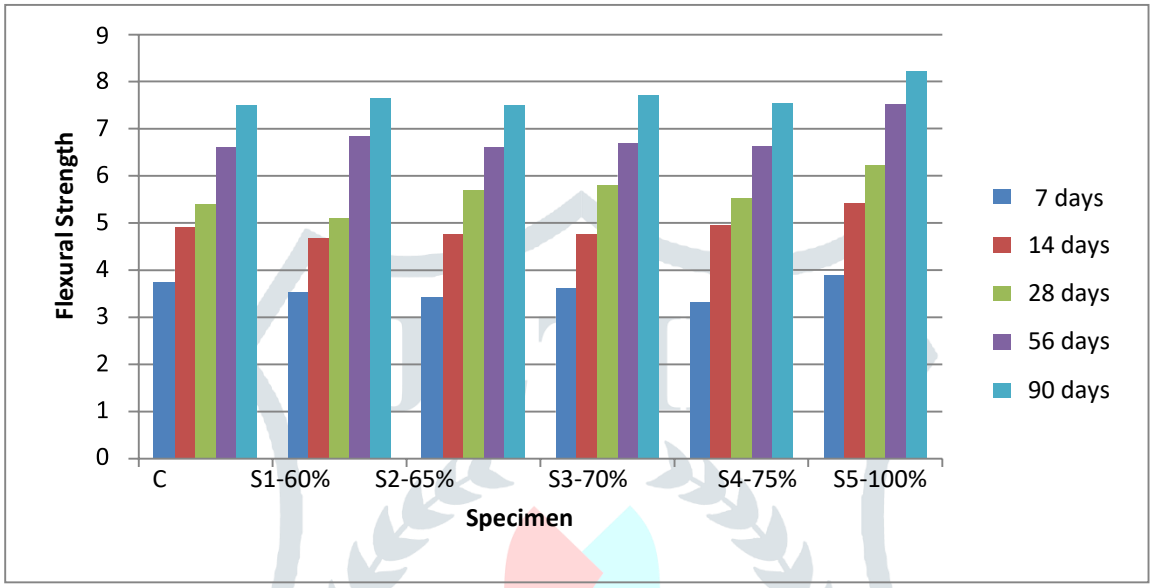
Bar Chart-4.0: Flexural strength (N/mm2) with different replacement levels of fly



Fig 4.5 Flexural Strength Test

Table 4.8 Flexural Strength (N/mm2) values with different replacement levels of stone dust

S.No	Specimen	7 Days	14 Days	28 Days	56 Days	90 Days
1	C	3.74	4.90	5.4	6.6	7.5
2	S1-60%	3.54	4.68	5.10	6.85	7.65
3	S2-65%	3.43	4.75	5.7	6.6	7.5
4	S3-70%	3.62	4.76	5.8	6.7	7.7
5	S4-75%	3.32	4.95	5.53	6.62	7.54
6	S5-100%	3.89	5.42	6.23	7.52	8.23



Bar Chart-5.0: Flexural Strength (N/mm2) values with different replacement levels of stone dust

Table 4.9 Workability

Workability	Fly Ash		Stone Dust	
S.No	Specimen	Slump(mm)	Specimen	Slump(mm)
1	C	30	C	30
2	C1-25%	50	S1-60%	45
3	C2-30%	51	S2-65%	43
4	C3-35%	53	S3-70%	40
5	C4-40%	55	S4-75%	37
6	---	----	S5-100%	35

Table 4.10 Final Mix – 1:0.35:2.43:0.78 with 25% Fly Ash &100% Stone Dust

Compressive Strength (N/mm2)			Split Tensile Strength (N/mm2)			FlexuralStrength (N/mm2)			Workability (mm)
28 days	56 days	90days	28 days	56days	90 days	28 days	56days	90 days	slump
61.4	73.8	85.3	4.65	5.43	6.3	5.6	7.4	8.3	50

4.7 Temperature Tests on Cubes, Cylinders, Beam Prisms at 100ºc

Table 4.11 Compressive Strength- Fly Ash at 100ºc temperature

S.No	Specimen	28 Days	56 Days	90 Days
1	C	5.72	6.26	6.76
2	C1-25%	4.70	4.98	5.88
3	C2-30%	4.48	4.78	5.59
4	C3-35%	4.37	4.58	5.22
5	C4-40%	3.84	4.09	4.51

Table 4.12 Compressive Strength- Stone Dust at 100ºc temperature

S.No	Specimen	28 Days	56 Days	90 Days
1	C	5.71	6.36	6.76
2	S1-60%	4.38	5.49	6.04
3	S2-65%	4.43	5.58	5.68
4	S3-70%	4.45	5.65	5.46
5	S4-75%	4.90	6.03	5.70
6	S5-100%	5.42	6.17	6.45

Table 4.13 Split tensile strength (n/mm2) - fly ash at 100ºc temperature

S.N	Specimen	28 Days	56 Days	90 Days
1	C	0.384	0.45	0.496
2	C1-25%	0.38	0.45	0.49
3	C2-30%	0.352	0.41	0.44
4	C3-35%	0.32	0.39	0.41
5	C4-40%	0.33	0.37	0.39

Table 4.14 Split Tensile Strength (N/mm2) - Stone Dust at 100ºc temperature

S.No	Specimen	28 Days	56 Days	90 Days
1	C	0.38	0.41	0.45
2	S1-60%	0.31	0.39	0.42
3	S2-65%	0.32	0.38	0.41
4	S3-70%	0.31	0.38	0.39
5	S4-75%	0.35	0.34	0.37
6	S5-100%	0.39	0.43	0.46

Table 4.15 Flexural strength (N/mm2) - fly ash at 100ºc temperature

S.No	Specimen	28 Days	56 Days	90 Days
1	C	0.46	0.53	0.60
2	C1-25%	0.47	0.54	0.62
3	C2-30%	0.43	0.49	0.57
4	C3-35%	0.43	0.48	0.56
5	C4-40%	0.42	0.45	0.50

Table 4.16 Flexural Strength (N/mm2) - Stone Dust at 100ºc temperature

S.No	Specimen	28 Days	56 Days	90 Days
1	C	0.43	0.53	0.60
2	S1-60%	0.41	0.55	0.61
3	S2-65%	0.45	0.52	0.60
4	S3-70%	0.46	0.53	0.62
5	S4-75%	0.44	0.52	0.60
6	S5-100%	0.50	0.60	0.66

5. CONCLUSIONS

In this the Concrete combine M40 has been designed as 1:2.43:0.78:0.35. The concrete with optimum replacement proportion of twenty fifth replacement of cement by ash and 100 percent absolutely replacement of fine mixture by Stone dirt in concrete combine quantities additionally arrived. The slump price for M40 grade mistreatment Stone dirt and ash get redoubled, once 100 percent replacement of Stone dirt and twenty fifth replacement of ash with one.2% super plasticizer. Therefore, ash and stone dirt replacement is effective for HPC to realize high strength. Compared to nominal concrete, M40 grade concrete attain increased strength by mistreatment of lower water/binder quantitative relation.

The fly ash samples contained 47.2 to 58.3 percent silicon dioxide (SiO2), present in both amorphous and crystalline forms. High volumes of fly ash increased the compressive strength of concrete, particularly at 50% replacement levels. For replacements above 30%, the compressive strength increased significantly. Maximum split tensile strength was observed at 50% replacement, but beyond this point, strength decreased due to high silica content affecting workability. The split tensile strength improvement was 18.77% higher than conventional concrete. Flexural strength initially increased with 30% fly ash and quarry dust replacement but decreased thereafter. Adding fly ash and quarry dust in high proportions increased the split tensile strength by 29.24% and overall concrete strength by 31.81%. Flexural strength improved by 17.54% compared to conventional concrete. High-performance concrete beams with 40% replacement showed less stiffness degradation and higher residual strength and ductility compared to conventional beams.

The results indicate that high levels of fly ash and quarry dust enhance the toughness and fracture resistance of concrete, although not uniformly across all cases. The average ductility ratio at the top was 0.71% and 0.76% at the bottom, with maximum stiffness degradation is observed. Overall, high levels of fly ash and quarry dust contribute to more ductile and less elastic high-performance concrete.

5.1 Future Scope of Study

Future research should focus on the long-term durability of concrete mixes with fly ash and stone dust, particularly in harsh environmental conditions. This includes examining resistance to chemical attacks, freeze-thaw cycles, and sustained loading conditions. This could include the use of advanced mix design techniques and statistical optimization methods to achieve the best balance between strength, workability, and durability. Exploring the synergistic effects of various chemical and mineral admixtures with fly ash and stone dust can lead to enhanced performance properties of concrete. This includes studying the combined use of different types of superplasticizers, accelerators, and supplementary cementitious materials.

Conducting detailed cost-benefit analyses to determine the economic feasibility of using fly ash and stone dust in different types of construction projects. This includes comparing initial costs, maintenance costs, and long-term savings. Engaging with regulatory bodies and standard-setting organizations to develop guidelines and standards for the use of fly ash and stone dust in concrete, ensuring consistent quality and performance across the industry. These areas of future research can significantly contribute to the development of more sustainable, high-performance concrete solutions, addressing both environmental and structural challenges in the construction industry. By continuing to explore and refine the use of fly ash and stone dust, this study paves the way for eco-friendly and cost-effective construction practices that can meet the demands of modern infrastructure development.

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LIST OF L.S. CODES

1	I.S. 12269-1989	Specification for 53 grade ordinary Portland cement
2	I.S. 383-1970	Specification for Coarse and Fine Aggregate from Natural Sources for Concrete
3	I.S. 456-2000	Indian Standard Plain and Reinforced Concrete – Code of Practice
4	I.S. 516-1959	Methods of test for strength of concrete.
5	I.S. 1489-1991	Specification for Portland – Pozzolana Cement Part-I Fly ash based.
6	I.S. 2386-1963 (all parts)	Methods of Tests for Aggregates for Concrete
7	I.S. 3085-1965	Methods of test for permeability of cement and concrete
8	I.S. 3812-1981	Indian Standard Specification for Fly Ash for use as Pozzolana and Admixture
9	I.S. 10262-1982	Recommended guidelines for concrete mix design
10	I.S. 4031-1988 (PT2)	Methods for physical tests for hydraulic cements: Part 2 determination of fineness by specific surface by Blaine's air permeability method.
11	I.S. 4031-1988 (PT5)	Methods for physical tests for hydraulic cements: Part 5 determination of initial and final setting times.
12	I.S. 4031-1988 (PT3)	Methods for physical tests for hydraulic cement: Part 3 determination of soundness
13	I.S. 1199-1959	Methods of sampling and analysis of concrete
14	I.S. 5512-1983	Specification for flow table for use in tests of hydraulic cement and pozzalanic materials
15	IS456-2000	Plain & Reinforced Concrete Code of Practice.
16	IS: 269 -1989	Ordinary Portland cement - 33 Grade (Reaffirmed 2004).
17	IS: 455-1989	Portland Slag Cement (Reaffirmed 2005).
18	IS 3812-2003	Pulverized Fuel Ash specification, part 1 for use as pozzolana in cement, cement mortar and concrete.

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