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EXPERIMENTAL STUDY ON PARTIAL REPLACEMENT OF CEMENT, FINE AGGREGATES & COARSE AGGREGATE WITH FLY ASH, STEEL SLAG & RECYCLED AGGREGATES RESPECTIVELY IN CONCRETE

Dandothkar Likitha[1], Dr. Sudeep Biswas[2]

[1] PG Student, Department of Civil Engineering, Bharat Institute of Engineering and Technology, Hyderabad, India.
[2] Assistant Professor Department of Civil Engineering, Bharat Institute of Engineering and Technology, Hyderabad, India.

Abstract: The construction sector encompasses a wide array of operations on a worldwide level. In contemporary society, there is a notable acceleration in the pace of advancement, leading to a fast depletion of naturally available building resources. Every year, a significant amount of garbage, amounting to millions of metric tons, is generated globally, with a substantial fraction of this waste being non-recyclable. Moreover, the process of recycling waste materials necessitates the use of energy resources and leads to the emission of detrimental pollutants. Furthermore, the management and elimination of garbage in suburban areas pose significant environmental hazards. The incorporation of waste materials into the manufacturing process of concrete is a viable approach to simultaneously address two objectives: waste reduction and the integration of beneficial features into the concrete mixture. This research paper talks about the results of the experiments that were done to find out the compressive strength of concrete when different amounts of cement, fine aggregate, and coarse aggregate were used instead. The concrete mixture was prepared in accordance with the specifications outlined in the IS-10262-2009 standard. The mixture was composed of a grade of M-20 (1:1.8:3.16) and a water-cement ratio of 0.5. After studying the results, it was found that replacing cement, fine aggregates, and coarse aggregates with fly ash, steel slag, and recycled aggregates at 10%, 20%, and 30% ratios does not significantly lower the compressive strength of concrete. The process of individually replacing materials is being undertaken in order to assess the possible improvement in their strength. Once a particular threshold is attained, there will be a subsequent rise, resulting in the simultaneous replacement of all elements with the objective of evaluating the compressive strength of concrete.

Keywords: Compressive Strength of Concrete, Cement, Fine Aggregate, Coarse Aggregate, Fly ash, Steel Slag, and Recycled aggregate

1. INTRODUCTION

According to the study results, it has been ascertained that the building sector utilizes around 20 billion tons of raw materials annually. The process under examination showcases a significant usage of natural resources, resulting in notable implications for the environment, energy, and economics. This phenomenon is shown by the utilization of 50% of the available raw materials, the consumption of 40% of the total energy resources,

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and the generation of 50% of the total waste output. Concrete is well recognized as the predominant construction material utilized globally. There exists a pressing need to enhance comprehension and optimize the characteristics of the subject matter. Concrete is a frequently utilized building material that consists of cement, often Portland cement, combined with extra cementitious materials, including fly ash and slag cement. Furthermore, the composition includes a combination of materials, often a coarse aggregate such as gravel, limestone, or granite, together with a fine aggregate like sand. Furthermore, the inclusion of water and chemical admixtures is evident. The term "concrete" may be traced back to its Latin source, "concretus," which denotes a state of firmness or solidity. The process of hydration is responsible for the solidification and strengthening of concrete when it is mixed with water and placed. The cementitious substance undergoes a chemical reaction when exposed to water, resulting in the formation of intermolecular bonds that ultimately result in the formation of a solidified material resembling stone. Concrete is a versatile construction material widely utilized in diverse civil engineering projects, encompassing the construction of pavements, architectural structures, foundations, motorways, highways, bridges, overpasses, parking facilities, brick and block walls, as well as footings for gates, fences, and poles.

Currently, a wide range of industries are generating innovative byproducts and waste materials. The improper disposal or uncontrolled dumping of waste items gives rise to several environmental and health issues. Hence, the use of waste materials through recycling has significant promise in the context of the concrete industry. The waste items being examined include fly ash, steel slag, and aggregates obtained from the demolition debris. These entities have responsibility for the incidence of environmental pollution. Within the context of our project, we are now engaged in the execution of a substitution strategy for the many constituents of concrete, with particular emphasis on cement, fine aggregates, and coarse aggregates. The objective of this research is to mitigate pollution by substituting cement with fly ash, fine aggregates with steel slag, and coarse aggregates with demolition waste materials, sometimes referred to as recycled aggregates.

1.1 Objectives of the Projects

- To compare the compressive strength of concrete to conventional concrete.
- To reduce the pressure on naturally available aggregates by waste plastic and to reduce the emission of CO2 during the production of cement.
- To compare the physical characteristics of recycled waste with natural aggregates.
- To study the properties of fresh and hardened concrete by replacement materials.
- To find out the percentage use of feasible for construction.
- To reduce the impact of waste materials on environment.
- To find out the ways of cost saving such as transportation, excavation etc.
- To explore possibilities of improving mechanical properties of concrete using steel slag instead of fine aggregate partially.
- To evaluate the effect of using steel slag in concrete.
- To evaluate the effect of just replacing the cement by fly ash used in concrete and to study the compressive strength of concrete under varying percentage of fly ash, as well as to study, the effect of varying curing time period under different exposure condition.
- To determine the optimum level of cement in concrete elements with highest compressive strength.
- Study the effect of fly ash incorporating in concrete on permeability in normal condition and aggressive condition.

2. PROPERTIES OF MATERIALS

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One well-known example of a composite material is concrete. Cement, fine and coarse aggregates, water, and other chemical admixtures make up fresh concrete. However, these days, there are a lot more restrictions on the resources' availability. Three substitutions are now under implementation: fly ash for cement, steel slag for fine aggregates, and waste materials from demolition operations for coarse aggregates. Regardless of whether the concrete is fresh or has already hardened, the ingredients and their relative proportions affect its properties. re that the concrete mix is properly constructed and can be compacted and put together with the least amount of effort, it is essential to have a thorough grasp and awareness of its workability.

2.1 Cement

A popular binding substance used in buildings is cement. Chemical compounds known as binders go through a solidification process that increases their stiffness and adherence to neighboring materials. This process makes it easier for many components to bind together to form a cohesive unit. This phenomenon can be explained by the widespread use of cement—rather than cement alone—as a binding agent for gravel and sand. While concrete is made by mixing cement with sand and gravel, mortar used in masonry buildings is made of cement mixed with fine aggregate. Typically, inorganic cements made mostly of lime or calcium silicate are used in building applications. Cement may be divided into two categories: hydraulic and non-hydraulic. The former is classified according to its capacity to set when it comes into contact with water. On the other hand, when non-hydraulic cement is exposed to moisture or water, it does not go through the hardening process. On the other hand, after drying, the material solidifies and reacts chemically with carbon dioxide in the atmosphere. Following the setting procedure, it exhibits a high degree of resistance against chemical assaults.

Table 1: Chemical Properties of cement

COMPOUNDS	**PERCENTAGE**
SiO_2	23
Al_2O_3	4
Fe_2O_3	2
CaO	64
MgO	2
SO_3	2

2.2 Fine Aggregate

A particulate substance called aggregate is used to make mortar and concrete. When the granular material's particles are tiny enough to pass through a 4.75-millimeter screen, aggregate is created. This chemical is a cost-effective additive that is commonly used in the construction sector to increase the volume of concrete. Fine aggregate, which is made up of crushed stone or natural sand, is an essential component of the composition of concrete. A key element is the fine aggregate. The qualities and density of the fine aggregate have a significant impact on the properties of hardened concrete. The small particles are responsible for the combination's dimensional stability. Both the amount of mixture and its hardening properties depend on the caliber of the small particles. The characteristics of the minuscule particles utilized in the mixture have a significant impact on the amount of shrinkage in concrete. Furthermore, fine aggregate is an essential component of concrete and, as such, has a significant impact on how the concrete mixture is made. The fineness modulus of the fine particles, moisture content, specific gravity, and sediment content are some of the variables that affect the mix proportions in concrete. Compared to other aggregate types, fine aggregates have a greater surface area. The fine aggregates are in charge of occupying

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the spaces left by the coarse aggregates. River sand, easily obtained from the market, and was used for the length of the experiment. The aggregate was evaluated to see whether it complied with physical requirements, such as gradation, fineness modulus, specific gravity, and bulk density, in line with the International Standard (IS) 10262-1998. The sand was dried on the surface before being used.

2.3 Coarse Aggregate

Particles having a coarse grain size can be successfully blocked from passing through a sieve with 4.75-millimeter openings. Particles in larger aggregates have a lower surface area than individual particles with the same volume. The amount of cement and water required may be decreased by using coarse aggregate with the largest allowable maximum size. When particles larger than the maximum allowable size of coarse aggregates are used, interlocking and the formation of arches or blockages inside a concrete structure may occur. This causes the lower portion to either become completely empty or, at worst, just partially packed with small particles made of cement and sand, creating a weak spot. The main ingredient used to make concrete is coarse aggregate, which takes up the most volume in the mixture. Therefore, it has a significant impact on the composition of the concrete mixture. The strength, maximum size, form, and water absorption characteristics of the concrete have a significant impact on the quantity of water, cement, and fine aggregate used in the mixture. Previous research has shown that the amount of water needed in the combination decreases as the maximum size of the coarse aggregate increases. This phenomenon can be explained by the fact that fine aggregates have a comparatively lower surface area than coarse particles with a smaller size. In the context of standard-strength concrete, using rounded-shaped aggregate is a practical way to achieve a cost-effective mix design, which emphasizes its importance in the field of composition. Angular coarse aggregate must be used in the construction of high-strength concrete. The likelihood of segregation is greatly reduced when coarser aggregate is graded correctly. This underlines the need of using a suitable grading system for concrete mixes. The things in issue have diameters of 20 millimeters, and they are easily accessible nearby.

2.4 Fly ash

The finely split residue left over after pulverized coal is burned is referred to as fly ash. Fly ash is released from the combustion chamber through the exhaust gases. Thermal power plants that rely on coal are essential for meeting the energy needs of developing countries, especially those that are emerging. Environmentalists are growing more concerned about the volume of solid waste that coal-fired thermal power plants produce because they must now properly dispose of this material. Because coal ash, often referred to as fly ash, is mostly composed of small particles roughly 80% of its mass electrostatic precipitators are used to collect it. Fly ash builds up in storage buildings that are intended for that purpose. Now, fly ash is a major contributor to India's environmental pollution. Over 140 million tons of fly ash are produced each year. Only three percent of fly ash is used in India, whereas in economically developed nations like Germany, the utilization rate is an impressive eighty percent. The byproduct that is created when coal is burned is called fly ash. Boiler and thermal power plants have historically been the main sources of output. Fly ash is added to concrete mixes to improve workability because of its unique physical properties. Fly ash has a heat of hydration because it is structurally stable by nature. Fly ash is obtained from the nearby brick production sector in order to meet the requirements of this activity.

Table 2: Thermal Power Generation, Coal consumption and ash generation in India.

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Year	Thermal power generation (mw)	Coal consumption (mt)	Ash generation (mt)
2010	54,000	200	75
2015	70,000	250	90
2020	98,000	300	110
2025	137,000	350	140

2.5 Steel Slag

Steel slag is produced during the steel production process in furnaces when molten steel is separated from impurities. This slag is a leftover from the production of iron and steel. Slag is a composite material made of oxides and silicates that solidifies as it cools. The material in issue is created during the melting process of a molten liquid. The steel slag produced in the first stage of steel manufacturing is frequently referred to as "tap slag" or "furnace slag." The steel industry has produced a sizable amount of solid waste. The processes of alloy creation and metal refining result in hundreds of tons of steel slag being produced worldwide each year. A byproduct of the steel manufacturing industry, which produces steel as its main product, is steel slag. The building industry has the ability to use steel slag in place of natural aggregates for creating concrete mixtures. After the iron-to-steel process is finished, the resultant slag is placed in specially designated beds and gradually cools with the help of the surrounding environment. The formation of crystalline slag and the subsequent creation of hard lump slag, which may then undergo additional processing by crushing and screening, are two distinct phases in the slag production process. The materials that are blended with it are crushed and screened to produce the aggregate.

Table 3: Chemical Analysis of the Steel Slag

OXIDES	PERCENTAGE
Fe_2O_3	97.05
MnO	1.07
TiO_2	0.01
SiO_2	0.8
MgO	0.4
CaO	0.4
C	0.23
S	0.21
Water Solubility	0.009

2.6 Demolition Waste Aggregate (Recycled Aggregate)

India, along with other countries, is accountable for the demolition of a significant number of concrete structures. However, the percentage of garbage that gets repurposed after demolition is rather small. This will lead to serious problems since it will cause environmental degradation and increase the amount of land needed for garbage disposal. Concrete recycling is becoming a prominent technique for recycling the waste produced during the construction or demolition of buildings reinforced with concrete. Recycling has become a very common technique since it offers many benefits in the modern era. These include the need to decrease building costs, tighter environmental rules, and increased environmental awareness. Recycling has supplanted the traditional method of disposing of concrete in landfills because it offers various benefits that make it a more desirable choice. The crusher machine crushes the concrete aggregate that comes from demolition sites. Crushing plants only take in clean concrete—that is, concrete that is devoid of wood, paper, garbage, and other such materials. Metals like rebar are considered appropriate since they can be extracted using magnets and other sorting devices, then further melted and recycled at other facilities. Depending on how big they are, the leftover aggregate particles are arranged differently. Larger pieces

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might potentially be processed further using the crusher. Following the completion of the first crushing operation, further particles are removed using a variety of techniques, such as manual selection and water flotation. The technique of on-site crushing employing portable crushers at the building site reduces construction costs and pollution emissions compared to the transportation of materials to and from a quarry. These systems usually consist of a side discharge conveyor, a screening plant, a rubble crusher, and a return conveyor that makes it easier to reprocess materials that are too big for the processing unit. Furthermore, mini-crushers are available that have a compact and independent construction, allowing them to efficiently crush materials at a rate of up to 150 tons per hour. These tiny crushers are made especially to squeeze into tight areas and locations. The use of crusher attachments makes on-site recycling methods, which are becoming more and more well-liked as waste production decreases, possible. These attachments are made to be mounted on a variety of construction tools and vehicles, such as excavators.

2.7 Water

Throughout the experiment, ordinary potable water that was devoid of any organic debris, turbidity, or salt impurities was used for the mixing and curing processes. Water must be added to concrete in order for it to reach the appropriate strength. An organism has to drink around thirty percent of its body weight in water to be well hydrated. Research data has confirmed that while making traditional concrete, a minimum water-to-cement ratio of 0.5 must be used. The chemical reaction between water and cement produces cement paste, which then makes it simpler for fine and coarse aggregate to bind together. Water segregation and bleeding result from increased water usage, which increases the concrete's susceptibility to fragility. As such, it may be able to reduce bleeding. Hemorrhaging might happen if the water content is higher than what is allowed. The required level of workability will not be achieved with insufficient use of water. For the purpose of using concrete, it is essential to utilize a potable water source that is safe for human consumption. Additionally, the water's pH level must be between 6 and 9.

3. RESULTS AND DISCUSSIONS

3.1 Conventional Concrete Cubes

In the first step we have made 6 cubes of conventional concrete. In those 2 cubes each of 3days, 7days and 28days are tested for compressive strength.

Table 4: Results for conventional cubes

S NO	AVERAGE COMPRESSIVE STRENGTH (N/mm2)		
	For 3days	**For 7days**	**For 28days**
1.	16.45	19.5	21.85

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Figure 1: Before & after Cracks of Conventional Cubes

Comparing the Compressive Strength of Concrete for Conventional Cubes with Replacement of Cement by Fly ash

Table No 5: Results for cement replaced by fly ash

S NO	PROPORTION	AVERAGE COMPRESSIVE STRENGTH (N/mm2)		
		For 3days	For 7days	For 28days
1.	0% Replacement	16.45	19.5	21.85
2.	10% Replacement	17.15	20.45	24
3.	20% Replacement	17.5	21.65	25.7
4.	30% Replacement	15.7	18.25	19.8

Figure 2: Before & after crack for replacement of cement byfly ash

Comparing the compressive strength of concrete for conventional cubes with replacement of fine aggregates by steel slag

Table No 6: Results for FA. Replaced by steel slag

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S NO	PROPORTION	AVERAGE COMPRESSIVE STRENGTH (N/mm2)		
		For 3days	For 7days	For 28days
1.	0% Replacement	16.45	19.5	21.85
2.	10% Replacement	17.4	21.75	26.85
3.	20% Replacement	18.25	23.75	32.85
4.	30% Replacement	17.45	22.45	31.2


Figure 3: Before & after crack for replacement of FA by steelslag

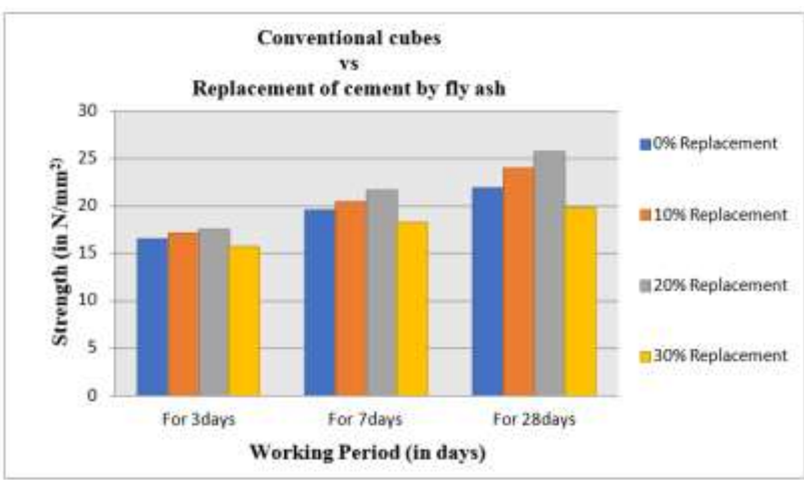

Figure 4: Bar charts show the Compressive Strength of Concrete in N/mm^2 forComparing Conventional Cubes with Replacement of Cement by Fly Ash

3.2 Comparing the Compressive Strength of Concrete for Conventional cubes with Replacement of Fine

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Aggregates by Steel Slag

Table 7: Results for FA. Replaced by steel slag

S NO	PROPORTION	AVERAGE COMPRESSIVE STRENGTH (N/mm2)		
		For 3days	For 7days	For 28days
1.	0% Replacement	16.45	19.5	21.85
2.	10% Replacement	17.4	21.75	26.85
3.	20% Replacement	18.25	23.75	32.85
4.	30% Replacement	17.45	22.45	31.2

Figure 5: Before & after crack for replacement of FA by steel slag

Bar charts show the Compressive Strength of Concrete in N/mm2 for Comparing Conventional Cubes with Replacement of Fine Aggregates by Steel Slag

3.3 Comparing the Compressive Strength of Concrete for conventional c\Cubes with Replacement of Coarse Aggregate by Recycled Aggregates

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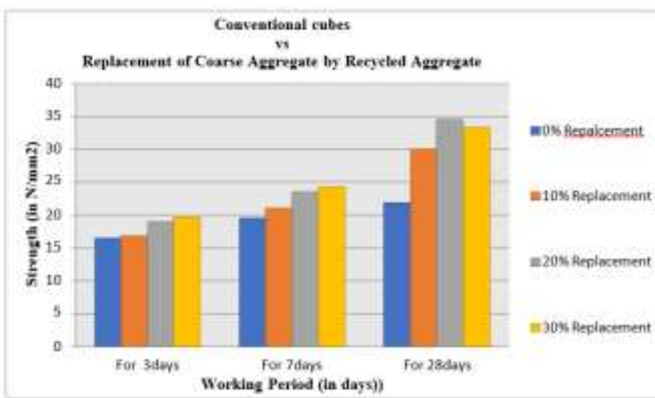
Table 8: Results for c.a. replaced by recycled aggregates

S NO	PROPORTION	AVERAGE COMPRESSIVE STRENGTH (N/mm2)		
		For 3days	For 7days	For 28days
1.	0% Replacement	16.45	19.5	21.85
2.	10% Replacement	16.8	21	30
3.	20% Replacement	18.95	23.5	34.5
4.	30% Replacement	19.7	24.3	33.35

Figure 6: Before & after crack for replacement c.a. by recycled aggregate

Bar charts show the Compressive Strength of Concrete in N/mm2 for Comparing Conventional Cubes with Replacement of Coarse Aggregate by Recycled Aggregate



3.4 Comparing the Compressive Strength of Concrete for Conventional Cubes with Combination Replacement of all 3 ingredients @20% of each material

Table 9: Results for combination replacement of all three ingredients

S NO	PROPORTION	AVERAGE COMPRESSIVE STRENGTH (N/mm2)		
		For 3days	For 7days	For 28days
1.	0% Replacement	16.45	19.5	21.85
2.	20% Replacement of all 3 materials	17	22.2	25.95

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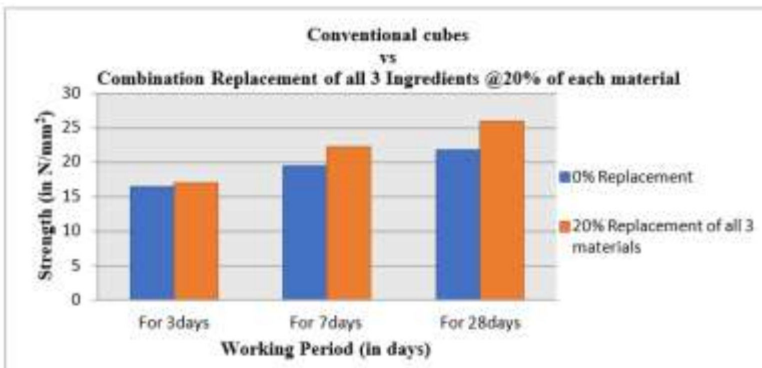
Figure 7: Before & after crack of replacement of all 3 materials @20%

Bar charts show the Compressive Strength of Concrete in N/mm2 for Comparing Conventional Cubes with Combination Replacement of all 3 Ingredients @20% of each material



4. CONCLUSION

This research concludes the study of the effect of replaced materials on the properties of concrete for nominal mix of M20 grade of concrete are as follows:

- According to the testing findings, the substitute concrete's compressive strength was comparable to that of regular concrete. It is possible to use fly ash in concrete up to a twenty percent partial replacement of ordinary Portland cement (OPC) without affecting the concrete's compressive strength. The gradual rise in the replacement amount of fly ash has a negative impact on the material's workability.
- After 28 days, the concrete's compressive strength is considered adequate when fly ash is substituted for 10% and 20% of the cement. However, when thirty percent fly ash is used in place of cement, the concrete's compressive strength resembles that of regular concrete cubes.
- When fine particles are substituted with steel slag at rates of 10% and 20% for 28 days, the compressive strength of the concrete cubes is found to be much higher than that of ordinary concrete cubes. Moreover, a significant improvement in compressive strength is seen when steel slag is substituted for 30% of the fine aggregates. By comparison, the replacement rate at 30% is significantly lower than the replacement rates at 10% and 20%.
- The purpose of this research is to investigate the fine aggregate use of steel slag, an economical waste resource, in M20-grade concrete. Additionally, the study's conclusions suggest that the material under investigation ought to be approved for use in concrete as a competitive substitute for fine aggregates. The modulus of elasticity and compressive strength of concrete may be improved by partially replacing natural aggregates with steel slag aggregates. This is feasible up to an optimal replacement threshold.

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- When recycled aggregates are replaced with coarse particles at rates of 15%, 20%, and 30%, concrete cubes' compressive strength is demonstrated to be much higher than that of regular concrete cubes. The observed increase in compressive strength persists for a duration of 28 days.
- Using demolition leftover aggregates in concrete buildings can result in increased cost effectiveness and efficiency.
- We have successfully created a composite substance that has all three of its basic parts at the same time, substituting 20% of each ingredient for the other two. The suggested changes include using fly ash in place of cement, steel slag in place of fine aggregates, and recycled aggregate in place of coarse material. When compared to standard concrete cubes, the compressive strength of concrete shows an improvement.

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