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Experimental Analysis Of Concrete Incorporating Partial Replacement Of Cement, Fine Aggregates, And Coarse Aggregates With Fly Ash, Steel Slag, And Recycled Materials.

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Abstract: The construction industry plays a vital role globally, with rapid development leading to an accelerated consumption of naturally available construction materials. Simultaneously, vast quantities of waste are generated each year, much of which is non-recyclable. Even when recycling is possible, the process often demands substantial energy and contributes to environmental pollution. Additionally, the accumulation and disposal of such waste, particularly in suburban areas, pose significant ecological threats. Incorporating waste materials into concrete production offers a sustainable solution—reducing waste and potentially enhancing the properties of concrete.

This project involves an experimental investigation aimed at evaluating the compressive strength, flexural strength, and split tensile strength of M20 grade concrete when cement, fine aggregates, and coarse aggregates are individually replaced with fly ash, steel slag, and recycled aggregates at varying proportions (10%, 20%, and 30%). The results indicate that such replacements can be made up to the mentioned percentages without compromising the compressive strength of the concrete. Furthermore, after identifying the optimal replacement percentage for each material individually, a combined replacement is carried out to assess the overall performance and compressive strength of concrete incorporating all three materials simultaneously.

Key Word:Compressive Strength, Flexural Strength, Split Strength, fly ash, steel slag, recycled aggregates.

I. INTRODUCTION

The construction industry is one of the largest consumers of raw materials globally, reportedly utilizing around 20 billion tons of natural resources annually. This intensive consumption contributes significantly to environmental degradation, energy usage, and economic strain. It is estimated that the industry accounts for 50% of raw material usage, 40% of total global energy consumption, and generates nearly half of the world's total solid waste. Among construction materials, concrete stands out as the most extensively used. There is a growing need to better understand and improve its characteristics to make it more sustainable and environmentally friendly.

Concrete is typically a composite material consisting of cement (primarily Portland cement), supplementary cementitious materials like fly ash or slag, fine aggregates (such as sand), coarse aggregates (such as gravel, granite, or limestone), water, and various chemical admixtures. The term "concrete" is derived from the Latin word concretus, meaning "hardened." This name reflects the material's behavior: when mixed with water, it undergoes a hydration reaction, binding the components together and hardening into a stone-like substance.

Its widespread applications include pavements, foundations, structural frameworks, bridges, roads, walls, and other civil infrastructure components.

1.1 OBJECTIVES

Objectives of the Study

- To assess and compare the compressive strength of modified concrete mixes with that of conventional concrete.
- To minimize the consumption of natural aggregates by incorporating waste plastic and thereby reduce CO_2 emissions from cement production.
- To analyze and compare the physical characteristics of recycled aggregates with those of natural aggregates.
- To investigate the behavior and properties of both fresh and hardened concrete incorporating alternative materials.
- To identify the optimal and feasible percentage of material replacement suitable for structural applications.
- To reduce the environmental burden caused by waste disposal through effective reuse in concrete.
- To explore cost-saving opportunities in areas such as transportation and raw material excavation by using locally sourced waste materials.
- To examine the potential for enhancing the mechanical properties of concrete through partial replacement of fine aggregates with steel slag.
- To analyze the performance of concrete when steel slag is introduced as a partial substitute for fine aggregates.
- To study the compressive strength of concrete when fly ash replaces cement at different percentages and under various curing durations and exposure conditions.
- To determine the optimal cement replacement level that results in maximum compressive strength of the concrete.
- To evaluate the effect of fly ash inclusion on concrete permeability under both normal and aggressive environmental conditions.

1.2 Experimental Methodology

In this study, concrete mix design was carried out in accordance with IS 10262:2009 standards for M20 grade concrete, ensuring a good level of quality control. Based on the designed mix proportions, various concrete specimens were cast and tested to evaluate their performance. The focus of the experimental work was to investigate the compressive strength of concrete in which cement was partially replaced with fly ash, fine aggregates with steel slag, and coarse aggregates with recycled concrete aggregates at replacement levels of 0%, 10%, 20%, and 30%. Concrete cubes were prepared and subjected to compressive strength testing to assess the impact of these substitutions on the strength characteristics of the concrete.

II. METHODOLOGY

STEP-1: COVENTIONAL CONCRETE FOR 6 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 NO : 2.1 WEIGHT OF CONVENTIONAL CUBES

CEMENT (Kg)	F.A. (Kg)	C.A. (Kg)	WATER (Lit)
9.12	16.44	28.8	4.56

STEP-2: CEMENT REPLACED BY FLY ASH FOR 6 CUBES OF EACH PROPORTION @ 10%, 20% & 30%:

In the second step we have made 18 cubes. In those 6 cubes are made for 10% replacement of cement by fly ash. Another 6 cubes are made for 20% replacement of cement by fly ash. Lastly the remaining 6 cubes are made for 30% replacement of cement by fly ash.

TABLE NO: 2.2 WEIGHTS FOR CEMENT REPLACED BY FLY ASH

CEMENT (Kg)	FLY ASH (Kg)	F.A. (Kg)	C.A. (Kg)	WATER (Lit)
8.208	0.912 (10% replacement)	16.44	28.8	4.56
7.296	1.824 (20% replacement)	16.44	28.8	4.56
6.384	2.736 (30% replacement)	16.44	28.8	4.56

STEP-3: FINE AGGREGATES REPLACED BY STEEL SLAG FOR 6 CUBES OF EACH PROPORTION @10%, 20% AND 30%:

In the third step we have made 18 cubes. In those 6 cubes are made for 10% replacement of fine aggregates by steel slag. Another 6 cubes are made for 20% replacement
of fine aggregates by steel slag. Lastly the remaining 6 cubes are made for 30% replacement of fine aggregates by steel slag.

TABLE NO: 2.3 WEIGHTS FOR F.A. REPLACED BY STEEL SLAG

CEMENT (Kg)	F.A. (Kg)	STEEL SLAG (Kg)	C.A. (Kg)	WATER (Lit)
9.12	14.796	1.644 (10% replacement)	28.8	4.56
9.12	13.152	3.288 (20% replacement)	28.8	4.56
9.12	11.508	4.932 (30% replacement)	28.8	4.56

STEP-4: COARSE AGGREGATES REPLACED BY RECYCLED AGGREGATES FOR 6 CUBES OF EACH PROPORTION @10%, 20% AND 30%:

In the fourth step we have made 18 cubes. In those 6 cubes are made for 10% replacement of coarse aggregate by recycled aggregate. Another 6 cubes are made for 20% replacement of coarse aggregate by recycled aggregate. Lastly the remaining 6 cubes are made for 30% replacement of coarse aggregate by recycled aggregate.

TABLE NO: 2.4 WEIGHTS FOR C.A. REPLACED BY RECYCLED AGGREGATES

CEMENT (Kg)	F.A. (Kg)	C.A. (Kg)	RECYCLED AGGREGATES (Kg)	WATER (Lit)
9.12	16.44	25.92	2.88 (10% replacement)	4.56
9.12	16.44	23.04	5.76 (20% replacement)	4.56
9.12	16.44	20.16	8.64 (30% replacement)	4.56

STEP-5: COMBINATION REPLACEMENT @20% OF ALL THREE INGREDIENTS FOR 6 CUBES:

In the fifth step we have made 6 cubes. These are made for combination replacement of all three materials at 20%.

TABLE NO: 2.5 WEIGHTS FOR COMBINATION REPLACEMENT OF ALL THREE INGREDIENTS @20%

CEMENT (Kg)	FLY ASH (Kg)	F.A. (Kg)	STEEL SLAG (Kg)	C.A. (Kg)	RECYCLED AGGREGATES (Kg)	WATER (Lit)
7.296	1.824 @20%	13.152	3.288 @20%	23.04	5.76 @20%	4.56

TOTAL QUANTITY OF MATERIALS REQUIRED:

Cement = 93.024Kgs
Fine Aggregates = 167.688Kgs
Coarse Aggregates = 293.76Kgs
Fly Ash = 7.296Kgs
Steel Slag = 13.152Kgs
Recycled Aggregates = 23.04Kgs
Water = 50.16Litres.

III.TEST RESULTS

The compressive strength of concrete cubes at various percentages as shown below:

3.1 Conventional Concrete Cubes:

S NO	AVERAGE COMPRESSIVE STRENGTH (N/mm^2)		
	For 3days	For 7days	For 28days
1.	16.45	19.5	21.85

TABLE NO: 3.1 RESULTS FOR COVENTIONAL CUBES

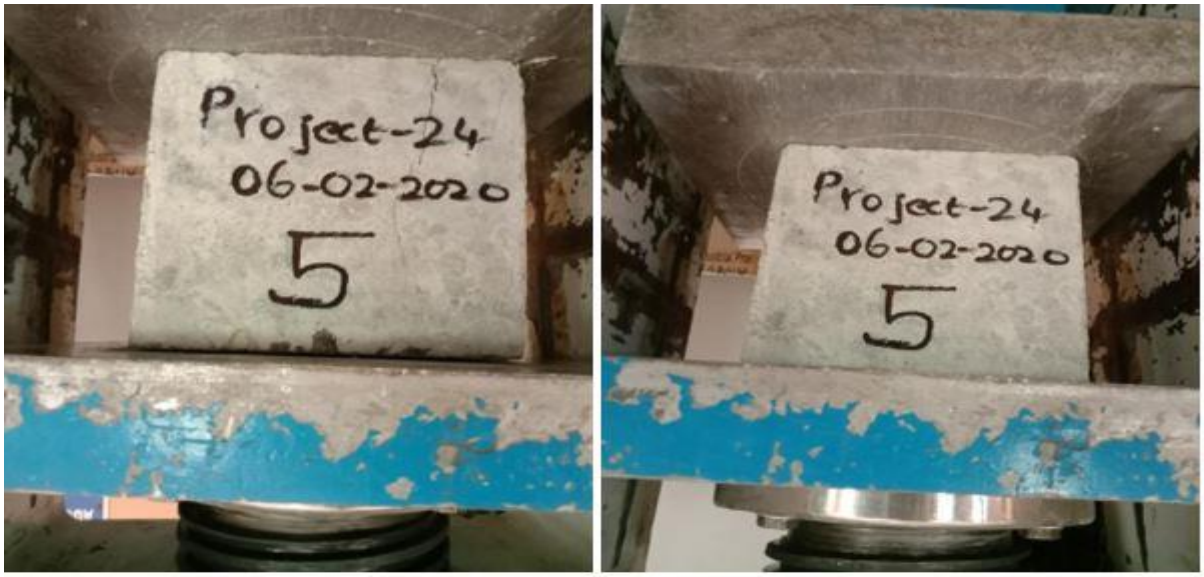


FIG NO: 3.2 BEFORE & AFTER CRACK OF CONVENTIONAL CUBES

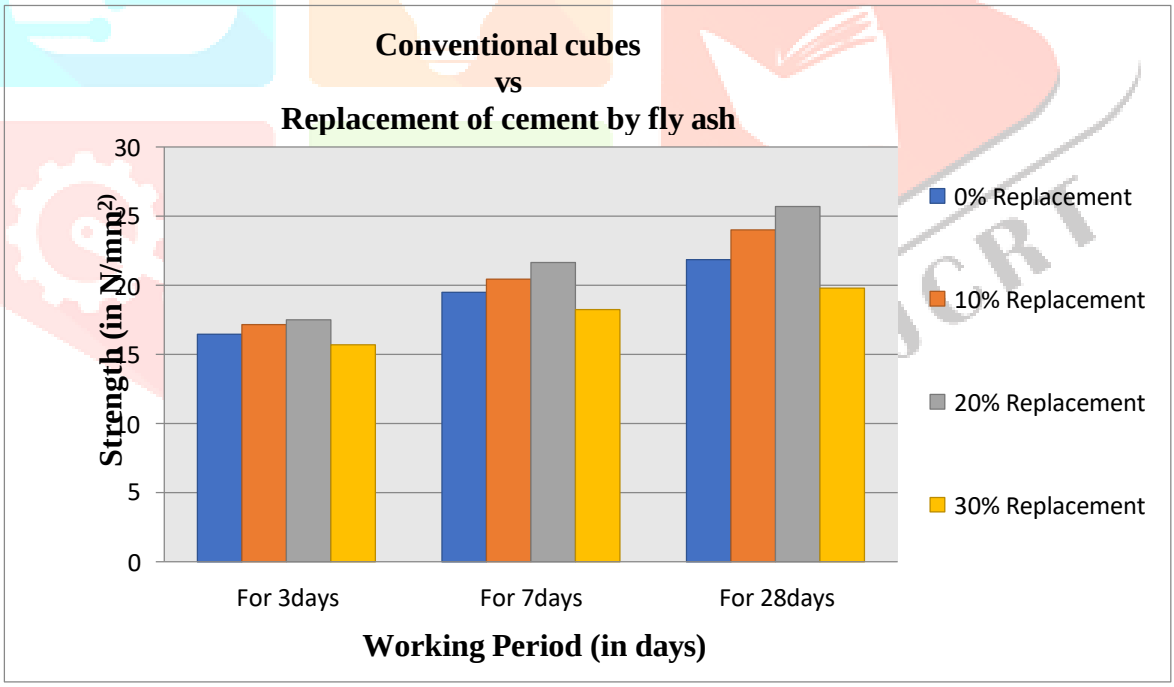
3.2 Comparing the Compressive Strength of Concrete for Conventional Cubes with Replacement of Cement by Fly Ash:

S NO	PROPORTION	AVERAGE COMPRESSIVE STRENGTH (N/mm^2)		
		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

TABLE NO: 3.3 RESULTS FOR CEMENT REPLACED BY FLY ASH

FIG NO: 3.4 BEFORE & AFTER CRACK FOR REPLACEMENT OF CEMENT BY FLY ASH

Bar charts show the Compressive Strength of Concrete in N/mm² for Comparing Conventional Cubes with Replacement of Cement by Fly Ash:



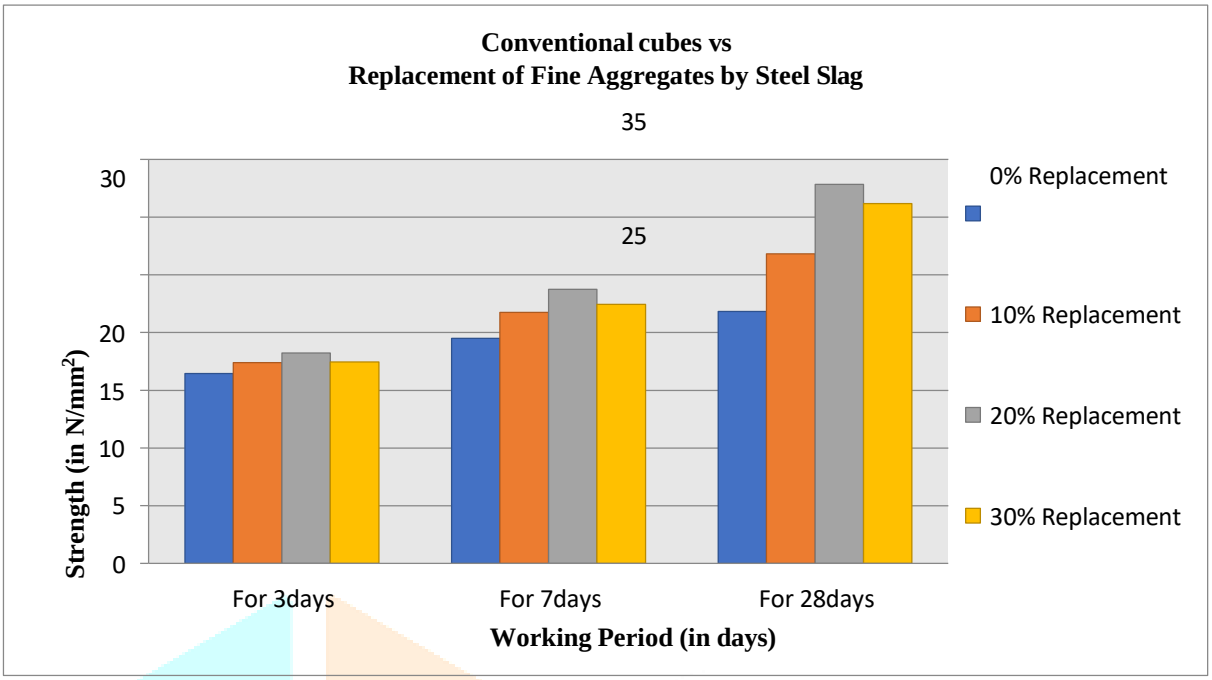
3.5 Comparing the compressive strength of Concrete for Conventional Cubes with Replacement of Fine Aggregates by Steel Slag:

TABLE NO: 3.4 RESULTS FOR F.A. REPLACED BY STEEL SLAG

S NO	PROPORTION	AVERAGE COMPRESSIVE STRENGTH (N/mm^2)		
		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

FIG NO: 3.6 BEFORE & AFTER CRACK FOR REPLACEMENT OF F.A. BY STEEL SLAG

Bar charts show the Compressive Strength of Concrete in N/mm^2 for Comparing Conventional Cubes with Replacement of Fine Aggregates by Steel Slag:



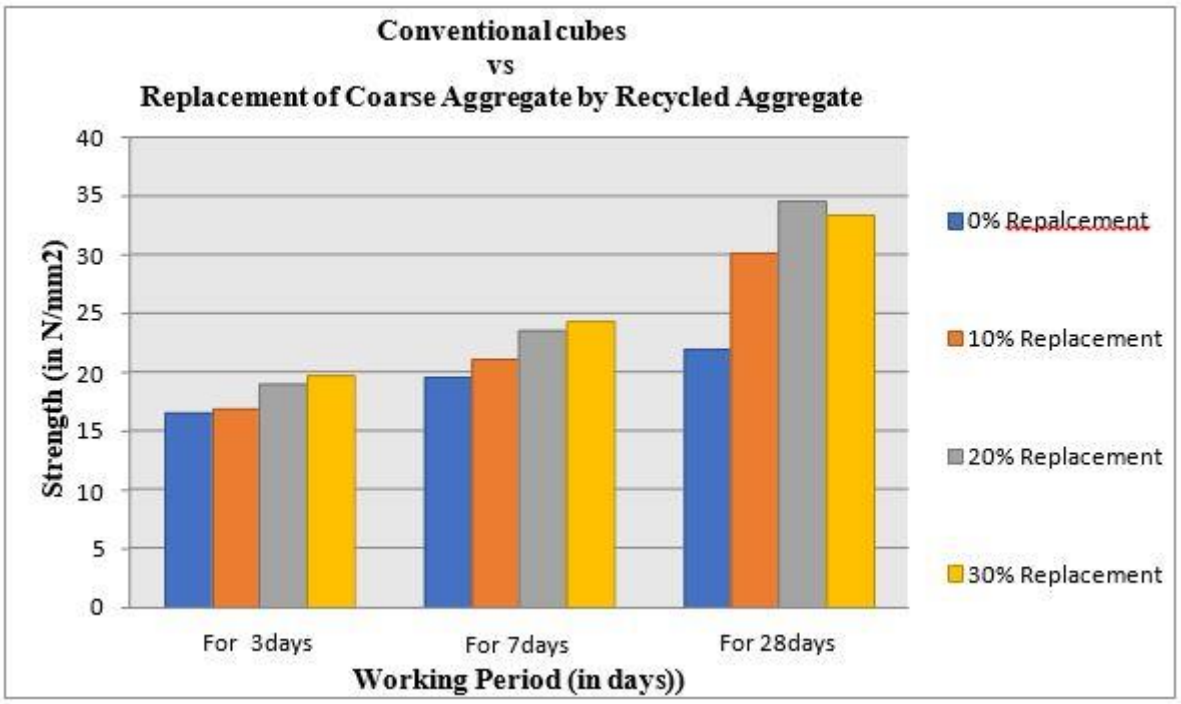
3.7 Comparing the Compressive Strength of Concrete for Conventional Cubes with Replacement of Coarse Aggregate by Recycled Aggregates:

S NO	PROPORTION	AVERAGE COMPRESSIVE STRENGTH (N/mm^2)		
		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

TABLE NO: 3.5 RESULTS FOR C.A. REPLACED BY RECYCLED AGGREGATES

FIG NO: 3.8 BEFORE & AFTER CRACK FOR REPLACEMENT C.A. BY RECYCLED AGGREGATE

Bar charts show the Compressive Strength of Concrete in N/mm^2 for Comparing Conventional Cubes with Replacement of Coarse Aggregate by Recycled Aggregate:



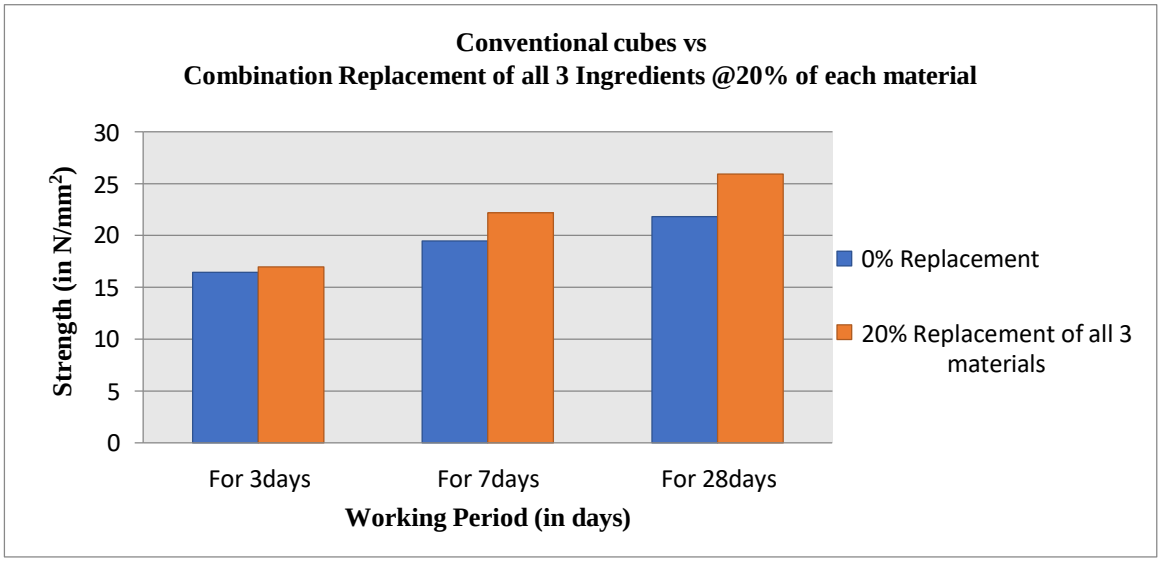
3.9 Comparing the Compressive Strength of Concrete for Conventional Cubes with Combination Replacement of all 3 Ingredients @20% of each material:

S NO	PROPORTION	AVERAGE COMPRESSIVE STRENGTH (N/mm^2)		
		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

TABLE NO: 3.6 RESULTS FOR COMBINATION REPLACEMENT OF ALL THREE INGREDIENTS

FIG NO: 3.10 BEFORE & AFTER CRACK OF REPLACEMENT OF ALL 3 MATERIALS @20%

Bar charts show the Compressive Strength of Concrete in N/mm^2 for Comparing Conventional Cubes with Combination Replacement of all 3 Ingredients @20% of each material:



IV.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:

- The compressive strength of concrete for replaced concrete was similar to conventional concrete.
- Fly ash can be added in OPC concrete as partial replacement of OPC up to 20% without compromising compressive strength of concrete. Workability is decreased with increase in replacement level of fly ash.
- The 10% and 20% replacement of cement with fly ash shows good compressive strength for 28days and but the 30% replacement of cement with fly ash, the compressive strength of concrete is slightly near as compare to conventional concrete cubes.
- The 10% and 20% replacement of fine aggregates with steel slag shows better compressive strength for 28days and the 30% replacement of fine aggregates with steel slag also good compressive strength as compare to conventional concrete cubes. But the 30% replacement is decreased as compared to 10% and 20% replacement.
- This work relates the use of steel slag; a waste cheap material used as fine aggregate in M20 grade of concrete and recommends the approval of the material for use in concrete as a replacement material for fine aggregates. The partial substitution of natural aggregates with steel slag aggregates permits a gain of compressive strength and modulus of elasticity of concrete up to an optimum value of replacement.
- The 10%, 20% and 30% replacement of coarse aggregates with recycled aggregates shows the better compressive strength for 28days as compared to conventional concrete cubes.
- When demolished waste aggregates are used in concrete, the cost of production will be economical.

At last we are prepared the combination replacement of all three materials at a time @20% of each material such as cement by fly ash, fine aggregates by steel slag and coarse aggregate by recycled aggregate, the compressive strength of concrete is increased as compared to conventional concrete cubes.

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