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# Comparative Strength Analysis of Sustainable Concrete Incorporating PPSA, RCA, and M-Sand

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**Abstract**

The growing demand for sustainable construction materials has encouraged the utilization of agricultural waste and recycled construction materials in concrete production. This review examines the strength performance of sustainable concrete incorporating Pigeon Pea Stalk Ash (PPSA) as a partial cement replacement, Recycled Coarse Aggregate (RCA) as a replacement for natural coarse aggregate, and 100% Manufactured Sand (M-Sand) as fine aggregate. Published studies indicate that the incorporation of PPSA and RCA can produce concrete with satisfactory mechanical properties when used within optimum replacement limits. The reviewed literature shows that replacement levels of up to 2% PPSA and 30% RCA, combined with 100% M-Sand, can achieve the strength requirements of M30 grade concrete. Among the reported mix combinations, a maximum compressive strength of 43.95 MPa at 28 days was observed for the optimum mix. The findings demonstrate that PPSA, RCA, and M-Sand can effectively reduce the consumption of natural resources while maintaining adequate strength performance, making them promising materials for sustainable concrete applications.

**Keywords:** Sustainable Concrete; Pigeon Pea Stalk Ash (PPSA); Recycled Coarse Aggregate (RCA); Manufactured Sand (M-Sand); Compressive Strength; M30 Grade Concrete; Mechanical Properties; Cement Replacement; Aggregate Replacement; Sustainable Construction.

## 1. Introduction

Concrete is the most widely used construction material in the world; however, its production requires large quantities of cement and natural aggregates, leading to environmental concerns such as carbon emissions, depletion of natural resources, and accumulation of construction waste. Sustainable construction practices encourage the utilization of alternative materials that can reduce these adverse impacts while maintaining the desired performance of concrete. Pigeon Pea Stalk Ash (PPSA), produced from agricultural waste, can be utilized as a partial replacement for cement due to its pozzolanic properties. Similarly, Recycled Coarse Aggregate (RCA) obtained from demolished concrete can be used as a substitute for natural coarse aggregate, thereby promoting effective waste management. Manufactured Sand (M-Sand) provides a sustainable alternative to natural river sand and helps overcome the shortage of fine aggregates. The present study investigates the comparative strength performance of M30 grade sustainable concrete incorporating different proportions of PPSA and RCA with 100% M-Sand. The objective is to evaluate the effect of these replacement materials on the compressive strength of concrete and determine the optimum replacement levels for practical construction applications.

## 2. Objectives of the Current Study

In this experimental procedure of investigation the following are the main objectives of study:-

1. To determine the particle size distribution of Natural Coarse Aggregate (NCA), Recycled Coarse Aggregate (RCA) and Manufactured Sand (M Sand) through sieve analysis and evaluate their suitability for use in concrete as per relevant IS standards.
2. To assess the quality and strength characteristics of Recycled Coarse Aggregate by conducting the Aggregate Impact Value test and comparing the results with the permissible limits specified in IS codes.
3. To evaluate the shape characteristics of Recycled Coarse Aggregate using the Combined Flakiness and Elongation Index test and determine its compliance with standard requirements for concrete production.
4. To determine the silt content of Manufactured Sand (M Sand) and assess its suitability as a replacement for conventional river sand in concrete.
5. To prepare M30 grade sustainable concrete mixes incorporating varying percentages of Pigeon Pea Stalk Ash (PPSA) as a partial replacement of cement and Recycled Coarse Aggregate (RCA) as a partial replacement of natural coarse aggregate while using Manufactured Sand (M Sand) as the fine aggregate.
6. To investigate the compressive strength characteristics of concrete containing different proportions of PPSA and RCA with 100% M Sand after 28 days of curing.
7. To compare the compressive strength performance of sustainable concrete mixes with the control mix and identify the mixes that satisfy the strength requirements of M30 grade concrete.
8. To determine the optimum replacement levels of PPSA, RCA and M Sand that provide satisfactory concrete performance and promote sustainable utilization of agricultural and construction waste materials.

## 3. Methodology and Experimental Work

The experimental investigation was carried out on M30 grade concrete incorporating Pigeon Pea Stalk Ash (PPSA) as a partial replacement of cement, Recycled Coarse Aggregate (RCA) as a partial replacement of natural coarse aggregate, and 100% Manufactured Sand (M-Sand) as fine aggregate. Preliminary tests such as sieve analysis, aggregate impact value, flakiness and elongation index, and silt content tests were conducted to evaluate the suitability of the constituent materials. Concrete cubes were cast using different replacement combinations of PPSA and RCA, cured for 28 days, and tested for compressive strength. The obtained results were compared with conventional concrete to determine the optimum replacement levels and assess the feasibility of sustainable concrete production.

**Table 1: Test used in this work**

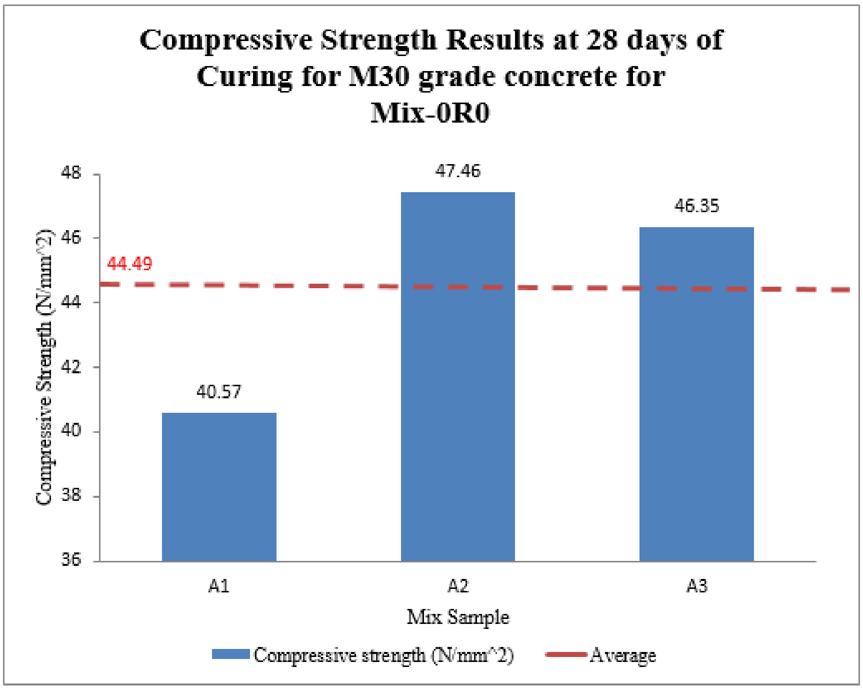
| Parameters | Indian Standardization used |
|---|---|
| Sieve Analysis for Natural Coarse Aggregate | IS 383-2016 and IS 2386-1963 Part 1 |
| Sieve Analysis for Recycled Coarse Aggregate (RCA) | IS 383-2016 and IS 2386-1963 Part 1 |

| | |
|---|---|
| Sieve Analysis for Fine Aggregate (M Sand) | IS 383-2016 and IS 2386-1963 Part 1 |
| Aggregate Impact Value Test | IS 2386-1963 Part IV |
| Combined Flakiness and Elongation Index Test | IS 2386-1963 Part IV |
| Silt Content Test for Fine Aggregate (M Sand) | IS 2116-1980 |
| Compressive Strength Test | IS 516-2021 |

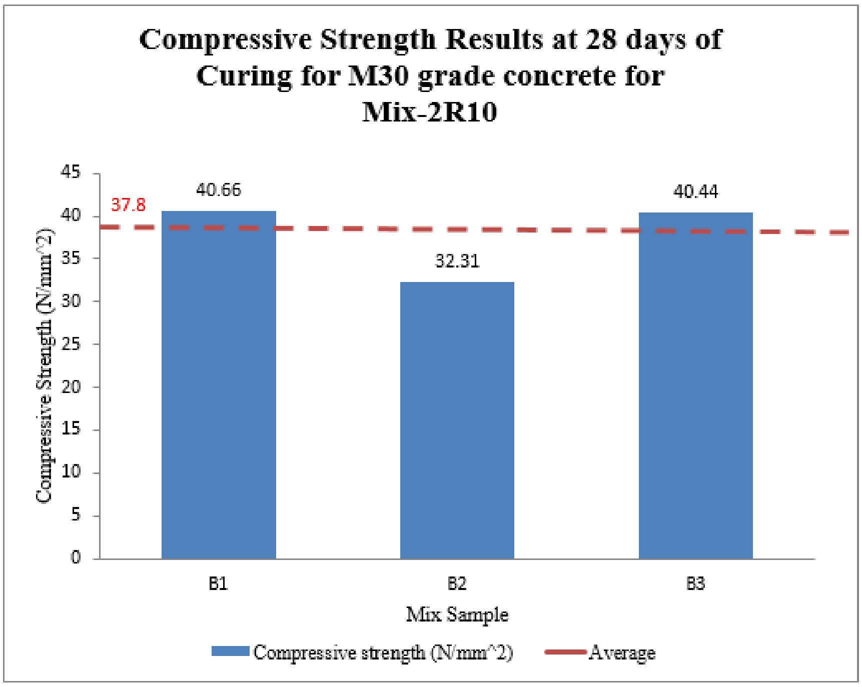
**Table 2: Mix design proportion for different selected mix ids**

| Mix ID | Mix Ratio |
|---|---|
| MIX-0R0 | 0% PPSA, 0% RCA, 100% M-Sand |
| MIX-2R10 | 2% PPSA, 10% RCA, 100% M-Sand |
| MIX-2R20 | 2% PPSA, 20% RCA, 100% M-Sand |
| MIX-2R30 | 2% PPSA, 30% RCA, 100% M-Sand |
| MIX-4R10 | 4% PPSA, 10% RCA, 100% M-Sand |
| MIX-4R20 | 4% PPSA, 20% RCA, 100% M-Sand |
| MIX-4R30 | 4% PPSA, 30% RCA, 100% M-Sand |
| MIX-6R10 | 6% PPSA, 10% RCA, 100% M-Sand |
| MIX-6R20 | 6% PPSA, 20% RCA, 100% M-Sand |
| MIX-6R30 | 6% PPSA, 30% RCA, 100% M-Sand |
| MIX-8R10 | 8% PPSA, 10% RCA, 100% M-Sand |
| MIX-8R20 | 8% PPSA, 20% RCA, 100% M-Sand |
| MIX-8R30 | 8% PPSA, 30% RCA, 100% M-Sand |

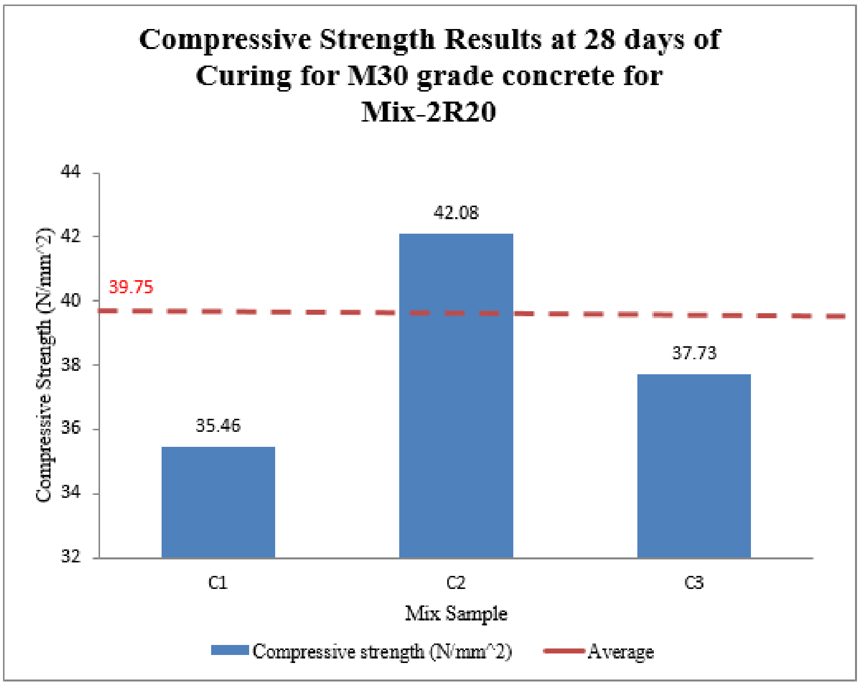
## 4. Results Analysis



**Graph 1: Compressive Strength Results at 28 days of Curing for M30 grade concrete for Mix-0R0**




**Graph 4: Compressive Strength Results at 28 days of Curing for M30 grade concrete for Mix-2R10**



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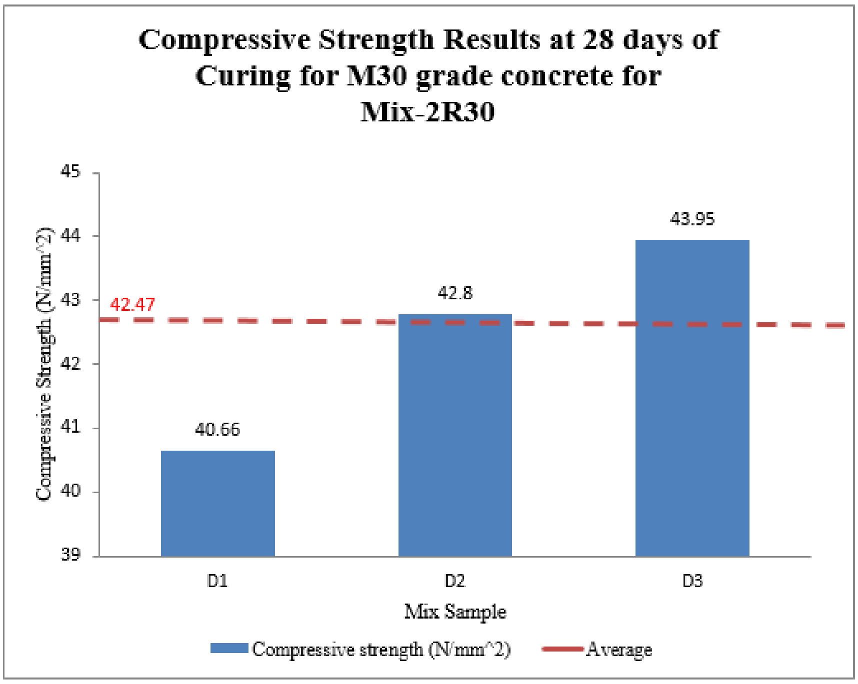
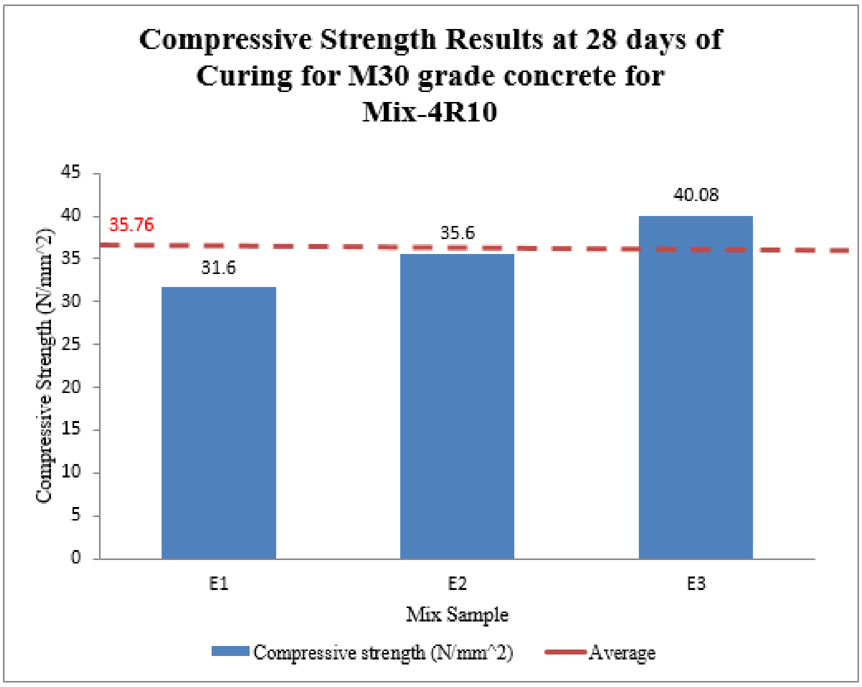
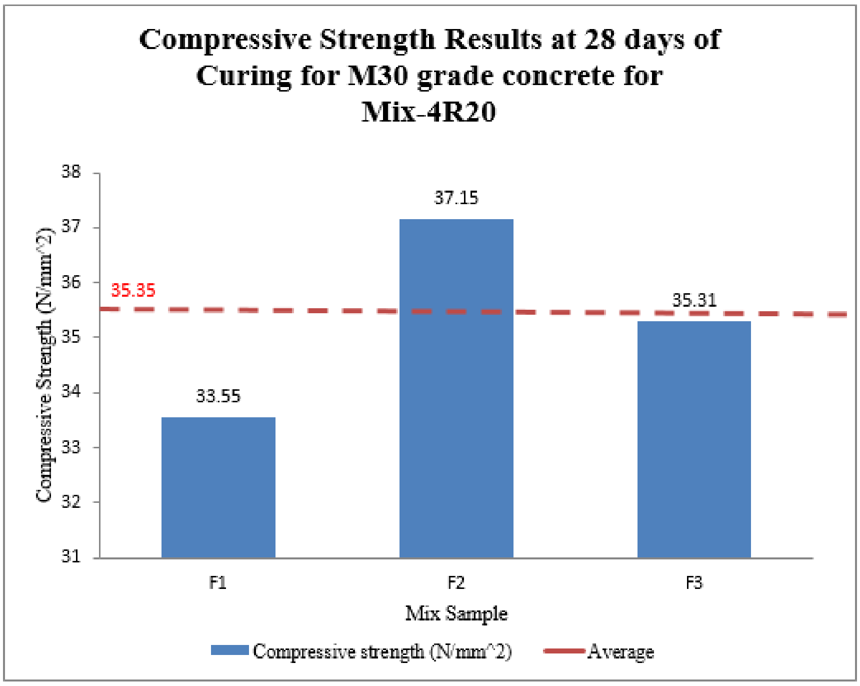
**Graph 3: Compressive Strength Results at 28 days of Curing for M30 grade concrete for Mix-2R20**



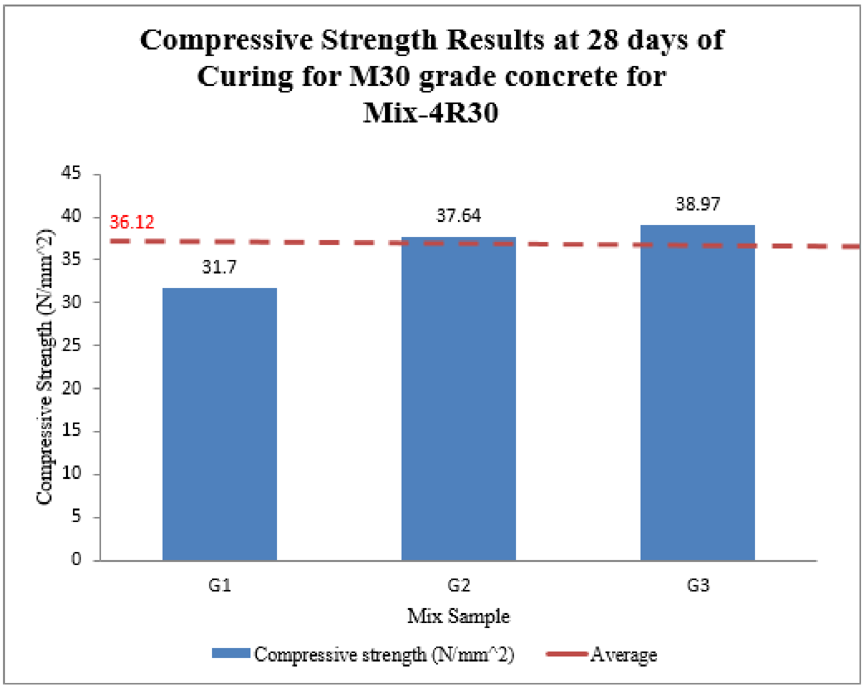

**Graph 4: Compressive Strength Results at 28 days of Curing for M30 grade concrete for Mix-2R30**



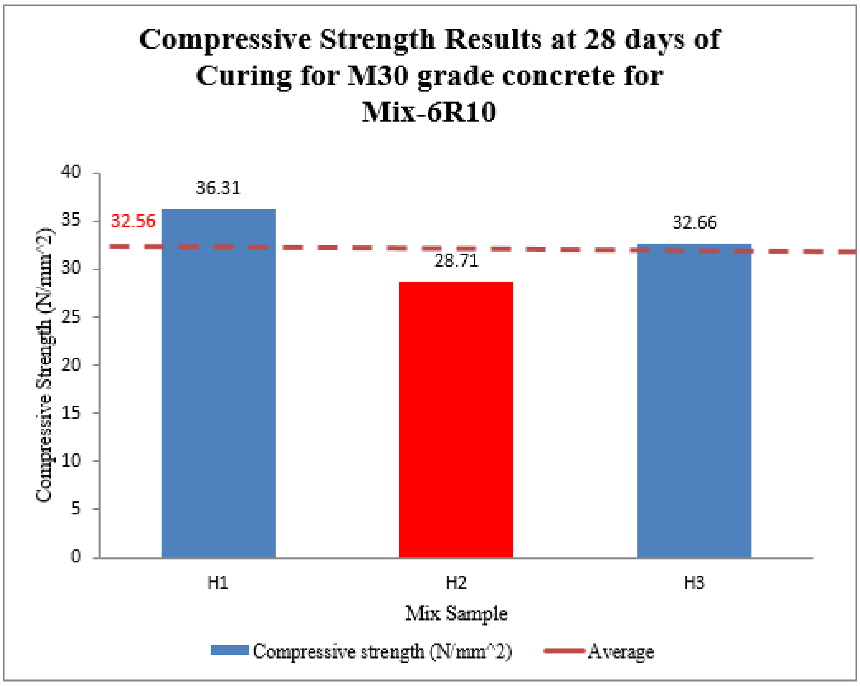
**Graph 5: Compressive Strength Results at 28 days of Curing for M30 grade concrete for Mix-4R10**



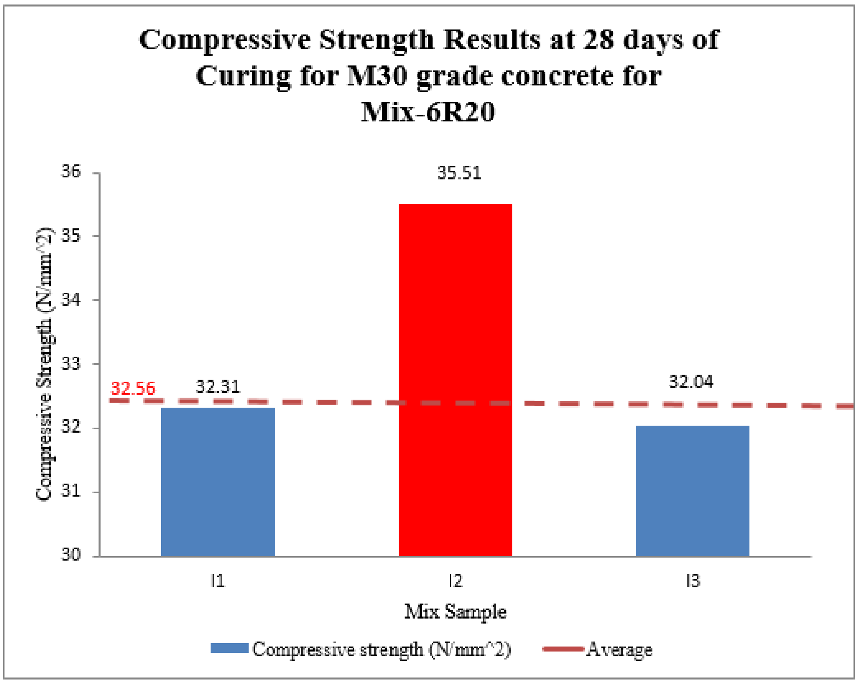

**Graph 6: Compressive Strength Results at 28 days of Curing for M30 grade concrete for Mix-4R20**



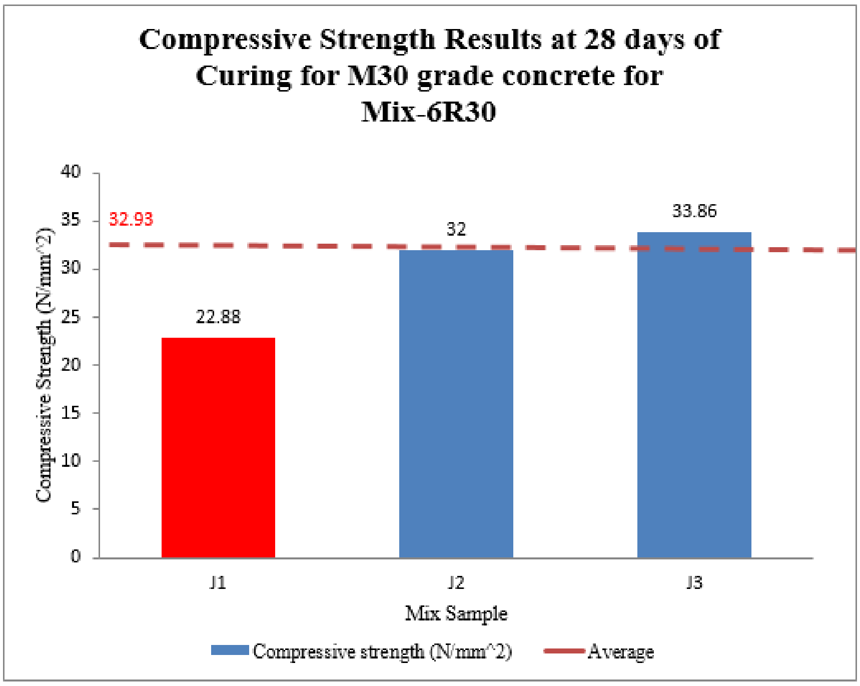
**Graph 7: Compressive Strength Results at 28 days of Curing for M30 grade concrete for Mix-4R30**



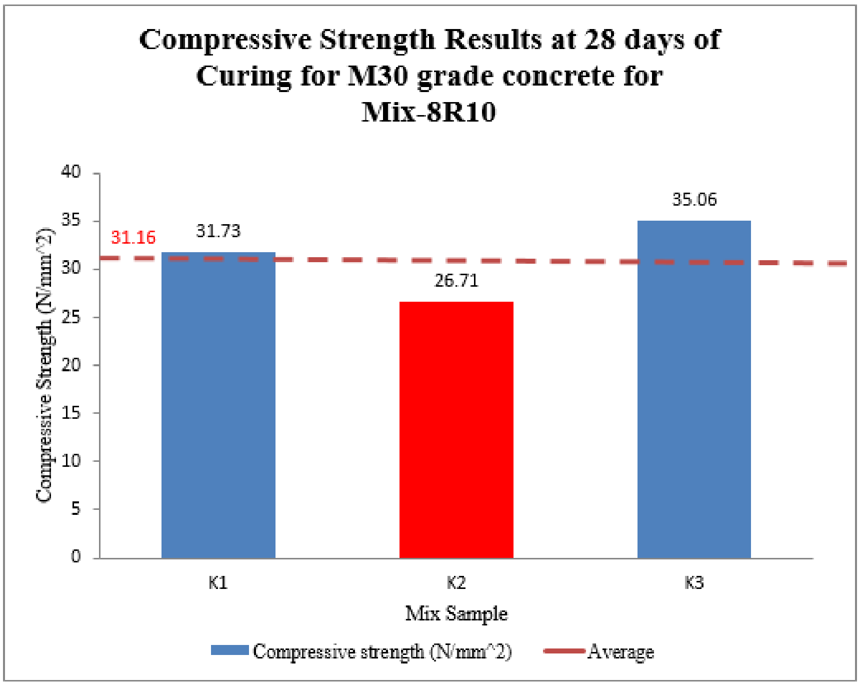

**Graph 8: Compressive Strength Results at 28 days of Curing for M30 grade concrete for Mix-6R10**



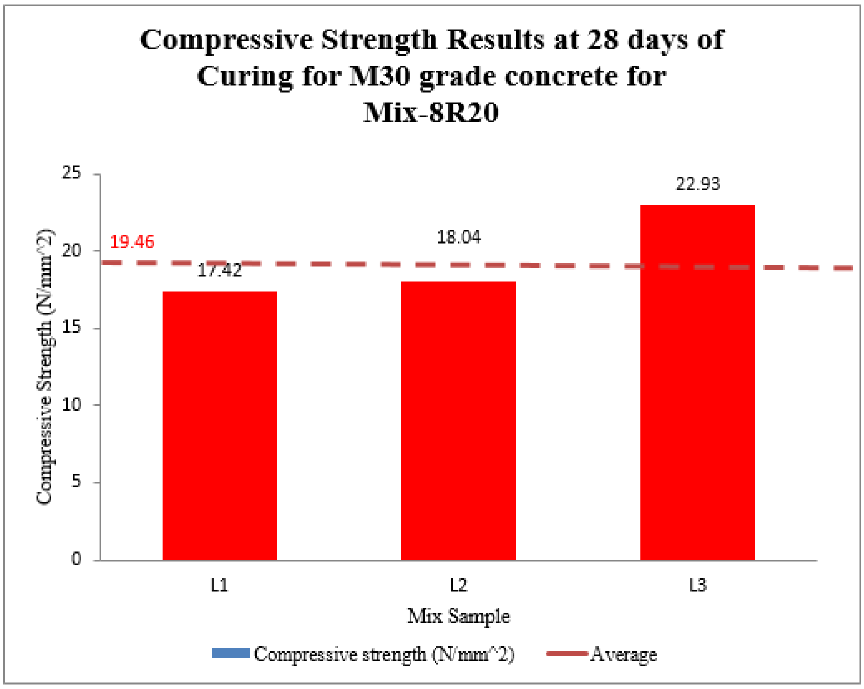
**Graph 9: Compressive Strength Results at 28 days of Curing for M30 grade concrete for Mix-6R20**



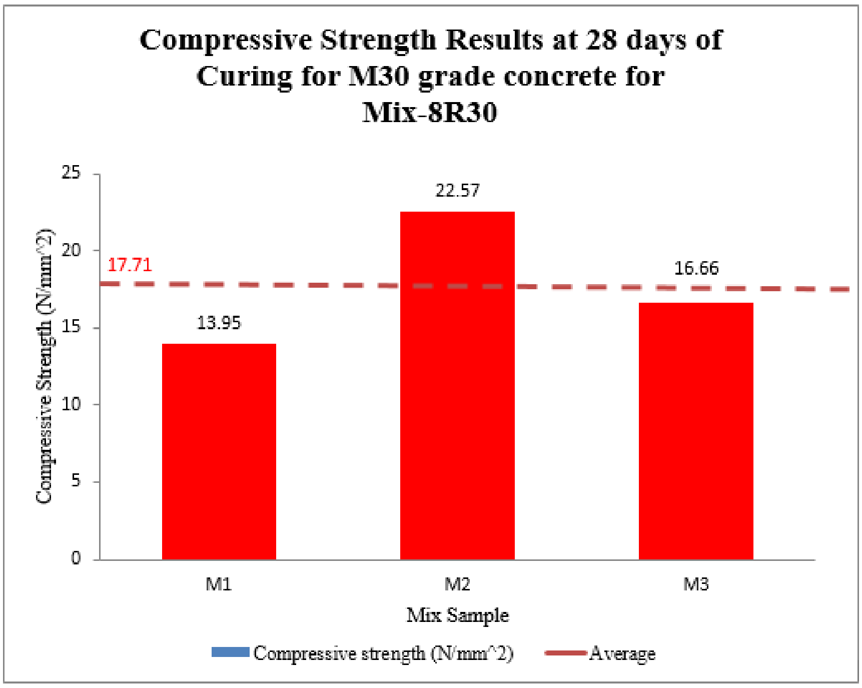

**Graph 10: Compressive Strength Results at 28 days of Curing for M30 grade concrete for Mix-6R30**



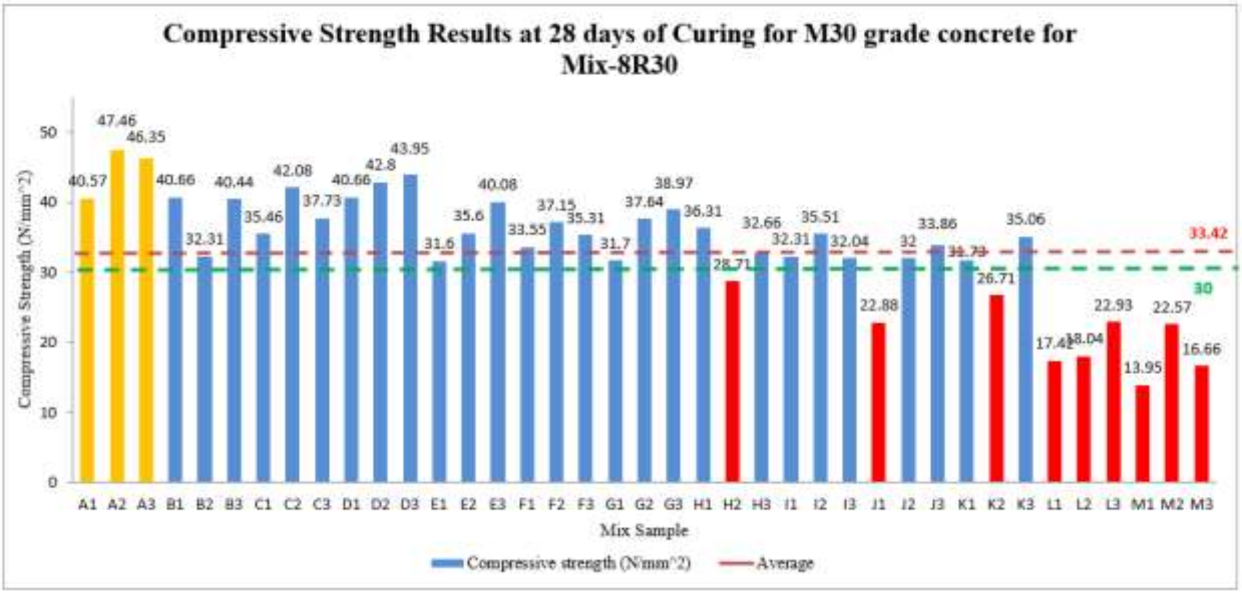
**Graph 11: Compressive Strength Results at 28 days of Curing for M30 grade concrete for Mix-8R10**




**Graph 12: Compressive Strength Results at 28 days of Curing for M30 grade concrete for Mix-8R20**



**Graph 13: Compressive Strength Results at 28 days of Curing for M30 grade concrete for Mix-8R30**




Graph 14: Maximum Torsional Moment in beams along X and Z directions for all five grade pair location cases in Zone III

## 5. Conclusions

From the results which are elaborated in previous chapter, it is concluded that the objectives which were fixed will result in the result and discussion part and from that the conclusions has drawn below:

1. The results obtained from results for Sieve Analysis for Natural Coarse Aggregate shows that 86.20% of material passed which is within the range of 85 to 100% as per standardization.
2. The same test of sieve analysis when performed on Recycled Coarse Aggregate (RCA) shows that 89.50% of material passed which is within the range of 85 to 100% as per standardization.
3. The test for sieve analysis for fine aggregate shows a better results when using M Sand in place of normal river sand shows Fineness Modulus (FM) =305.7/100=3.05 which has acceptable to use in concrete.
4. The Aggregate Impact Value test performed shows 12.96%, this value is less than the maximum limit of 45% specified in IS code, hence safe.
5. The test for combined Flakiness and Elongation Index value comes out to be 28.39%. This value is less that the max limit of 40% specified in IS code, hence safe.
6. The test for silt content of M Sand comes out to be 6.862%. This value is less that the maximum limit of 15% as specified in IS code.
7. On conducting the Compressive Strength test at 28 days of curing for M30 grade concrete, on comparing the basic combination of 0% PPSA, 0% RCA with 100% M Sand (A1, A2 and A3) with all the different combinations, it has clearly shown that among all the results, some combinations are fail, i.e. H2, J1, K2, L1, L2, L3, M1, M2, M3 while others are passed and to the mark. The best mix case observed is **D3** with a **highest value of 43.95** respectively with obtaining the limits of usage are:

- **PPSA = up to 2%**
- **RCA = up to 30%**

- **M Sand = up to 100%**

The main aim of the dissertation has achieved and will be recommended this work when such type of combination will be used in construction purpose for sustainable concrete construction.

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