Effect of Metallic and Non-Metallic Fibre and Recycled Aggregate on High Strength Concrete

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Abstract. The most prominent building material utilized within the field of civil engineering was concrete. Among structural elements concrete have very poor scrap value, so that it cannot be used anywhere. This paper deals about the possibility of utilizing the structural waste as replacement for ingredients used in concrete. Recycled aggregate were replaced of about 20%, 30%, 40% in the coarse aggregate. In order to increase the strength of concrete, the fibres like steel fibre, polypropylene fibre and glass fibre were used. They are all added of 0.5% each from the total weight of cement. Additional admixtures like lime and silica fume were incorporated to expand the strength of the concrete. The specimens were casted to consider its mechanical properties. By comparing the consequences of various proportions the specimens having 20% of Recycled aggregate has accomplished the best compressive strength of 62.2 N/mm². The result is of 8.86% not exactly typical mix. This proportion also shows great outcome for split tensile strength and flexural strength (i.e., 5.10 N/mm² and 5.6N/mm²). Thus by expanding the level of reused aggregate, the strength of concrete is tends to decrease.

1. Introduction
The concrete could be a compound material comprised of crushed stone aggregate reinforced along with cement paste which solidifies over the period. There are numerous sort of concrete accessible made by changing the proportion of important additives by means of using the substitution materials that having the same properties of materials that normally used in field. The wrapped up item was custom fitted to the area where the desired properties required. The strategies and innovation for creating this concrete of high strength were not considerably diverse from the ordinary conventional concrete.

W/C ratio proportion ought to be within the value of 0.3 – 0.35 or indeed it may lesser. A wide extend of aggregates can be utilized in spite of the fact that pulverized crushed aggregates (appropriately having crushing value of high) were ideal. And a few of 20%, 30%, and 40% of recycled aggregate are replaced within the coarse aggregate and in addition of admixtures like lime powder, silica fume, super plasticizer and fibre like Glass fibre, Steel fibre, Polypropylene fibre. High strength concrete was formed by reducing the w/c ratio to 0.35 and even lesser. Lower the water/binder ratio and by utilization of fine silica fume will reduced the concrete workability, it was one of the major problems while dealing with high strength concrete application where dense reinforcement cages were used. In order to compensate the decrease in workability, plasticizers were commonly included to high strength blends.
Brindhaet al. investigated the mechanical and durable property by adding the copper slag waste from copper refining industries as a partial replacement for fine aggregate. The different proportions of copper slag were being added and out of which upto 40% replacement, the concrete shows good strength. It shows good resistance to sulphate attack.

Fual Koksal et al. studied about the effect of adding the hybrid fibres on the mechanical properties of the concrete. In addition to that silica fume is also added as partial material replacement for cement. The addition of silica fume shows good results in terms of strength perspective, where the addition of fibre also good improvement in mechanical properties of concrete. However the addition of fibre affects the workability of concrete to some extent.

Manu Santhanam et al. perform the experimental investigation by trying the different combinations of metallic and non-metallic fibres and for different proportions. The addition of metallic fibres increase the impact strength of concrete and the addition of non-metallic fibres will delays the formation of cracks on structure. Out of different combinations, the steel and polypropylene fibre combination shows good results when compared to other combinations.

Vinay Kumar et al. studied about the effect of adding the recycled aggregate both in terms of fine and coarse aggregate in concrete. All the combination of four different mixes shows the satisfying results, but the addition of recycled aggregate will be somewhat reduced the workability of concrete. There will be slight decreased in compressive strength of concrete also. Wu Yao et al. studied about the effect of adding the hybrid fibres on strength of concrete, in which three different types of fibres were used. By comparing the mechanical properties of concrete having single fibre, the concrete contains two or more fibres shows good results in terms of strength.

2. Materials
Cement of OPC (53 grade) having specific gravity of 3.15 was used. The common sand with a specific gravity of 2.72 was used for fine aggregate. The coarse aggregate is of measure which retained in 12.5mm and having specific gravity of 2.78 was used. The broken concrete blocks from the demolished buildings were taken, in that coarse aggregate alone taken. The cement mortar on the aggregate surface was cleaned off. The specific gravity of recycled aggregate was found to be 2.76. The percentage of aggregate get replaced by recycled aggregate was mentioned in Table 1.

Table 1: % of Aggregate Replacement

| Mix ID | Coarse Aggregate (%) | Recycled Aggregate (%) |
|--------|----------------------|------------------------|
| S      | 100                  | -                      |
| S1     | 80                   | 20                     |
| S2     | 70                   | 30                     |
| S3     | 60                   | 40                     |

Silica fume was usually a finer round shape material having particle size < 1 micron as of diameter, normally the size may be of approximately 0.15 micron. Since of the fineness it acts as void filler and it makes a difference in maintaining a strategic distance from voids which by implication diminish the formation of cracks. The percentage by weight of cement get replaced by silica fume is mentioned in Table 2.

Table 2: % of cement replacement

| Mix ID | Cement (%) | Silica Fume (%) |
|--------|------------|-----------------|
| S      | 100        | -               |
| S1     | 90         | 10              |
| S2     | 90         | 10              |
| S3     | 90         | 10              |
The steel fibre used here having aspect ratios of about 30 - 250 and its diameters varies from 0.25 mm to 0.75 mm as shown in Figure 1. Generally compared to other fibres, glass fibres usually have high tensile strength as in the range of 1020 – 4080 N/mm$^2$ and length of 25mm were normally was utilized as shown in Figure 2. Polypropylene fibre was one of artificial fibre made from petrochemical and from textile industries as shown in Figure 3. Due to its high softening point and low modulus of elasticity it sort’s applications in boards and shotcrete. The utilization of fine silica fume will increase the strength of concrete, but in turns decrease the workability of the concrete, so in order to maintain the workability of concrete, the super plasticizers were included to increase the strength of the mixtures.

![Figure 1](image1.png) ![Figure 2](image2.png) ![Figure 3](image3.png)

**Figure 1**: Steel Fibre  **Figure 2**: Glass fibre  **Figure 3**: Polypropylene fibre

3. Mix proportions
The mix proportions used for the various concrete mix proportions were mentioned in Table 3

| ID | Cement % | Silica fume % | Sand % | Coarse Aggregate % | Recycled Aggregate % | Polypropylene Fibre % | Steel Fibre % | Glass Fibre % | Lime % |
|----|----------|---------------|--------|-------------------|----------------------|-----------------------|---------------|---------------|--------|
| S  | 100      | -             | 100    | 100               | -                    | -                     | -             | -             | -      |
| S1 | 90       | 10            | 100    | 80                | 20                   | 0.5                   | 0.5           | 0.5           | 1.5    |
| S2 | 90       | 10            | 100    | 70                | 30                   | 0.5                   | 0.5           | 0.5           | 1.5    |
| S3 | 90       | 10            | 100    | 60                | 40                   | 0.5                   | 0.5           | 0.5           | 1.5    |

4. Experimental procedure
The test samples were cast in cast-iron steel moulds of cube having size of 150 mm x 150 mm x 150 mm, cylinder having size of 150 mm diameter and 300mm height, prism having size of 100 mm width, 100 mm depth and of 500 mm length. The interior of the moulds were applied with oil to encourage the easy removal of specimens. The concrete was put within the moulds in three layers of equal thickness with appropriate tamping. After approximately for 24 hours of hardening, the samples were demoulded and were set promptly for water curing for period of 28 days as shown in Figure 4.
The bearing surfaces of the testing machine will be cleaned off and any free sand or other material expelled from the surfaces of the specimens which are to be in contact with the compression platens. On account of cubes, the specimens will be set in the machine in such a way, that the load will be applied to inverse sides of the cubes as cast, that is and not to the top and base. The axis of specimens will be lined up with the focal point of push of the circularly situated square is brought to be in contact with the specimens, so that uniform seating might be gotten as shown in Figure 5. The load will be applied without stun and at a uniform pace until the resistance of specimens to the expanding load separates and no more loads can be supported. The ultimate load applied to the samples will at that point be recorded and used for further studies.

**Figure 4:** Concrete cubes after 28 days curing

**Figure 5:** Compressive strength of concrete

5. **Result and discussion**
From the specimens that had been molded and cured for 28 days they were testing for the mechanical properties via compression, tension and flexure, the results were mentioned in the form of tables.
5.1 Compressive strength
The tested compressive strength results for all the test specimens were mentioned in the form of Table 4.

Table 4: Compressive strength of concrete

| Mix ID | Compressive Strength (N/mm²) |
|--------|------------------------------|
| S      | 68.89                        |
| S1     | 62.20                        |
| S2     | 55.11                        |
| S3     | 49.33                        |

From the testing results for compressive strength, it is apparently shows that there is decrease in strength of samples containing recycled aggregate in contrasted with the normal mix. This happens for the reason that the increase in addition of recycled aggregate results in decrease in strength, the reason behind was irregular shape of recycled aggregate affects the density of concrete and rough surface of aggregate absorbs large amount of water and thus it reduced its strength. The another one important factor is aggregate used here is already subjected to load, so that it can carry less load in contrast to that of normal aggregate.

Graph 1: Compressive strength of concrete

The strength attained for 28 days were found to be about 8.86% lesser than of normal mix. The addition of silica fume 10% to the weight of cement appears to have valuable impact on improving the strength of mixes having recycled aggregate. The average 28 days strength for various mix proportions were presented in Graph 1.

5.2 Split tensile strength
The test consequences for the cylindrical samples were accounted for in Table 5 alongside their average split tensile strength.
Table 5: Split Tensile strength of concrete

| Mix ID | Split Tensile Strength (N/mm²) |
|--------|-------------------------------|
| S      | 5.51                          |
| S1     | 5.10                          |
| S2     | 4.55                          |
| S3     | 4.10                          |

The split tensile strength of normal mix was viewed as higher diverged from reference to that of specimens having recycled aggregate. From Table 5, it will in general be seen that the concrete containing 20% substitution of recycled aggregate and 10% of silica fume shows strength almost like that of typical mix. Anyway for different proportions, the strength is lesser than that of typical mix. The average 28 days strength for various mix proportions were presented in Graph 2.

Graph 2: Split tensile strength of concrete

5.3 Flexural strength
The flexural strength results were presented in Table 6. In comparison to normal mix without recycled aggregate, all the mixes having recycled aggregate indicated a considerable decrement in flexural strength as appeared in Graph 3.

Table 6: Flexural strength of concrete

| Mix ID | Flexural Strength (N/mm²) |
|--------|--------------------------|
| S      | 6.40                     |
| S1     | 5.60                     |
| S2     | 4.80                     |
| S3     | 4.40                     |
From the over tables the proportion of S1 had accomplished the most extreme strength among the distinctive proportion specified. The greatest compressive strength of cube gotten 62.2 N/mm$^2$ and the most outrageous tensile strength of cylinder had gotten of 5.10 N/mm$^2$. By then the best flexural strength gotten is of 5.6 N/mm$^2$. Regardless these characteristics are all underneath the ordinary mix strength gotten.

6. Conclusion
It had been concluded that lime 1.5%, coarse aggregate 80% recycled total 20%, Silica fume 10% steel fibre 0.5%, glass fibre 0.5% ,polypropylene 0.5% accomplishes most extreme compressive strength at 28 days. It accomplishes 91.13% of the characteristic compressive strength. At that point lime 1.5%, coarse aggregate 80% recycled aggregate 20%, Silica fume 10% steel fibre 0.5%, glass fibre 0.5% ,polypropylene 0.5% achieves greatest tensile strength at 28 days. It accomplishes 92.5% that of control mix. Then lime 1.5%, coarse aggregate 80% recycled aggregate 20%, Silica fume 10% steel fibre 0.5%, glass fibre 0.5% ,polypropylene 0.5% achieves most extreme flexural strength at 28 days. Silica Fume was normally 100 times smaller in size that of ordinary binding material. Since of the fineness it acts as void filler and it makes a difference in maintaining a strategic distance from voids which by implication diminish the formation of cracks.The addition of steel fibres reduced the width of cracks and controls the further extension of crack firmly, in this way progressing toughness. Make strides that it can withstand the high impact and act as an abrasion resistance to concrete. Normally utilized for the high strength precast structures and highways, air terminal asphalts, headstrong and for canal linings etc. The glass fibres due to its high impact strength and having high expanded flexural strength increased its application over large areas. It accomplishes 100% of the flexural strength. The mechanical properties of concrete with encourage substitution recycled aggregate can be carried as a future study.

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