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*Technical Note*

# COMPRESSIVE STRENGTH OF CONCRETE MADE WITH COAL WASHERY REJECTS AS COARSE AGGREGATE

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## ABSTRACT

The demand of natural aggregates is rapidly becoming high day by day in the construction industry. Various attempts are being made to find substitutes for natural aggregates. In India, about 70% of electricity is produced by combustion of good quality coal. In the process of coal washing, large quantities of impure coal are being rejected and causing disposal problems. These rejected impure coals are called as Coal Washery Rejects (CWR). To maintain the environmental sustainability, an attempt has been made in the present study to use new material CWR as partial replacement of coarse aggregate in concrete. This investigation studied the compressive strength of concrete containing CWR at different replacement levels (0% - 50%). The compressive strength values were compared to M 25 grade of conventional concrete (CC). From the results, it is observed that the increase in CWR replacement level decreased the compressive strength. This decrease was marginal at 20% and 30% replacement levels, but beyond 30%, the decrease was very much significant. Hence, it is revealed that 30% CWR replacement can be considered as optimum level in the construction industry.

**Keywords:** Coarse aggregate; coal washery rejects; compressive strength; conventional concrete.

## 1. INTRODUCTION

Aggregates which occupy approximately 70-80% of concrete volume play a vital role in the concrete properties. The availability of good quality aggregates is depleting day by day due to tremendous growth in the construction industry. Hence, several researches are being focused on the use of various industrial waste materials and by-products as aggregate

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substitutes such as coal ash, granulated blast furnace slag, fiber glass waste materials, waste plastics, rubber waste and others [1 & 2]. The workability of concrete decreased with the increase in bottom ash content due to the increase in water demand. The compressive, splitting tensile and flexural strength properties of concrete using bottom ash as fine aggregate were lower than control concrete at all ages. But, after 28 days the strength difference between bottom ash concrete and control concrete specimens was less distinct [3]. The early age compressive strength of concrete using granulated blast furnace slag (GBFS) as fine aggregate was lower than concrete made with river sand, but at later ages the strength was higher [4].

The total substitution of coarse aggregate with crystallized slag affects positively the compressive, splitting tensile and flexural strength properties [5]. It was suggested that copper slag can be used as a replacement for fine aggregate to obtain a concrete with good strength and durability requirements [6]. The incorporation of plastic aggregate (PA) decreased the slump of the fresh concrete. The strength properties and modulus of elasticity of concrete using PA as coarse aggregate are always lower than the control concrete [7]. Bhikshma and Manipal pointed out that significant improvement in the concrete properties when recycled aggregate is used along with the steel fibres [8].

About 67% of electricity produced in India is by combustion of coal. The total reserves of coal in India are estimated to be 106,260 million tones. As the demand of coal has the highest forward linkage effect with thermal power, railways locomotives, fertilizers industry, cement, steel, electric power and a number of other industries, the consumption of coal is expected to increase at faster rate. India continues to be the sixth largest producer of coal with its annual production of nearly 100 million tones. The reserves of high ranking coal i.e. anthracite and coking bituminous coals are less as compared to the low ranking bituminous and lignite coals. The coal as it comes from mines consist of many impurities such as magnesium sulphate, sulphur in form of pyrites, slate and fire clay. These substances have higher specific gravity than pure coal and hence, it requires coal washing technique to clean coal before using. Specific gravity of pure coal is 1.2 to 1.7 and for impure coal is 1.7 to 4.9. Therefore, coal must be screened to size and it must be cleaned by jigging or by heavy-media separation [9].

Indian coal is considered to be of low quality since it contains ash as high as 45%, high moisture content (4–20%), low sulfur content (0.2–0.7%), and low calorific values (between 2500–5000 kcal/kg) (IEA, 2002). High ash content in the coal supplied to the power pants not only poses environmental problems but also results in poor plant performance. Thus, coal washing is necessary from economic and environment point of view.

During the coal washing process, cleaned coal carried out by the water flow over a weir and the refuse sinks at the bottom. Refuse is removed time to time from the washer and stored in bunker storage. This refuse which is stored in bunker storage is called coal washery rejects (CWR) [10]. The generation of rejects from washeries in Coal India Limited (CIL) in 2004-05 was 2.44 Mt. Accumulated stock of washery rejects up to March’05 was 18.15Mt. The coal washery rejects (CWR) are the major environmental hazard during the process of coal washing. Disposal of this huge quantity of rejects in an environment friendly manner creates a real problem. For solving the disposal of large amount of coal washery rejects, reuse of CWR in concrete industry can also be considered as the most feasible application [11]. Hence, this investigation is aimed to introduce CWR, as an alternative to coarse

aggregate in the concrete industry and study the mechanical properties of CWR based concrete.

## 2. EXPERIMENTAL STUDY

Our objective was to study the compressive strength of concrete containing CWR as partial substitute of coarse aggregate at different proportions (0% - 50%) at different curing periods (7, 28 and 56 days). The mix designations are denoted as CWR_0, CWR_20, CWR_30, CWR_40 and CWR_50 for the 0%, 20%, 30%, 40% and 50% CWR replacements respectively.

### *2.1 Materials*

In this study, Ordinary Portland Cement 53 grade corresponding to IS 12269:1987 [12] was used and the chemical and physical properties of cement are shown in Table 1. The physical properties of crushed granite stone and CWR are shown in Table 2. Natural river sand was used as fine aggregate. The bulk specific gravity in oven dry condition and water absorption of the sand as per IS 2386 [13] were 2.6 and 1% respectively.

Table 1: Chemical and physical properties of cement

| **Chemical properties (%)** | | | | | | **Physical properties** | |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $SO_3$ | Specific gravity | Fineness ($m^2$/Kg) |
| 19.79 | 5.67 | 4.68 | 61.81 | 0.84 | 2.48 | 3.15 | 311.5 |

Table 2: Physical properties of aggregates

| **Properties** | **Coarse aggregate** | **CWR** |
|---|---|---|
| Specific gravity | 2.6 | 2.06 |
| Water absorption (%) | 0.3 | 0.48 |
| Bulk density (Kg/$m^3$) | 1580 | 1431 |
| Impact strength (%) | 17.9 | 19.5 |
| Crushing strength (%) | 22.8 | 26.8 |

### *2.2 Test methods*

Compressive strength test was conducted on the cubical specimens for all the mixes after 7, 28 and 56 days of curing as per IS 516 [14]. Three cubical specimens of size 150 mm x 150 mm x 150 mm were cast and tested for each age and each mix.

### *2.3 Mix design*

Coarse aggregate particles of size 20 mm and 10 mm were blended in 60:40 proportion by percentage weight of total aggregate to better bond with the reinforcement in the building structures. 20 mm coarse aggregate was replaced by 20 mm CWR at 0%, 20%, 30%, 40% and 50%. M 25 grade of Conventional Concrete (CC) has been designed as per IS 10262:2009 [15] and IS 456:2000 [16]. Mix proportions of constituent materials are shown in Table 3.

Table 3: Mix proportions of constituent materials of concrete mixes

| Mix type | Cement kg/m$^3$ | Water l/m$^3$ | 20 mm kg/m$^3$ | 10 mm kg/m$^3$ | CWR 20 mm kg/m$^3$ | Sand kg/m$^3$ |
|---|---|---|---|---|---|---|
| CWR_0 | 384 | 192 | 683 | 456 | 0 | 636 |
| CWR_20 | 384 | 192 | 546 | 456 | 137 | 636 |
| CWR_30 | 384 | 192 | 478 | 456 | 205 | 636 |
| CWR_40 | 384 | 192 | 410 | 456 | 273 | 636 |
| CWR_50 | 384 | 192 | 341 | 456 | 341 | 636 |

## 3. RESULTS AND DISCUSSION

*3.1 Compressive strength*

Table 4 shows the compressive strength values of concrete with partial replacement of CWR at different curing periods. From the results it is seen that the concrete mixes with partial replacement of CWR have attained lower values of compressive strength at all ages as compared to that of conventional concrete (CWR_0) as shown in Fig. 1.

Table 4: Compressive strength of concrete

| Mix type | Compressive strength (Mpa) | | |
|---|---|---|---|
| | 7 days | 28 days | 56 days |
| CWR_0 | 23.20 | 33.06 | 35.84 |
| CWR_20 | 22.76 | 32.20 | 34.68 |
| CWR_30 | 22.18 | 31.14 | 33.39 |
| CWR_40 | 20.02 | 28.53 | 30.81 |
| CWR_50 | 18.56 | 25.37 | 27.94 |

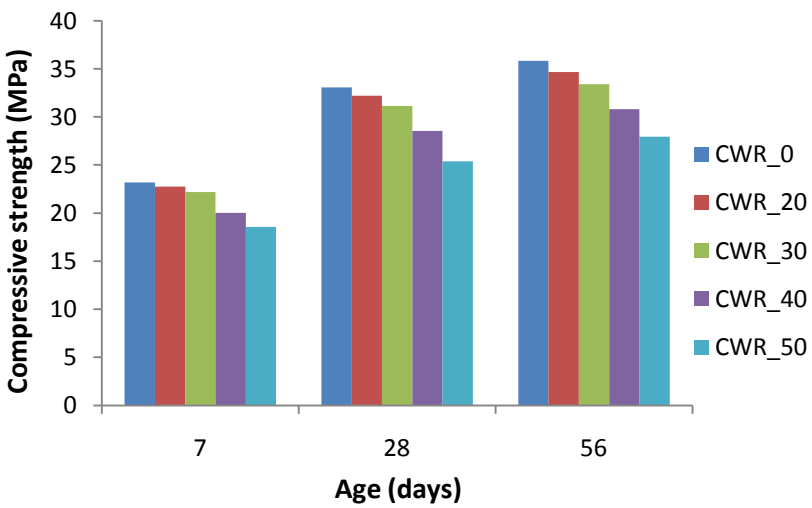


Figure 1. Compressive strength versus Age

It is clearly observed that as replacement of CWR increased from 20% to 50%, the compressive strength values are found to be decreased approximately 20% for all ages of concrete as shown in Fig. 1. From the aggregate properties, it is known that CWR have lower values of crushing and impact strength when compared to those of coarse aggregate. The lower value of crushing and impact strength of CWR is mainly attributed to the decrease in compressive strength of CWR based concrete mixes. Interestingly, it is observed that the compressive strength values have been decreased for the concrete mixes CWR_20 and CWR_30. The 28 day compressive strength of the concrete mixes CWR_20 and CWR_30 are comparable to that of M 25 grade of CC. The further increase in replacement of CWR decreased the compressive strength values significantly as in the case of the concrete mixes CWR_40 and CWR_50. Hence, it can be recommended to use CWR at 30% partial replacement of coarse aggregate in order to attain the desired 28 day strength of CC.

## 4. CONCLUSIONS

Based on the results of this experimental investigation, the following conclusions can be drawn:

1. From the results it is seen that the concrete mixes with partial replacement of CWR have attained lower value of compressive strength at all ages as compared to that of conventional concrete.
2. The lower value of crushing and impact strength of CWR is mainly attributed to the decrease in compressive strength properties of CWR based concrete mixes.
3. It is observed that the strength properties have been decreased marginally for the concrete mixes CWR_20 and CWR_30. The 28 day compressive strength of the concrete mixes CWR_20 and CWR_30 are comparable to that of M 25 grade of CC.
4. The further increase in replacement of CWR decreased the compressive strength significantly as in the case of the concrete mixes CWR_40 and CWR_50.
5. Hence, it can be recommended that 30% partial replacement of CWR as coarse aggregate is optimum in the view of CC.

This investigation is given a path in the research area to explore the other mechanical and durability properties of CWR based concrete.

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