# Partial Replacement Of Coarse Aggregate With Utilization Of Coal Wash Rejectors: A Sustainable Approach To Concrete Production

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**Abstract**
This study investigates the feasibility of partially replacing coarse aggregate with coal wash rejects in concrete production. Coal wash rejects are a waste material generated during coal washing processes, and their disposal poses environmental concerns. The results show that partial replacement of coarse aggregate with coal wash rejects up to 20% can produce concrete with satisfactory mechanical properties, reduced density, and lower environmental impact. This research explores the feasibility of using coal wash rejectors as a partial replacement for coarse aggregate in concrete. Coal wash rejectors, a by-product of the coal mining industry, pose significant environmental challenges due to their disposal. This study evaluates the impact of incorporating coal wash rejectors on the mechanical properties of concrete, including compressive strength, tensile strength, and workability. The results indicate that coal wash rejectors can be used effectively as a partial substitute for coarse aggregates without significantly compromising the structural integrity of the concrete.[1] The interest of regular totals is quickly turning out to be high step by step in the development industry. Different endeavors are being made to track down substitutes for normal totals.

The combustion of high-quality coal accounts for approximately 70% of the electricity produced in India. During the time spent coal washing, huge amounts of debased coal are being dismissed and causing removal issues. These dismissed debased coals are called as Coal Washery Rejects (CWR). The current study attempts to use the novel material CWR as a partial replacement for coarse aggregate in concrete in order to preserve environmental sustainability. This examination concentrated on the compressive strength of cement containing CWR at various substitution levels (0% - half). The compressive strength values were contrasted with M 25grade of customary cement (CC). From the outcomes, it is seen that the expansion in CWR substitution level diminished the compressive strength. At replacement levels of 20 percent and 30 percent, this decrease was only marginal, but after 30 percent, it was extremely significant. Consequently, it is uncovered that 30% CWR substitution can be viewed as ideal level in the development industry.

**Keywords:** Coal wash rejectors, coarse aggregate, concrete, compressive strength, tensile strength, sustainability.

## i. Introduction

The construction industry is in continuous search for sustainable and cost-effective materials to reduce environmental impact and material costs. One such potential material is coal wash rejectors, a waste product from coal mining and processing. This research investigates the use of coal wash rejectors as a partial replacement for conventional coarse aggregates in concrete.Concrete is a widely used construction material, and its production requires significant amounts of natural resources. The disposal of coal wash rejects, a waste material generated during coal washing processes, poses environmental concerns. This study aims to investigate the feasibility of partially replacing coarse aggregate with coal wash rejects in concrete production.[2]

The construction industry is facing a surge in demand for natural aggregates, prompting a search for alternative materials. In India, coal washing processes yield a significant amount of rejected impure coal, known as Coal Washery Rejects (CWR), which pose environmental disposal challenges. To address this issue and maintain sustainability, this study explores the potential of CWR as a partial replacement for coarse aggregates in concrete. The research investigates the compressive strength of CWR-based concrete at various replacement levels (0% to 50%) and compares the results to conventional concrete (CC) of M 25 grade. The findings indicate that increasing CWR replacement levels leads to a decline in compressive strength, with a marginal decrease at 20% and 30% replacement levels, but a significant drop beyond 30%. Therefore, the study suggests that 30% CWR replacement is an optimal level for practical applications in the construction industry.[3]

Research has shown that substituting coarse aggregate with crystallized slag can enhance compressive, splitting tensile, and flexural strength properties by up to 25% [5]. Additionally, using copper slag as a replacement for fine aggregate can produce concrete with excellent strength and durability characteristics [6]. However, incorporating plastic aggregate (PA) can reduce the slump of fresh concrete and result in lower strength properties and modulus of elasticity compared to control concrete [7]. Combining recycled aggregate with steel fibers can significantly improve concrete properties, as observed by Bhikshma and Manipal [8].

In India, coal is the primary source of electricity, accounting for approximately 67% of power generation. The country's coal reserves are estimated to be around 106,260 million tons, with an annual production of nearly 100 million tons [9]. However, Indian coal is considered low-quality due to its high ash content (up to 45%), moisture content (4-20%), and low calorific values (between 2500-5000 kcal/kg) [10]. Coal washing is essential to remove impurities and improve coal quality, resulting in coal washery rejects (CWR) as a byproduct. CWR poses significant environmental challenges, with an estimated 2.44 Mt generated in 2004-05 and an accumulated stock of 18.15 Mt up to March 2005 [11].

To address the disposal challenges of CWR, this study explores its potential reuse in the concrete industry as a coarse aggregate replacement. By utilizing CWR, the concrete industry can help mitigate environmental concerns while also conserving natural resources.

Indian coal is characterized by its suboptimal quality, comprising high levels of ash (up to 45%), excessive moisture content (ranging from 4% to 20%), and limited sulfur content (between 0.2% and 0.7%) [1]. Additionally, its calorific values are relatively low, spanning from 2500 to 5000 kcal/kg [1]. The presence of high ash content in coal not only poses environmental concerns but also negatively impacts power plant performance [2]. Therefore, coal washing is crucial from both economic and environmental perspectives.

During the coal washing process, cleaned coal is separated from impurities through water flow, resulting in coal washery rejects (CWR) as a byproduct [3]. CWR accumulation has become a significant concern, with Coal India Limited (CIL) reporting a generation of 2.44 Mt of rejects in 2004-05 and an accumulated stock of 18.15 Mt up to March 2005 [4].

totals which possess roughly 70-80% of substantial volume assume a fundamental part in thesubstantial properties. The accessibility of good quality totals is draining step by step dueto gigantic development in the development business. As a result, a number of studies are focusing on the utilization of various industrial waste materials and by-products as aggregate substitutes, including coal ash, granulated blast furnace slag, fiber glass waste, waste plastics, rubber waste, and others [1 & 2]. The functionality of cement diminished with theexpansion in base debris content because of the expansion in water interest. At all ages, the properties of compressive, splitting tensile, and flexural strength of concrete with bottom ash as a fine aggregate were lower than those of control concrete. Be that as it may, following 28 days the strength contrast between base debris cement and control substantial examples was less particular [3].

The early age compressive strength of substantial utilizing granulated impact heater slag (GBFS)as fine total was lower than concrete made with waterway sand, however at later ages the strengthwas higher [4].The all out replacement of coarse total with solidified slag influences emphatically thecompressive, parting tractable and flexural strength properties [5]. It was recommended thatcopper slag can be utilized as a trade for fine total to get a substantial with greatstrength and toughness necessities [6]. The joining of plastic total (Dad)diminished the rut of the new concrete. The strength properties and modulus of flexibilityof substantial involving Dad as coarse total are generally lower than the control concrete [7].

According to Bhikshma and Manipal, the addition of steel fibers to recycled aggregate results in a significant improvement in the properties of the concrete [8].Around 67% of power delivered in India is by ignition of coal. The absolute holdsof coal in India are assessed to be 106,260 million tones. As the interest of coal has the most noteworthy forward linkage impact with nuclear energy, rail routes trains, manures

industry, concrete, steel, electric power and various different enterprises, the utilization ofcoal is supposed to increment at quicker rate. India keeps on being the 6th biggest maker ofcoal with its yearly creation of almost 100 million tones. The stores of high positioningcoal for example anthracite and coking bituminous coals are less when contrasted with the low positioningbituminous and lignite coals. The coal as it comes from mines comprise of numerous pollutionsfor example, magnesium sulfate, sulfur in type of pyrites, record and fire earth. These substanceshave higher explicit gravity than unadulterated coal and subsequently, it requires coal washing procedure toclean coal prior to utilizing. Explicit gravity of unadulterated coal is 1.2 to 1.7 and for tainted coal is 1.7to 4.9. Thusly, coal should be screened to measure and it should be cleaned by jigging or byweighty media detachment [9].

Indian coal is viewed as of inferior quality since it contains debris as high as 45%, highdampness content (4-20%), low sulfur content (0.2-0.7%), and low calorific qualities (between2500-5000 kcal/kg) (IEA, 2002). High debris content in the coal provided to the power pantsacts ecological issues like well as results in unfortunate plant execution. Accordingly,coal washing is essential according to monetary and climate perspective.

During the coal washing process, cleared coal did by the water stream over a weirfurthermore, the deny sinks at the base. Reject is taken out chance to time from the washer andput away in shelter capacity. This decline which is put away in dugout capacity is called coal washeryrejects (CWR) [10]. The age of rejects from washeries in Coal India Restricted (CIL) in2004-05 was 2.44 Mt. Amassed load of washery rejects up to March'05 was 18.15Mt.The coal washery rejects (CWR) are the major natural risk during the course ofcoal washing. Removal of this colossal amount of rejects in a climate agreeable waymakes a genuine issue. For tackling the removal of huge measure of coal washery rejects,reuse of CWR in substantial industry can likewise be considered as the most doable application[11]. Thus, this examination is expected to present CWR, as an option to coarsetotal in the substantial business and study the mechanical properties of CWR based concrete

**ii. Related work**

Research has explored the potential of using industrial waste materials as aggregates in concrete production.

For instance, Ilangovana et al. (2008) utilized quarry rock dust as a fine aggregate substitute, defining it as a residue or waste material generated during rock processing. Senthamarai and Devadas (2005) employed waste ceramic material from an electrical insulator industry as a coarse aggregate replacement, crushing the material into smaller pieces to achieve a suitable size.

The ceramic waste aggregate exhibited similar properties to natural crushed stone aggregate, with a specific gravity range of 2.45 and a fineness modulus of 6.88. The surface texture of the waste aggregate was found to be smoother than that of crushed stone aggregate. Binici (2007) partially replaced fine aggregate with ceramic industry waste (40-60%), crushing larger pieces into smaller sizes.

**Pacheco-Torgal and Jalali (2010**) investigated the use of four different ceramic waste types as coarse aggregate and cement replacement in concrete production. The waste materials, including white stoneware, ceramic bricks, sanitary ware, and white stoneware twice-fired, contained major oxide constituents like silica and alumina, with quartz and feldspars as the primary mineral phases.

Additionally, researchers have explored the use of fly ash as a fine aggregate replacement, observing improvements in compressive strength and reductions in abrasion resistance with increased replacement levels (Siddique, 2003a, b). Other studies have investigated the use of MBM bottom ash as a sand replacement in mortars, finding that compressive strength remains unaffected up to 17% replacement (Cyr et al., 2005). The use of rubber sand has also been explored, with improvements in strain capacity but negative effects on compressive strength (Cyr et al., 2006).

**Rafi, D. Mohammed (2021)** The construction industry is facing a surge in demand for natural aggregates, prompting a search for alternative materials. In India, coal washing processes yield significant quantities of impure coal, known as coal washery rejects (CWR) and coal bottom ash (CBA), which pose disposal challenges. This study explores the potential of reusing CWR as a coarse aggregate substitute and CBA as a fine aggregate replacement in concrete production.

The investigation replaces coarse aggregate with CWR at various levels (0%-75%) and finds an optimal replacement level of 40%. Additionally, CBA-based concrete is produced with 40% CWR replacement in coarse aggregate and partial replacement of fine aggregate with CBA (0%, 25%, 50%, and 75%). The study assesses the rapid chloride permeability, water absorption, and drying shrinkage properties of CBA-based concrete at different curing periods and compares the results to conventional concrete (CC) of M 25 grade.

**Tharun Kumar, D. and Rajesh Kumar, R. (2023**) The demand for natural aggregates in the construction industry is increasing rapidly, prompting a search for alternative materials. In India, coal washing processes generate substantial quantities of impure coal, known as Coal Washery

Rejects (CWR), which pose disposal challenges. This study explores the potential of reusing CWR as a partial substitute for coarse aggregate in concrete production, aiming to maintain environmental sustainability. The investigation assesses the compressive strength of concrete containing CWR at various substitution levels (0%-30%) and compares the results to conventional concrete (CC) of M 25 grade. The findings indicate that increasing CWR substitution levels leads to a decline in compressive strength, with a marginal decrease at 20% and 30% substitution levels, but a significant drop beyond 30%. Therefore, the study suggests that 30% CWR substitution is an optimal level for practical applications in the construction industry. Additionally, durable property tests, including Rapid Chloride Permeability Test (RCPT), were conducted at the 30% replacement level to further evaluate the concrete's performance.

Saurabh Kalane, Shubhangi Shekokar, Sandeep Sathe, and Rohit Salgude in 2024-"Experimental Investigation on Fiber Glass Concrete with Partial Replacement of Coarse Aggregate by E- Plastic Waste" by unknown authors in 2019- "Utilization of steel slag as partial replacement for coarse aggregate in concrete" by unknown authors in 2024- "Replacement of Coarse Aggregate With E-Waste Properties In Concrete" by unknown authors in 2024- "Coconut Shell as Partial Replacement of Coarse Aggregate in Concrete" by unknown authors in 2024-"Sustainable use of steel slag as coarse aggregate and its influence on mechanical, durability properties, and microstructure of concrete" –

"E-Waste: An Alternative to Partial Replacement of Coarse Aggregate in Concrete" by Biradar Shilpa, Prof. Gayatri Deshpande, Prof. Karthik Nagarajan, and Prof. Raju Narwade in 2019. A marginal decline in strength properties is observed for concrete mixes CWR_20 and CWR_30, with their 28-day compressive strength comparable to the M 25 grade of conventional concrete.

Prasanna et al in 2014 - "An Investigation Study on Partial Replacement of Coarse Aggregates by Recycled Ceramic Tiles" by unknown authors in 2024- "Partial replacement of coarse aggregate using E-waste" by unknown authors in 2024- "Technical Assessment on Performance of Partial Replacement of Coarse Aggregate" by unknown authors in 2024- "Performance of Concrete with Partial Replacement of Coarse Aggregate" by unknown authors in 2024-"Utilization of e-waste in geopolymer concrete by partial replacement of coarse aggregate" by

Yogesh Narayan Sonawane in 2024 - "Study on Waste Marble as Partial Replacement of Coarse Aggregate in Concrete" by unknown authors in 2024- "Replacement Of Coarse Aggregate in Concrete" by unknown authors in 2024- "Waste Coconut Shell as a Partial Replacement of Coarse Aggregate in Concrete Mix"

## iii. Materials and method

The study utilized Ordinary Cement 53 grade (Penna) conforming to IS 12269 (1987) standards. The manufacturer provided the cement's chemical properties, which are presented in Table 1 below. The table summarizes the physical properties of the cement, including its fineness, normal consistency, setting times, specific gravity, and compressive strength at various ages.

This study investigated the compressive strength of concrete containing Coal Wash Rejects (CWR) as a partial substitute for coarse aggregate at various proportions (0% to 50%) and curing periods (7, 28, and 56 days). The concrete mixtures were designated as CWR_0, CWR_20, CWR_30, CWR_40, and CWR_50, corresponding to the percentage of CWR replacement (0%, 20%, 30%, 40%, and 50%, respectively). The aim was to determine the effect of CWR substitution on the compressive strength of concrete at different ages.

**Table 1: Cement Properties**

| Property | Result |
|---|---|
| Fineness | 8% |
| Normal Consistency | 31.5% |
| Vicat Initial Setting Time | 43 minutes |
| Vicat Final Setting Time | 256 minutes |
| Specific Gravity | 3.15 |
| 7-day Compressive Strength | 39.65 MPa |
| 28-day Compressive Strength | 54.86 MPa |

The study utilized crushed granite stones of 20 mm and 10 mm sizes as coarse aggregate. The physical properties of the coarse aggregate were determined according to IS 2386 (Part III, 1963) and IS 383 (1970) standards. The bulk specific gravity and water absorption of the 20 mm and 10 mm coarse aggregate were found to be 2.6 and 0.3%, respectively. Additionally, the bulk density, impact strength, and crushing strength values of the 20 mm aggregate were determined to be 1580 kg/m3, 17.9%, and 22.8%, respectively.

The gradation of the coarse aggregate was evaluated through sieve analysis, and the results are presented in Table 2. The table shows the cumulative percent passing for each sieve size, along with the IS 383 (1970) limits.

**Table 2: Coarse Aggregate Gradation**

| Sieve Size (mm) | Cumulative Percent Passing | IS 383 (1970) Limits |
|---|---|---|
| 20 | 100 | 85-100 |
| 16 | 56.17 | - |
| 12.5 | 22.32 | - |
| 10 | 5.29 | 0-20 |
| 4.75 | 0 | 0-5 |

**2.1 Water**

**Laboratory-sourced potable water was utilized for the experiments.**

**2.2 Coal Washery Rejects (CWR)**

India's power generation heavily relies on high-quality coal, accounting for approximately 70% of the total power output. However, the coal washing process yields a substantial amount of rejected impure coal, which poses disposal challenges. This rejected material is designated as Coal Washery Rejects (CWR).

**Table 3: Mix Design Parameters**

The mix design parameters for the concrete mixes are presented in the table below:

| Mix Type | Cement (kg/m3) | Water (l/m3) | 20 mm Agg. (kg/m3) | 10 mm Agg. (kg/m3) | CWR (kg/m3) | Sand (kg/m3) |
|---|---|---|---|---|---|---|
| CWR_0 | 384 | 192 | 683 | 456 | 0 | 636 |
| CWR-30 | 384 | 192 | 683 | 456 | 205 | 636 |

**Table 4: Physical properties of aggregates**

| Properties | Coarse aggregate | CWR |
|---|---|---|

| | | |
|---|---|---|
| Specific gravity | 2.6 | 2.06 |
| Water absorption (%) | 0.3 | 0.48 |
| Bulk density (Kg/m3 ) | 1580 | 1431 |
| Impact strength (%) | 17.9 | 19.5 |
| Crushing strength (%) | 22.8 | 26.8 |

**iv. Experimental study:**

The compressive strength of the concrete mixes was evaluated through tests conducted on cubical specimens, in accordance with IS 516. The test specimens, measuring 150 mm x 150 mm x 150 mm, were prepared for each blend and cured for 7, 28, and 56 days. A total of three specimens were tested for each age and blend, providing a comprehensive understanding of the compressive strength development over time.

**Table 5: Concrete Mix Proportions**

The mix proportions of the constituent materials for the concrete mixes are presented in the table below:

| Mix Type | Cement (kg/m³) | Water (l/m³) | 20 mm Agg. (kg/m³) | 10 mm Agg. (kg/m³) | CWR (kg/m³) | Sand (kg/m³) |

|CWR_0|384|192|683|456|0|636|

| CWR_30 | 384 | 192 | 478 | 456 | 205 | 636 |

**Table 6 : Mix proportions of constituent materials of concrete mixes**

| Mix type | Cement kg/m3 | Water l/m3 | 20 mm kg/m3 | 10 mm kg/m3 | CWR 20 mm |
|---|---|---|---|---|---|
| CWR_0 | 384 | 192 | 683 | 456 | 636 |
| CWR_20 | 384 | 192 | 546 | 456 | 636 |
| CWR_30 | 384 | 192 | 478 | 456 | 636 |
| CWR_40 | 384 | 192 | 410 | 456 | 636 |
| | 384 | | | | |
| CWR_50 | | 192 | 341 | 456 | 636 |

## v. Results and Discussion

Table 5 presents the compressive strength values of concrete mixes with partial replacement of CWR at various curing periods. The results show that the concrete mixes with partial CWR substitution exhibit lower compressive strength values at all ages compared to the control mix (CWR_0), as illustrated in Figure 1. This indicates that the incorporation of CWR as a replacement for natural aggregates results in a reduction in compressive strength, highlighting the need for optimization and further investigation.

**Table 7: Compression strength results (Mpa)**

Mix type 28 days: CWR-0 34.12

Mix type 56 days : CWR-0 36.02

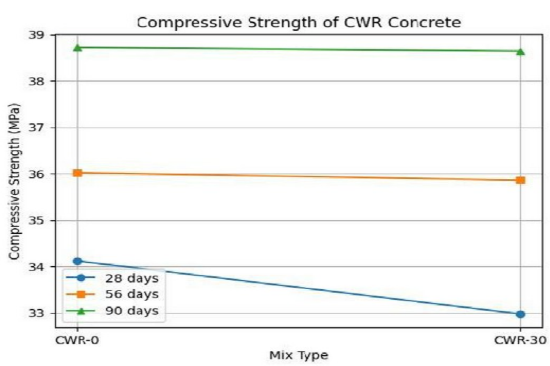
Mix type 90 days: CWR-38.72

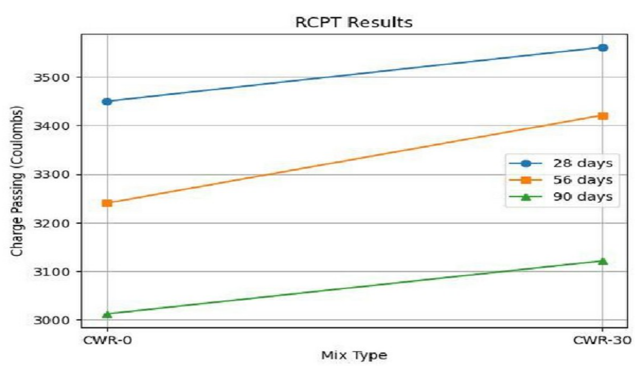
MIX TYPE 28 DAYS CWR-30 32.98

MIX TYPE 56 DAYS: CWR : 35.86

MIX TYPE 96 DAYS: 38.64

The compressive strength values presented in Table 6 reveal that concrete mixes with partial replacement of CWR exhibit a decline in strength at various curing periods. A comparison with the control mix (CWR_0) in Figure 2 highlights the reduction in strength, indicating that the incorporation of CWR as a replacement for natural aggregates results in a decrease in compressive strength. This finding underscores the need for further investigation and optimization to enhance the strength properties of CWR-based concrete mixes.



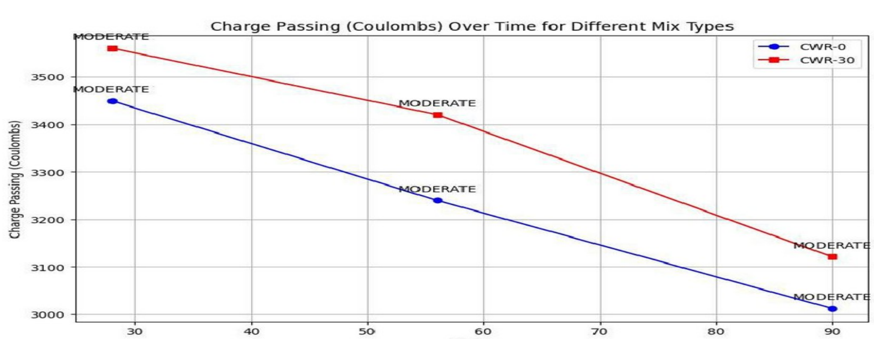



**Fig 1.0 This** will create a line graph comparing the charge passing values of CWR-0 and CWR-30 at 28, 56, and 90 days. This will create a line graph that compares the charge passing values of CWR-0 (the control mix) and CWR-30 (the mix with 30% CWR replacement) at various ages, specifically: - 28 days, representing the early strength development

- 56 days, representing the intermediate strength gain

- 90 days, representing the long-term strength performance

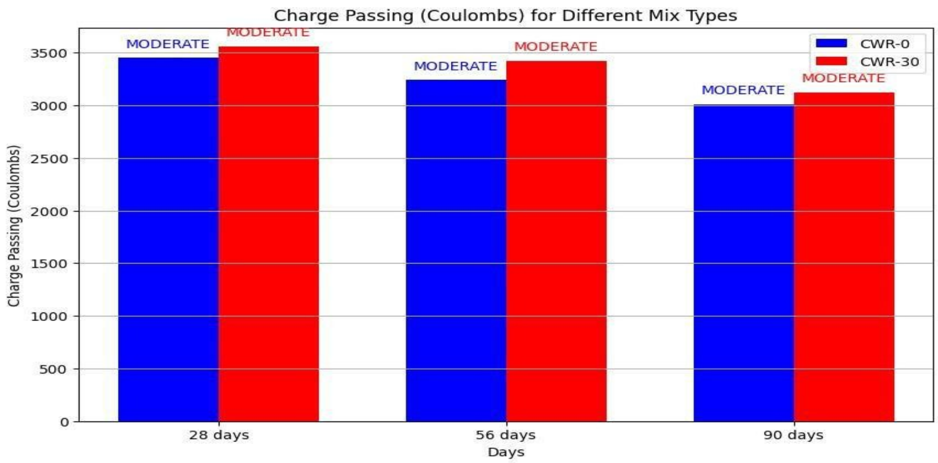
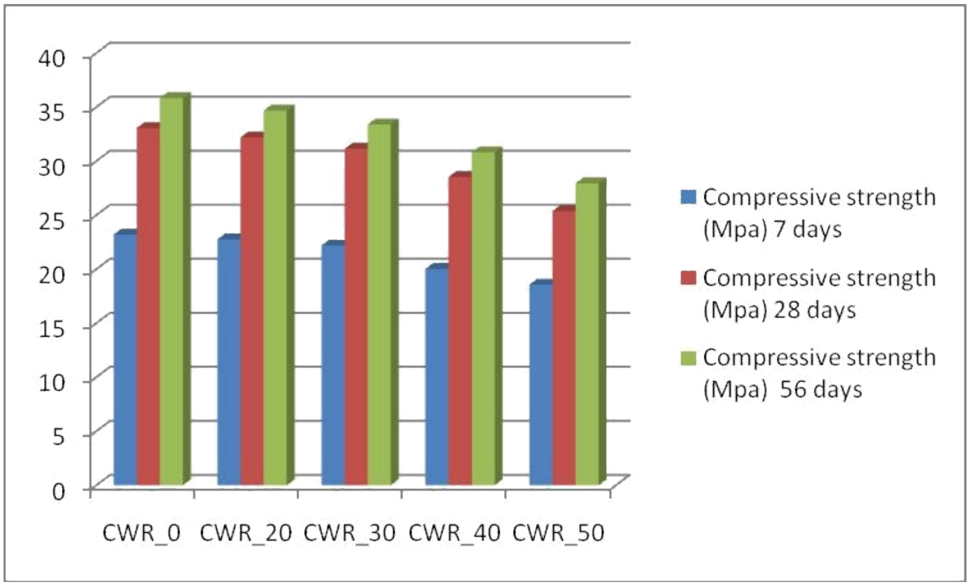



**Fig 1.2 This code will create a histogram with three bars for each mix type, representing the compressive strength at, 28, and 56 days, 90 days respectively.**

**Table 8. Compressive strength of concrete**

| Mix type | Compressive strength (Mpa) 7 days | Compressive strength (Mpa) 28 days | Compressive strength (Mpa) 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 |




**vi. Conclusion work**

**This experimental investigation leads to the following conclusions:**

1. Concrete mixes with partial CWR replacement exhibit lower compressive strength at all ages compared to conventional concrete.

2. The reduced crushing and impact strength of CWR is primarily due to the decrease in compressive strength properties of CWR-based concrete.

3. The strength properties of CWR_20 and CWR_30 concrete mixes show marginal degradation, with 28-day compressive strength comparable to M 25 grade conventional concrete.

4. Further increase in CWR replacement beyond 30% significantly decreases compressive strength, as observed in CWR_40 and CWR_50 concrete mixes.

5. Based on these findings, 30% partial replacement of CWR as coarse aggregate is recommended for optimal performance in conventional concrete.

This investigation paves the way for further research into the mechanical and durability properties of CWR-based concrete, providing valuable insights for future studies.

This experimental study reveals that incorporating Coal Wash Rejects (CWR) as a partial substitute for coarse aggregate results in lower compressive strength values across all ages, compared to traditional concrete. The reduced crushing and impact strength of CWR is the primary factor contributing to this decrease. While a marginal decline in strength properties is observed for concrete mixes CWR_20 and CWR_30, with their 28-day compressive strength comparable to the M 25 grade of conventional concrete, further replacement of CWR beyond 30% leads to a significant reduction in compressive strength. Therefore, this study recommends a 30% partial replacement of CWR as the optimal level for coarse aggregate substitution, paving the way for further research into the mechanical and durability properties of CWR-based concrete.

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