Performance of overburden waste rocks as aggregate in concrete

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Abstract - *The objective of this research study was to investigate sustainable aggregate replacements in concrete. Waste overburden rock from the mining industry was added as a coarse-aggregate replacement by 0%, 15%, 30 %, 45%, 60% and 75 %. This has the potential to reduce material cost while having a beneficial impact on the environment. Mechanical properties of concrete were evaluated and the results were analyzed using SPSS. The study involves 130 concrete specimens with various combinations of these materials, which were prepared, cured, and tested. The mechanical properties, including compressive strength, tensile strength, and modulus of elasticity of concrete were investigated and compared to those of ordinary concrete. The results were numerically analyzed indicating the R2 coefficient, which provided a consistency of 0.77 indicating positive results for the replaced concrete. A generalized formula was developed for analyzing the strength, in linear form, which indicated decreased concrete strength, while remaining useful up to 50% replacement. The aggregate improved the mechanical properties of concrete and can potentially replace up to 50% of natural coarse aggregate. A combination of overburden waste dumps can be used to allow replacement of coarse aggregate in concrete by 50% with considerable in concrete strength.*

Key Words: Principal Component Analysis , Compressive strength analysis, waste to wealth

1.INTRODUCTION

The research work is to estimate the impact of aggregate replacement in the concrete with overburdened waste dumps and to minimize the usage of natural aggregates in the concrete production.

The term sustainable utilization implies the use of waste to their full potential.

While at the same time conserving natural resources and finding ways to minimize the environmental impacts associated both with overburden dumping in the mining region.

The results of previous research indicate that the complete replacement of natural aggregate with waste materials is impractical. Decreases in both tensile and compressive strength have been previously observed when identified wastes are used at high replacement rates. However, there is a lack of research into quantifying the decrease or increase in strength using mathematical correlation in concrete development. In addition, overburden rocks have negative impacts on the environment. However, these materials are readily available in Bhandara District due to the presence of mining belts. The Chikla mines have abundant and inexpensive sources of waste rock materials which are a constant problem as they consume fertile land and are non-degradable. In this research, gneissic rocks as per IS2358 were added to concrete with natural aggregate partially replacing it. This was done to increase the concrete tensile and compressive strength. This combination may have improved mechanical properties when compared to normal mixtures containing only natural aggregates.

1.1 OBJECTIVES

Before you To assess the strength and toughness of concrete mixtures containing partial coarse- aggregate replacement with overburden waste rocks. The mechanical properties of the modified concrete were compared to those of ordinary concrete, while keeping local conditions in consideration. Developing empirical equations in order to analyze the concrete behavior due to similar replacement in the near future.

2. MATERIAL COLLECTION

2.1 Cement:- In this work, Ordinary Portland cement (OPC) [IS 122269] was used. The main reason of using OPC is that suitable for all type of concrete, and it gives high compressive strength at early stages and at 28 days. OPC cement also has increased workability and higher strength at later stages.

2.2 Fine Aggregate:- According to IS 383, most of the aggregate which will pass through 4.75mm IS sieve and entirely retained on 75 μ sieve is considered as fine aggregate. Eg: Sand crushed stone, ash or cinder, river sand.

2.3 Coarse Aggregate:- If the size of aggregate is bigger than 4.75 mm, then the aggregate is considered as coarse aggregate. Collected from mine area.

2.4 Water:- water is the main ingredient used to mix all the contents. Tap water at room temperature was used for all concrete mixtures.

3. Test report

3.1 Test report on Cement:

Test on Cement	Values
Standard Consistency	33%
Initial Setting Time	33 min
Final setting Time	8 hour
Compressive Strength	53.4 MPa
Specific Gravity	3.12

3.2– Summary of normal mixture proportions.

Material	Quantity	Proportion
Cement	340kg	1
Sand	509 kg	1.5
Coarse aggregate	1020 kg	3
Water	152 kgs	0.45

3.3 – Summary of mixture proportions for plastic aggregates.

Material	OB15 kg	OB30 kg	OB45 kg	OB60 kg	OB75 kg	OB90 kg
Cement	680	680	680	629	673.20	629
Sand	1020	1020	1020	1001	1020	995
Coarse aggregate	1734	1428	1122	1734	1734	1734
Water	306	306	306	306	306	306
OB waste	104.8	209.6	314.4	104.8	104.8	104.8

3.4 – Summary of mixture proportions for combined aggregates.

Material	C15 kg	C30 kg	C45 kg
Cement	622.20	622.20	622.20
Sand	1000	1000	1000
Coarse aggregate	1734	1428	1122
Water	306	306	306
Overburden Dumps	52.40	104.80	157.20

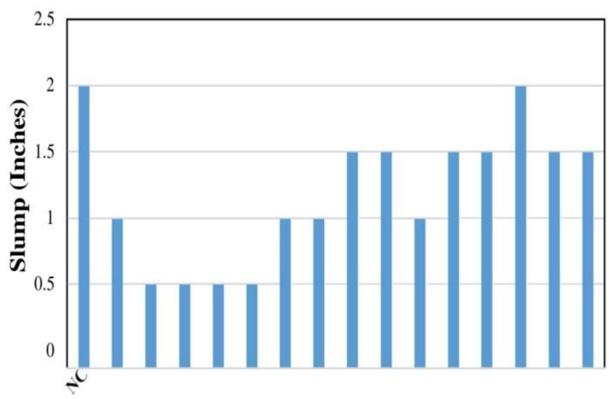
4. RESULTS AND DISCUISSIONS

4.1 Slump test:- Slump test was performed to determine the workability of fresh concrete by following ASTM C143 standard procedure. It shows the results of normal concrete, plastic aggregate, slag aggregate and combine aggregate mixtures. Compared to normal aggregate mixture, the slump decreases for plastic aggregate and slag aggregate mixtures. However, for combine mixture C15 slump remained similar to normal concrete, however, decreased for C30 and C45.

4. 1.1 Summary of slump test results

Mix #	% Replacement Aggregate	W/C Ratio	Slump (in)
NC	0	0.45	2
OB 15	15		1
OB 30	30		0.5
OB 45	45		0.5
OB 60	15		0.5
OB 75	15		0.5
OB 90	15		1
OB 100	15		1

Fig. Summary of slump test result

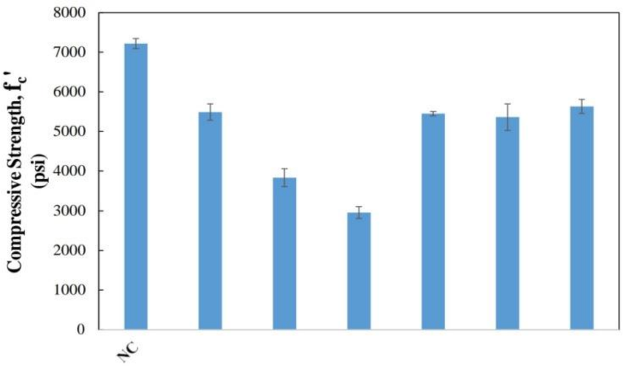


4.2 Compressive Test Results:- summarize the 28-day test results of compressive strength of concrete. The concrete mixtures contained replacement rates of overburden waste rocks at 15%, 30%, 45%, 60%, 75%, 90% and 100% respectively, and a W/C ratio of 0.45. The same mixtures were used for tensile test and modulus of elasticity test. **Overburden replacement:** The results indicate that with comparison to reference concrete (NC), there was a statistically significant decrease in compressive strength of concrete as the plastic percentage increases in concrete mix from 15% to 45% (P15, P30, P45).

4. 2.1 - Summary of OB replacement results.

	Load Applied kg			Average Load	Comp. Strength
	A1	A2	A3		
NC	44524	45612	42561	45623	43.32
OB 15	44524	45612	42561	45623	32.94
OB 30	44524	45612	42561	45623	23.04
OB 45	44524	45612	42561	5623	35.56
OB 60	44524	45612	42561	45623	39.50
OB 75	44524	45612	42561	45623	40.561
OB 90	44524	45612	42561	45623	42.32

Fig. Summary of OB replacement result



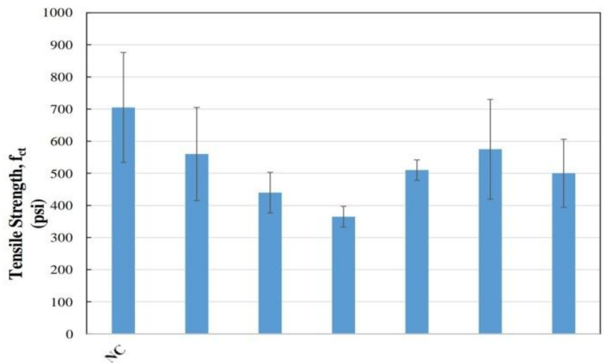
4.3 -Tensile Test Results

The 28-day concrete tensile strength test results are shown in Table Overburden waste Rock replacement The results indicate that with comparison to reference concrete (NC), the tensile strength decreases for OB 15, OB 30, and OB 45 by 20.56%, 37.58%, and 49.50% respectively A decrease in tensile strength was shown when silica fume and glass fibers are added to P15, individually and combined. Individually, the percent strength decrease was 27.65% for the P15-SF7.5 mix and 18.43% for P15-GF1 mix when compared to the NC mixture. The combined mix P15-SF7.5-GF1 had a decrease in strength of 29.07% relative.

4.3.1- Summary of Plastic replacement results

	Load Applied kg			Average Load	Tensile Strength N/mm2
	A1	A2	A3		
NC	18523	32798	36930	35396	4.32
OB 15	13245	15230	13266	28215	2.33
OB 30	11342	10244	11440/ 10720	11022	2.60
OB 45	18808	18724	17720/ 18528	18445	3.23
OB 60	25632	25156	25988	25592	3.45
OB 75	28892	31429	29893/ 25813	29006	3.5
OB 90	26532	25291	23734	25186	4.1

Fig. Summary of tensile test result of OB in CA



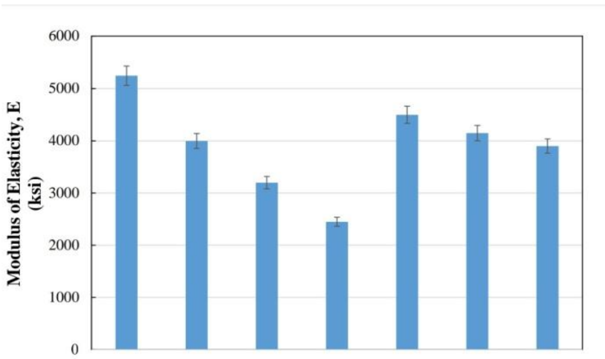
4.4- Modulus of Elasticity Test Results

The 28-day Modulus of elasticity (MOE) test results are shown in **Tables Overburden replacement:** An increase of overburden waste quantity in concrete had a statistically significant effect on the modulus of elasticity of concrete. The results in **Table** indicate that when compared to reference concrete NC, the MOE of concrete decreases with the increase of waste quantity in concrete. Silica fume and glass fibers were added to OB15 and additional modulus of elasticity tests were performed. In comparison to reference materials (NC) the MOE decreased for P15-SF7.5, P15-GF1 and P15-SF7.5-GF1. The percent decrease in MOE of concrete in comparison to reference materials are 23.8%, 39.05%, 53.3%, 14.28%, 20.95% and 25.71%, respectively.

4.4.1-Summary of OB replacement results

	C1			C2			Average N/mm2
NC	5078	5467	5334	5209	5447	4844	36197.48
OB 15	4113	4349	4335	3738	3833	3707	27579.03
OB 30	2738	2848	2887	3591	3625	3660	22063.22
OB 45	2413	2486	2532	2427	2436	2422	15168.47
OB 60	4053	3967	4063	4936	4992	4930	31026
OB 75	3899	4113	4154	4115	4345	4378	28613
OB 90	3773	3829	3802	3916	4079	4051	26889.55

Fig. Summary of MOE test result of OB in CA



4.5 Statistical Analysis of Data for developing the Equation

The test results were used as input data against each of the category of test. The correlation was established between Normal Concrete and each dataset with the replacement concrete. The detail of the test result is presented under annexure I. Three correlation equations are presented below from Eq. 1 to 3. The equation considers the Property test result as dependent and the composition of OB 10 to OB 90 as Independent. The R^2 of the three relations had indicated weak collinearity and hence these equations can predict strength characteristics up to 77% of the total experimentally valid strength of replaced concrete. This makes the concrete relatively safe.

The Equations are represented as under:

a) Compressive Strength

X_{ob90}= -21.976 +(T)'Y_{NC}------------(i)

b) Tensile Strength

X_{ob90}= -19.976+ T'Y_{NC}------------------(ii)

c) MoE

X_{ob90}= -20.332+ (T)'Y_{NC}----------------------(iii)

The Analysis was carried out using the result on 28th day between normal concrete and replaced overburden waste mixed concrete. The result data removed anomalies like results of OB45 and OB60 and presented a uniform relation between NC and OB90.

5. CONCLUSIONS

5.1 Compressive strength: Natural aggregate can be replaced by recycled/waste plastic by 15% without reducing the mechanical properties to preclude the use in structural applications. Similarly, slag can partially replace natural stone aggregates up to 45%. Significant reduction in mechanical properties were observed when the plastic replacement percentage was increased from 15% to 30% or 45%. For slag replacement, initially compressive strength was increased to 15% replacement, however, a slight decrease of compressive strength was shown for 30% and 45%. The Overburden dump waste rock were used in this study in order to evaluate the approximate strength in relationship to the normal concrete. The study found out that it had an approximate 89% near equivalence with normal concrete.

In comparison to NC, increase or decrease in strength of mixtures are as follows:

- Aggregate replaced by plastic up to 15% decreases the compressive strength by approximately 24%, while 15% overburden replacement resulted in a compressive strength increases of 6.05 %.
- ForOBP15-OB50, the compressive strength reduction was 22% while the compressive strength of OB90 increased 6.93%.
- For the combined mixture OB90, the compressive strength remains the same as NC.
- The results indicate that the compressive strength of concrete was unsatisfactory effected by increasing quantity of Overburden waste dump. However, an addition of slag quantity can have a positive impact on compressive strength with combination as reviewed in the literature.

5.2 Tensile strength: Comparing to NC, an increased percentage in concrete of plastic and slag reduced the tensile strength of concrete [15-30].

In comparison to NC, a decrease in tensile strength of the mixtures were as follows:

- For 15% aggregate replaced by plastic OB15, a significant reduction of tensile strength up to 20.5% was observed.
- Similarly, strength reduction for OB15 was 29.07%, as compared to 11.35% for OB50.
- For the combine mixture C15 and C30, the strength was reduced by 14.18%, and24.82%, respectively.

5.3 Modulus of Elasticity:

In comparison to NC, the modulus of elasticity of concrete decreases with an increase in plastic quantity in concrete. However, increasing the slag quantity in concrete had no effects on MOE up to 15% of slag replacement and MOE increased for 30% slag replacement[12-14]. When 7.5% silica fume and 1% glass fibers were added to plastic and slag individually and altogether, a significant decrease in MOE was shown for plastic. However, for Overburden mixtures the MOE either remained the same or a slight decrease was noted.

In comparison to NC, increase or decrease in MOE of concrete as follows:

- For P15, the MOE reduction was 23.8%. While for S15, the MOE remained the same. The MOE decreased by 25.71% for P15-SF7.5-GF1 and 5.7% for S15-SF7.5-GF1. The combined mixtures C15 and C30 resulted in a MOE reduction of 17.14%, and 22.85%, respectively.
- The results indicate that the quantity of plastic had an unsatisfactory impact on tensile strength of concrete. However, the slag quantity indicated a satisfactory impact on MOE of concrete.

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