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"Examining Compressive and Flexural Properties of Concrete by Partially Replacing Sand with Quarry Dust"

[1]Ashita Shrivas, [2]Vishal Chandrakar

[1]PG Scholar, [2]Assistant Professor
[1,2]Department of Civil Engineering,
[1,2]SSTC-SSGI, Bhilai

***Abstract:** Because of the increase in construction activity, the accessible sources of natural sand are becoming depleted as a result of the use of sand in construction. High-quality sand can be transported over long distances, causing economic hardship. As a result, the quality of the structure is completely reliant on the partial or complete replacement of alternate material with natural sand. The effect of quarry dust on the mechanical properties of concrete has been experimentally studied and reported in this research work. The concrete was made by partially replacing sand content 20% and 30% by weight with quarry dust. In first stage, concrete with no sand replacement of grade M25 is prepared so as to compare with the other trial cases of concrete having partial quarry dust. Cube and prism specimens were prepared for the two replacement levels of 20% and 30% to obtain the compressive strength, flexural strength at 28 days. Total no of 18 specimens were made for this research work. From the results, it was observed that the flexural strength of concrete with 20% and 30% quarry dust were higher compared with concrete with no quarry dust. It was found that incorporating quarry dust in concrete improves its flexural strength.*

***Keywords:** Sand, Quarry Dust, Compressive, Flexural.*

1. Introduction

Sudhir S.Kapgate and S.R.Satone (2013) investigated the use of quarry dust as a partial replacement for sand in concrete. They discovered that increasing the dust content by up to 30% increases the compressive strength of concrete; however, increasing the dust content by more than 30% gradually decreases the compressive strength. **Titiksh and Wanjari (2021);** concluded that the samples containing 100 % FA showed a noticeable increase in the 28-days compressive strength of 15 % when contrasted with the control blend. By and large, every one of the preliminaries displayed worthy strength properties according to the codal prerequisites of IS 456: 2000, empowering us to reason that total substitution of river sand in concrete with FA within the sight of NSPs is a maintainable option in contrast to the conventional mix design approach. **Talukder et al. (2020);** observed that because of slower rate of hydration of fly ash at earlier ages, strength of OPC (Ordinary Portland Cement) concrete was higher than those of cement-fly ash mixed concrete. Overall test results reveal that blended concrete of cement-fly ash mix ratio 45:55 & 35:65 provides better result in terms of strength and chloride penetration after 90 days. **Sun et al.(2019);** concluded that HVFA concrete exhibited much higher water absorption than that of the control concrete at 28 days. With 28 to 90 days of curing, the pozzolanic reaction of FA progresses significantly and consumes large amounts of CH with producing additional secondary C-S-H gels, resulting in denser and more compact microstructure, thus decreasing the amount of water absorption of HVFA concrete. **Chen et al. (2019);** concluded that the concrete with a higher amount of total binder (S30 series), higher fly ash substitution ratio (>50%) and high-LOI (8%) fly ash (FA2) tended to have higher air content. However, except for S30F80-2, the air content of the remaining concrete (2.1% to 3.7%) was still within acceptable limits. Under the same substitution ratio, the setting time of the S30 series high-LOI loss (8%) fly ash (FA2) concrete was longer than that of the low-LOI (5%). The fly ash (FA1) concrete took seven hours to reach initial setting and more than nine hours to the final setting. **Das and Gattu (2018)** suggested the suitability of quarry dust as alternative material for the river sand in concrete manufacturing. The physical properties of quarry dust namely specific gravity; water absorption; silt content; and fineness modulus were measured using standard tests which was followed by compression, split tensile and bending tests on cubes, cylinders and RC beams respectively to study the strength of concrete made of quarry rock dust. The results showed that with increasing proportion of quarry dust, the strength increased to peak value.

2. Material

The raw materials used in this research work are collected from different parts of Raipur, Chhattisgarh. Each materials have such physical properties which is to be studied for the production of concrete blocks. The ingredients used for this study are Portland pozzolana cement, FlyAsh, Sand, Quarry Dust, Coarse Aggregate.

Fig. 1 Materials Used in this Study (a) Cement (b) Sand (c) Aggregate (d) Quarry Dust (e) Fly Ash

3. Methodology

3.1 Test Stipulation required for Mix-Design

The test Stipulation required for Mix-Design for the sand, cement and coarse aggregate are such that the determination of consistency of cement according to IS 4031:1988 is done and found to be 32.5% and the specific gravity of cement as per IS 4031:1988-Part 11 is 2.35 using flask apparatus.

3.2 Sieve Analysis of Aggregates

The sieve analysis test is done based on IS 383 are as follows-

Table 1 Sieve Analysis of Fine Aggregate

Sieve Sizes	Mass Retained	Percentage Retained	Percentage Cumulative Retained	Percentage Fine	Avg. Percentage Passing
10 mm	0	0	0	100	100
4.75 mm	13	2	2	98	98.06
2.36 mm	55	8.45	10.45	89.55	89.63
1.18 mm	97	14.9	25.35	74.72	74.72
600 µm	204	31.34	56.68	43.36	43.32
300 µm	159	24.42	81.11	18.88	18.89
150 µm	91	13.98	95.08	4.94	4.94

Fineness Modulus = Fineness Modulus = Sum (Cumulative percentage retained)/100 = **2.704.** Based on the above result, we can say as per IS 383 that the fine aggregate is in Zone-II**.**

3.3 Mix-Design for Conventional M25 Grade concrete

- The Target Mean Strength for Mix Proportioning is given by $f'_{ck} = f_{ck} + 1.65S \; or \; f'_{ck} = f_{ck} + X \; , whichever \; is \; higher$ where, f'ck = target avg compressive strength after twenty-eight days of curing, fck = characteristic compressive strength at twenty-eight days of curing, S = standard deviation for M20 grade = 4 N/mm^2 given in IS 10262:2019, table 2.Therefore, **target strength = 25 + 1.65 x 4 = 31.6 N/mm^2**
- The air entrapped in concrete varies based on size of aggregate given in table 3. The approximate entrapped air in this case is considered to be 1 percent for 20 mm size of CA.
- The maximum water-cement ratio as given in IS 456:2000 table 5 is 0.5 under severe condition. The actual free water-cement ratio for target strength of 31.6 N/mm^2 and curve 1 as per figure 1 given IS 10262:2019 **is0.36**. This value is lower than the maximum.
- The selection of water content is given in table 4 of IS 10262 based on 20 mm maximum size of aggregate and 50 mm slump value is 186 kg. Here, for 125 mm slump value the following water content is increased by 3 percent for each 25 mm slump which is equal to **186 + (186*9)/100 = 202.74 kg.**
- Super plasticizers are utilized to reduce the water content hence the above value is reduced for 23 % on trial based while utilization of super plasticizer is 1% by weight of cement (i.e.

  Therefore, the final water content = 202.74 X 0.77 = 156.11 kg = 156 kg
- The calculation of cement content = $(Water \; content)/(Water - Cement \; ratio)$ = 156/0.36 =**433 Kg/m^3.** The minimum cement content as per Table 5 in IS 456:2000 is **320 kg/m^3** in severe exposure condition. Hence, the calculated value is greater than the recommended value.
- For mix-portioning of concrete, increase in Cementitious content is considered based on trials and experience. Here, an increase of 10 % cementitious material is been considered = **433 X 1.10 = 476Kg/m^3**
- Water-cementitious ratio = $Water \; content/Cementitious \; Content$ = **156 /476 = 0.327**
- For mix-portioning of concrete having fly ash, the current trail has 30 percent fly ash of total cementitious content. Hence, fly ash content = **476 X 0.30 = 142.8Kg/m^3 = 143Kg/m^3**
- Cement content = 476 – 143 = **333Kg/m^3**
- The minimum cementitious content as per Table 5 IS 456:2000 is **320 kg/m^3** in severe exposure condition. Hence, the calculated value is greater than the recommended value (i.e., 476 kg/m^3).
- The volume of coarse aggregate corresponding to Table 5, IS 10262:2019 for 20 mm seize of aggregate and sand of zone II for W/c of 0.50 is **0.62**. At present trial W/c is **0.40**, there is a decrease in W/c ratio by **0.22**, the proportion of volume of CA is increased by **0.044** (i.e., at the rate of ± 0.01 for every ± 0.05 change in water-cement ratio). Therefore, the modified proportion of volume of CA for the water-cement ratio of 0.40 **= 0.62 + 0.044 = 0.666**.
- Volume of sand content = Total Volume of aggregate – Volume of CA = **1- 0.666 = 0.334.**
- Determination of mix per unit volume of concrete are as follows -

Concrete volume = 1 m^3

Entrapped Air Volume = 0.01 m^3

Volume of Cement = $\frac{\text{Mass of Cement}}{\text{Specific Gravity of Cement}} X \frac{1}{1000} = \frac{333}{2.35} X \frac{1}{1000}$ = **0.141 m^3**

Volume of Fly Ash = $\frac{\text{Mass of Fly Ash}}{\text{Specific Gravity of Fly Ash}} X \frac{1}{1000} = \frac{143}{2.1} X \frac{1}{1000}$ = **0.0681 m^3**

Volume of Water = $\frac{\text{Mass of Water}}{\text{Specific Gravity of Water}} X \frac{1}{1000} = \frac{156}{1} X \frac{1}{1000}$ = **0.156 m^3**

Volume of Super plasticizer (where 1% by mass of cementitious material is used)

$$= \frac{\text{Mass of Chemical Admixture (Superplasticizer)}}{\text{Specific Gravity of Admixture}} X \frac{1}{1000}$$

$$= \frac{4.76}{1.145} X \frac{1}{1000} = \mathbf{0.0041\ m^3}$$

Volume of all in aggregate = [(Total Volume – Volume of air entrapped) – (Volume of Cement + Volume of Fly Ash + Volume of Water + Volume of Super plasticizer)] = [(1-0.01) - (0.141+ 0.0681 + 0.156 + 0.0041)] = **0.6208 m^3.**

Mass of CA = Volume of all in aggregate X Volume of CA X Specific Gravity of CA X 1000 = 0.6208 X 0.666 X 2.785 X 1000 = **1151.46 = 1152 kg.**

Mass of FA = Volume of all in aggregate X Volume of FA X Specific Gravity of FA X 1000 = 0.6208 X 0.334 X 2.669 X 1000 = **553.41 = 553 kg.**

The proportions required after the mix -design for 1 cube (150 mm) is given in table below-

Table 2 Proportion of Concrete Mix Trials for 1 cubic meter

Case ID	Cement (kg/m^3)	Fly ash(kg/m^3)	Coarse Aggregate (kg/m^3)	Sand(kg/m^3)	Quarry Dust (kg/m^3)	Water(kg/m^3)
CC25	1.1238	0.4826	3.888	1.8663	-	0.5265
Q2520	1.1238	0.4826	3.888	1.4917	0.3746	0.5265
Q2530	1.1238	0.4826	3.888	1.3061	0.5602	0.5265

4.Compressive Strength Reports for M25 concrete cases

As discussed above about the guidelines of the compressive test of concrete as per IS 516:1959, the following trail case study described in chapter 3 are evaluated by experimental techniques for twenty-eight days. Below table shows the compressive strength data for M25 concrete having quarry dust partially replaced by 20 percent and 30 percent. The case trials are tested such that each cases have three cube specimens ranging from specimen 10 to 18 for the maintaining the accuracy and elimination of errors. Thus, here nine cube specimens (i.e., Specimen 10 to Specimen 18) are utilized for the M25 concrete trial cases.

Table 3 Test result of compressive strength for M25 concrete cases

Case ID	Case Trials	Area (mm2)	Load (KN)	Compressive Strength after 28 days curing (N/mm2)	Average Compressive Strength (N/mm2)
CC25	Specimen 10	22500	889.2	39.52	39.21
	Specimen 11	22500	872.1	38.76	
	Specimen 12	22500	885.6	39.36	
Q2520	Specimen 13	22500	845	37.55	37.31
	Specimen 14	22500	828	36.8	
	Specimen 15	22500	846	37.6	
Q2530	Specimen 16	22500	826.2	36.72	36.4
	Specimen 17	22500	808.2	35.92	
	Specimen 18	22500	822.6	36.56	

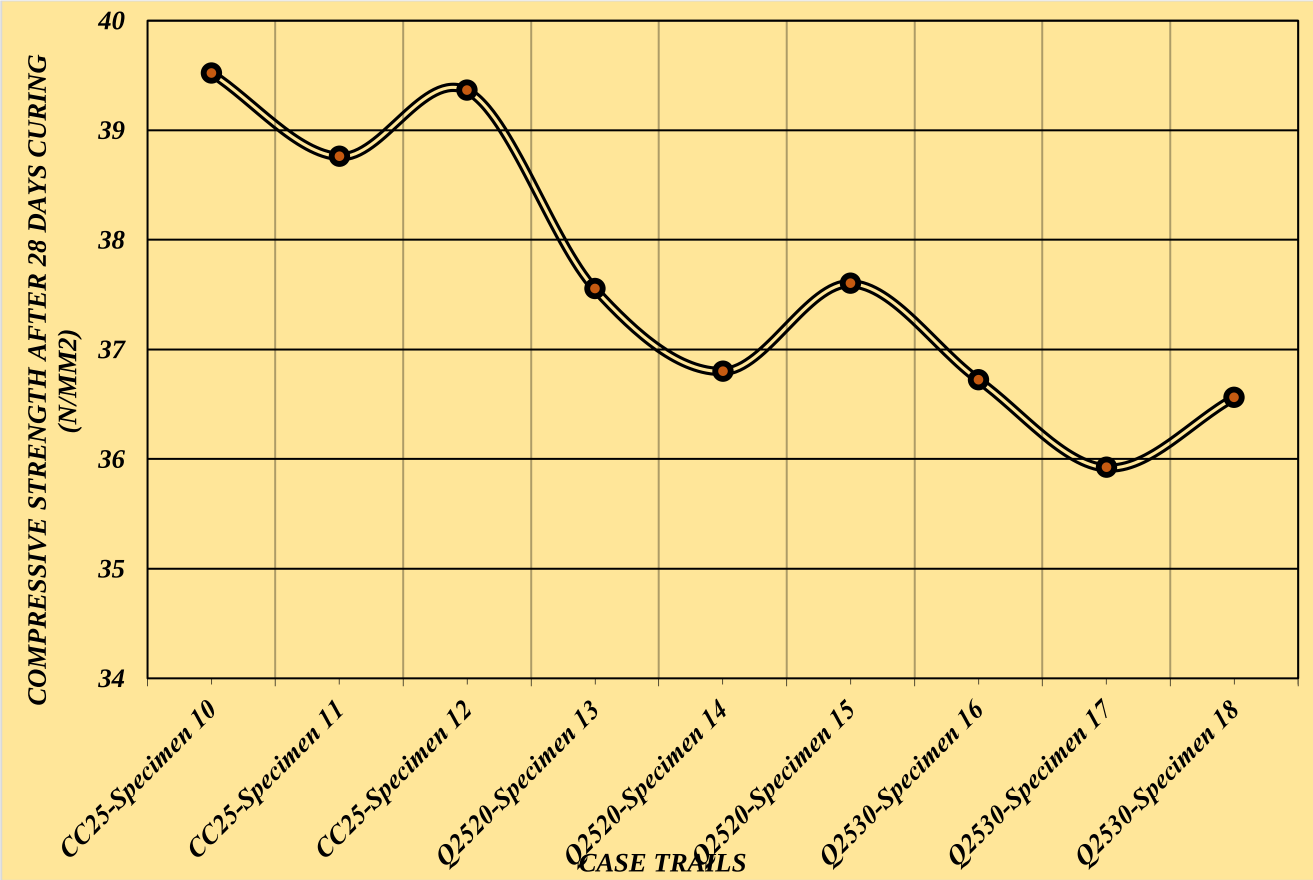


Fig. 2 Compressive Strength for Case Trials for M25 concrete

From the above experimental investigation, the average compressive strength for CC25 shows value of 39.21 Newton per squ. mm. which is greater than both Q2520 and Q2530 samples. The average compressive strength for Q2520 is 37.31 N/mm^2 while the compressive strength for Q2530 is 36.4 N/mm^2.However, both material of Q2520 & Q2530 are 4.8 % and 7 % approximately less than the conventional concrete sample CC25. This states that the addition of twenty percent quarry dust in M25 concrete cases much better result than M20 case trials in respect to similar compressive strength applicable for 20% and 30 partially replacement cases.

(a) (b)

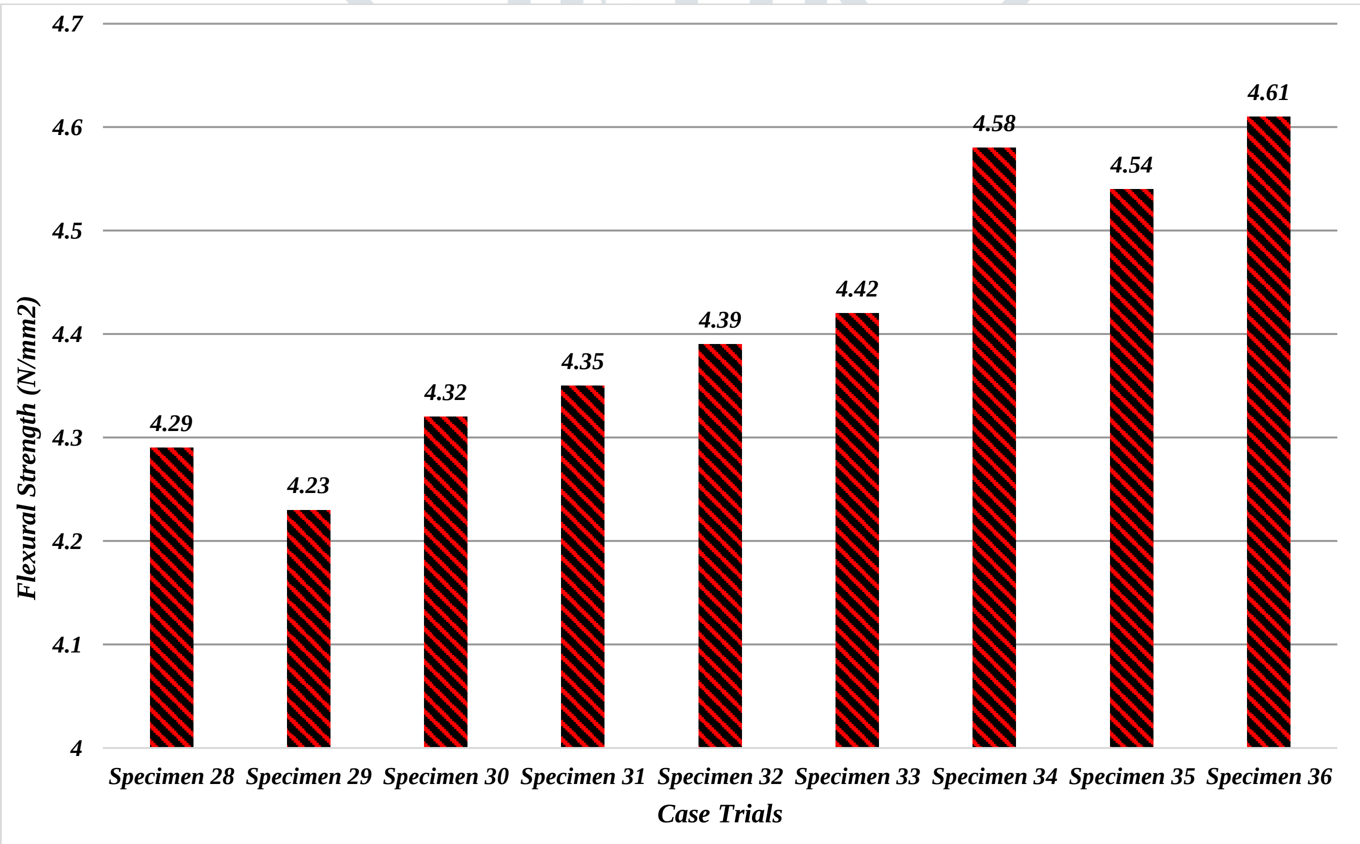
Fig. 4.1 Compressive testing of Cube Specimen (a) Before Applying load (b) At Failure

5. Flexural Strength Reports for M25 cases

Below table shows the flexural strength data for M25 concrete having quarry dust partially replaced by 20 percent and 30 percent. The case trials are tested such that each cases have three prism specimens ranging from specimen 28 to 36 for the maintaining the accuracy and elimination of errors. Thus, here total of nine prism specimens (i.e., Specimen 28 to Specimen 36) are utilized for the M25 concrete trial cases.

Table 4Test result of flexural strength for M25 concrete cases

Case ID	Case Trials	Flexural Strength after 28 days curing (N/mm2)	Average Flexural Strength (N/mm2)
CC25	Specimen 28	4.29	4.28
	Specimen 29	4.23	
	Specimen 30	4.32	
Q2520	Specimen 31	4.35	4.386
	Specimen 32	4.39	
	Specimen 33	4.42	
Q2530	Specimen 34	4.58	4.576
	Specimen 35	4.54	
	Specimen 36	4.61	



Graph 4.4Flexural Strength for Case Trials for M25 concrete

From the above experimental investigation, the average flexural strength for CC25 shows value of 4.28 Newton per squ. mm. which is less than that of Q2520 and Q2530 specimens. The average flexural strength for Q2520 is 4.386 N/mm2 while the flexural strength for Q2530 is 4.576 N/mm2.However, both material of Q2520 & Q2530 are 2.3 % and 6.3 % approximately more than the conventional concrete sample CC25. The addition of twenty percent quarry dust showing higher strength when compared to conventional CC25 concrete signifies that higher the quarry dust content better will flexural strength up to 30 percent partial sand replacement.

5. Conclusions

- The concrete specimen of carrying quarry dust exhibits better workability than conventional cement concrete.
- The CC20 trial cases is exhibiting better compressive strength as compared to Q2020 and Q2030 trial case.
- Flexural strength exhibit better performance in case of 30 percent partial replacement.
- In the above data, the strength characteristics of conventional concrete with respect of quarry dust-based trial specimen with 20% and 30% replacement of sand exhibits fair strength. This study also gives a proper solution of quarry dust utilization over fine aggregate.

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