An Alternate Aggregate & Metakaolin Blend In Concrete to Assess Compressive Strength

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Abstract— The current experimental investigation focuses on the influence of Quarry residues and Metakaolin on the compressive strength of concrete. Sand is partially replaced with Quarry dust and cement by Metakaolin in M25 grade of concrete. The present experimentations reveal that Metakaolin can replace cement, and quarry dust can substitute fine sand in concrete to some extent. At 30% replacement of fine sand with Quarry dust, increase in compressive strength was noticed. Simultaneously, 8% replacement of cement with Metakaolin, displayed better compressive strength. The test results were found to be satisfactory with the individual replacements but the combination of Quarry dust and Metakaolin did not yield positive results with respect to compression of concrete.

Keywords: Metakaolin, Quarry dust, Compressive strength, Partial Replacement

I. INTRODUCTION

One of the major achievements of cement and concrete industry during the last few years is the combined use of mineral admixtures and recycled or waste materials. Cement manufacture causes environmental impacts at all stages of the process. These incorporate discharge of airborne contamination as residue and gases, commotion and vibration while operating machinery during blasting operations in the quarries. Concrete generation contributes ozone harming substances straightforwardly through the creation of carbon dioxide when calcium carbonate is warmed and in a roundabout way using energy especially if the energy is sourced from petroleum derivatives. Concrete industry delivers about 5% of worldwide man made carbon dioxide emanations of which half is from synthetic procedure and 40% is from consuming fuel.

High reactive Metakaolin is made through the calcination of a highly pure kaolinite and grinding the products to a fine particle size. Metakaolin presents various advantages in concrete, such as increased strength, increased resistance to chemical attack, enhanced concrete finishes, reduced shrinkage, and reduced permeability. Due to these advantages, Metakaolin is widely used in producing high performance and high strength concrete [11].

Stream sand is most generally utilized fine total in cement yet because of intense deficiency in numerous zones; accessibility, cost and natural effect are the real concern. By substitution of quarry dust, the necessity of land fill region can be decreased and can likewise take care of the issue of common sand shortage. To defeat from this emergency, fractional supplanting of sand with quarry residue can be a financial option. Quarry dust fulfills the purpose for the elective material as a substitute for sand with ease. Concrete shows higher compression quality in the wake of supplanting fine total by stone residue. Stone residue can be utilized as an added substance in concrete preparation [7].

The main objective of the present experimental investigation is to obtain the influence of the combined application of Quarry dust and Metakaolin on compressive strength of M25 grade concrete. Utilizing distinctive extents of Quarry residue and Metakaolin, compressive quality tests were performed on 150 mm x 150 mm x 150 mm cubes and the outcomes were contrasted with conventional concrete.

II. LITERATURE REVIEW

D V Prasada Rao et.al performed a test examination on the utilization of Metakaolin and Nano-Silica on different properties of concrete. Metakaolin and Nano-Silica are utilized as halfway swap of cement for the preparing of concrete. In light of the test outcomes, it was seen that concrete arranged with a blend of 5% MK and 2% NS demonstrated expanded quality contrasted with the controlled concrete.

C K Kankam et al distributed aftereffects of concentrate on concrete utilizing quarry residue to supplant sand at dimensions of 0%, 25%, and 100% by weight. It was seen that the stress strain bends were comparable for all sand supplanting levels and that concrete with 100% quarry dust had the greatest strain esteems.

Xiao-Yong Wang examined and introduced an incorporated hydration-mechanical-toughness show for assessing different properties of Metakaolin mixed concrete. The proposed coordinated hydration-mechanical-toughness demonstrates was important for the material plan of Metakaolin mixed concrete.

Suzan S Ibrahim et.al carried out studies on blended pastes of partially replaced ordinary Portland cement with different Metakaolin proportions of 5%, 10% and 15%. Scanning electron microscopy micrographs showed the arrangement of denser microstructure for the solidified OPC-MK10 paste when contrasted with flawless OPC pastes after 28 days period of hydration.

P. Dinakar et.al published the effect of incorporating Metakaolin on the mechanical and durability properties of high strength concrete for a steady water/binder ratio of 0.3.
Metakaolin blends with cement substitution of 5, 10 and 15% were intended for target quality and slump of 90 MPa and 100 ± 25 mm. This examination has demonstrated that the Metakaolin can possibly deliver high quality and elite concretes.

J M Khatib et.al decided the compressive quality, density and ultrasonic pulse velocity of mortar containing high volume of Metakaolin as fractional substitution of cement. The results indicated that the maximum strength of mortar occurs at around 20% MK. Compressive strength starts to reduce when MK goes beyond 30% MK as cement replacement. Attempts were made to link the compressive strength with ultrasonic pulse velocity.

F. Ntimugura et.al evaluated the feasibility of reducing clinker in the Portland cement production using local Metakaolin in Burkina Faso. The results in the paper, have confirmed the possibility of using Metakaolin to partially substitute cement, a possibility to reduce the CO2 production by the cement industry.

III. MATERIALS

A. Cement:

Ordinary Portland cement (OPC) conforming to Grade 53, is used in the proposed work. Cement used conforms to IS: 8812-1989 & IS: 12269-1987 respectively.

Quarry dust: Normal sand has been the ordinary fine total in concrete creation for a long time. However, there has been broad investigation into elective materials appropriate to supplant sand in concrete. The need to discover substitution for sand originates from the way that in many parts of the world, there is developing worry about the exhaustion of sand stores, natural and financial dangers related with extraction of sand from stream banks, beach front zones and ranch lands. Among the numerous materials researched, quarry dust has all the earmarks of being the most reasonable on the grounds that it is accessible in huge amounts in many pieces of the world [2]. The properties of concrete (Compressive and flexural quality) made with halfway or full supplanting with stone dust are equivalent to natural sand results [8].

B. Fine aggregate:

It is the aggregate most of which passes through a 4.75 mm IS sieve and contains only that much coarser material as is permitted by specifications. Sand is generally considered to have a lower size limit of about 0.07 mm. The sand used in this investigation is ordinary river sand obtained from the banks of Tungabhadra River. The sand is free from clayey matter, silt and organic impurities etc. The sands are generally divided into different zones according to the percentages passing the IS: 600 micron sieve. IS: 383-1970 classifies the sand into four zones, I, II, III and IV so that the range of percentage passing the 600 micron sieve in each zone does not overlap. The sand used for the present investigation falls in zone-II as per the grading limits.

C. Coarse aggregate:

The aggregates most of which are retained on 4.75 mm IS sieve and contain only that much of fine material as permitted by the specifications are termed as coarse aggregates. 20 mm nominal size of coarse aggregate was used in the experimentation. A graded aggregate of nominal size 20 mm means an aggregate most of which passes the 20 mm IS sieve. Since the aggregates are formed due to natural disintegration of rocks or by the artificial crushing of rock or gravel, they derive many of the properties from the parent rocks. The physical properties have been determined in accordance with the guidelines mentioned in IS: 2386-1963.The coarse aggregate was free from clayey matter, silt and organic impurities etc. The specific gravity of the coarse aggregate was 2.71 and fineness modulus was 3.79.

D. Water:

Potable water free from suspended solids and organic materials was used. The water utilized for both blending and curing of concrete was free from polluting influences, damaging measures of acids, antacids, oils, salts, natural issue or different substances that might be malicious to cement or steel. The presence of chlorides and sulfates are injurious to reinforcing bars as they may be corroded. The general requirements of water for blending and curing of concrete shall be as per guidelines of IS 456- 2000.

E. Metakaolin:

Metakaolin is a profoundly dynamic pozzolanic material and is progressively utilized in creating superior concrete [11]. It is an anhydrous calcined type of the dirt mineral kaolinite. Minerals that are wealthy in kaolinite are known as china earth or kaolin, generally utilized in the assembling of porcelain. The molecule size of Metakaolin is littler than bond particles, yet not as fine as silica smolder. It is the unpurified thermally actuated common earth and kaolin dirt. It indicates high pozzolanic reactivity and decrease in $Ca(OH)_2$ even as early as one day. The fractional substitution of cement by Metakaolin considers expanding compressive quality of cement pastes, mortars (concretes) alongside lessening their porosity and permeability [12]. It is discovered that cement paste experiences particular densification and subsequently serves to expands the quality and diminishes the permeability. The solidified blended pastes made of standard Portland cement with various measures of Metakaolin demonstrated improvement in their compressive quality and hydration energy than that of the perfect OPC [1].

IV. TESTS ON MATERIALS

Different tests have been carried out on materials utilized in the examination and the outcomes are classified beneath.

S.No	Property	Values obtained	Standard values according to IS Codes
1	Specific Gravity	2.78	IS 2720 Part 3 (3.15)
2	Fineness	2.9%	Not greater than 10% as per IS:4031 Part 1
3	Standard Consistency	30%	IS 4031 Part 4
4	Initial Setting Time	39 min	At least 30 minutes as per IS:4031 Part5
5	Final Setting Time	390 min	Not more than 600 minutes as per IS:4031
6	Compressive strength	36.1 N/mm^2	IS : 4031 Part 6

Table 1: Test results of cement

S.No	Property	Values obtained	Standard values as per IS Codes

1	Specific Gravity	2.71	IS 2720 Part 3 (3.15)
2	Fineness	5.8%	Not greater than 10% as per IS 4031 Part 1
3	Standard Consistency	28%	IS 4031 Part 4
4	Initial Setting Time	41 min	At least 30 minutes as per IS:4031 Part 5
5	Final Setting Time	420 min	Not more than 600 minutes as per IS:4031 Part 5

Table 2: Test results of Metakaolin

S.No	Sieve size	Weight Retained in gms	% weight retained	Cumulative % of weight Retained (F)	% passing (100-F)
1	4.75 mm	64	3.75	3.75	96.25
2	2.36 mm	96	5.62	9.37	90.63
3	600 µm	1378	80.68	90.05	9.95
4	300 µm	120	7.03	97.08	2.92
5	150 µm	50	2.93	100	0
Fineness modulus = F/100 = 300.25/100 = 3.00					

Table 3: Strainer investigation of fine aggregate

S.No	Sieve size	Weight Retained in gms	% weight retained	Cumulative % of weight Retained (F)	% passing (100-F)
1	4.75 mm	64	3.75	3.75	96.25
2	2.36 mm	96	5.62	9.37	90.63
3	600 µm	1378	80.68	90.05	9.95
4	300 µm	120	7.03	97.08	2.92
Fineness modulus = F/100 = 379.76/100 = 3.79					

Table 4: Strainer investigation of coarse aggregate

S.No	Sieve size	Weight Retained in gms	% weight retained	Cumulative % of weight Retained (F)	% passing (100-F)
1	4.75 mm	10	10	1.173	98.83
2	2.36 mm	44	54	6.33	93.67
3	600 µm	306	360	42.25	57.75
4	300 µm	66	594	69.72	30.28
5	150 µm	204	798	93.66	6.34
Fineness modulus = F/100 = 213.33/100 = 2.13					

Table 5: Strainer investigation of Quarry dust

V. MIX DESIGN OF CONCRETE

Blend configuration is the way toward choosing appropriate elements for creating concrete and deciding their relative extents. The reason for the solid blend configuration is to guarantee the most ideal extents of the constituent materials to satisfy the prerequisite of the structure being constructed. The blend extents for M25 grade concrete are determined by following the rules given in IS: 10262-2009. The accompanying blend extents were gotten, on considering the water assimilation conditions.

Cement	Fine Aggregate	Coarse Aggregate	Water
469	594	975	201.89
1	1.26	2.07	0.43

VI. EXPERIMENTAL INVESTIGATIONS

The present experimental investigation includes casting and testing of specimens for compressive strength. Cement, sand and aggregate were taken in mix proportion of 1:1.26:2.07. Fine aggregate is replaced with Quarry dust in the proportion of 10%, 20%, 30%, 40% & 50%. All the ingredients were dry mixed homogeneously. To this dry mix, required quantity of water was added (W/C= 0.43) and the entire mix was again homogeneously mixed. The water binder ratio was kept constant for all mixes. This wet concrete was poured in the standard molds (150mmx150mmx150mm) which was compacted through hand compaction in three layers and after that set on the vibrator for compaction. After the compaction, the concrete was given smooth completions. Following 24 hours, the cube molds were demolded and exchanged to restoring tanks where in they were permitted to cure regularly for a time of 3, 14 and 28 days individually. Later on, cement was replaced with Metakaolin in the proportion of 4%, 8%, 12% & 16%. Based on the similar procedure mentioned above, the specimens were casted. On testing the specimens for compression under 2000 kN Compression Testing machine, it was found that the 28 day compressive strength was maximal at 30% quarry dust. Maintaining 30% quarry dust, Metakaolin was used to replace cement in the proportion of 0%, 4%, 8%, 12% & 16%. The outcomes obtained are shown below in the form of the graphs.

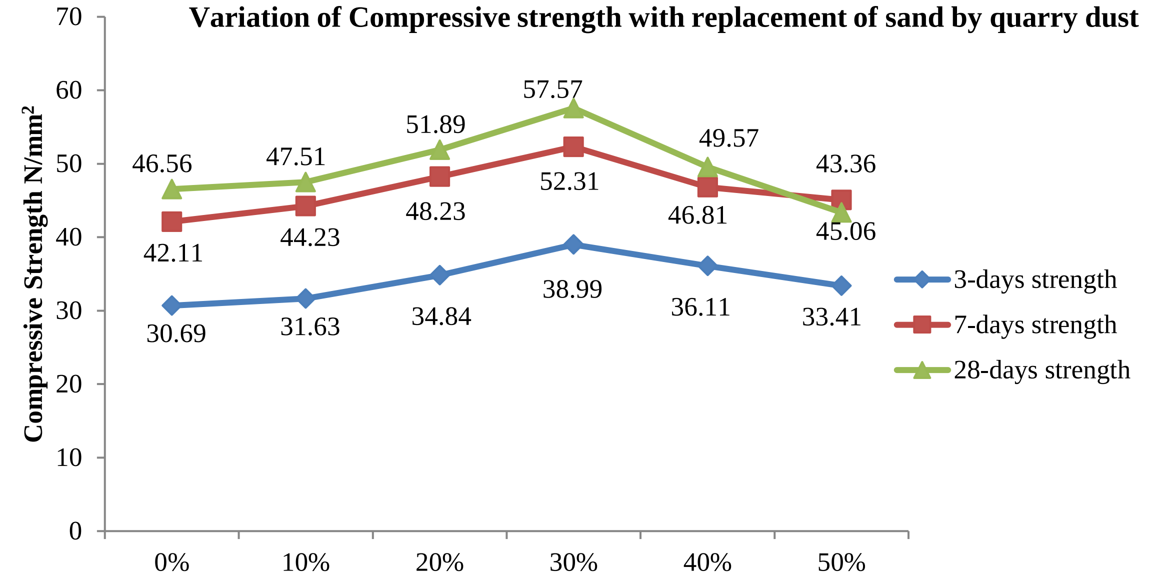

Fig. 1: Percentage Replacement of Sand by Quarry Dust

Compressive quality tests were performed at the age of 7, 14 and 28 days. The concrete were tested in the dry state following the clammy relieving. Compressive strength of the concrete cube specimen was calculated by dividing the maximum load applied to the specimen during the test by the cross sectional area. The average of three estimations of compressive quality was taken as the agent compressive quality. High quality control requirements in terms of mixing, curing, and testing of specimens were strictly followed during the experimental phase. Tests not holding fast to such necessities were dismissed and rehashed.

Figure-1 demonstrates the variety of compressive quality of concrete cubes with the substitution of sand by quarry dust. The substitutions go was from 0 to 50% in the interim of 10%. In all the blends, a continuous increment in compressive quality was seen from 3-day to 28-day curing. For each 10% augmentation of quarry dust an expansion of compressive quality was seen up to 30%. At 30% substitution, a greatest compressive quality of 57.57 N/mm^2 was recorded at 28 days. Past 30% substitution, a progressive decrease in the compressive quality was watched.

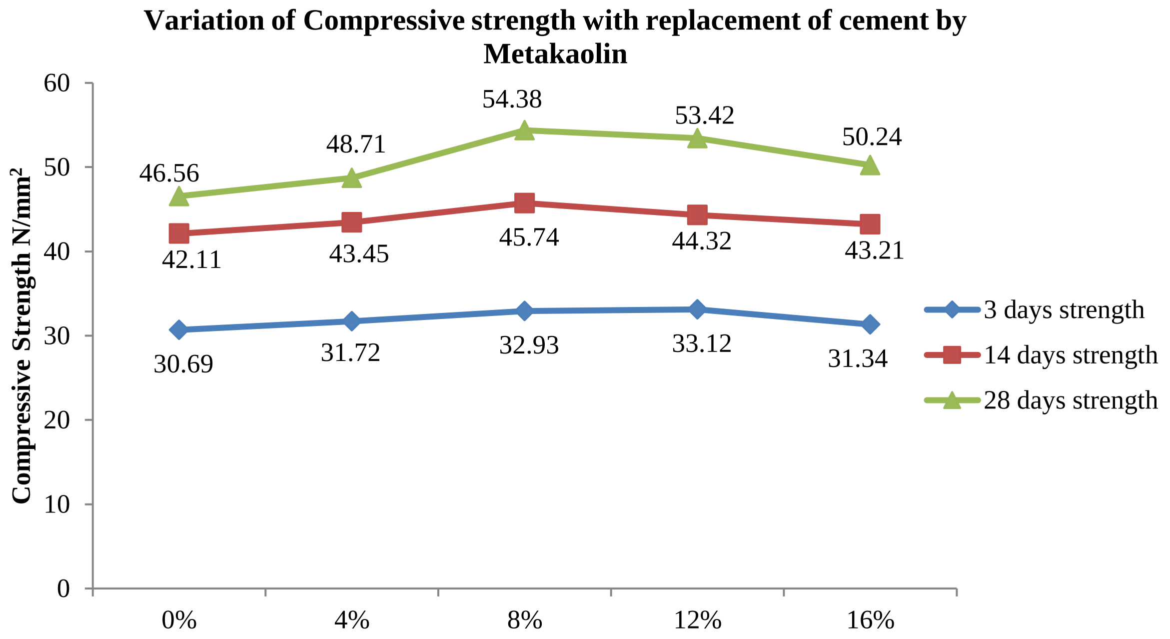

Fig. 2: Percentage Replacement of Cement by Metakaolin

Figure-2 shows the variety of compressive quality of concrete specimens in which the cement substance is supplanted by Metakaolin in the extents of 4, 8, 12 and 16%. In these blends, the fine aggregate is not supplanted yet just the cement substance is supplanted with Metakaolin. Following 28-day standard curing, a compressive quality of 54.38 N/mm2 was watched for 8% substitution. The partial substitution of cement by Metakaolin takes into account expanding compressive quality of concrete glues, mortars (concretes).The impact of Metakaolin on the hydration of bond and the development of strong structure depends on the high explicit surface of its particles and its pozzolanic properties. The pozzolanic properties of Metakaolin, i.e., its capacity to connect with Ca(OH) 2 to frame a C-S-H, which helps for further densification of the microstructure of cement paste, mortar or concrete, show up in the ensuing time frame (3 - 7 days on). Inside the initial 24 hours after the hydration begins, the miniaturized scale particles of Metakaolin fill in as smaller scale filler to densify the structure of cement paste, just as nucleation communities for the principle result of concrete hydration, which is (C-S-H).

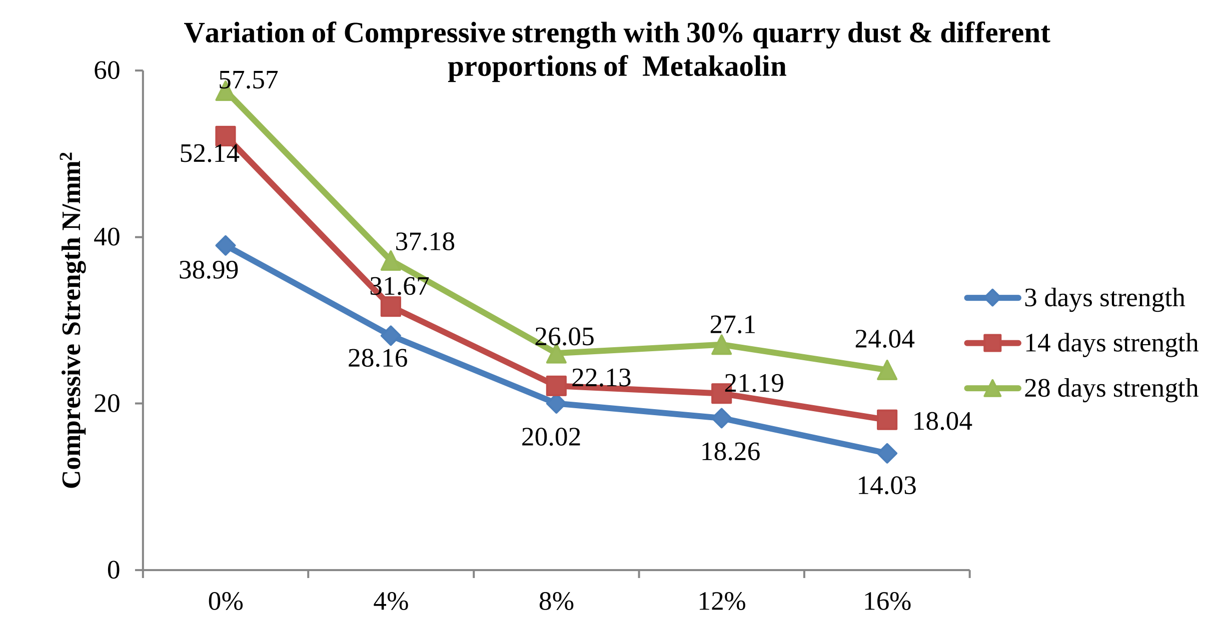

Fig. 3: Percentage Replacement of Cement by Metakaolin

Figure-3 depicts the variation of compressive strength of concrete specimens in which 30% quarry dust is allowed to remain constant and only the cement content is replaced in the percentages ranging from 0 to 16%. With the combined use of quarry dust and Metakaolin, the compressive strength started declining. Quality of the concrete is for the most part subject to holding of the fine particles which fills the voids between the coarse aggregates. The water content utilized for blending the ingredients gets consumed by Quarry residue and Metakaolin, accordingly meddling with the hydration procedure. The amount of water required for hydration won't be accessible for further synthetic responses. This reason can be ascribed for the decrease of compressive quality.

VII. Conclusions

The examination researched the impacts of Quarry residue and Metakaolin on the compressive quality of cement. The consideration of Metakaolin in quarry dust concrete has positive effect on the rheological properties as far as workability, compaction, bleeding and segregation. In light of the examinations did on Quarry dust squander, it is reasoned that it tends to be utilized as halfway substitution of fine aggregate.

It is affirmed that the blend with 8% of substitution of Portland cement by Metakaolin gives higher compressive strength values than those of the traditional concretes. The expansion in the quality of concrete containing Metakaolin can be ascribed to the accessibility of extra hydration items. As the Portland cement in concrete starts to respond synthetically, it discharges calcium hydroxide. Metakaolin responds with the calcium hydroxide to frame extra establishing mixes and consequently improving pore structure of concrete. Because of extra pozzolanic activity the impermeability and density of concrete is extraordinarily improved. The accessibility of extra binder upgrades the paste aggregate bond which results in the concrete that has improved strength properties. The compression test results were observed to be agreeable with the individual supplantings of fine sand with Quarry dust and cement with Metakaolin. Be that as it may, the joined use of both Quarry residue and Metakaolin did not yield the positive outcomes regarding compressive quality of concrete.

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