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EXPERIMENTAL STUDY ON FRESH AND MECHANICAL PROPERTIES OF CONCRETE REPLACED WITH MINERAL ADMIXTURES

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ABSTRACT
Concrete is a group of cement, fine and coarse aggregate and water. The present study is about the replacement of cement with metakaolin and quarry dust. Because, now a days the waste products are increasing every day. To reduce those waste products and to improve the strength and durability of concrete, the cement is replacing with quarry dust and metakaolin. Here, the cement firstly replaced with 25% of quarry dust and this as constant replacement of cement without loss of standard strength of cement. After the replacement of 25% of quarry dust, the mixture is replaced with 0%, 2.5%, 7.5% , 10% and 12.5% metakaolin. By taking the above replacements in cement, the concrete mixture is to be prepared to find the strength properties like compressive strength, split-tensile strength and flexural strength of concrete. The strengths of the concrete were found at the age of 7days, 28days and 90days.

KEYWORDS: Cement concrete, quarry dust, metakaolin, fine aggregate, strength properties.

INTRODUCTION
General
Ordinary Portland cement and water are the most commonly used building material throughout the world and they retain their status, because of demand and expansion of construction industry all over the world. Further the greatest challenge before the concrete construction industry is to serve the two pressing needs of human society, namely the protection of environment and meeting the infrastructure requirements of our growing population. The cement is the most costly and energy intensive component of concrete. The unit cost of concrete can be reduced as much as possible by partial replacement of cement with quarry dust and metakaolin. The cement industry is one of the two primary product producers of carbon dioxide(CO_2),creating up to 5% of worldwide man –made emissions of this gas, of which 50% is from the chemical process and 40% from burning fuel. The CO_2 emission from the concrete is directly proportional to the cement content used in the concrete mix; 900 kg of CO_2 are emitted for the production of every ton of cement.

Objective of the project:
The objectives of this experimental project study are

- Developing mix design for concrete relevant to IS: 10262-2009.
- To study the workability and strength properties of concrete of grades M30.
- To study the effect of concrete when cement with partial replacement of quarry dust and metakaolin.

This work presents the laboratory investigations carried out Studies on fresh and hardened properties concrete.

Scope of the present study:
The scope of present study includes the following aspects:

Laboratory tests on cement, fine aggregate, coarse aggregate, quarry dust, metakaolin, water. Mix design for concrete M30 with partial replacement of cement with quarry dust 25% and metakaolin with 0%, 2.5%, 5%, 7.5%, 10% and 12.5% based on the IS: 10262-2009 was done , Conducting trail mixes as per designed workability and target mean compressive strength of concrete. Specimens were tested at the age of 7days, 28days and 90days of curing in water.Fresh properties of concrete were tested by slump cone test and compaction factor test. For hardened properties of concrete specimens were tested at the age of 7 days, 28days and 90 days of curing in water.

Literature review on metakaolin and quarry dust:

M. Si-Ahmed, A. Belakrouf, and S. Kenai examined that "Influence of Metakaolin on the Performance of Mortars and Concretes". The experimental results have shown that the rates of Substitutions of 10 and 15% metakaolin increases the compressive strength and flexural strength at both early age and long term. The durability and the permeability were also improved by reducing the coefficient of sorptivity.Jiping BAI, Stan WILD, Albinas GAILIUS in 2004 examined the accelerating Early Strength Development of Concrete Using Metakaolin and quarry dust. This paper reports strength development, particularly at early curing ages, to evaluate the effectiveness of NCCM as an accelerating admixture. The Portland cement concrete covering five different addition levels of NCCM (1 % – 5 %) to binder and with four water to cement ratios of 0.3, 0.4, 0.5 and 0.6 (0.4 and 0.5 for PC 60 % – PFA 40 % concrete) were cured in water up to 28 days. The compressive strengths were evaluated at 1, 3, 7, 14 and 28 days. The compressive strength development of the concrete at various curing times is compared with control concrete (PC only). It is found that NCCM contributes significantly to early strength development as an accelerating admixture for PC and PC-PFA concrete.

TEST MATERIALS

Ordinary Portland cement:

Ordinary Portland cement is used for general constructions. The raw materials required for manufacture of Portland cement are calcareous materials, such as limestone or chalk and argillaceous materials such as shale or clay

S. No	Property	Test results
1	Normal consistency	29%
2	Specific gravity	3.13
3	Initial setting time	92 minutes
4	Final setting time	195 minutes
5	Compressive strength at 3days,7days,28days	27.40 N/mm^2 29.23 N/mm^2 41.62 N/mm^2

Table1: Physical properties of cement

Aggregates:

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. Aggregates occupy 70 to 80 percent of volume of concrete. Aggregates are obtained either naturally or artificially.

S. No	Property	Value
1	Specific gravity	2.57
2	Fineness modulus	2.46
3	Bulk density: Loose Compacted	 15kN/m^3 16kN/m^3
4	Grading	Zone-II

Table 2: Physical properties of fine aggregate

Sieve size	Retained	% retained	Cumulative % retained	%passed

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10	-----	----	-----	100
4.75	-----	----	-----	100
2.36	40	4	4	96
1.18	185	18.5	22.5	77.5
600	320	32	54.5	45.5
300	350	35	89.5	10.5
150	100	10	99.5	0.5
Pan	5	0.5	100	0

Table 3: Sieve analysis of fine aggregate

Coarse aggregate:
The material whose particles are of size are retained on IS sieve of size 4.75mm is termed as coarse aggregate and containing only so much finer material as is permitted for the various types described in IS: 383-1970 is considered as coarse aggregate.

S. No	Property	Value
1	Specific gravity	2.78
2	Fineness modulus	8.83
3	Bulk density Loose Compacted	14 kN/m^3 16 kN/m^3
4	Nominal maximum size	20 mm

Table 4: Physical properties of coarse aggregate

Sieve size	Retained	% retained	Cumulative % retained
20mm	1.76	17.6	17.6
16mm	5.50	55.0	72.6
12.5mm	2.10	21.0	93.6
10.0mm	0.61	6.1	99.7
480	0.03	0.3	100
240	---	---	100
120	---	---	100
60	---	---	100
30	---	---	100
15	---	---	100
Total			883.3

Table 5: Sieve analysis of coarse aggregate Sample 10kg

$$\text{Fineness Modulus} = \frac{\text{Cumulative \% reatained}}{100}$$

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$$= \frac{883.3}{100}$$

$$= 8.833$$

Quarry dust:

Quarry dust is collected from local stone crushing units of Chowdavaram village, Guntur, Andhra Pradesh. It was initially dry in condition when collected and was sieved by IS: 90 micron sieve before mixing in concrete. Specific gravity observed for quarry dust is 2.5.

Physical properties of quarry dust:

Table 6: Physical properties of quarry dust

Property	**Quarry dust**	**Test method**
Specific gravity	2.54-2.60	IS 2386 (Part III) 1963
Bulk relative density (kg/m3)	1720-1810	IS 2386 (Part III) 1963
Absorption (%)	1.20-1.50	IS 2386 (Part III) 1963
Moisture content (%)	Nil	IS 2386 (Part III) 1963
Fine particles less than 0.075mm (%)	12-15	IS 2386 (Part I) 1963
Sieve analysis	Zone II	IS 383 – 1970

Chemical composition of quarry dust:

Table 7: Chemical compositions of quarry dust

Items	**Quarry rock dust (%)**	**Test method** Test method
SiO_2	62.48	IS: 4032-1968
Al_2O_3	18.72	
Fe_2O_3	06.54	
CaO	04.83	[10]IS: 4032-1968
MgO	02.56	
Na_2O	Nil	
K_2O	03.18	
TiO_2	01.21	
Loss of ignition	00.48	

Metakaolin: Metakaolin is a highly Pozzolanic material. It is obtained by calcinations of Algerian kaolin at 700° C for 7 hours. It is derived from the calcinations of high purity kaolin clay.

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Properties of metakaolin:

Table 8: Physical properties of metakaolin

Properties	Value
Density (gm/cm^3)	2.17
Bulk density (gm/cm^3)	1.26
Particle shape	Spherical
Colour	Grey
Specific gravity	2.1

Table 9: Chemical composition of metakaolin

Constituents	Values
Silica	53%
Alumina	43%
Iron Oxide	0.5%
Calcium Oxide	0.1%
Sulphate	0.1%
Sodium Oxide	0.05%
Potassium Oxide	0.4%

MIX PROPORTIONING:

Design of M30 grade concrete:

Stipulations for proportioning:

a) Grade designation : M30
b) Type of cement : OPC 53grade confirming IS: 12269
c) Cement content : 424.41kg/m³
d) Maximum nominal size of aggregate : 20 mm
e) Maximum water – cement ratio : 0.45
f) Workability : 125 mm (slump)
g) Exposure condition : Mild (for reinforced concrete)
h) Method of concrete placing : Pumping
i) Degree of supervision : Good
j) Type of aggregate : Crushed angular aggregate

Test data for materials:

a) Cement used : OPC 53 grade confirming IS: 12269
b) Specific gravity of cement : 3.13
c) Mineral admixture : Metakaolin
d) Specific gravity of
1) Coarse aggregate : 2.78
2) Fine aggregate : 2.57
3) Mineral admixture : 1.2
e) Water absorption
1) Coarse aggregate : 0.5%s
2) Fine aggregate : 1.0%
f) Free (Surface) moisture
1) Coarse aggregate : NIL
2) Fine aggregate : NIL
g) Sieve analysis
Fine aggregate : Confirming to grading Zone II of Table 4 of IS: 383

Mix proportions for trail:

Cement = 424.41kg/ m³

Water =182.5litre
Fine aggregate: = 641kg
Coarse aggregate = 1202kg
Water Cement ratio = 0.43

Table 10: No. of specimens prepared for determining hardened properties.

Specimens	**No. of specimen cured in water**						
	NC C	NCCM 0	NCCM 2.5	NCCM 5	NCCM 7.5	NCCM 10	NCCM 12.5
Cubes	9	9	9	9	9	9	9
Cylinders	9	9	9	9	9	9	9
Beams	9	9	9	9	9	9	9

RESULTS AND DISSCUSSIONS

Compressive strength test results of quarry dust:

S. No	**Quarry dust (%)**	**Average strength at 28 days(N/mm^2)**
1	0	41.6
2	10	40.5
3	20	41.4
4	25	42.8
5	30	38.9

Table 11: Compressive strength test results of quarry dust

S. No	**Mix Id**	**Slump (mm)**	**ompaction actor**
1	NCC	125	.91
2	NCCM0	126	.90
3	NCCM2.5	123	.89
4	NCCM5	122	.88
5	NCCM7.5	124	.87
6	NCCM10	127	.92
7	NCCM12.5	125	.90

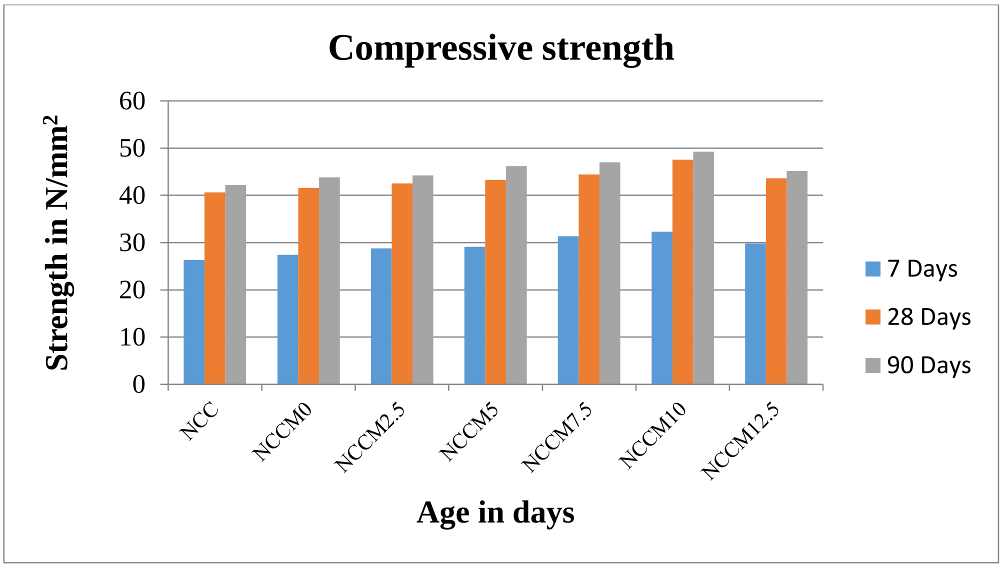
Table 12: Slump cone and compaction factor test results

Compressive strength of concrete:

The compressive strength of the concrete was done on 150 x 150 x 150 mm cubes. A total of 63 cubes were cast for the five mixes. i.e., for each mix 9 cubes were prepared. Testing of the specimens was done at 7 days, 28 days and 90 days, at the rate of three cubes for each mix on that particular day. The average value of the 3 specimens is reported as the strength at that particular age.

Table 13: Compressive strength test results

S. No	Mix Id	Compressive strength(N/mm^2)		
		7 days	28 days	90 days
1	NCC	26.35	40.62	42.21
2	NCCM0	27.42	41.6	43.80
3	NCCM2.5	28.80	42.53	44.23
4	NCCM5	29.13	43.25	46.23
5	NCCM7.5	31.33	44.45	47.02
6	NCCM10	32.34	47.58	49.26
7	NCCM12.5	29.8	43.6	45.2



Graph 1: Compressive strength Vs Age

Split tensile strength:

The indirect tensile strength was measured on 150 x 300 mm cylinders and the results were shown below. A total of 63 cylinders were cast for the five mixes. Three specimens were tested each time and the average value at the particular age was reported as the tensile strength of the concrete.

Table 14: Split tensile strength test results

S. No	Mix Id	Split tensile strength(N/mm^2)		
		7 days	28 days	90days
1	NCC	2.45	3.12	3.21
2	NCCM0	2.61	3.21	3.32
3	NCCM2.5	2.65	3.26	3.35
4	NCCM5	2.73	3.34	3.41
5	NCCM7.5	2.92	3.62	3.76
6	NCCM10	3.02	3.91	3.95
7	NCCM12.5	2.81	3.30	3.36

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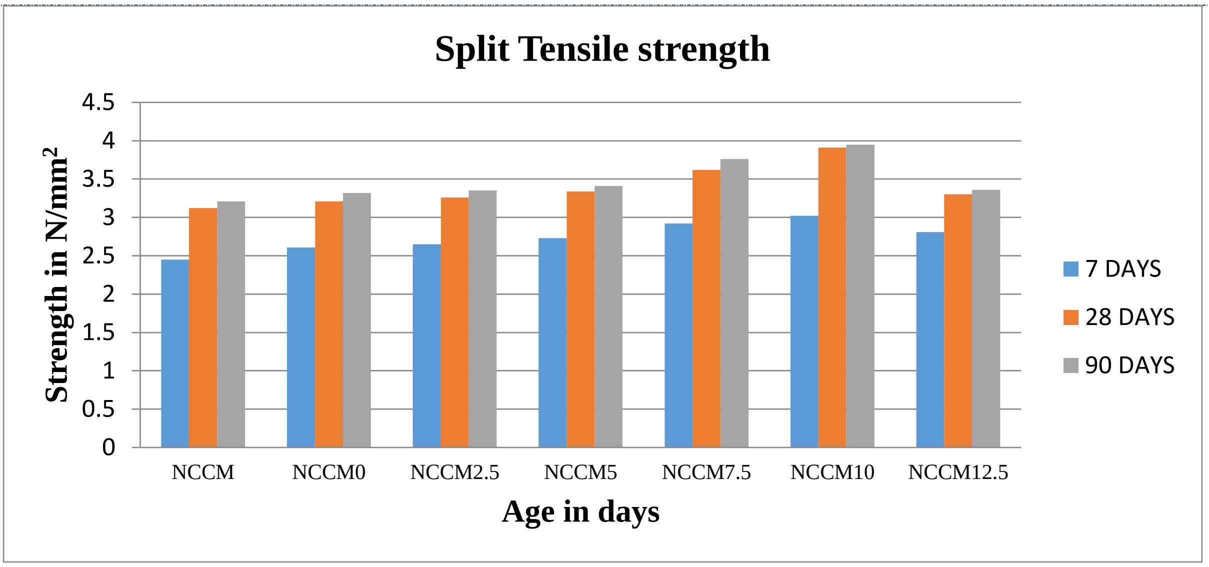

Graph 2: Tensile strength Vs Age

Flexural strength:

Flexural strength of the concrete was determined from modulus of rupture test on beam specimens of 100 x 100 x 500 mm size. Here also, a total of 63 specimens were cast out of which three specimens were tested for each mix at 7days, 28 days and 90 days.

S. No	Mix Id	Flexural strength(N/mm^2)		
		7 days	28 days	90 days
1	NCC	4.41	6.05	7.12
2	NCCM0	4.63	6.28	7.23
3	NCCM2.5	4.93	6.49	7.35
4	NCCM5	5.02	6.50	7.54
5	NCCM7.5	5.23	6.64	7.75
6	NCCM10	5.34	6.93	7.85
7	NCCM12.5	5.21	6.70	7.62

Table 15: Flexural strength test results

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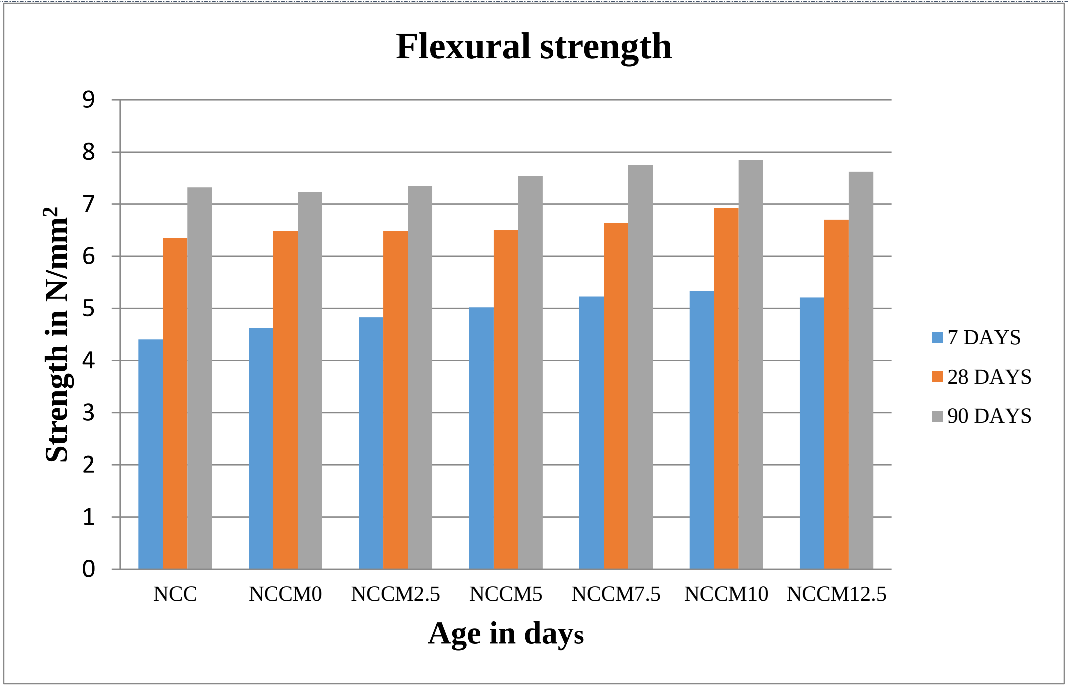

Graph 3: Flexural strength Vs Age

CONCLUSIONS

Based on the study, following conclusions may be drawn.

- There was a change in slump for NCCM0 has increased 0.79% when compared with NCC.
- The slump for NCCM2.5, NCCM5, and NCCM7.5 has reduced by 1.6%, 2.4%, 0.79% when compared with NCC.
- The slump for NCCM10 has increased by 1.57% when compared with NCC and there was no change in slump for NCCM12.5 when compared with NCC.
- The compaction factor for NCCM0, NCCM2.5, NCCM5, and NCCM7.5 was reduced by 1%, 2.19%, 3.29%, and 4.39% respectively when compared with NCC mix and mix NCCM10 was increased by 1.08% when compared with NCC mix. Hence the degree of workability was found to be almost same.
- The compaction factor for mix NCCM12.5 was reduced 1% respectively when compared with NCC.
- It was observed that the compressive strength of NCCM0, NCCM2.5, NCCM5, NCCM7.5, NCCM10, and NCCM12.5 at the age of 28 days has reached its target mean strength however it was observed that the compressive strength increased by 1.6%, 2.1%, 3.7%, 6.3%, 12.5% and 6.6% respectively when compared with NCC.
- It was observed that the compressive strength of NCC at the age of 28 days reached its target mean strength however it was observed that the compressive strength reduced by 2.3% respectively when compared with NCCM0, mixes NCCM2.5, NCCM5, NCCM7.5, NCCM10 and NCCM12.5 at the age of 28 days has reached its target mean strength however it was observed that the compressive strength increased by 2.1%, 3.8%, 6.4%, 14.6% and 4.5% respectively when compared with NCCM0.
- It was observed that the compressive strength of NCCM12.5 has reduced by 8.36% respectively when compared with NCCM10 at the age of 28 days.
- Flexural strength (At 28 days) of NCCM0, NCCM2.5, NCCM5, NCCM7.5, NCCM10 and NCCM12.5 has increased by 2%, 2.15%, 2.3%, 4.3%, 8.3% and 9.7% respectively when compared with mix NCC.
- Flexural strength (At 28 days) of NCC has reduced 3.66% by respectively when compared with mix NCCM0.
- Flexural strength (At 28 days) of mix NCCM2.5, NCCM5, NCCM7.5, NCCM10 and NCCM12.5 has increased by 3.23%, 3.38%, 5.42%, 8.88% and 6.26% respectively when compared with mix NCCM0.
- Flexural strength (at 28 days) of mix NCCM10 has reduced by 3.3% respectively when compared to NCCM12.5.

- The split tensile strength(at 28 days) of mixes NCCM0, NCCM2.5 NCCM5, NCCM7.5, NCCM10 and NCCM12.5 has increased by 2.8%, 4.2%, 6.5%, 13.8%, 20% and 5.4% respectively when compared with mix NCC.
- The split tensile strength of mix NCC has reduced by 2.8% respectively when compared to NCCM0.
- The split tensile strength of mixes NCCM2.5, NCCM5, NCCM7.5, NCCM10 and NCCM12.5 (at 28 days) has increased by 1.53%, 3.89%, 11.32%, 17.9% and 2.7% respectively when compared with mix NCCM0.
- The Split tensile strength of mix NCCM10 has reduced by 15.6% respectively when compared with mix NCCM12.5.
- Cement can be replaced with quarry dust up to 25% without much loss in compressive strength.

Considerable decrease in compressive strength was observed from 25% cement replaced with quarry dust.

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