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Pcc Constituents Quantification Through Partial Replacement of Fine Aggregate and Cement

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***Abstract:** The paper aim is to acknowledge the use of Quartz Sand (silica sand) & Metakaolin in replacement of natural sand and cement. As the natural sand is depleting at an alarming rate due to perpetual mining and on other side the emission of co2 from production of cement causing global warming. The M30 grade is prepared as well as evaluated for strength characteristics viz. split tensile, compressive and flexural. Ordinary Portland cement is replaced with metakaolin at 0,10,20,30,40 and 50%, while the fine aggregate is replaced with Quartz sand at 40% constant by weight. The specimens are casted and tested for split tensile, compressive and flexural strengths after curing for 7,14,28 days.*

***Keywords-** Quartz sand, Metakaolin, Conventional concrete, Partial replacement, Physical properties.*

I. INTRODUCTION

Concrete, the most far-flung man-made material on planet. The cement industry is one of the primary producers of CO_2. In 2018 the cement produced in India is 290 million metric tons and 4250 million metric tons worldwide. The excessive sand mining causes the degradation of rivers which leads to increased flooding and threat to biodiversity. This both leads to global warming and environmental pollution to overcome these issues the usage of Metakaolin to decrease the consumption of cement and Quartz sand to decrease the consumption of sand must be adopted without compromising in strength of concrete. Metakaolin is the white powder of A.2Si by dehydrating kaolin (Al_2O_3 $2SiO_3.2H_2O$) at an acceptable temperature ($700-900^{o}C$). kaolin is in a very stratified silicate structure, with the layers binding with one another via the Vander Weal's bond, among that "O" is bound determinedly. When Kaolin is heated in air it might undergo many structural changes and heated to around $600^{o}C$ its superimposed structure will be broken because of dehydration and makes a transient phase with poor crystallinity. The resultant material is called metakaolin. It has irregular arrangement in molecular structure having thermodynamic meta-stable condition and cementitious beneath a satisfactory excitation..

With this exalted activity, it is used to production of cementitious materials and elevated strength superior concrete mix. The most prominent sand making material is quartz as it is resistant to different weathering conditions. Sand which has enriched quartz is probably going conventional and has moved off from the source region to several kilometres

It takes longer duration for breakdown of weaker minerals of rocks by phenomena of weather. Sand having this sort of mineral grains from source rocks have formed many years ago and have seen many lithification and weathering cycles. The preceding researches observed better results when the cement and quartz with Metakaolin and subtle aggregate respectively in concrete. In the present work an attempt was made to study mechanical properties of M30 grade concrete with the above replacements. In preceding research, quality of sand made concrete degraded as replacement level increases [1]. The effect of adding metakaolin overshoot the strength of OPC mixes [2]. In some journals they concluded that the optimum usage of metakaolin gives the great result compared to conventional concrete [3]. It was observed that the split tensile strength and flexural strength development in the concrete had similar tendency with compressive strength i.e. the strengths are directly proportional to each other [4]. The better strengthen results were observed by replacement of sand with robo-sand [5]. The various strength characteristics of concrete were improved by the adding 2% of nano silica & 5% of metakaolin [6].

II. MATERIAL CHARACTERISTICS

The different materials and their characteristics were observed such that better concrete mix results can be obtained with combinations

A. Cement

53 grade OPC was used for all the concrete mixes conforming to IS12269:1987.

Table- I: Physical Characteristics

S.NO.	PROPERTY	RESULT
1	Fineness modulus	0.16
2	Specific gravity	3.15
3	Initial setting time	30 min
4	Final setting time	450 min

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B. *Fine Aggregate*

For fine aggregate, sand of river was used conforming to IS383:1970

Table- II: Physical Characteristics

S.NO.	PROPERTY	RESULT
1	Bulk density	4.13
2	Specific gravity	2.63
3	Fineness modulus	2.76

C. *Coarse Aggregate*

For coarse aggregates,20mm Crushed angular aggregates were used conforming to IS383:1970

Table- III: Physical Characteristics

S.NO.	PROPERTY	RESULT
1	Fineness modulus	6.42
2	Specific gravity	2.6
3	Water absorption	1.10

D. *Quartz Sand*

The crushed powder of Quartz rock is taken from the local manufacturer. The micro filling effect of quartz sand improves the particle packing of concrete.

Table- IV: Physical Characteristics

S.NO.	PROPERTY	RESULT
1	Fineness modulus	2.7
2	Specific gravity	2.65

Table- V: Chemical Properties

S.NO.	PROPERTY	PERCENTAGE
1	SiO_2+Ai_2O_3+Fe_2O_3	99.53
2	CaO	0.11
3	So_3	0.17
4	Ko	0.07
5	Cl	0.02
6	Na_2O	0.1
7	Loss of Ignition	1

E. *Metakaolin*

It is the calcined form of kaolinite which is also known as china clay. The Metakaolin was obtained from the supplier ASTRRA Chemicals, Chennai.

Table- VI: Physical Characteristics

S.NO.	PROPERTY	RESULT
1	Bulk density	0.45
2	Specific gravity	2.5

Table- VII: Chemical Properties

S.NO.	PROPERTY	RESULT
1	Sio_2	58.3
2	Al_2O_3	34.3
3	Fe_2O_3	4.29
4	CaO	0.38
5	MgO	0.08
6	Na_2O	0.12
7	K_2O	0.05

F. *Super Plasticizer*

To increase the workability of concrete super plasticizer was used. The super plasticizer used in the experiment was RHEOBUILD 920SH. As per IS9103-1999. The super plasticizer was used 1% of binder and the specific gravity is 1.20.

G. *Mix Proportion*

The mix proportion for the present study designed as per 10262-2009 is 1:2.17:3. Water/cement ratio is 0.43 The concrete mixes used in the study are

MQ0 – conventional mix

MQ1 – [90% cement + 10% metakaolin]: [60% fine aggregate + 40% quartz sand]: coarse aggregate.

MQ2 – [80% cement + 20% metakaolin]: [60% fine aggregate + 40% quartz sand]: coarse aggregate.

MQ3 – [70% cement + 30% metakaolin]: [60% fine aggregate + 40% quartz sand]: coarse aggregate.

MQ4 – [60% cement + 40% metakaolin]: [60% fine aggregate + 40% quartz sand]: coarse aggregate.

MQ5 – [50% cement + 50% metakaolin]: [60% fine aggregate + 40% quartz sand]: coarse aggregate.

III. EXPERIMENTAL RESULTS

A. *Compressive Strength*

The ability of the material to withstand loads which tends to reduce size. Table 9 shows the effects of metakaolin and quartz sand on 7,14 &28 days strengths.

Table- VIII: compressive strength test results

Mix design	Proportion	Compressive strength N/mm^2		
		7days	14days	28days
MQ0	0% M 0% Q	26	36	39
MQ1	10% M 40% Q	28.2	39	41.1
MQ2	20% M 40% Q	30.5	42.2	43.8
MQ3	30% M 40% Q	23.3	32.3	36.1
MQ4	40% M 40% Q	19.1	26.5	32.3
MQ5	50% M 40% Q	16.9	23.4	30.4

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M-metakaolin Q-quartz sand The results of compressive strengths show that the compressive strength increased when the metakaolin increased up to 20% and quartz sand 40%. After that the compressive strength is decreased when the metakaolin is increased above 30%. It was clear that the metakaolin and quartz sand influence the strength significantly.

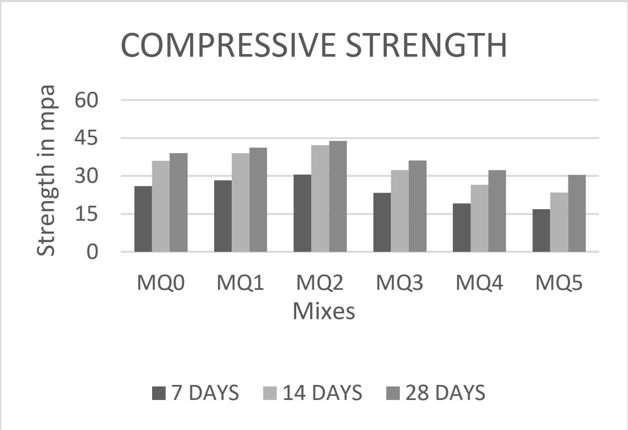

Fig.1 Compressive Strength Results

B. Split Tensile Strength

Ability of the concrete to withstand loads which tend to elongate without breaking. Table 10 shows the effects of metakaolin and quartz sand on 7,14 & 28 days split tensile strength of concrete.

Table- IX: split tensile strength test results

Mix design	Proportion	Split Tensile strength		
		7days	14days	28days
MQ0	0% M 0% Q	2	2.8	3.2
MQ1	10% M 40% Q	2.2	3.1	3.4
MQ2	20% M 40% Q	2.5	3.5	3.7
MQ3	30% M 40% Q	2.1	2.8	3.3
MQ4	40% M 40% Q	1.9	2.6	3
MQ5	50% M 40% Q	1.7	2.45	2.7

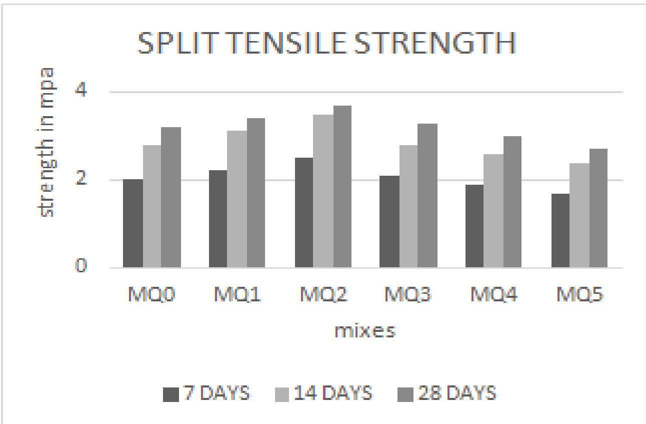

Fig.2 Split Tensile Strength Results

The results of Split tensile strengths show that the tensile strength increased when the metakaolin increased up to 20% and quartz sand 40%. After that the tensile strength is decreased when the metakaolin is increased above 30%. It was clear that the metakaolin and quartz sand influence the strength significantly

C. Flexural Strength

The ability of beam to resist failure in bending. Table 11 shows the effect of metakaolin and quartz sand on 7,14 &28 days flexural strength of concrete.

Table- X: flexural strength test results

Mix design	Proportion	Flexural strength		
		7days	14days	28days
K0	0% M 0% Q	2.9	4.1	4.5
K1	10% M 40% Q	3.1	4.3	4.7
K2	20% M 40% Q	3.2	4.5	5
K3	30% M 40% Q	2.9	4	4.4
K4	40% M 40% Q	2.8	3.9	4.3
K5	50% M 40% Q	2.5	3.5	3.9

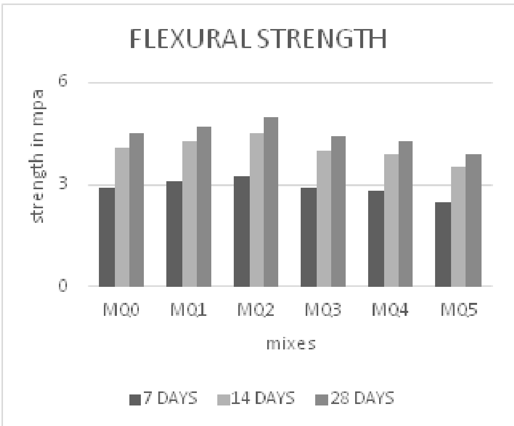

Fig.3 Flexural Strength Results

The results of flexural strengths show that the tensile strength increased when the metakaolin increased up to 20% and quartz sand 40%. After that the flexural strength is decreased when the metakaolin is increased above 30%. It was clear that the metakaolin and quartz sand influence the strength significantly

IV. CONCLUSION

The incorporation of 20% metakaolin and 40% quartz sand is found advantageous (43.8 MPa) for 28 days. Compared to conventional concrete the strength increased 12% for K2 mix. The combination of 20% metakaolin and 40% quartz sand is found peerless for split tensile for 28 days. The K2 split tensile mix was increased 14% compared to conventional concrete. The mix K2 with 20% metakaolin and 40% quartz sand is found beneficial for flexural for 28 days. An improvement of 15% was observed in flexural than conventional concrete. As per the test results it was noticed that split tensile as well as flexural strengths of concrete had similar liabilities with compressive strength. The strengths are directly proportional to each other.

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