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AN EXPERIMENTAL INVESTIGATION ON THE STRENGTH PROPERTIES OF CONCRETE BY PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN AND FINE AGGREGATE WITH QUARRY DUST

Dr. D. V. Prasada Rao[1] and N.Harika[2]

[1]*Professor, Department of Civil Engineering,*
Sri Venkateswara University College of Engineering, Tirupati, Andhra Pradesh, India.
[2]*PG Student, Department of Civil Engineering*
Sri Venkateswara University College of Engineering, Tirupati, Andhra Pradesh, India.

ABSTRACT:- *In the present study, an investigation is done to find out the strength properties of concrete by partial replacement of cement with Metakaolin (MK) and Fine Aggregate with Quarry Dust(QD). Metakaolin is a substance obtained from calcination(heat treatment) of Kaolin (clay mineral) at a temperature of 650-800 ^{0}C.It has good pozzolonic properties and is used as a replacement of cement. The other substance used in this study is Quarry Dust which is obtained from crushing of stones during quarrying activities. Hence Natural Sand is being replaced with Quarry Dust. The replacement percentages of Metakaolin with Cement are 0%,10%,15% and 20% .25%,50%,75% and 100% of Quarry Dust are adopted as a replacement of Fine Aggregate. The effect of Quarry Dust with varying percentages of Metakaolin on strength properties of M25 Grade of concrete is studied. The tests performed are Compressive Strength test, Split Tensile Strength, Flexural Strength and Modulus of Elasticity. All the test results are compared with Controlled concrete. From the results it is known that the optimum replacement percentages of Metakaolin (MK) and Quarry Dust (MS) are 15% and 50% respectively. At a combination of 15% Metakaolin and 50% Quarry Dust, the results of all the tests performed has shown the optimum value.*

Keywords*: Metakaolin,, Quarry Dust, Partial Replacement, Compressive Strength*

1.INTRODUCTION

For all the construction works all over the World, Concrete is the most widely used material. Concrete is a mixture which constitutes Cement, Fine Aggregate, Coarse Aggregate and Water. In the recent times, the demand for Natural Sand has been increased because it has to be dredged from the far off river beds. Also the Natural sand contains more percentage of clay, silt, debris and impurities. Also there will be increase in the cost of construction because of increase in transportation charges. The Government has made laws for the reduction of dredging the river beds for Sand which causes ecological imbalance due to enormous illegal sand mining activities. Due to these reasons and also keeping our future generations in view, we need to preserve some of the Natural resources. So there is a need to find alternatives for Natural Sand. Quarry Dust has been used as a replacement for Natural Sand.

Quarry Dust is obtained from crushing process during quarrying activities as a by-product. It is replaced either as partly or full substitution of Natural Sand. It is used as a substitute for Natural Sand because of its low cost. Due to the usage of this material there will be reduction in the pollution as it contains more dust particles.

Now-a-days the consumption of Cement is more and it affects the environment. During the production of Cement tonnes of CO_2 is released into atmosphere which is very harmful. Due to these emissions the life span of humans reduces, also it effects the beauty of the monuments. In this scenario, there is a need to reduce these CO_2 emissions and find alternatives for

cement. One of such alternative for Cement is Metakaolin, which is obtained from kaolin,a clay mineral. Metakaolin has good pozzolonic properties and it gives better workability to the concrete.

2.OBJECTIVE

The aim for this present investigation is to determine the strength characteristics of concrete by partial replacement of cement with Metakaolin and Fine aggregate with Quarry Dust for application in structural concrete, which will give better understanding on the properties of concrete.

3. EXPERIMENTAL PROGRAMME

3.1 Properties of Materials

3.1.1 Cement

The cement which is used in the present study is Ordinary Portland Cement(OPC) of 53 grade. The properties of Cement are confirming to IS Specifications.

3.1.2 Fine Aggregate

Fine Aggregate which is used in the study is locally available and it conforms to IS Specifications. The properties are shown below**.**

Table 1 Physical properties of Fine Aggregate

S.No	Property	Result
1	Specific Gravity	2.52
2	Fineness Modulus	3.76
3	Zone	Zone – II

3.1.3 Coarse Aggregate

Coarse aggregate of nominal size 20 mm and 12.5 mm, obtained from the local quarry confirming to IS specifications was used. The properties of Coarse aggregate are shown in Table 2.

Table 2 Properties of Coarse Aggregate

S.No	Property	Result
1	Specific Gravity	2.67
2	Water Absorption	0.4 %

3.1.4 Quarry Dust

Quarry Dust used in the present study is obtained from Chandragiri quarry, Tirupathi , Andhra Pradesh. The properties of QD are shown in the below table.

Table 3 Properties of Quarry Dust

S.No	Property	Result
1	Specific Gravity	2.3
2	Fineness Modulus	2.18
3	Water absorption	3.5%

3.1.5 Metakaolin

Metakaolin used in the study is obtained from AASTRA Chemicals, Chennai. The Physical and Chemical properties of Metakaolin supplied by the manufacturer are listed in the tables given below.

Table 4 Physical Properties of Metakaolin

S.no	Property	Values
1	Specific Gravity	2.1
2	Density (gm/cm^3)	2.17
3	Colour	Half-white
4	Particle Shape	Spherical

Table 5 Chemical Properties of Metakaolin

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

3.1.6 Water:

The water used for casting and curing of concrete test specimens was free of acids, organic matter, suspended solids and impurities which when present can adversely affect the strength of concrete. Laboratory water is used in the present study.

3.2 CONCRETE MIX PROPORTION

M25 grade of concrete is used in the present investigation. The mix design is done as per Indian Standard Code of Practice.

Table 6. Quantities of Ingredients per cum of Concrete (M25 Grade)

S.NO	Cement (%)	QD (%)	MK (%)	Water (Lit)	Cement (kg)	QD (kg)	Fine Aggregate (kg)	Metakaolin (kg)	Coarse Aggregate (kg)
1	100	0	0	155	310	0	711	0	1230
2	100	25	0	155	310	177.75	533.25	0	1230
3	100	50	0	155	310	355.5	355.5	0	1230
4	100	75	0	155	310	533.25	177.75	0	1230
5	100	100	0	155	310	711	0	0	1230
6	90	25	10	155	279	177.75	533.25	31	1230
7	90	50	10	155	279	355.5	355.5	31	1230
8	90	75	10	155	279	533.25	177.75	31	1230
9	90	100	10	155	279	711	0	31	1230
10	85	25	15	155	263.5	177.75	533.25	46.5	1230
11	85	50	15	155	263.5	355.5	355.5	46.5	1230
12	85	75	15	155	263.5	533.25	177.75	46.5	1230
13	85	100	15	155	263.5	711	0	46.5	1230
14	80	25	20	155	248	177.75	533.25	62	1230
15	80	50	20	155	248	355.5	355.5	62	1230
16	80	75	20	155	248	533.25	177.75	62	1230
17	80	100	20	155	248	711	0	62	1230

4. RESULTS AND DISCUSSIONS

4.1 Compressive Strength

The Compressive strength test was performed on cube specimens of size 150mmx150mmx150mm. All the specimens were cast and tested at the age of 3,7,28 and 56days. The graph shown below is drawn for 0% Metakaolin with varying Quarry Dust percentage (25%, 50%, 75% and 100%)

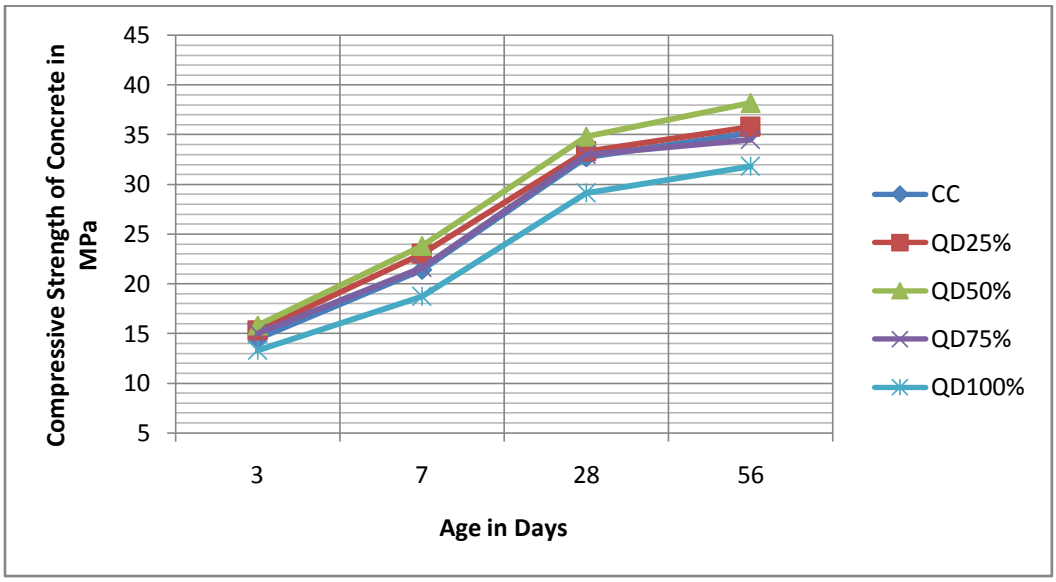

FIG 1 Variation of Cube Compressive strength of M25 grade of Concrete with varying percentages of Quarry Dust

From the above graph it is clear that the Compressive strength of concrete increases with increase in age. From the curves obtained it is concluded that the compressive strength obtained is maximum at 50% Quarry Dust replacement with Fine Aggregate at all the ages. Beyond 50% replacement of Fine Aggregate with quarry dust the strength of the concrete decreases.

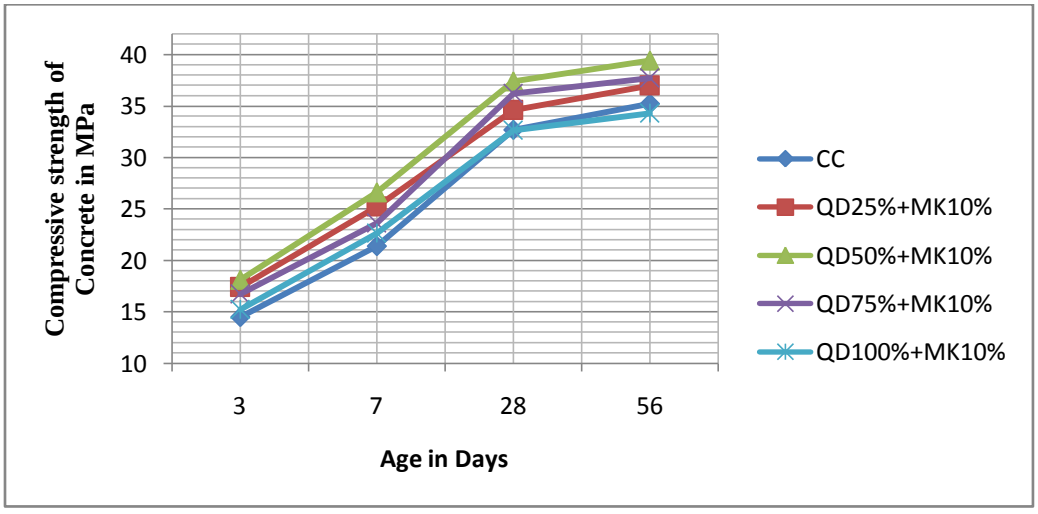

FIG 2 Compressive strength variation with 10% Metakaolin and different percentages of QD

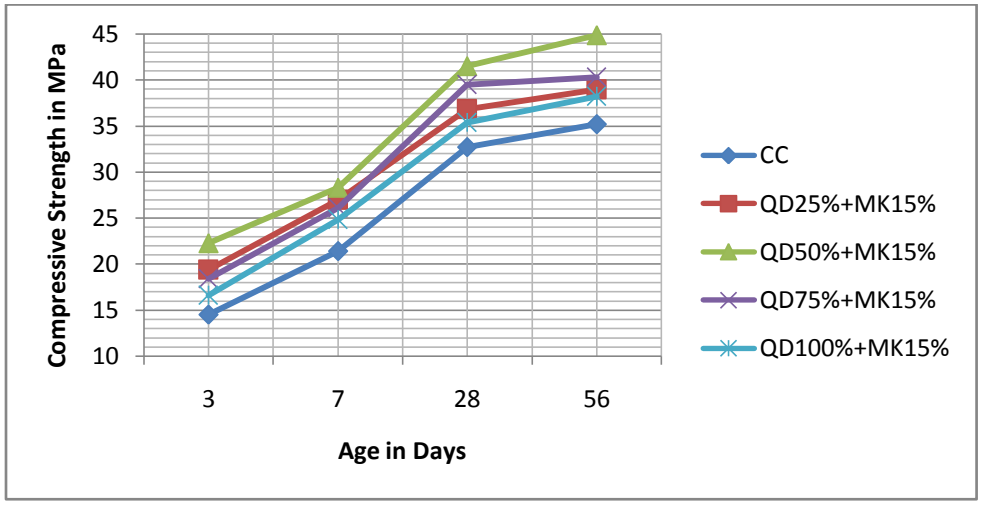

FIG3 Compressive strength variation with 15% Metakaolin and different percentages of QD

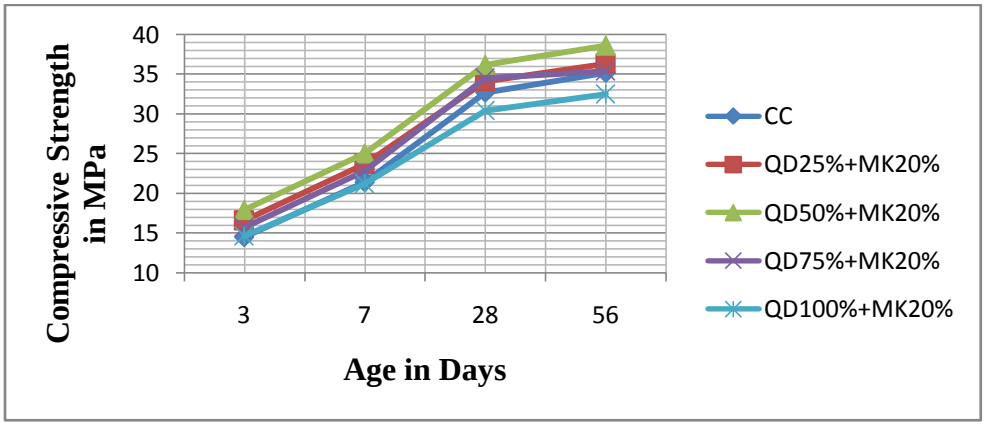

FIG 4 Compressive Strength variation with 20% Metakaolin and different percentages of QD

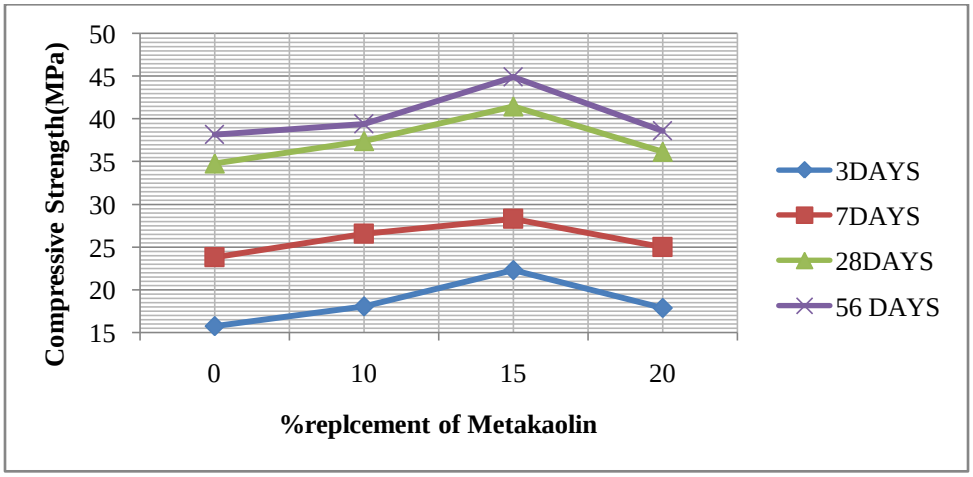

FIG 5 Variation of Compressive Strength of Concrete at different ages with different percentages of Metakaolin at optimum percentage of QD (50%)

Table 7 showing the increase in Compressive Strength at 28 days for optimum mix percentage

Concrete Mix	Compressive Strength (MPa)	% Increase
Control Concrete	32.7	-
MK15% + MS 50%	41.5	26.91

Split Tensile Strength:

Split tensile Strength is carried out by casting Cylinder specimens of 300mm length and 150mm dia. The specimens were cast, cured and tested at 28 days.

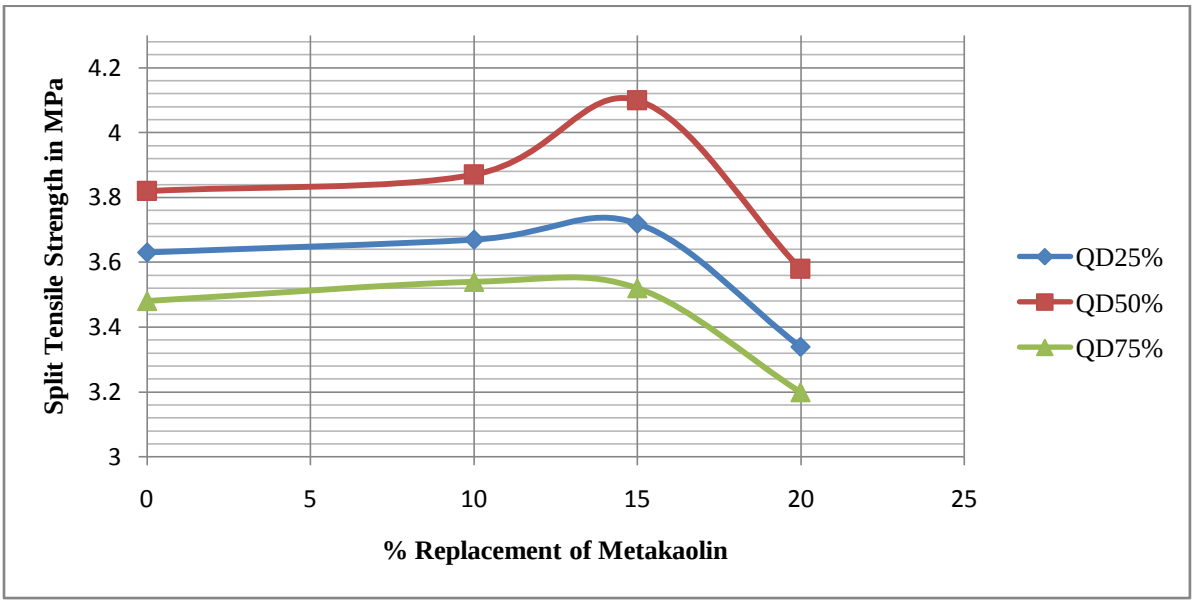

FIG 6 Variation of Split Tensile Strength of Concrete (M25 Grade) for different percentages of Metakaolin and QD.

The graph has shown the variation of Split Tensile Strength of M25 Grade of concrete. From the graph it is clear that at all the different percentages of Metakaolin and Quarry Dust the same trend has followed. The Split Tensile strength of concrete increases from 0% to 15% and then it decreases. The maximum Split Tensile Strength is for a concrete replaced with 50% of Quarry Dust with Fine Aggregate and 15% replacement of Cement with Metakaolin.

Table 8 showing the increase in Split Tensile Strength at 28 days

Concrete Mix	Split Tensile Strength (MPa)	% Increase
Control Concrete	3.55	-
MK15%+QD25%	3.72	4.78
MK15%+QD50%	4.1	15.49
MK15%+QD75%	3.8	7.04

Flexural Strength:

Flexural Strength is generally performed on concrete beams of size 500mmx100mmx100mm. Flexural strength is also known as Modulus of Rupture. It is a measure of unreinforced concrete beam or slab to resist failure in bending.

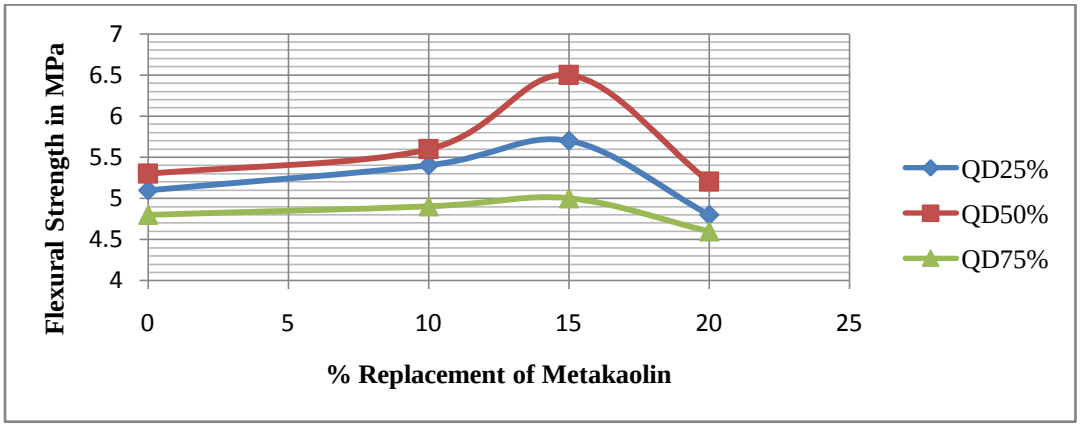

FIG 7 Variation of Flexural Strength of Concrete (M25 Grade) for different percentages of Metakaolin and QD.

From the graph it is concluded that the Flexural Strength is maximum for a combination of 15% Metakaolin and 50% Quarry Dust. Beyond 15% replacement of Cement with Metakaolin the strength decreases.

Table 9 showing the increase in Flexural Strength at 28 days for optimum mix

Concrete Mix	Flexural Strength in MPa	% Increase
Control Concrete	4.9	-
MK15%+QD50%	6.5	32.65

Modulus of Elasticity:

Modulus of Elasticity is calculated from the graph drawn for stress and strain. It is performed on cylinder specimens of size 300mmx150mm. Modulus of Elasticity increases with increase in Metakaolin percentage upto 15% and then it decreases. The optimum replacement percentages are 15% Metakaolin and 50% Quarry Dust.

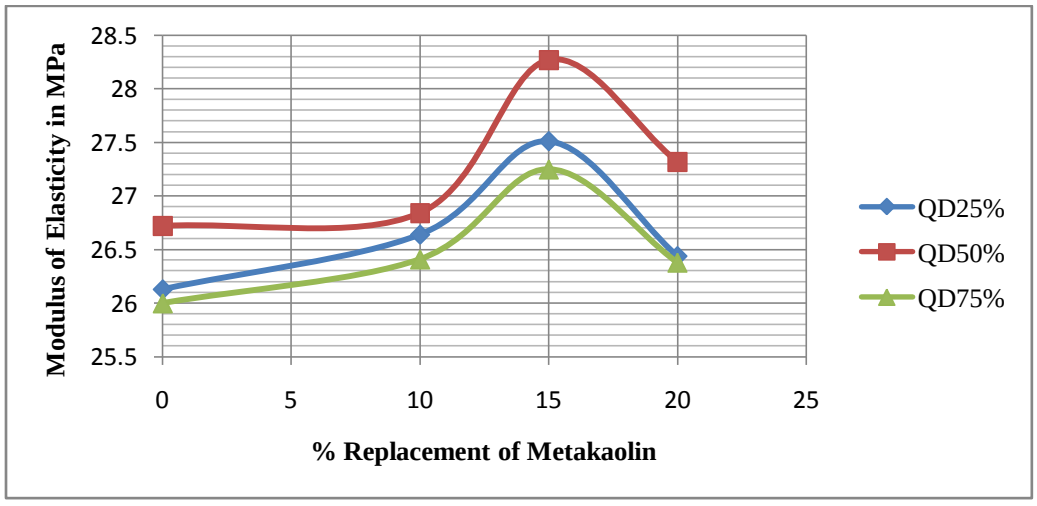

FIG 8 Variation of Flexural Strength of M25 Grade Concrete for different percentages of Metakaolin and QD.

Table 10 Percentage increase in Modulus of Elasticity for optimum mix

Concrete Mix	Modulus of Elasticity in GPa	% Increase
Control Concrete	25.8	-
MK15%+QD50%	28.27	9.57

Modulus of Elasticity for the Control Concrete is 25.8GPa. For a replacement percentage of 15% Metakaolin and 50% Quarry Dust the strength is 28.27 GPa, which is 13.08% more than the Control Concrete.

5. CONCLUSIONS

- From the above results, it can be concluded that the strength increases with increase in Metakaolin percentage upto 15% replacement of Cement with Metakaolin and with further increase in Metakaolin percentage the strength decreases with varying percentages of Quarry Dust.
- The increase in strength of concrete made with different percentages of Metakaolin and QD is due to the usage of the additional binder material (Metakaolin) and the further decrease is due to excessive binding of the mix which makes the concrete brittle.
- The strength of all the tests conducted increased upto 50% replacement of fine aggregate with Quarry Dust. Beyond 50% replacement of fine aggregate with Quarry Dust the strength decreases because of the decrease in workability of concrete mix.
- From this study, it can be concluded that the optimum replacement percentages of Metakaolin and Quarry Dust are 15% and 50% respectively.

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