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EFFECT OF NANO-SILICA AND METAKAOLIN ON PROPERTIES OF RECYCLED COARSE AGGREGATE CONCRETE

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Abstract:- *The aim of the experimental investigation is to find the influence of Nano-Silica (NS) and Metakaolin (MK) on strength properties of Recycled Coarse Aggregate concrete.In the present investigation, Recycle Coarse Aggregate (RA) was used as 25%, 50%, 75% and 100% replacement of Natural Coarse Aggregate. Cement is replaced by the combined application of Metakaolin and Nano-Silica by weight. Cement is replaced by 10%, 15% and 20% of Metakaolin and 1%, 2% and 3% of Nano-Silica. The influence of combined application of Recycled Coarse Aggregate, Metakaolin and Nano-Silica on compressive strength, split tensile strength, flexural strength and modulus of elasticity of M25 grade of concrete is investigated. Tests were conducted on standard concrete specimens prepared using the different combinations of Recycled Coarse Aggregate, Metakaolin and Nano-Silica then the test results are compared with that of controlled concrete. Based on the test results, it can be observed that concrete prepared with 50% Recycled Coarse Aggregate, 15% Metakaolin and 2% Nano-Silica combination possesses improved strength properties compared to the controlled concrete.*

Keywords: *Recycled Coarse Aggregate, Nano-Silica, Cement Replacement, Controlled Concrete, Compressive Strength, Flexural Strength, Split Tensile Strength and Elastic Modulus.*

I. INTRODUCTION

Concrete is the most common material used in the construction. Concrete is a composite material made up of cement, sand, coarse aggregate and water. Cement is the most active component of concrete. The use of large quantities of cement results in increasing CO_2 emissions and as a consequence of the green house effect. Hence, one of the solutions to these problems is to reduce the consumption of cement and utilize Pozzolana materials for the preparation of concrete.On the other hand scarcity of natural resources and needs to be preserved for the future generations. In addition to the environmental benefits, reducing the demand of land for disposing the waste, the recycling of demolition wastes can also help to conserve natural resources and to reduce the cost of waste treatment prior to disposal. Using old crushed concrete as coarse aggregate for new concrete to partially or completely replace natural aggregate is a good example of higher efficiency in concrete life. In Recycled Coarse Aggregate (RCA) Concrete, the Recycle Coarse Aggregate (RCA) can be used as partial or full replacement in place of natural coarse aggregate. The factors like depletion of natural aggregates, strict environmental laws and waste disposal problems are also influenced the application of recycled coarse aggregate.

The demand for Portland cement is increasing dramatically in developing countries. Portland cement production is one of the major reasons for CO_2 emissions into atmosphere. Metakaolin when used as a partial replacement of cement in concrete, itreacts with $Ca(OH)_2$ one of the by-products of hydration of cement and results in additional C-S-H gel which results in increased strength. Hence, by partially replacing Portland cement with Metakaolin not only reduces carbondioxide emissions but also increases the servicelife of buildings.

Recent developments in Nano-technology and the availability of nano-silica made the use of such materials in concrete. Nano-Silica (NS) is a Nano-sized, highly reactive amorphous silica. Due to the smaller particles size and high surface areas compared to the other pozzolanic materials, the use of nano-silica possibly enhances the performance of concrete more effectively.

II. OBJECTIVE

The objective of the present research work is to find the influence of the combined application of Metakaolin and Nano-Silica on various strength properties of Recycled Coarse Aggregate Concrete. Recycled Coarse Aggregate Concrete is obtained by replacing Natural Coarse Aggregate with 25%, 50% and 100% Recycled Coarse Aggregate. Combination of 10%, 15% and 20% of Metakaolin and 1%, 2% and 3% of Nano-Silica are adopted as cement replacement by weight. Compressive strength, split tensile strength, flexural strength and modulus of elasticity of concrete with the addition of various proportions of Metakaolin and Nano-Silica are to be obtained and then the results are to be compared with the controlled concrete.

III. EXPERIMENTAL PROGRAMME

3.1 Properties of Materials

3.1.1 Cement

In the present investigation Ordinary Portland cement (OPC) of 53 Grade confirming to IS specifications was used.

3.1.2 Fine Aggregate

Locally available river sand confirming to IS specifications was used as the fine aggregate in the concrete preparation. The properties of fine aggregate are shown in Table 1.

Table 1: Properties of Fine Aggregate

S.No	Property	Values
1	Specific Gravity	2.56
2	Fineness Modulus	2.60
3	Grading of Sand	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 pacifications was used. The properties of coarse aggregate are shown in Table2. The coarse aggregate used for the reparation of concrete is a mixture of 60% 20 mm and 40% of 12.5 mm size aggregates.

Table 2: Properties of Coarse Aggregate

S.NO	PROPERTY	VALUES
1	Specific Gravity	2.61
2	Water Absorption	0.4%
3	Fineness Modulus	6.53

3.1.4 Recycled Coarse Aggregate:

The recycled coarse aggregate used in this investigation is obtained by crushing the tested laboratory concrete cubes. Water absorption and specific gravity of recycled coarse aggregate used in this study were 1.75 and 2.56 respectively.

3.1.5 Metakaolin:

Metakaolin, used in this present experimental study is obtained from ASTRRA chemicals. Physical and chemical properties of the Metakaolin are presented in the Table 3 and 4.

Table 3: Physical Properties of Metakaolin

Properties	Value
Density (gm/cm^3)	2.17
Bulk density (gm/cm^3)	1.26
Particle shape	Spherical
Color	Half-white
Specific gravity	2.1

Table 4: Chemical Properties 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%

3.1.6 Nano-silica:

In this investigation, colloidal form of sample **Cemsyn XFX** grade Nanosilica has been used i.e. Nano-silica in dispersion with water in 40: 60 ratio (40% Nanosilica). Specifications of Nano-Silica are presented in the Table 5.

Table 5: Specification of Nano-Silica

S.No	Parameter	Cemsyn XFX
1	Active nano content (% wt/wt)	40.00 – 41.50
2	pH (20^{o}C)	9.4 – 10
3	Specific gravity	1.3 – 1.32
4	Description	Colloidal

3.1.7 Water

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

3.2 CONCRETE MIX PROPORTION

M25 grade of concrete mix was designed as per the Indian Standard code of practice. As the nano-silica is available in the colloidal form, the quantity of water is adjusted to account for the water available in colloidal Nano-Silica.

3.3 TEST SPECIMENS

Concrete test specimens consist of 150 mm × 150 mm × 150 mm cubes, cylinders of 150 mm diameter × 300 mm height and prisms of 100 mm × 100 mm × 500 mm. Concrete cubes were tested at different curing periods (3, 7, 28, 56 and 90 days) of curing to get the compressive strength. Cylindrical specimens were also tested at the age of 28 days to obtain the split tensile strength and the modulus of elasticity of concrete. The prisms were tested at the age of 28 days to obtain the flexural strength of concrete. The rate of loading is as per the Indian Standard specifications.

IV. RESULTS AND DISCUSSION

4.1 Compressive Strength

Fig.1, represents the compressive strength of Recycled Coarse Aggregate Concrete compared with Control concrete. The 28 days Compressive Strength of Controlled concrete is 32.3 MPa. It can also be observed that as the replacement of

Recycled Corse Aggregate is increased from 25% to 50%, the compressive strength is increased from 32.6 MPa to 33.3MPa and further addition to 75% and 100% there is decrease in the compressive strength from 26.1MPa to 25.48MPa.

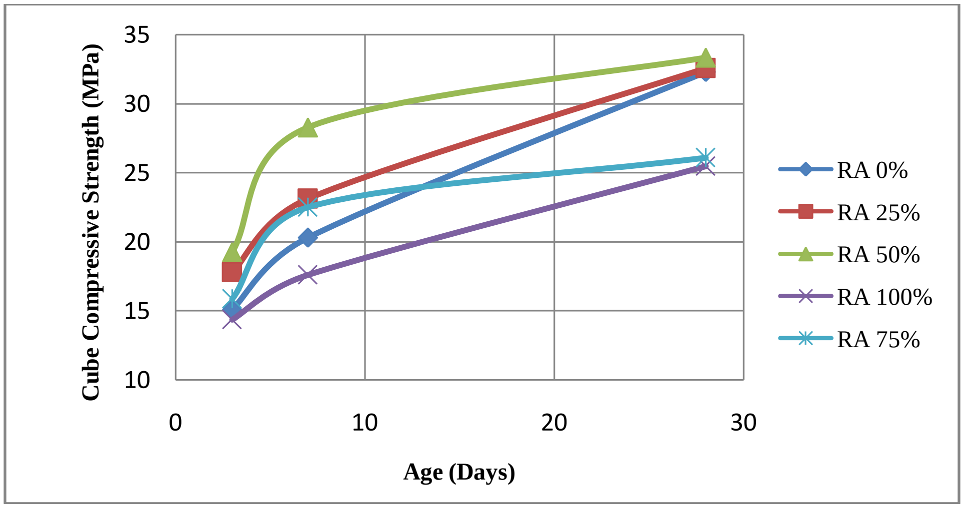

Fig1: Compressive Strength of Recycled Aggregate Concrete

Fig.2, shows the variation of compressive strength of Recycled Coarse Aggregate Concrete with Metakaolin. It can be observed that the compressive strength changes from 29.0 MPa, 38.4 MPa to 28.6 MPa with 10%, 15% and 20% of Metakaolin at 25% of Recycled Coarse Aggregate and the compressive strength further changes from 35.7 MPa, 38.97 MPa to 34.37 MPa with 10%,15%, 20% Metakaolin at 50 % Recycled Coarse Aggregate.

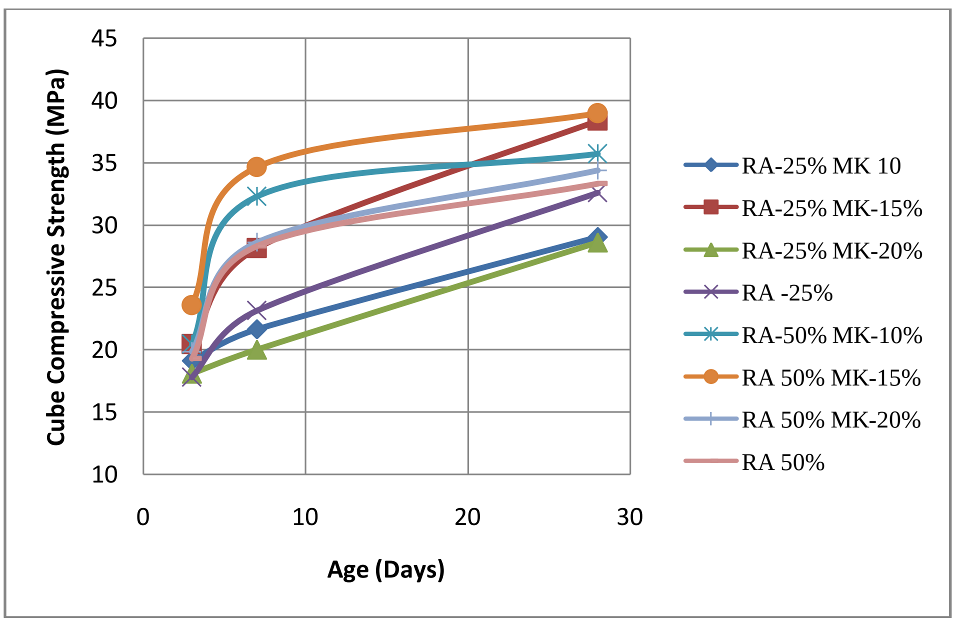

Fig 2: Compressive Strength Variation with Replacement of Metakaolin and Recycled Aggregate

Fig.3, indicates that the variation of compressive strength of Recycled Coarse Aggregate Concrete with Metakaolin and Nano-Silica. It can be observed that the compressive strength varies from 40.44 MPa, 41.77 MPa to 39.26 MPa with 1%, 2%, 3% of Nano-Silica, 15% Metakaolin and 50% of Recycled Coarse Aggregate.

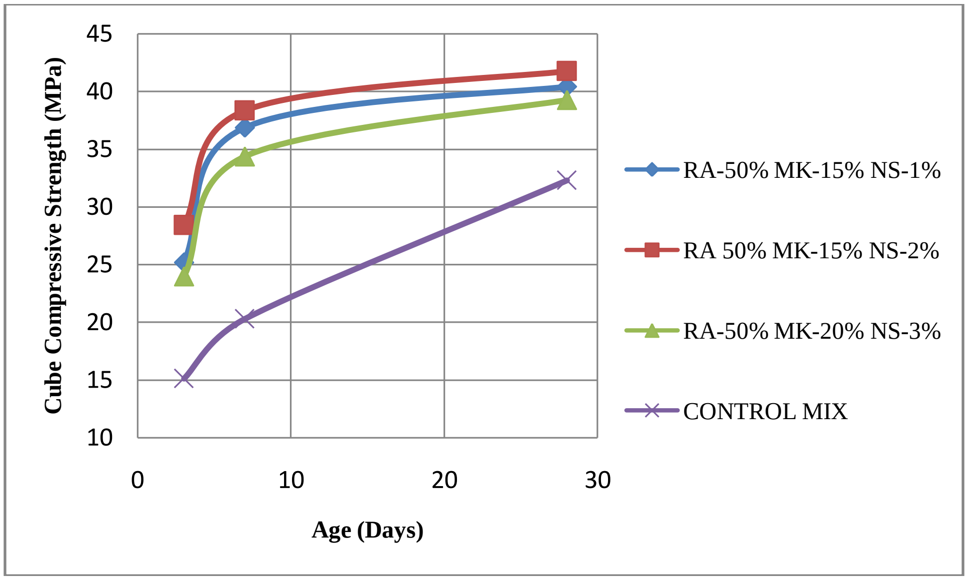

Fig 3: Variation of Compressive Strength with Nano-Silica, Metakaolin and Recycled Coarse Aggregate

4.2 Split Tensile Strength:

Fig. 4, represents the variation of split tensile strength of Nano-Silica, Metakaolin and Recycled Coarse Aggregate of RCA concrete. It can be observed that the split tensile strength increased to 4.47MPa compared to control concrete of strength 3.44 MPa

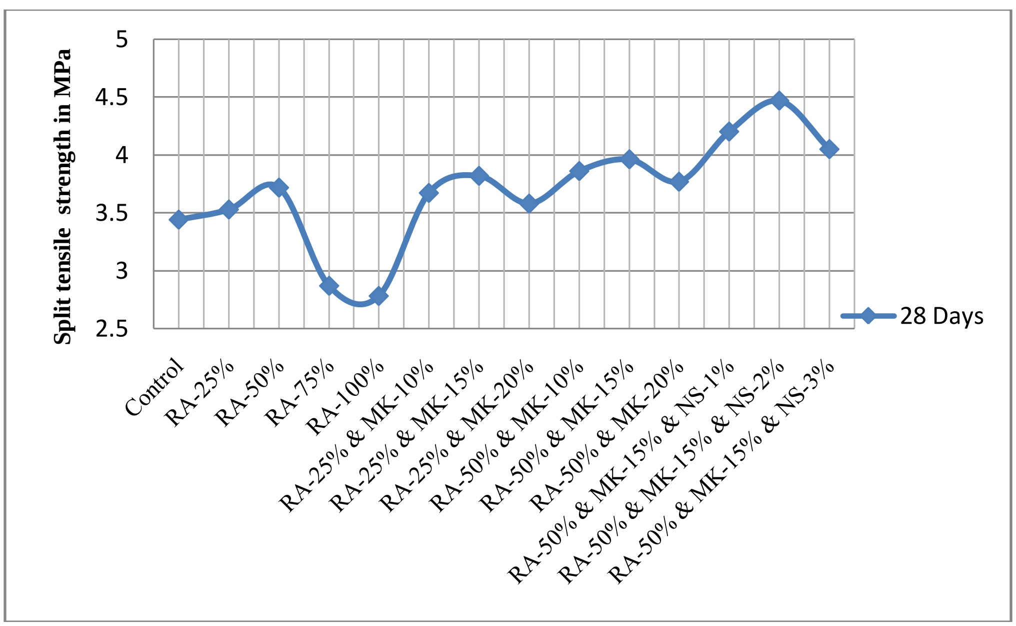

Fig 4: Split Tensile Strength Variation with Replacement of Nano-Silica, Metakaolin and Recycled Coarse Aggregate

4.3 Flexural Strength:

Fig.5, represents the variation of flexural strength of Nano-Silica, Metakaolin and Recycled Coarse Aggregate of RCA concrete. It can be observed that the flexural strength increases to 5.97MPa compared to control concrete of strength 4.622MPa.

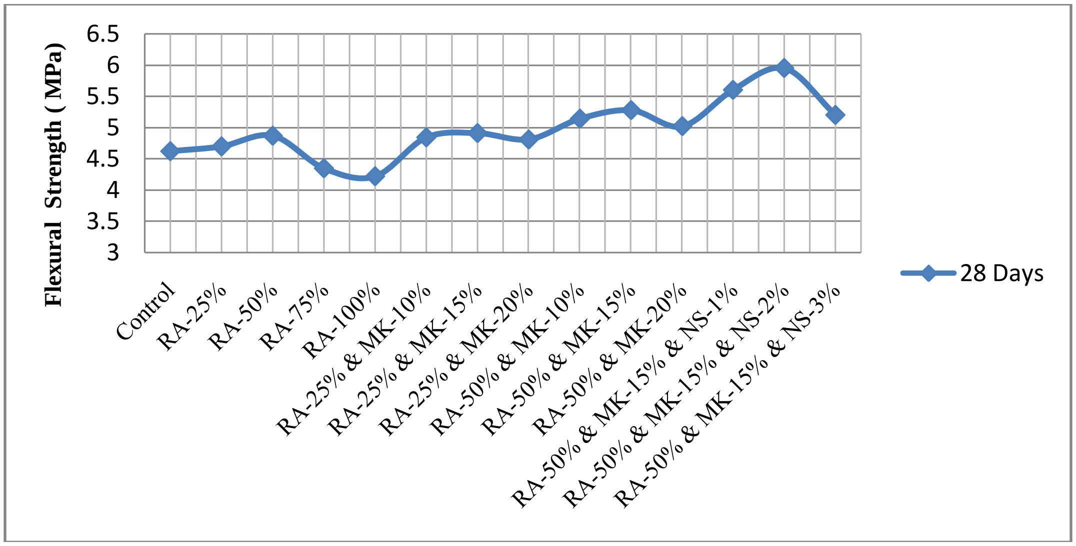

Fig 5: Flexural Strength Variation with Replacement of Nano-Silica, Metakaolin and Recycled Coarse Aggregate

4.4 Elastic Modulus:

Fig.6, shows the variation of modulus of elasticity of various concrete mixes. The modulus of elasticity of controlled concrete is 25.2 GPa. It can be observed that the modulus of elasticity is 26.9 GPa for the replacement levels of Recycled coarse aggregate 50%, Metakaolin 15% and Nano silica 2%.

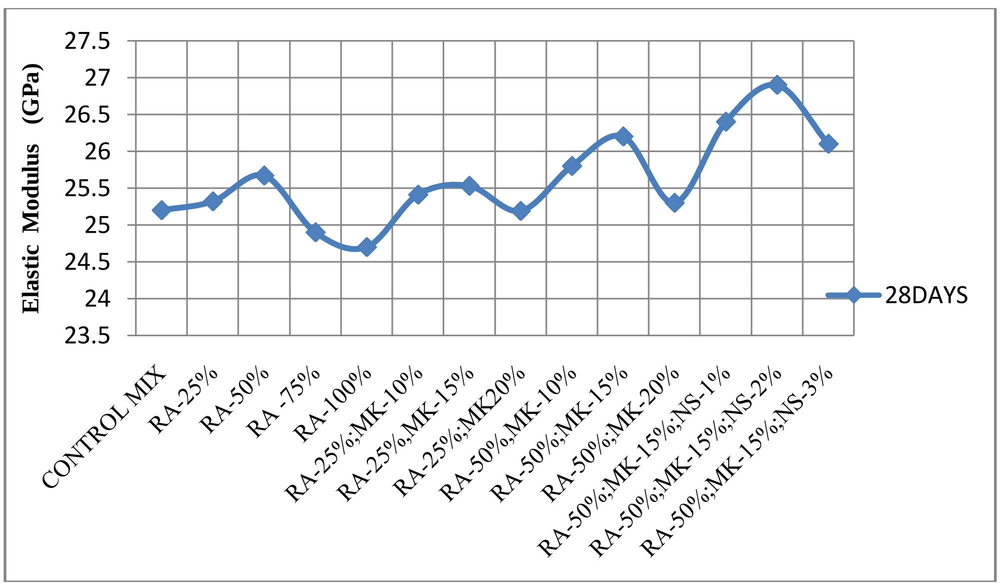

Fig 6: Elastic Modulus Variation with Replacement of Nano-Silica, Metakaolin and Recycled Coarse Aggregate

V. CONCLUSIONS

On the basis of experimental investigation, the strength characteristics of the M25 grade concrete are improved with the addition of Recycled Coarse Aggregate, Metakaolin and Nano-silica. The Compressive strength, Split tensile strength, Flexure strength and Elastic Modulus of RCA concrete indicates considerable increase compared to the controlled concrete. The improved strength properties are obtained with the replacement of Metakaolin and Nano-silica at 15% and 2% respectively at 50% of Recycled Coarse Aggregate of RCA Concrete. So cement can be replaced effectively by supplementary cementitious materials like Metakaolin and Nano silica.

The use of mineral admixtures such as Nano Silica and Metakaolin, results in dense micro-structure of the concrete matrix which enhance the strength properties. The combined replacement of Recycled Coarse Aggregate, Nano-Silica and Metakaolin exhibited increased strength properties compared to the replacement of only Metakaolin or Recycled Aggregate. Hence it can be concluded that, the various strength properties of RCA concrete can be enhanced by the addition of a specified percentages of 2%-Nano-Silica, 15%- of Metakaolin and 50% - Recycled Coarse Aggregate.

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