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# A Study on effect of Alccofine on the performance of the Concrete for Rigid Pavement Design and Analysis by using Kenpave Software

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*Abstract*—*In India, road network is the world's second largest. It is 3.5 million km including both paved and unpaved surfaces. The major types of materials are used to construct the roads in the country are, bitumen and concrete. Concrete is a superior material in many counts, a very small share is used for road construction. Due to increase of utility of cement, many environmental problems are faced at the National level. It is necessary to think about the materials which can be used as alternative in the concrete. The use of specific amount of Alccofine in replacement of cement provides better strength. It is very much essential to develop profitable building materials from Alccofine. The innovative use of Alccofine in concrete making formula as a cement replacement material was tested as an alternative to traditional concrete in the present study. To find optimum dosage of Alccofine, Cement is replaced by Alccofine in the range of 0%, 5%, 10%, 15%, 20%, 25% & 30% by weight for M-40 grade concrete. Concrete mixtures were produced, tested and compared in terms of compressive and flexural strength with the conventional concrete. These tests were carried out to evaluate the mechanical properties for 7, 14 and 28 days. The present study is focused on investigating the behaviour of concrete while replacing Alccofine in different proportion in concrete.*

*Keywords— Alccofine; Hardened concrete properties; dosage; flexural strength; impact test; grading; abrasion; Flakiness Index; Elongation*

## I. INTRODUCTION

Barring a meager 2% of the total road length in the country that is made of concrete roads, the remaining vast share is made largely of unbound aggregates surfaced with bitumen or asphalt based wearing courses of varying and inadequate thicknesses. Concrete roads by themselves offer tremendous advantages over conventional bitumen roads in both operational and financial terms. These advantages are well known. The most salient of these advantages are durability and relative freedom from maintenance which go to offer substantial long term economies in our cash strapped cities.

ALCCOFINE 1203 is having high glass content and high reactivity obtained by the process of controlled granulation. The raw materials of Alccofine, are composition of low calcium silicates. The computed blain value based on PSD is around 12000cm2/gm and is truly ultra fine. Due to its unique chemistry and ultra fine particle size, ALCCOFINE1203 provides reduced water demand for a given workability, even up to 70% replacement level as per requirement of concrete performance. ALCCOFINE 1203 can also be used as a high range water reducer to improve compressive strength or as a super workability aid to improve flow.

If the advantages of ALCCOFINE 1203 are observed in the concrete mix design, the initial rate of strength development was found to be increased or similar as that of Silica Fume.

Durability test measuring the water permeability showed better results than the Silica Fume. But in case of chloride permeability we have compared ALCCOFINE 1203 with OPC and the results shows less permeability incase of ALCCOFINE 1203 than that of OPC. The use of ALCCOFINE 1203, as an alternative to Silica Fume can be effective in enhancing the properties of concrete, both in its fresh and hardened state.

## II. EXPERIMENTAL MATERIALS

### *A. Cement*

Ordinary Portland cement of 53 grade confirming to IS 8112-1989 is used. The various properties like fineness, consistency, setting time and soundness has been determined. Fineness of cement was measured by sieving it through a standard sieve, consistency and setting were measured using Vicat apparatus and soundness was measured using Le-

 

| Properties | Test Results |
|---|---|
| Fineness (m2/Kg) (Specific surface) | 305 |
| Specific Gravity | 3.15 |
| Initial Setting time (minutes) | 180 |
| Final setting time (minutes) | 240 |
| Soundness (mm) by Lechatelier | 1 |

Chatleier apparatus. The various properties of cement are mentioned below.

TABLE I. PROPERTIES OF CEMENT

*B. Fine Aggregate*

River sand having bulk density 1754 kg/m3 has been used for the present study. The specific gravity was found to be 2.68. Sieve analysis results are shown below.

TABLE II. SIEVE ANALYSIS OF FINE AGGREGATES

| IS Sieve | Weight Retained in gms | % weight Retained | Cumulative %weight retained | % passing |
|---|---|---|---|---|
| 4.75 mm | 85 | 8.5 | 1 | 91.5 |
| 2.36 mm | 168 | 16.8 | 3.2 | 83.20 |
| 1.18 mm | 448 | 44.8 | 12.2 | 55.20 |
| 600µ | 565 | 56.5 | 33.2 | 43.50 |
| 300µ | 795 | 79.5 | 61.7 | 20.50 |
| 150µ | 959 | 95.9 | 94 | 4.10 |
| Pan | 1000 | 100 | 100 | 0 |

*C. Aggregates*

Coarse aggregates having bulk density 1480kg/m3 has been used. The specific gravity of coarse aggregate is 2.81.The properties of coarse aggregate used for the present study is given in the table below. Normal aggregates are shown in figure below.

TABLE III. PROPERTIES OF COARSE AGGREGATE

| Properties | Test results |
|---|---|
| Specific gravity | 2.81 |
| Water absorption | 0.98% |
| Impact value | 11.85% |
| Flakiness Index | 1095% |
| Elongation Index | 11.45% |
| Abrasion Value | 10.6% |
| Polished Stone Value | 11 |
| Crushing Value | 20.94% |
| Angularity Number | 4.71 |

TABLE IV. PROPERTIES OF FINE AGGREGATE

 

| Properties | Test results |
|---|---|
| Specific gravity | 2.5<br>1 |
| Water absorption | 2.60% |
| Silt Content | 2.9<br>0 |
| Fineness Modulus | 3.0<br>2 |

*D. Alccofine*

TABLE V. PROPERTIES OF FINE ALLCOFINE

| Physical Properties of Alccofine | | | | | |
|---|---|---|---|---|---|
| Fineness (cm2/gm) | Specific Gravity | Bulk Density (Kg/m3) | **Particle Size Distribution** | | |
| | | | d10 | d50 | d90 |
| >12000 | 2.9 | 700-900 | 1.5 micron | 5 micron | 9 micron |
| **Chemical Properties of Alccofine** | | | | | |
| C2O | SO3 | SiO2 | AL2O3 | Fe2O3 | MgO |
| 61-64% | 2-2.4% | 21-23% | 5-5.6% | 3.8-4.4% | 0.8-1.4% |
| *As Per Manufactures booklet | | | | | |

## III. MIX DESIGN

Mix design of concrete is done in accordance with IRC:15-2002, Indian Standard Code (IS 10262-2009).The grade of concrete selected for the present study was M 40 and the mix design is given below.

TABLE VI. *MIX DESIGN WITH DIFFERENT PROPORTION OF ALCCOFINE*

| Mixture | 0%AF | 5%AF | 10%AF | 15%AF | 20%AF |
|---|---|---|---|---|---|
| w/c Ratio | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |
| Water(Kg/m3) | 146 | 146 | 146 | 146 | 146 |
| Cement (Kg/m3) | 365 | 346.75 | 328.5 | 310.25 | 392 |

 

| | | | | | |
|---|---|---|---|---|---|
| Alccofine (Kg/m3) | 0 | 18.25 | 36.5 | 54.75 | 73 |
| Natural Sand (Kg/m3) | 648 | 648 | 648 | 648 | 648 |
| Natural coarse aggregate (Kg/m3) | 1348 | 1348 | 1348 | 1348 | 1348 |

## IV. TEST SPECIMENS AND TEST PROCEDURE

The concrete cubes of 150mm size are used as test specimens to determine the compressive strength and modulus of elasticity of concrete for the both cases i.e., nominal concrete and Alccofine modified concrete. Concrete cubes of size 150mm size were casted with Alccofine from o to 20% with 5% increment levels as given below. The ingredients of concrete were thoroughly mixed till uniform consistency was achieved. Figure 4.1 shows a typical photo of fresh concrete cube with 20% replacement of Alccofine.

### *A. Compressive Strength(IS 516: 1959)*

The development of compressive strength in concrete has been widely studied for many years. Factors such as amount and type of cement and admixture, temperature, curing conditions, and water/ cementious materials ratio effect the development of concrete strength (Mehta and Monterio 2006 (19)). Cement type amount may affect the amount of heat developed in the concrete member. Temperature affects the rate at which the cement hydrates. Therefore, early-age and long term strength can be affected due to changes in these mixture proportions. Variable such as water cement ratio, air entrainment, and cement type can be varied to increase or decrease strength. As water-cement ratio is increased, the compressive strength is decreased (Kosmatka et al.(30) ).The decrease in the compressive strength can also occur as the total air content of the mixture increases (Kosmatka et al.(30) ).

Concrete cubes of dimensions 150 x150 mm were cast for compressive strength. After 24 hours of casting, the specimens stripped and were kept for curing. After 7 and 28 days respectively, the specimens were removed from the curing tank. Compressive strength tests were conducted on compression testing machine of capacity 20000 KN. The specimen was gradually loaded till failure occurred. After knowing the failure load, compressive strength was calculated by the equation; Compressive strength= P/A where P= Failure load, A= Cross sectional area.The variation of compressive strength after 7 days and 28 days for various properties of Alccofines is given in table 7.

### *B. Flexural Strength (IS 516: 1959)*

The flexural strength is determined by the central point method. Standard metallic beam moulds (100 mm * 100 mm * 500 mm) were cast for the preparation of concrete specimens for flexural strength. A table vibrator was used for compaction of hand filled concrete beams. The specimens were demoulded after 24 hours and subsequently immersed in water for testing. The test was performed on Universal Testing Machine (UTM) having capacity of 50 BT. The load applied slowly without shock at a rate to increase the stress at a rate of .06 + .04 N/mm$^2$ per second. The beams cast with various proportions of Alccofine tested as described above.

Three specimens of beam are tested for each type of concrete and average flexural strength is obtained. The flexural strength of the specimen is expressed as the modulus of rupture fb, which, where _a‘ equals the distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen, in cm, shall be calculated to the nearest 0.5 kg/sq cm as follows:

fb=pl/bd2

 

when _a‘ is greater than 20.0 cm for 15.0 cm specimen, or greater than 13.3 cm for a 10.0 cm specimen,

b = measured width in cm of the specimen,

d = measured depth in cm of the specimen at the point of failure,

l = length in cm of the span on which the specimen was supported, and

p = maximum load in kg applied to the specimen

*C.* Modulus Of Elasticity

The development of elastic modulus of concrete varies in proportion to the square root of the compressive strength gain in concrete (IS 456-2000).The same factor that alter the development of strength affect development of the elastic modulus, with some exceptions. The modulus of elasticity is affected primarily by the aggregate type and quantity used in the concrete mixture (Mindess,Young, and Darwin (31)).As the stiffness and amount of the aggregate fractions in concrete increases, the stiffness of the concrete increases. The modulus of elasticity is also a function of the porosity of the paste function of the concrete. As the water-cement ratio is increased, the porosity of the paste fraction is increased. If the porosity is increased, the modulus will decrease (Mindess, Young, and Darwin (31)). Based on the commonly used IS 456-2000 relationship, the design modulus of elasticity for the concrete was expected to be approximately, Ec = 5000 √fck whereEc= is the short term static modulus of elasticity in N/mm2.

## V. EXPERIMENTAL RESULTS

TABLE VII. *Compressive strength and modulus of elasticity of M40 grade concrete with various percentage Alccofine replacement with Cement.*

| % Alccofine | Comp-ressive strength @ 7days (Mpa) | Comp-ressive strength @ 28days (Mpa) | Flexure strength @ 28days (Mpa) | Modulus of elasticity (N/mm2) x 10^4 Ec = 5000 *√ fck |
|---|---|---|---|---|
| 0 | 35.36 | 48.20 | 5.97 | 3.47 x 10^4 |
| 5 | 39.84 | 53.38 | 6.66 | 3.65x 10^4 |
| 10 | 42.36 | 56.31 | 7.04 | 3.75x 10^4 |

| | | | | |
|---|---|---|---|---|
| 15 | 44.16 | 58.65 | 7.35 | 3.83x 10^4 |
| 20 | 42.15 | 55.46 | 6.93 | 3.72x 10^4 |

Compressive strength vary from 48.20 Mpa to 58.65Mpa. Higher value of compressive strength was obtained for a 15% replacement of cement for 7 days (44.16 Mpa) and 15% replacement of cement for 28 days(58.65 Mpa). The modulus of elasticity was found to vary between 3.47*10^4 to 3.83*10^4

## VI. DESIGN OF A ROAD PAVEMENT (IRC: 58-2011)

CASE- I NORMAL CONCRETE(AF0)

| **Design for Bonded Pavement Option** | |
|---|---|
| Subgrade CBR (%)= | 8 |
| Granular Subabse Thickness (mm) = | 250 |
| Effective k-value from Tables 2 and 3 (MPa/m) = | 72.0 |
| For k of 72.0 MPa/m and for | |
| Doweled Joint and Tied Concrete Shoulders, Slab Thickness (m) = | 0.3 |
| Trial Slab thickness (m) over DLC, h1 | 0.25 |
| Provide DLC thickness (m), h2 | 0.15 |
| Elastic Modulus of Pavement Concrete (MPa), E1 | 34700 |
| Elastic Modulus of DLC (MPa), E2 | 13600 |
| Poisson's Ratio of Paving Concrete, 1 | 0.15 |
| Depth to Neutral axis, m (See Fig.6) | 0.16 |
| Flex Stiffness of design Slab | 79.87 |
| Flex Stiffness of Partial Slab Provided | 59.09 |

 

| | | | | | |
|---|---|---|---|---|---|
| Flex Stiffness of DLC | | | 23.40 | | |
| Total Flexural Stiffness Provided = | 59.09 | + | 23.40 | = | 82.49 |
| which is more than the Flexural Stiffness of the Design Slab = | | | | | 79.87 |
| Hence, Provide a Slab of thickness (m) | 0.25 | over DLC of thickness (m) | | | 0.15 |

CASE- II AF15

| **Design for Bonded Pavement Option** | | | | |
|---|---|---|---|---|
| `Subgrade CBR (%)= | | | | 8 |
| Granular Subabse Thickness (mm) = | | | | 250 |
| Effective k-value from Tables 2 and 3 (MPa/m) = | | | | 72.0 |
| Doweled Joint | and | Tied Concrete Shoulders, | Slab Thickness (m) = | 0.3 |
| Trial Slab thickness (m) over DLC, h1 | | | | 0.255 |
| Provide DLC thickness (m), h2 | | | | 0.15 |
| Elastic Modulus of Pavement Concrete (MPa), E1 | | | | 38300 |
| Elastic Modulus of DLC (MPa), E2 | | | | 13600 |
| Poisson's Ratio of Paving Concrete, 1 | | | | 0.19 |
| Poisson's Ratio of DLC, | | | | 0.2 |
| Depth to Neutral axis, m (See Fig.6) | | | | 0.16 |
| Flex Stiffness of design Slab | | | | 89.40 |
| Flex Stiffness of Partial Slab Provided | | | | 67.31 |
| Flex Stiffness of DLC | | | | 22.59 |

| | | | | | |
|---|---|---|---|---|---|
| Total Flexural Stiffness Provided = | 67.31 | + | 22.59 | = | 89.90 |
| which is more than the Flexural Stiffness of the Design Slab = | | | | | 89.40 |
| Hence, Provide a Slab of thickness (m) | 0.255 | over DLC of thickness (m) | | | 0.15 |

## VII. COSTS ANALYSIS

*A.* Cost Of Materials

| No. | Materials | Rate(Rs/Kg) |
|---|---|---|
| 1 | OPC 53 grade Cement | 6.00 |
| 2 | Fine aggregate (Regional ) | 0.60 |
| 3 | Coarse aggregate (Regional ) | 0.65 |
| 4 | Alccofine | 22 |

*B.* Total Cost Of Materials For M40 Designe Mix Concrete (1:1.54:3.21) Per M

| T. C. | Consumption of Design Mix Proportions For M40 Concrete (1:1.54:3.14) | | | | Total Cost /$m^3$ |
|---|---|---|---|---|---|
| | C | F.A. | C.A. | AF | |
| A0 | 425*6 | 615*.6 | 1256.27*.65 | 0*22 | 3735.57 |
| A1 | 403.75 | 615 | 1256.27 | 21.25 | 4075.57 |
| A2 | 382.50 | 615 | 1256.27 | 42.5 | 4415.57 |
| A3 | 361.25 | 615 | 1256.27 | 63.75 | 4755.57 |

T. C. = Types of Concrete, C= Cement, F.A. = Fine Aggregate,C.A. = Coarse Aggregate, AF=Alccofine

C. Relative Cost Of Slab For M40

| Types of Concrete | Slab Thickness (cm) | Cost of 1m x 1m Slab (Rs.) | Relative cost (%) |
|---|---|---|---|
| A0 | 23.00 | 859.18 | 100.00 |
| A1 | 23.50 | 957.75 | 101.4 |
| A2 | 24.00 | 1059.73 | 101.23 |
| A3 | 24.50 | 1165.11 | 101.36 |

## CONCLUSION

2, Maximum Compressive strength 58.65Mpa can be achieved by replacing 15% Cement with Alccofine @ 28 Days

3, Maximum Flexural Strength 7.35Mpa can be achieved by replacing 15% Cement with Alccofine @ 28 Days

4, Maximum Modulus of Elasticity 3.83x 10^4 is achieved @ 28 Days

## FUTURE SCOPE OF WORK

1, More admixtures with the Mineral Admixture Alccofine can be used to get more strength and economic design

2, Durability of above mix can be checked.

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