Strength Evaluation of Rigid Pavement by using Silica Xerogel and Ceramic Waste Powder

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Abstract – *In this experimental study, the objective is to improve the compressive strength of concrete by Pozzolanic materials to provide a proper engineering principle applied to design a new form of Rigid Pavement by partially replacement of cement by varying percentage of Silica Xerogel – (0.5,1,1.5 and 2) % and Ceramic Waste Powder – (4,8,12 and 16) % respectively in the grade of M40 concrete. As we know that Silica Xerogel is a drying agent easily available in market can also be used as a strengthening agent in concrete. For the properties of this material, it can resist Tensile strength which may provide strength in concrete in Tensile zone. The number of researches is going on about the waste management is highly preferable in the constructions. Ceramic waste is increasing day by day due to the waste produce from constructions can be recycled and reusing as substituents of materials used for making concrete. The concrete which we are using to design the Rigid pavement is to increasing the compressive strength of the concrete which can resist the shear stress and deforming equally to the ground.*

Key Words: Design of Rigid Pavement, Partial Replacement of cement, Silica Xerogel, Ceramic Waste Powder, Waste Management.

1.INTRODUCTION

Rigid pavements are constructed of Portland cement concrete slabs resting on a prepared sub base of granular material or directly on a granular subgrade. The main function of a pavement is to transmit loads to the sub-base and underlaying soil. Rigid pavement is mainly made of concrete, composed of course and fine aggregates and Portland cement, usually reinforcement with steel rod or until the introduction of heavy monoplane aircraft in the latter part of the 1930s, civil air transport aircraft were able to operate from grass runways with take-off distances of less than 600 meters (2,000 feet). Cement is most effective material in the world widely used in concrete for constructions. As being a major constituent of concrete cement is being costly and only moderately available material are researched to study the variation of the characteristic strength may decrease or increase of concrete can be experimented by partially replacing cement with other material which can be use as substituents to increase the strength and to make it cost effective. As this research may help to design a cost effective and more durable Rigid pavement.

2. OBJECTIVE

Cement can be partially replaced in concrete by different substitute cementitious materials. Nowadays, the researches going on the waste management all over the world focusing on the utilization of waste pozzolanic materials, glass powder, silica fume, ceramic waste powder, fly ash, baggage waste ash, are used in concrete as a partial cement replacement to improve the strength of concrete. The durability as well as workability has increase to large extent by use of Ceramic Waste Powder, Silica Xerogel, Fine aggregates and Coarse Aggregates. The effect on properties of concrete were investigated and concluded that optimum percentage for replacement of CWP and Silica Xerogel is almost 15%. So, our main intention of this experiment would be to reduce costing and to test how Silica Xerogel reacts with concrete in presences of finely grinded Ceramic Waste Powder. The need of this study is to increase the compressive strength of concrete and to reduce permeability of cement and concrete. It may also reduce Alkali Silica reaction which cause in abnormal expansion and cracking of concrete. To make a economy design to Rigid Pavement in a new form. Rebound hammer test gives initial compressive strength and pulse velocity tests indicate quality of concrete.

3. LITERATURE REVIEW

Demirbas, et.al (1998)

In this study, the mechanical properties of Portland cement mixes with an admixture such as ground hazelnut shell, spruce and beech woods and tea waste were studied. The compressive strength and bending strength test results obtained from these mixes were investigated with comparing to the control mix. Wood-cement composite were investigated by different researches. In general, the addition of lignocellulosic material to cement decreases compressive strength values.

Naga Venkat, et.al (2020)

Environmental pollution and the relatively high cost of waste disposal has been a major focus for scientists around the world, leading researches to find solution to reuse waste materials in different applications. Pozzolanic materials such as Silica Fume, Metakaolin, GGBS contains cementitious properties which improve the strength compared to river sand and is less economic.

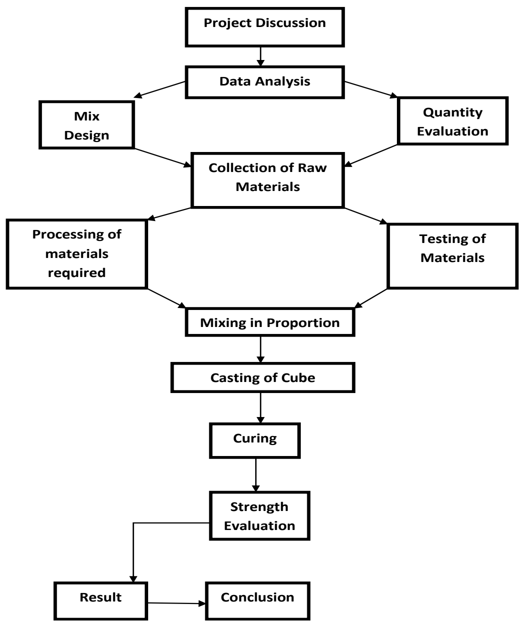
4. MATERIALS AND METHODOLOGY

- **Silica Xerogel -** Silica Xerogel is a non-crystalline and porous form of Silicon Dioxide. Its is mainly used as drying agent, widely used to absorb moisture from the packaging contents. As from study we get that it can be used as a healing agent in concrete which may preventing the concrete to form cracks. Silica Gel is used in concrete mainly effective in under water construction dams and tunnels and now where we are experimenting these to make effective in the use of Rigid Pavement. Silica Gel can give resistance to sulfate attack can lead to expansion, strength loss and disintegration of the concrete.
- **Ceramic Waste -** Ceramics is widely used material in construction around the world, mainly it is used as tiles and sanitary furnishes like as basin, urinals, commode etc. Ceramic waste is increasing day by day due to the waste produced from constructions is a major problem in the world. According to survey 30% of ceramic waste is daily produced from construction and ceramic industry all over the world. In this study the utilization of ceramic waste is maybe a good step towards waste management and constructions. After the collection of ceramic waste is completed from the industries and construction sites the piece of ceramics is thoroughly washed to remove dirts and dust particles. The wet ceramic particles are thereby placed in oven for drying at a temperature of 100°C for 24 hrs. As the ceramic pieces are completely dried are send into the Los Angeles apparatus for grinding until it become powder and should be ensiled.

4.1 Methodology

Our interest peak on the topic of rigid Pavement since it looks like an interesting subject where we could use our creative as well as engineering skills for new innovation. We decided to go ahead with partial replacement of cement with products like Silica Xerogel and Ceramic Waste Powder. Which would serve us in two ways one being utilization on waste products and the other being very obvious economical. Once the topic we decided we started collection of information. We sorted few journal that could help us in our project. After researching about Rigid Pavement, we selected M40 as the most appropriate mix design. Calculation of the proportion of quantities was done in this phase of the project.

4.2 Flowchart of methodology



5. MIX DESIGN

1. TARGET STRENGTH

f'ck = fck = 1.65S

Where,

f'ck = Target average compressive strength at 28 days.

fck = Characteristic Compressive strength at 28 days.

S = Standard Deviation from Table 1 of IS:10262 (2019), Standard deviation, S = 5N/mm^2.

Therefore, Target strength = 40 + 1.65 x 5 = 48.25 MPa.

2. WATER CEMENT RATIO

As per IS:456-2000 Table 5

Maximum water cement ratio = 0.40

As per IS:10262-2009

Maximum water content = 186 lit (For 20mm aggregates)

Estimated water content = 186 + (186 x 6)/100

= 197 lit

3. CEMENT CONTENT

Cement content = maximum water content / water cement ratio

= 197/0.4

= 492.5kg/m^3 > 300kg/m^3

Hence ok.

4. PROPORTION OF VOLUME OF C.A. AND F.A.

Fine aggregates = Zone 1

Coarse aggregates = 20 mm (down size)

W/C = 0.4

For every decrease aggregate of 0.5 w/c, C.A. raised by 0.01

For 0.4 w/c

Volume of coarse aggregates = 0.6 + 0.02

= 0.62

Volume of fine aggregates = 1 – 0.62

= 0.38

5. MIX DESIGN CALCULATION

The mix design calculation per unit volume of concrete shall be as follow:

a) Volume of concrete = 1m^3

b) Volume of cement = (Mass of concrete/specific gravity of cement) x (1/1000)

= 492.5/3150

= 0.156 m^3

c) Volume of water = (Mass of water/specific gravity of water) x (1/1000)

= 197/1 x 1/1000

= 0.197 m^3

d) Volume of all aggregates = 1 – (0.156 + 0.197)

= 0.647 m^3

e) Mass of Coarse aggregate = d x Volume of coarse aggregate x specific gravity of coarse aggregate x 1000

= 0.647 x 0.62 x 2.68 x 1000

= 1075.05 Kg

f) Mass of Fine aggregate = d x volume of fine aggregate x specific gravity of fine aggregate x 1000

= 0.647 x 0.38 x 2.65 x 1000

= 651.53 Kg

Mix proportion/m^3

Cement = 492.5 Kg

Fine aggregate = 651.53 Kg

Coarse aggregate = 1075.05 Kg

= Cement : Fine aggregate : Coarse aggregate

= **1 : 1.32 : 2.18**

6. CALCULATION WITH VARYING PERCENTAGES

- **Quantity of materials required for 2 cubes: -**

  Volume of cube = (0.15 x 0.15 x 0.15) x 2

  = 6.75 x 10^{-3} m^3

  Mass of concrete = Density x Volume

  = 2400 x 6.75 x 10^{-3}

  = 16.2 Kg

- **For M40 normal concrete**

  Cement = 1/4.5 x 16.2

  = 3.6 Kg

  Fine Aggregate = 1.32/4.5 x 16.2

  = 4.752 Kg

  Coarse Aggregate = 2.18/4.5 x 16.2

  = 7.848 Kg

- **For 0.5 % (Silica Gel) and 4% (Ceramic Powder)**

  Silica Gel = 0.5/100 x 3.6 = 18g

  Ceramic Powder = 4/100 x 3.6 = 144g

  Cement = (0.018+0.144) – 3.6 = 3.438 Kg

  Fine Aggregate = 4.752 Kg

  Coarse Aggregate = 7.848 Kg

- **For 1% (Silica Gel) and 8% (Ceramic Powder)**

  Silica Gel = 1/100 x 3.6 = 36g

  Ceramic Powder = 8/100 x 3.6 = 288g

  Cement = (0.036+0.288) – 3.6 = 3.276 Kg

  Fine Aggregate = 4.752 Kg

  Coarse Aggregate = 7.848 Kg

- **For 1.5% (Silica Gel) and 12% (Ceramic Powder)**

  Silica Gel = 1.5/100 x 3.6 = 54g

  Ceramic Powder = 12/100 x 3.6 = 432g

  Cement = (0.054+0.432) – 3.6 = 3.114 Kg

  Fine Aggregate = 4.752 Kg

  Coarse Aggregate = 7.848 Kg

- **For 2% (Silica Gel) and 16% (Ceramic Powder)**

  Silica Gel = 2/100 x 3.6 = 72g

  Ceramic Powder = 16/100 x 3.6 = 576g

  Cement = (0.072+0.576) – 3.6 = 2.952 Kg

  Fine Aggregate = 4.752 Kg

  Coarse Aggregate = 7.848 Kg

7. TEST PROCEDURE

Test specimen of size (150 x 150 x 150) mm were prepared for testing the compressive strength of concrete. The concrete mixes with varying percentages (0.5%, 1%, 1.5%, 2%) Silica Gel were and (4%, 8%, 12%, 16%) Ceramic Waste Powder as partial replacement of cement was cast into cubes for subsequent testing. In this study, to make concrete, cement and fine aggregate were first mixed dry to uniform color and then coarse aggregates added and mixed with the mixture of cement and aggregates along with different proportion of Silica Gel and Ceramic Powder in variable percentage as mentioned above. Water is then added to the whole mix for workability and for binding. The interior surface of the moulds is oiled up and the concrete is placed in it by 2 layers with 25 tamping for each. After 24hrs the specimens were removed from the moulds and placed in with clean fresh water at room temperature 20°C. The specimens so casted were tested after 7 and 28 days of curing. For testing in compression no crushing materials was placed between the specimen and the plate of the machine. Then the load is applied axially without shock till the specimen was crushed.

6. RESULT AND ANALYSIS

0.5% Silica Gel and 4% Ceramic Powder replacement

Compressive Strength of concrete in 7 and 28 days			
No of Days	Weight of Specimen (g)	Load taken by Concrete Cube (KN)	Compressive Strength (MPa)
7	8230	580	25.77
28	8195	835	37.11

1% Silica Gel and 8% Ceramic Powder replacement

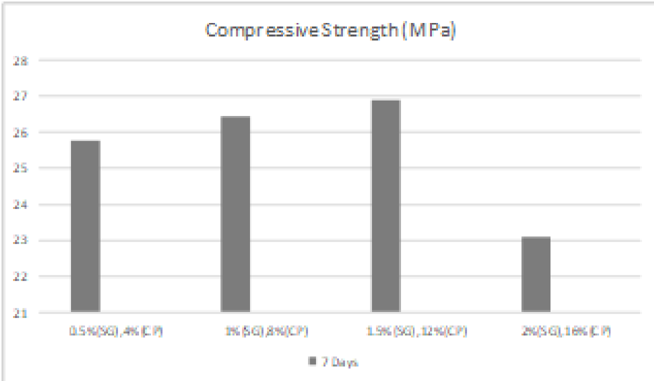
Compressive Strength of concrete in 7 and 28 days			
No of Days	Weight of Specimen (g)	Load taken by Concrete Cube (KN)	Compressive Strength (MPa)
7	8158	595	26.44
28	8132	880	39.11

1.5% Silica Gel and 12% Ceramic Powder replacement

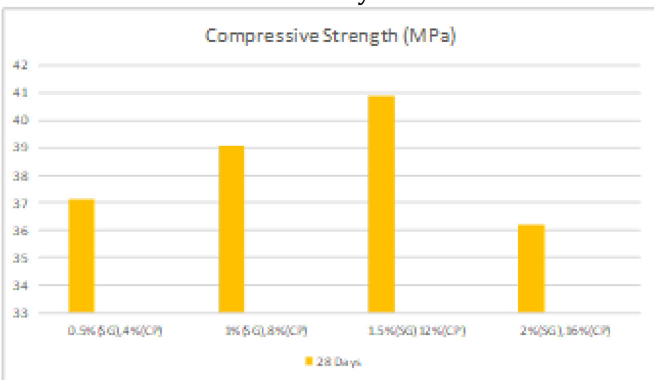
Compressive Strength of concrete in 7 and 28 days			
No of Days	Weight of Specimen (g)	Load taken by Concrete Cube (KN)	Compressive Strength (MPa)
7	8242	605	26.88
28	8109	920	40.88

2% Silica Gel and 16% Ceramic Powder replacement

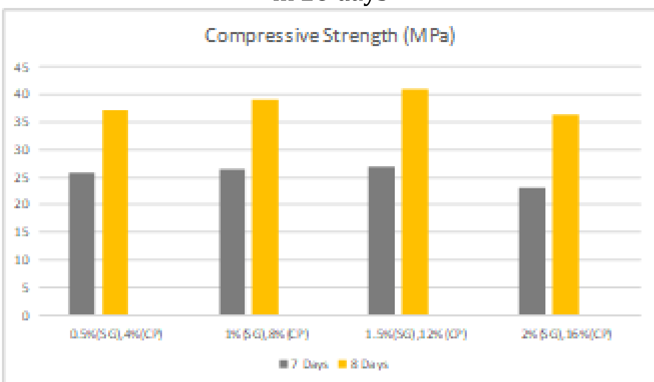
Compressive Strength of concrete in 7 and 28 days			
No of Days	Weight of Specimen (g)	Load taken by Concrete Cube (KN)	Compressive Strength (MPa)
7	8097	520	23.11
28	8214	815	36.22



Compressive strength of all variable percentage of cubes in 7 days



Compressive strength of all variable percentage of cubes in 28 days



Comparing the compressive strength of 7 and 28 days

As in this experiment we get the results of the tests of the concrete cubes after 7 and 28 days of curing. As we observed that the partial replacement of cement by increasing the percentage of ceramic powder and silica gel the compressive strength is increasing but up to 12% CP and 1.5% SG in total of 13.5% replacement it will increases the strength, more than 13.5% replacement cause decrease in strength. The vertical cracks occur due to lateral tensile strains. A flow in the concrete which may cause a micro crack along the vertical axis of the member will take place on the application of axial compression load and propagate further due to the lateral tensile strains. As Silica gel is helps to gains strength in tensile zone of concrete.

7. CONCLUSIONS

1. Compressive strength of concrete increases by 13.5% of replacement in which ceramic powder is the most effective material, more than 15 % of replacement cause decrease in strength.
2. The ceramic waste is easily available from industrial waste and construction waste around all over the world and to reuse of disposal and reduce the environmental pollution.
3. Use of Silica gel is much more effective to increase tensile strength in concrete by little percentages of replacement. Silica gel is also useful for retaining damps in concrete.
4. The study is based on the utilization of ceramic powder as a substituent of cement to obtain green concrete with enhanced strengths and decrease the use of cement to some extent for economical construction material.
5. Further study should be executed to understand the influence of silica gel on different motar characteristics.

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10. BIOGRAPHIES

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