EXPERIMENTAL STUDY ON THE BEHAVIOUR OF SELF HEALING CONCRETE USING SILICAGEL IN MICROCAPSULES AS A HEALING AGENT

A. Anbuselvi[1], K. Saravanakumar[2], G. Pradeepa[3], S. Tamilarasi[4]

[1,2,3]PG scholars, M.E.,(Structural Engg.,) Dept of Civil Engineering, Gnanamani College of Engineering, Namakkal
[4]Assistant Professor, Dept. of Civil Engineering, Gnanamani College of Engineering, Namakkal, TamilNadu, India

---***---

Abstract - *Concrete as a structural material received extensive application as the prime construction material use all over the world. It is a versatile material to resist the load within the limit. If the load applied on the concrete is more than their limit of resisting load, it causes the strength reduction of concrete by producing the cracks in the concrete. Cracks and fissures are a common problem in building structures, pavements and historic monuments. Cracks in concrete form an open pathway to the reinforcement can lead to durability problems like corrosion of the steel rebar's. Further more cracks can cause leakage in case of liquid retaining structures, due to alkali, sulphate and drying shrinkage.*

In order to overcome this problem, a variant of smart concrete is rapidly developing, which is known as "Self-healing concrete". The self-healing concrete is one that senses its crack formation and reacts to cure itself without human intervention. The available self-healing agents are polyurethane, silica gel, fly ash, ceramic tubes, blast furnaces, bacteria, calcium sulfo aluminate and crystalline additive, and geo materials. The self-healing mechanism of silica gel – crack ruptures the capsules and the healing agent contacts the catalyst, triggering polymerization that bonds the crack faces. When crack appears, the capsules rupture and the healing mechanism starts also the strength has been regained.

In this experimental investigation silica gel was used as a healing agent with trials of substitution in 0.1%, 0.2%, 0.3%, 0.4%, 0.5% dosage by weight of cement for silica gels. The specimens were cast and subjected to an initial load *to induce initial crack. These specimens were again given a prior curing for a period of seven days and the specimens were retested. Based on the observations to find the influence of silica gel on the strength properties of self-healing concrete it is found that 0.3% as a optimum dosage..*

***Key Words*: *Silica gel, Microcapsules,* compressive strength, split tensile strength.**

1. INTRODUCTION:

Concrete is a composite material composed of coarse aggregate bonded together with a fluid cement that hardens over time. Most concretes used are lime-based concretes such as Portland cement concrete or concretes made with other hydraulic cements, such as cement found. However, asphalt concrete, which is frequently used for road surfaces, is also a type of concrete, where the cement material is bitumen, and polymer concretes are sometimes used where the cementing material is a polymer.

When aggregate is mixed together with dry Portland cement and water, the mixture forms a fluid mass that is easily moulded into shape. The cement reacts chemically with the water and other ingredients to form a hard matrix that binds the materials together into a durable stone- like material that has many uses. Most concrete is poured with reinforcing materials (such as rebar) embedded to provide tensile strength, yielding reinforced concrete Famous concrete structures include the Hoover Dam, the Panama Canal, and the Roman Pantheon. The earliest large-scale users of concrete technology were the ancient Romans, and concrete was widely used in the Roman Empire. The Colosseum in Rome was built largely of concrete, and the concrete dome of the Pantheon is the world's largest unreinforced concrete dome. Today large concretes Structures (for example, dams and multi-storey car parks are usually made with reinforced concrete.

Fig 1: Silicagel In Microcapsules

2. METHODOLOGY

The Research in the field of concrete with replacement of materials has as accelerated growth in the recent years. The concrete are studied by many researches, reveal the facts about concrete, thus making it a practically wide applicable. In this experimental investigation silica gel was used as a healing agent with trials of substitution in 0.1%, 0.2%, 0.3%, 0.4%, 0.5% dosage by weight of cement for silica gels. The required different materials which are described below.

2.1 Cement

Portland Pozzolana cement 53 grade is used. A cement is a binder, a substance used in construction that sets, hardens and adheres to other materials, binding them together. Cement is seldom used solely, but is used to bind sand and gravel (aggregate) together. Cement is used with fine aggregate to produce mortar for masonry, or with sand and gravel aggregates to produce concrete. The properties of cement were determined as per the IS 4031:1968

2.2 Fine Aggregate

The material which is smaller than 4.75mm size is called fine aggregate. Natural sands are generally used as fine aggregate. Angular grained sand produces, good and strong concrete because it has good interlocking property, while round grained particle of sand do not afford such interlocking. The specific gravity and water absorption were found to be 2.63 and 2.5% respectively, with sieve analysis data and fineness modulus value of sand confirms to grading zone I as per IS:383-1970.

2.3 Coarse Aggregate

Maximum size of aggregate affects the workability and strength of concrete. It also influences the water demand for getting a certain workability and fine aggregate content required for achieving a cohesive mix. For a given weight, higher the maximum size of aggregate, lower is the surface area of coarse aggregates and vice versa. As maximum size of coarse aggregate reduces, surface area of coarse aggregate increases. Higher the surface area, greater is the water demand to coat the particles and generate workability. Smaller maximum size of coarse aggregate will require greater fine aggregate content to coat particles and maintain cohesiveness of concrete mix . Hence 40 mm down coarse aggregate will require much less water than 20 mm down aggregate. The grading of aggregate should be conformed to the requirement as per IS: 383-1970

2.4 Water

Water is an essential ingredient for the hydration of cement and is an important resource for concrete. water in concrete controls many fresh and hardened properties of concrete including workability, compressive strengths, permeability and water tightness, durability and weathering, drying shrinkage and potential for cracking. For these reasons, limiting and controlling the amount of water in concrete is important for both constructability and service life.

2.5 Silica Gel

Silica gel is an amorphous form of silicon dioxide, which is synthetically synthetically produced in the form of hard irregular granules or hard irregular beads[33]. A micro porous structure of interlocking cavities gives a very high surface area. It is the structure that makes silica gel a high capacity desiccant[36]. Water molecules adhere to the gels surface because it exhibits a lower vapour pressure than the surrounding air. When equilibrium of equal pressure is reached, no more adsorption occurs. Thus the higher the humidity of the surrounding air, the greater the amount of water that is adsorbed before equilibrium is reached. During higher humidity conditions that stored or in-trans it items are susceptible to damage. The beauty of silica gel is the physical adsorption of water vapour into its internal pores. There is no chemical reaction, no by products or side effects [30]. Super plasticizer can increase the workability of concrete mix and reduce the amount of water needed. Therefore, it enables the use of very low water-to-cement ratio. Further lowering of water-to-cement ratio can be achieved by adding other mineral admixtures. The super plasticizer used for this project is polycarboxylate ether.

Determining the relative amounts of materials is known as mix design. Thus it can be defined as the process of selecting suitable ingredients of concrete and determining their relative quantities for producing the concrete of desired properties strength, durability and consistency, as per IS 10262:2009 economically as possible. Mix design are done as per IS 10262:2009 for M30 and M40 Grade concrete and it is shown in table1.

Water (L)	Cement (kg)	Aggregates (Kg)	
		Fine	Coarse
191.6 liters	479	529.85	1155.93
0.4	1	1.18	2.41

Table -1: Mix Design

3. EXPERIMENTAL INVESTIGATION

Testing of concrete plays an important role in controlling and confirming the quality of cement concrete. Cube, Beam & Cylinder is tested for its strength characteristics. The following tests are conducted, Compression strength test, Split tensile strength test, Flexural strength test (Two point loading).

3.1 Compressive Strength Test

The following procedure is adopted to conduct the compressive strength test.

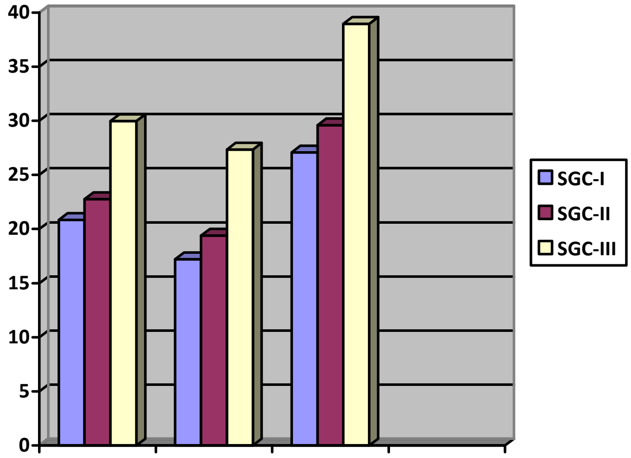
Size of the specimen is 150×150×150mm cubes determined by averaging perpendicular dimensions at least at two places. Place the specimen centrally on the compression testing machine and load is applied continuously and uniformly on the surface parallel to the direction of tamping. The load is increased until the specimen fails and record the maximum load carried by each specimen during the test. Compressive strength was calculated as follows

Compressive strength = P/A×1000

where,
P= Load in KN
A=Area of cube surface=150×150 mm^2

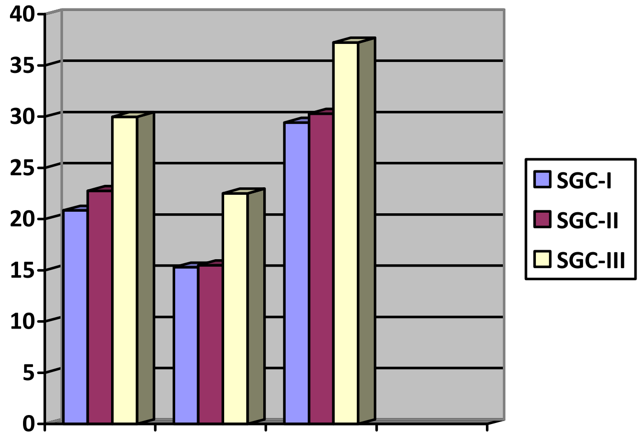
S.no	Specimen ID	Control specimen	Before healing	After Healing
		Compressive Strength test (N/mm^2)	Compressive Strength test (N/mm^2)	Compressive Strength test (N/mm^2)
1	SGC-I	20.84	17.21	27.09
2	SGC-II	22.76	19.39	29.6
3	SGC-III	29.99	27.34	38.98

Table -2: Compressive Strength results for 0.1 % of Silica gel



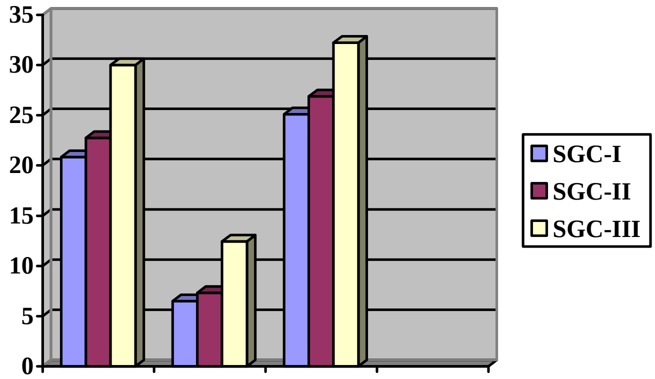
S.no	Specimen ID	Control specimen	Before Healing	After Healing
		Compressive Strength test (N/mm^2)	Compressive Strength test (N/mm^2)	Compressive Strength test (N/mm^2)
1	SGC-I	20.84	15.3	29.43
2	SGC-II	22.76	15.5	30.3
3	SGC-III	29.99	22.5	37.24

Table -2: Compressive Strength results for 0.2 % of Silica gel



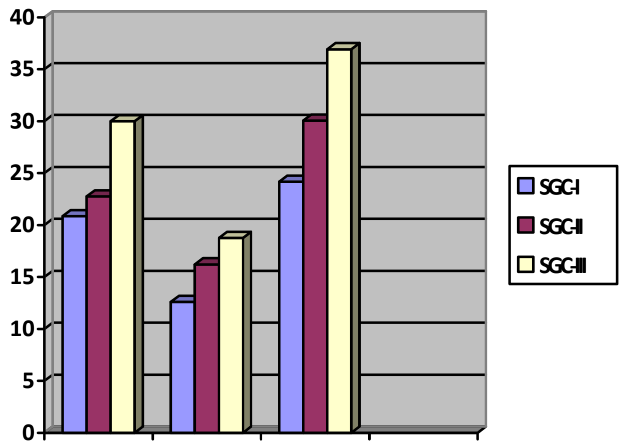
S. no	Specimen ID	Control specimen	Before Healing	After Healing
		Compressive Strength test (N/mm^2)	Compressive Strength test (N/mm^2)	Compressive Strength test (N/mm^2)
1	SGC-I	20.84	6.5	25.12
2	SGC-II	22.76	7.31	26.9
3	SGC-III	29.99	12.45	32.24

Table -4: Compressive Strength results for 0.3% of Silica Gel



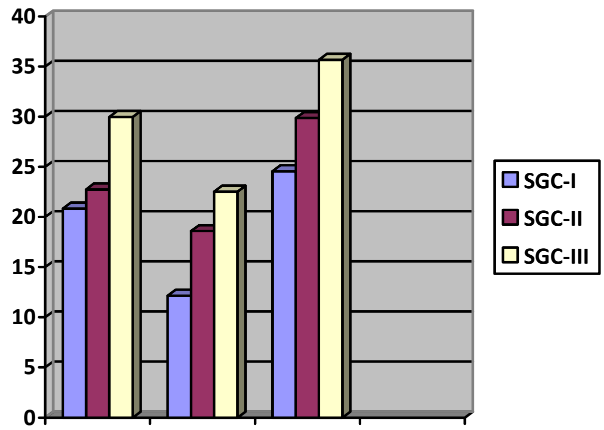
S.no	Specimen ID	Control specimen	Before healing	After Healing
		Compressive Strength test (N/mm²)	Compressive Strength test (N/mm²)	Compressive Strength test (N/mm²)
1	SGC-I	20.84	12.59	24.17
2	SGC-II	22.76	16.21	30.05
3	SGC-III	29.99	18.75	36.93

Table -5: Compressive Strength results for 0.4% of Silica Gel



S.no	Specimen ID	Control specimen	Before healing	After Healing
		Compressive Strength test (N/mm²)	Compressive Strength test (N/mm²)	Compressive Strength test (N/mm²)
1	SGC-I	20.84	12.16	24.56
2	SGC-II	22.76	18.6	29.87
3	SGC-III	29.99	22.53	35.67

Table -6: Compressive Strength results for 0.5% of Silica Gel



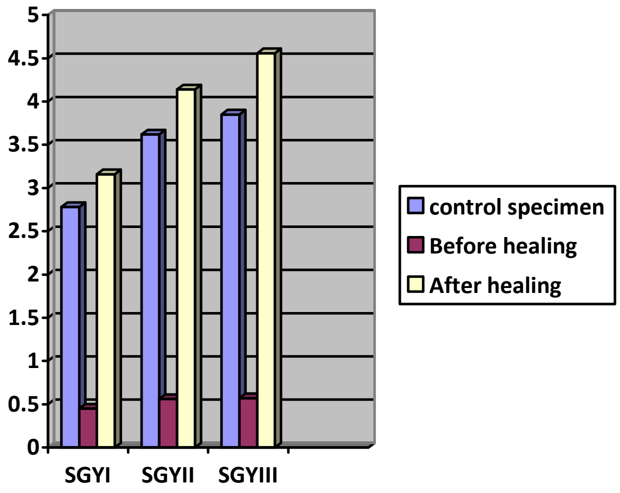
2.2 Split Tensile strength Test

optimum % (0.3%) found from compressive strength test and flexural strength test the cylindrical specimens were given an initial crack using a compressive testing machine (CTM), which is then heal e to ambient atmospheric condition for a period of 7 days and again the specimen were retested and the split tensile strength test was determined[16].It is found that the strength has been regained when 0.3% of silica gel is used. The strength has been regained to 55.34% for the self-healed specimen while comparing with the before healed specimen.

Split tensile strength = 2P/πdL×1000

S.no	Specimen ID	Control specimen	Before healing	After Healing
		Split Tensile Strength test (N/mm²)	Split Tensile Strength test (N/mm²)	Split Tensile Strength test (N/mm²)
1	SGCY-I	2.78	0.45	3.16
2	SGCY-II	3.62	0.56	4.14
3	SGCY-III	3.85	0.57	4.56

Table -5: Split Tensile Strength results for 0.3% of Silica Gel



Split Tensile Strength Test With 0.3% of Silica Gel

4. TEST RESULTS AND DISCUSSION

The fresh concrete test, compressive strength test on cube, Split tensile test on cylinder has been conducted and its results have been discussed. Based on the observations to find the influence of silica gel on the strength properties of self-healing concrete it is found that 0.3% as a optimum dosage.

5. CONCLUSION

Based on the experimental investigation, specimens were cast for control mix as well as mixes substituted with dosages of silica gel varying from 0.1%,0.2%, 0.3%, 0.4%, and 0.5% .Introducing the healing agents using microcapsules [36] in to the concrete makes it very beneficial and easily adaptable in to the concrete mix. The use of healing agents (silica gel) in microcapsules results in an increase of healing efficiency. From the experimental investigation the following conclusions were made:(i) Large size of microcapsules could hamper the increasing rate of healing efficiency. This might be due to the large microcapsules introduces large voids itself, which need to be filled in by the healing agent when the healing mechanism is excited. As a result the healing mechanism starts and strength has been regained. Hence silica gel has the ability to reduce the cracks [20], improve the strength of the concrete which has been by [33].(ii) The workability of concrete incorporated with silica gel has increased, this is due to the various dosages of silica gel that adds plasticizing effect in the mix. However the variation in workability among the mixes is minimum.(iii) It is observed that the strength properties mix substituted with 0.3% dosage of silica gel as healing agents performs well.(iv) The compressive strength of the healed specimen with 0.3 % of silica gel has been regained 70% improvement in strength has been regained when compared with the initial healing which correlates with Michelle Metal [36].(v) The split tensile strength of the healed specimen with 0.3 % of silica gel has been regained 55.34% improvement in strength has been regained when compared with the initial healed specimen. 66

REFERENCES

1. Salmabanu Luhar et al, A Review Paper on Self-Healing Concrete 2015,5(3): 53-58 DOI: 10.5923/j.jce.20150503.01

2. Toshiharu Kishi et al, Crack Self-healing Behavior of Cementitious Composites Incorporating Various Mineral Admixtures, Journal of Advanced Concrete Technology Vol. 8,No.2,171-186,June2010.

3. RA.B. Depaa and T. Felix Kala, Experimental Investigation of Self-Healing Behavior of Concrete using Silica Fume and GGBFS as Mineral Admixtures, Indian Journal of Science andTechnology,Vol8(36),DOI:10.17485/ijst/2015/v8i36/87644, December 2015.

4. Lowweikeat, study of silica gel as self-healing agent in ge polymer mortar exposed to extremely high temperature, June 2015.

5. Aaron C. Jackson et al, Silica-Protected Micron and Sub-Micron Capsules and Particles for Self Healing at the Micro scale, 2010

.6. E. Schlangen et al, Recent advances on self-healing of concrete, 2010.

7. James Gilford et al, microencapsulation of self-healing concrete properties, B.S., Prairie View A&M University, August 2012.8. Michelle M.Pelletier et al, Self-healing concrete with a micro encapsulated healing agent, University of Rhode Island, Kingston, RI, 02881, USA,2011

9. Jianyun Wang et al, Use of silica gel or polyurethane immobilized bacteria for self-healing concrete, December 2010.