Flexural Behaviour of Self-curing Concrete with Lightweight Aggregate and Polyethylene Glycol

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ABSTRACT

Curing of concrete is maintaining satisfactory moisture content in concrete during its early stages in order to develop the desired properties. Any laxity in curing will badly affect the strength and durability of concrete. The aim of the investigation is to evaluate the use of water-soluble polyethylene glycol as self-curing agent with partial replacement of conventional fine aggregate with light weight fine aggregate such as sand stone and to optimise the quantity of lightweight aggregate and poly-ethylene glycol. By studying the mechanical properties of concrete by replacing the fine aggregate with lightweight fine aggregate by 0%, 10%, 20%, 30%, 40% and 50%, the optimum quantity of lightweight aggregate was found as 25%. Self-curing concrete of M30 grade were cast by replacing fine aggregate with 25% lightweight fine aggregate, whose water absorption property is high, and by varying quantity of polymeric glycol by 0.5%, 1%, 1.5% and 2%, the optimum percentage of polyethylene glycol was found as 1%. In this study, compressive strength, split tensile strength of self-curing concrete with varying quantity of polyethylene glycol was evaluated and compared with the conventional concrete specimens.

Keywords - *Water-soluble, Self-curing, Mechanical property, Light weight, polyethylene.*

1. INTRODUCTION

Proper curing of concrete structures is important to ensure they meet their intended performance and durability requirements. In conventional construction, this is achieved through external curing, applied after mixing, placing and finishing. Internal curing (IC) is a very promising technique that can provide additional moisture in concrete for a more effective hydration of cement and reduced self-desiccation. Internal curing implies the introduction of a curing agent into concrete that will act as an internal source of water. Currently, there are two major methods available for internal curing of concrete. The first method uses saturated porous lightweight aggregate (LWA) in order to supply an internal source of water, which can replace the water consumed by chemical shrinkage during cement hydration. The second method uses super-absorbent polymers (SAP), as these particles can absorb a very large quantity of water during concrete mixing and form large inclusions containing free water, thus preventing self-desiccation during cement hydration. For optimum performance, the internal curing agent should possess high water absorption capacity and high water desorption rates.

2. EXPERIMENTAL INVESTIGATION

2.1. Materials

Cement: The Bureau of Indian Standards (BIS) has classified OPC in three different grades. The classification is mainly based on the compressive strength of cement-sand mortar cubes of face area 50 cm^2 composed of 1 part of cement to 3 parts of standard sand by weight with a water-cement ratio arrived at by a specified procedure. The grades are (i) 33 grade (ii) 43 grade (iii) 53 grade. The grade number indicates the minimum compressive strength of cement sand mortar in N/mm^2 at 28 days, as tested by above mentioned procedure. In this project, Chettinad 53 Grade Ordinary Portland Cement was used conforming IS 12269:1987.

Fine Aggregate: Aggregate which passed through 4.75 mm IS Sieve and retained on 75 micron (0.075 mm) IS Sieve is termed as fine aggregate. Fine aggregate is added to concrete to assist workability and to bring uniformity in mixture. Usually, the natural river sand is used as fine aggregate. Ordinary river sand conforming IS 383-1970 was used in this project.

Coarse Aggregate: The coarse aggregate for the works should be river gravel or crushed stone. Angular shape aggregate of size is 20 mm and below. The aggregate which passes through 75 mm sieve and retain on 4.75 mm are known as coarse aggregate.It should be hard, strong, dense, durable, clean, and free from clay or loamy admixtures or quarry refuse or vegetable matter. The pieces of aggregate should be cubical, or rounded shaped and should have granular or crystalline or smooth (but not glossy) non-powdery surfaces. Aggregate should be properly screened and if necessary washed clean before use. Coarse aggregate containing flat, elongated or flaky pieces or mica should be rejected. The grading of coarse aggregate should be as per specifications of IS 383-1970.In this project, maximum normal size of coarse aggregate was 20 mm for controlled concrete.

Water: The water should be fit for mixing. The water should not have high concentrations of sodium and potassium and there is a danger of alkali-aggregate reaction. Natural waters that are slightly acidic are harmless, but water containing organic acids may adversely affect the hardening of concrete. Such water as well as highly alkaline water should be tested. The water should conform to IS 456-2000 standards. Generally, water satisfactory for mixing is also suitable for curing purposes. However, it is essential that curing water should be free from substances that attack hardened concrete like free CO_2 etc.

LIGHTWEIGHT FINE AGGREGATE:
Lightweight fine aggregate used in this project was a natural lightweight aggregate, which was obtained from a sandstone quarry from Wayanad..

Fig 1 Sample of Lightweight Fine Aggregate

Polyethylene Glycol: Polyethylene glycol is a condensation polymers of ethylene oxide and water with the general formula H $(OCH_2CH_2)_nOH$, where n is the average number of repeating oxyethylene groups typically from 4 to about 180. The abbreviation (PEG) is termed in combination with a numeric suffix which indicates the average molecular weights. One common feature of PEG appears to be the water-soluble. In this project, polyethylene glycol with molecular weight of 400 (PEG-400) was used as a self-curing agent, which was manufactured by Merck Pharmaceuticals.

2.2 Mix Proprotion

GENERAL:
As per IS method, mix design for M30 grade concrete was carried out using the test data for cement, coarse aggregate, and fine aggregate obtained by preliminary investigations.

Table 1-Mix proportion

	Cement	Water	F.A.	C.A
kg/m^3	443	186	618.083	1178.928
Ratio	1	0.42	1.395	2.661

3.Result And Discussion

3.1.slump:
Slump test is used to determine the workability of fresh concrete. Slump test as per IS 1199 : 1959 is followed. The apparatus used for doing slump test were slump cone and tamping rod. The internal surface of the mould was thoroughly cleaned and freed from superfluous moisture and adherence of any old set concrete before commencing the test. The mould was then filled in four layers, each 1/3 of the height of the mould, each layer being tamped 25 times with a standard tamping rod taking care to distribute the strokes evenly over the cross section. After top layer had been rodded, the concrete was struck off level with a trowel and tamping rod. The mould was removed from the concrete immediately by raising it slowly and carefully in a vertical direction. This allowed concrete to subside. This subsidence was referred as slump of concrete. The difference in level between the height of the mould and that of the highest point of the subsided concrete was measured. This difference in height in mm was taken as slump of concrete.

2 Compressive Strength:
The compressive strength test for cubes was conducted in compression testing machine as per IS 516 : 1964. The cubes were tested in compressive testing machine at the rate of 140 kg/cm^2/min and the ultimate loads were recorded.

The bearing surface of machine was wiped off clean and the surface of the specimen was cleaned. The specimen was placed in machine in such a manner, load was applied to opposite sides of the cubes such that casted side of specimen was not top and bottom. The axis of the specimen was carefully aligned at the centre of loading frame. The load applied was increased continuously at a constant rate until the resistance of the specimen to the increasing load breaks down and no longer can be sustained. Maximum load applied on specimen was recorded.

3.3 Split Tensile Strength:

The split tensile strength test for cylinders was carried out as per IS 516 : 1964. This test was carried out by placing a cylinder specimen horizontally between the loading surfaces of a universal testing machine and the load was applied until failure of the cylinder along the vertical diameter. When the load was applied along the generatrixan element on the vertical diameter, the cylinder is subjected to a horizontal stress and the split tensile strength was found using subsequent formula.

Split tensile strength, f_{cr} (N/mm^2) = $2P/\pi LD$

Where,

P = Ultimate load (N)

L = Length of cylinder (mm)

D = Diameter of cylinder (mm)

3.4 Lightweight Aggregate:

The results of the investigation carried out for finding the optimum percentage of lightweight aggregate by determining the mechanical properties of concrete were as mentioned below in table 2

Table.2. Test Results for M30 Concrete with Replacement of Fine Aggregate with Lightweight Aggregate From 10% To 50%

Sl. No	Description	M30	Percentage of LWA				
			10%	**20%**	**30%**	**40%**	**50%**
1	Slump value	80	76	**73**	**69**	65	61
2	Average 7th day compressive strength of cubes (N/mm^2)	31.30	32.66	**33.28**	**33.25**	30.59	28.66
3	Average 28th day compressive strength of cubes (N/mm^2)	42.22	43.60	**44.20**	**44.30**	41.77	40.88
4	Average split-tensile strength of cylinders (N/mm^2)	3.89	3.91	**3.96**	**3.97**	3.88	3.81

3.4.1Slump Value

From table 2, it was observed that the slump value decreased with increase in percentage of lightweight aggregate. The graphical representation is shown in figure 2

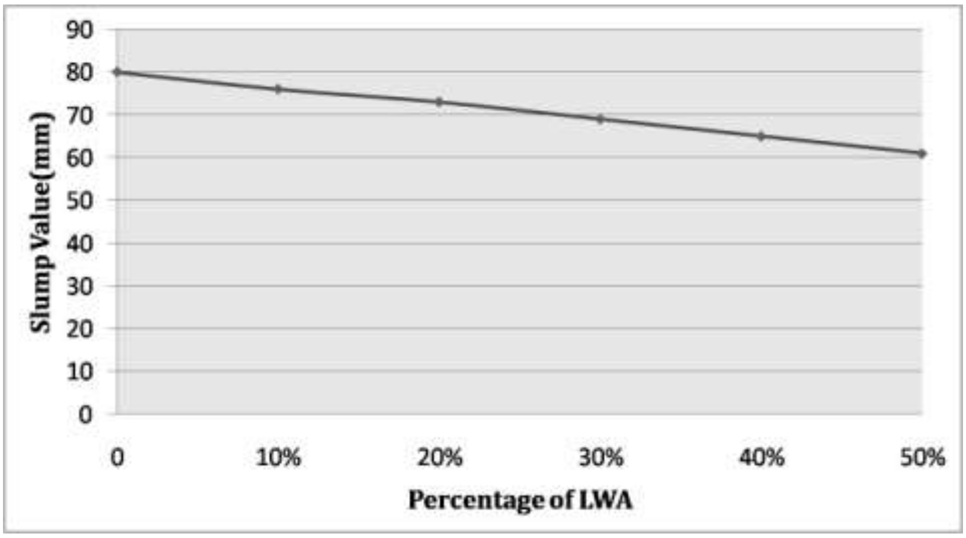

Fig 2 Variation of Slump Value for M30 Concrete with Replacement of Fine Aggregate with Lightweight Aggregate from 10% to 50%

3.4.2 Compressive Strength

From table 2, it was observed that, average compressive strength at 7 days and 28 days increased with increase in percentage of lightweight aggregate up to 30% and then decreased for 40% and 50%. The graphical representation of the variation of average compressive strength at 7 days and 28 days is shown in figure 3.

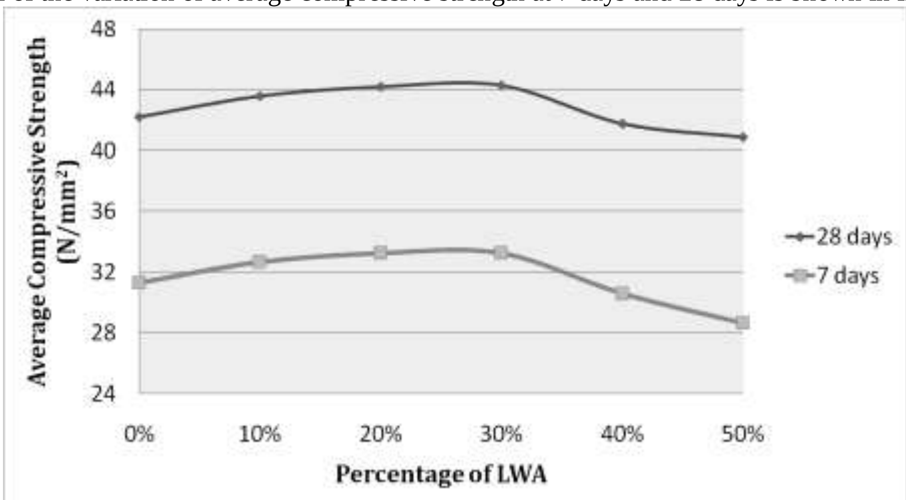

Fig 3 Variation of Compressive Strength at 7 and 28 days for M30 Concrete with Replacement of Fine Aggregate with Lightweight Aggregate from 10% to 50%

3.4.3 Split-Tensile Strength

From table 2, it was observed that, average split-tensile strength at 28 days increased with increase in percentage of lightweight aggregate up to 30% and then decreased for 40% and 50%. The graphical representation of the variation of average split-tensile strength at 28 days is shown in figure 4 .

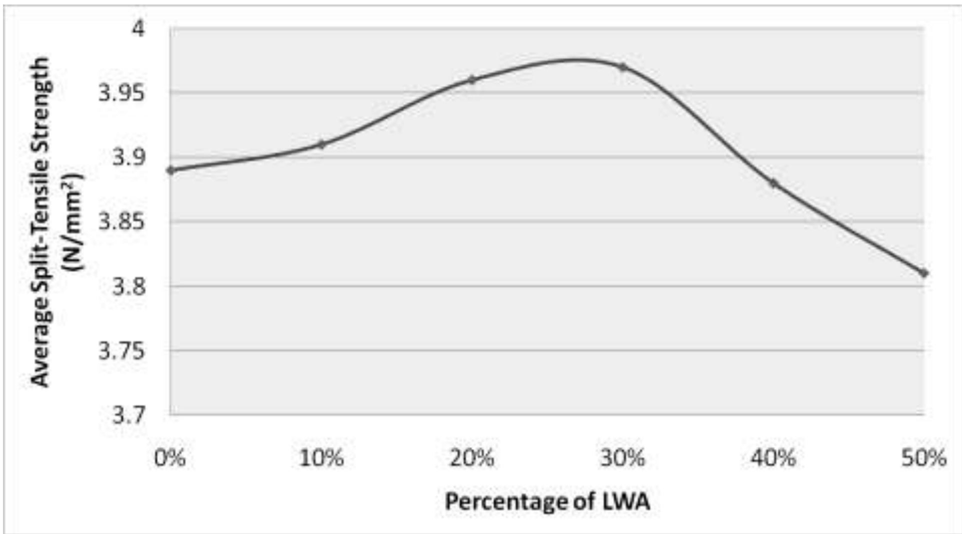

Fig 4 Variation of Split-Tensile Strength at 28 days for M30 Concrete with Replacement of Fine Aggregate with Lightweight Aggregate from 10% to 50%

3.5 POLYETHYLENE GLYCOL

The results of the investigation carried out for finding the optimum percentage of polyethylene glycol by determining the mechanical properties of M30 concrete with 25% replacement of fine aggregate with lightweight aggregate and varying polyethylene glycol-400 from 0% to 2% were as mentioned below in table 2.

Table 3 Test Results for M30 Concrete with 25% LWA and Variation of Polyethylene Glycol 400 from 0% to 2%

S. No	Description	Percentage of PEG with 25% LWA					
		With Curing	Without Curing				
		0%	0%	0.5%	1%	1.5%	2%
1	Slump Value (mm)	70	70	74	**80**	88	94
2	Average 7th day compressive strength of cubes (N/mm^2)	33.26	26.21	27.99	**31.7**	27.85	25.18
3	Average 28th day compressive strength of cubes (N/mm^2)	44.33	37.43	38.37	**42.07**	36.74	33.48
4	Average split-tensile strength of cylinders (N/mm^2)	3.96	3.69	3.75	**3.87**	3.71	3.62

3.5.1Slump Value

From table 3, it was observed that the slump value increased with increase in percentage of polyethylene glycol. The graphical representation is shown in figure 5.

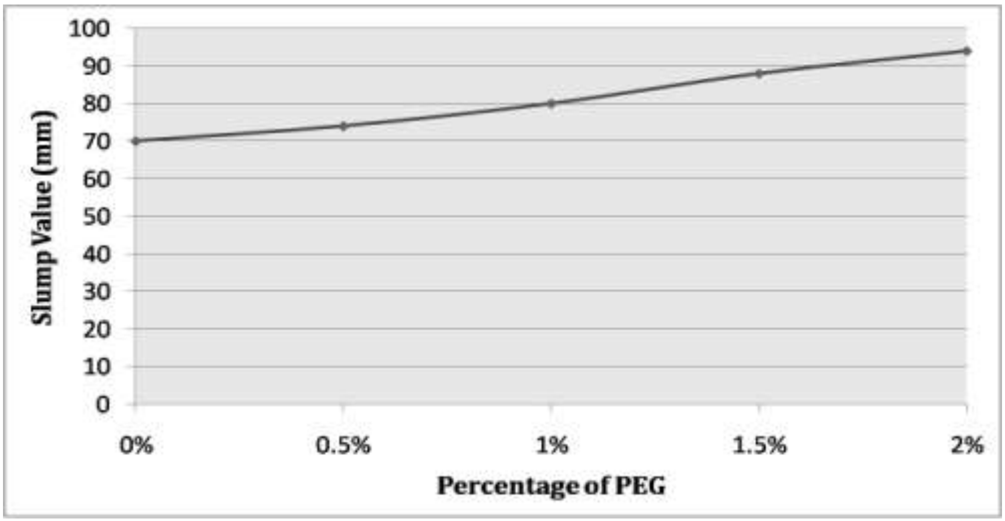

Fig 5. Variation of Slump Value for M30 Concrete with 25% LWA and Variation of Polyethylene Glycol 400 from 0% to 2%

3.5.2 Compressive Strength

From table 3, it was observed that, average compressive strength at 7 days and 28 days increased with increase in percentage of polyethylene glycol up to 1% and then decreased for 1.5% and 2%. The graphical representation of the variation of average compressive strength at 7 days and 28 days is shown in figure 6.

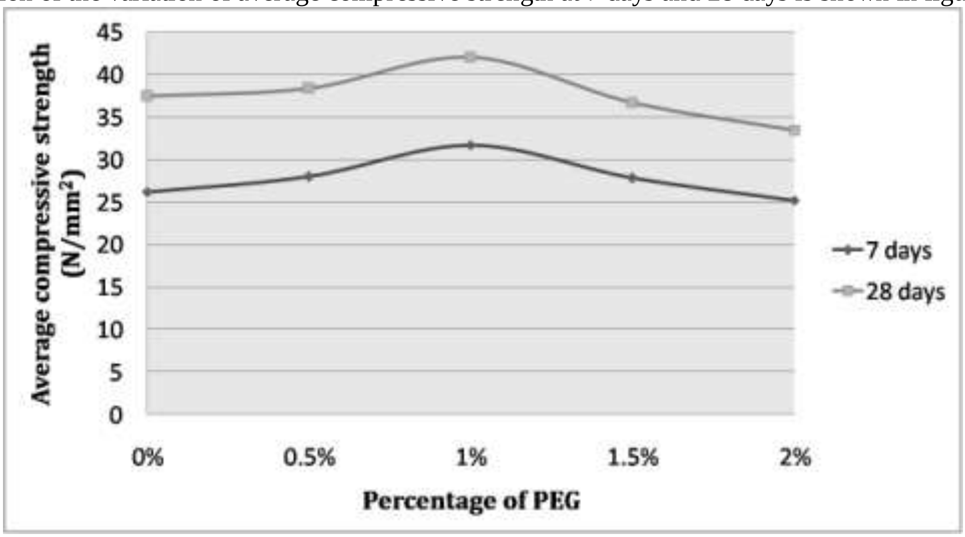

Fig 6 Variation of Compressive Strength at 7 and 28 days for M30 Concrete with 25% LWA and Variation of Polyethylene Glycol 400 from 0% to 2%

3.5.3 Split-Tensile Strength

From table 3, it was observed that, average split-tensile strength at 28 days increased with increase in percentage of polyethylene glycol up to 1% and then decreased for 1.5% and 2%. The graphical representation of the variation of average compressive strength at 28 days is shown in figure 7.

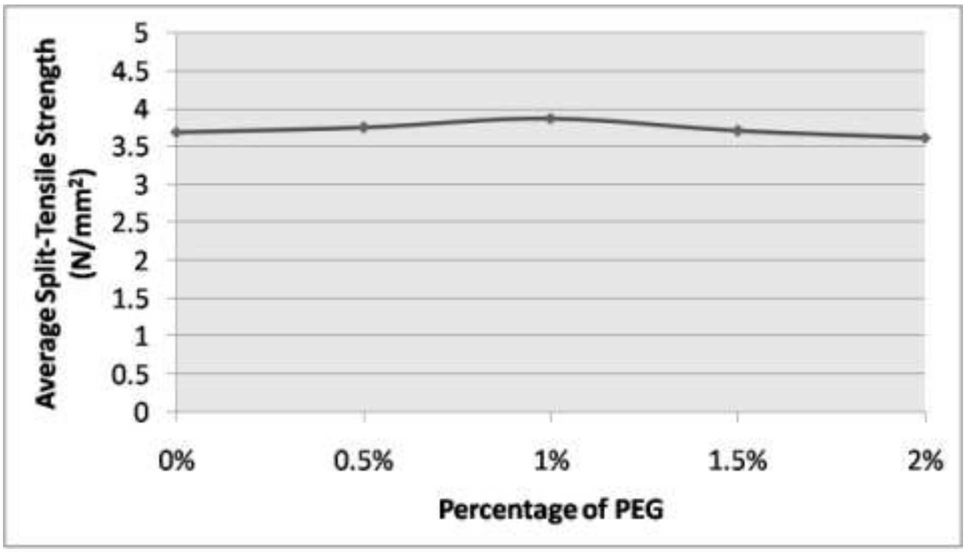

Fig 7 Variation of Split-Tensile Strength at 28 days for M30 Concrete with 25% LWA and Variation of Polyethylene Glycol 400 from 0% to 2%

CONCLUSIONS

In this project, the mix design for control concrete grade of M30 had been designed. Self-curing concrete is useful in water scarce areas and in places where good quality water is not available. The self-curing concrete required had been arrived from the control concrete by optimizing the percentage of lightweight aggregate and polyethylene glycol. From the test results observed, the following conclusion had been drawn:

- The optimum percentage of lightweight aggregate for maximum strengths (compressive, split-tensile and modulus of rupture) was found to be 25% for M30 grade of concrete.
- As the percentage of lightweight aggregate increased, the slump value decreased.
- The optimum dosage of PEG400 with 25% lightweight aggregate for maximum strengths (compressive, tensile and modulus of rupture) was found to be 1% for M30 grade of concrete.
- As percentage of PEG400 increased, slump increased for M30 grade of concrete.

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