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SELF-CURING CONCRETE –CASE STUDY

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ABSTRACT:

As water is becoming a scarce material day-by-day, there is an urgent need to save the water in making concrete and in constructions. Though water is being used in making concrete, its usage is high in the curing process. Curing is more necessary for gaining strength at the same time and lack of proper curing can badly affect the strength and durability of the concrete. When concrete is exposed to the environment evaporation of water takes place and loss of moisture will reduce the initial water-cement ratio which will result in the incomplete hydration of the cement and hence lowering the quality of the concrete. So the use of self-curing concrete admixtures is very important from the point of view that saving of water is necessary everyday (each $1m^3$ of concrete requires $3m^3$ of water in construction, most of which is used for curing). This paper summaries the case study to evaluate the effect (strength and durability) of self-curing methods in self-curing concrete. In this study hardened propertiesof the concrete containing self-curing agents at various percentage is investigated and compared with the conventional concrete. From this study we have planned to perform the comparative experimental tests between self-curing concrete (both external self-curing and internal self-curing) by using PEG and conventional concrete for M40 grade.

Keywords: self-curing agents, polyethylene glycol (PEG), polyvinyl alcohol (PVA), self-desiccation, light weight aggregate (LWA), concure wb [13], masterkure 107i [13].

1. INTRODUCTION

Curing of concrete is maintaining satisfactory moisture content in concrete during its early stages in order to develop the desired properties. However good curing is not always practical in many cases. So the usage of SAP should be introduced to reduce the water evaporation from concrete and hence increase the water retention capacity of the concrete when compared to conventional concrete. The aim is to study the use of water soluble polymeric glycol and other super absorbent polymers as self-curing agent. The benefit of self-curing admixtures is more significant in desert areas where water is not adequately available

2. OBJECTIVE:

The main objective is to assess the effect of minimizing the quantity of water required and the use of shrinkage reducing admixture PEG and SAP molecules in concrete which helps in self-curing and helps in better hydration [1] and hence strength. And to study the mechanical characteristics of concrete such as compressive strength, split tensile strength and modulus of rupture by varying the percentage of PEG by weight of cement for any particular grade

3. RANGE AND TYPE OF CASE STUDY:

In this case study, initially the methods of self-curing, materials for self-curing, water soluble polymers like PEG, PVA [14] and their advantages are discussed which are taken from various reference papers [6],[14],[11],[4],[7] etc. About twenty seven case studies were made with the sufficient and detailed in formations referred from the various journal papers which are listed in the reference section.

The table2 lists the name of the journal, authors, test experiment conducted, materials, quantity of admixtures, testing date, grade, w/c ratio, test result comparison between normal and self-cured concrete.

The table3 lists the year of publication, authors, test experiments conducted, literature reviews, materials, inference. The most significant part of the analysis in this paper is quantity of PEG and its mechanical property. Out of these only two studies are regarding PVA while four studies include LWA as a self-curing potential materials whereas two studies are regarding membrane curing and the remaining are regarding PEG as self-curing agent.

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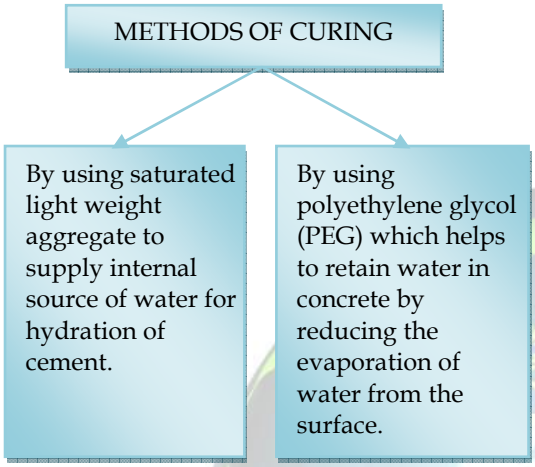
Water retention and the hydration in self-cured concrete were studied and discussed from the paper [1]. And the comparative study was made on M20[3], M25[9] and M40[3] grade concrete with sufficient information gathered from the papers [3],[9],[3].

4. METHODS OF SELF-CURING [4]:



5. SMART MATERIALS FOR SELF-CURING:

The following materials can provide internal water reservoirs: [6]

1) Light weight aggregates (natural and synthetic, expanded shale)
2) Super absorbent polymers (SAP) (60-300 mm)
3) SRA (Shrinkage Reducing Admixture) polyethylene glycol/ polyvinyl alcohol.

6. POLYETHYLENE GLYCOL:

Polyethylene glycol is a condensation polymer of ethylene oxide and water with the general formula H-(OCH_2CH_2)n-OH, where n is the average number of repeating oxy-ethylene groups typically from 4 to about 180. One of the common features of PEG appears to be the water soluble nature. Polyethylene glycol is non-toxic, odorless, neutral, lubricating, non-volatile and non-irritating and it is used in a variety of pharmaceuticals.[7], [11].

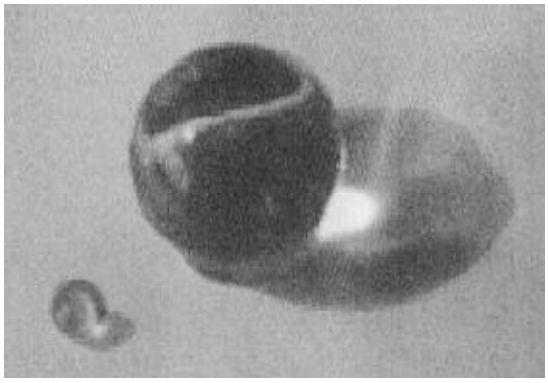


FIGURE:1 POLYETHYLENE GLYCOL[11]

TABLE:1 [11]

FORM – dry	Crystallinewhitepowder / grar
FORM – wet	Transparent gel
Particle size	0.2 mm
Water absorption with distilled	800 g for 1g
pH of absorbed water	Neutral
Density	1.08 g/cm3
Bulk density	0.85 g/cm3
Hydration/dehydration	Reversible
Decomposition in sun light	6 months
Available water	95% approx.

7. MECHANISM OF PEG:

Continuous evaporation of moisture takes place from an exposed surface due to the difference in chemical potentials (free energy) between the vapor and liquid phases the polymers added to the mix mainly from hydrogen bonds with water molecules and reduces the chemical potential of the molecules and reduces the vapor pressure, thus reducing the rate of evaporation from the surface [6],[7].

8. SIGNIFICANCE OF PEG:

When the mineral admixtures react completely in a blended cement system, their demand for curing water (external or internal) can be much greater than that in a conventional OPC concrete. When thiswater is not readily available, significant autogenous deformation and cracking may result at early ages. Due to the chemical shrinkage occurring during cement hydration, empty pores are created within the cement paste, leading to a reduction in its internal relative humidity and shrinkage which may cause early age cracking.[6]

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9. POLYVINYL ALCOHOL:

Polyvinyl alcohol is produced commercially from polyvinyl acetate, usually by a continuous process. The acetate groups are hydrolyzed by ester interchange with methanol in the presence of anhydrous sodium methylate or aqueous sodium hydroxide. Polyvinyl alcohol is an odorless and tasteless, translucent, white or cream colored granular powder. Polyvinyl alcohol contains two OH groups. It helps to retain water from concrete. It is soluble in water, slightly soluble in ethanol, but insoluble in other organic solvents. [14]

10. ADVANTAGES OF PEG AND SAP:

a) Each one cubic meter of concrete requires about $3m^3$ of water for construction most of which is for curing. By the usage of SAP enormous saving of water is achieved.[9]
b) Helps to reduce the cost of laborers required for curing.[6]
c) SAP is a smart material for making self-curing concrete when there is problem for occurrence of water scarcity.[6]
d) SAP is a good solution in the place large buildings and in complicated areas where curing process is difficult.[2]
e) High strength concrete with super absorbent polymer as a self-curing agent significantly reduces the autogenous shrinkage and thus prevents the early age cracking of bridge decks.[6]
f) In high rise structures, improper curing can be prevented by adopting self-curing concrete.[2]
g) Provides water to keep the relative humidity high, keeping self-desiccation from occurring.[2]
h) Reduces permeability, insufficient external curing and maintenance in concrete.[2]

TABLE:2

(NOTE: OPC- ORDINARY PORTLAND CEMENT, PPC- POZZALONA PORTLAND CEMENT, FA- FINE AGGREGATE, CA- COARSE AGGREGATE, PEG- POLYETHYLENE GLYCOL, PVA- POLYVINYL ALCOHOL, LWA- LIGHTWEIGHT AGGREGATE, CONTENT WITHIN { } REPRESENTS THE CORRESPONDING SPECIFIC GRAVITY, C.S REPRESENTS COMPRESSIVE STRENGTH, ST.S REPRESENTS SPLIT TENSILE STRENGTH AND F.S REPRESENTS FLEXURAL STRENGTH)

JOURNAL	AUTHORS	EXPERIMENTS CONDUCTED	MATERIALS	QUANTITY OF ADMIXTURES	TESTING DATE	GRADE	W/C RATIO	STRENGTH OF NORMAL CONCRETE			STRENGTH OF SELF-CURED CONCRETE			RAISE OF STRENGTH IN %	RESULT AND DISCUSSION
								C.S	ST.S	F.S	C.S	ST.S	F.S		
[9]	J. Saran Kumar T. Suresh Babu	Compressive strength and split tensile strength between conventional and self-cured concrete	OPC-53 {3.15} FA-zone 2 {2.89} CA-20mm {2.69 angular}	0.5 % 1.0 % 1.5 % of PEG	7th day and 28th day	M25	0.45	29.89	2.12	---	36.55	2.90	---	22.2% for C.S and 36.7% for ST.S	Addition of 1% of PEG is optimum for M25. Self-cured concrete gives 1.25 and 1.1 times the strength than the conventional concrete in compressive test and split tensile strength.
[10]	S. Saddam , M.Junaid , K.Yusu, S.A.Huzaifa	Compressive strength comparison between self-cured and normal concrete	PPC-53{3.15} FA-2 {2.78} CA-20mm {2.78} Fly ash ,Super-plasticizer	1% of PEG	7th , 14th and 28th day	1:2.23:3.08	0.39	28.87	---	---	34.20	---	---	17% for C.S	It gives 6%, 10.1% and 17% more strength in 7th, 14th, and 28th day than normal concrete respectively and less shrinkage.
[11]	M.Manoj kumar	Compressive , split tensile , flexural strength and slump comparison	PPC-53 {3.15} FA-2 {2.6} CA-20mm {2.6} Super-plasticizer	0.2% 0.3% 0.4% SAP	3rd , 7th and 28th day	M40	0.40	42.2	4.3	5.82	43.11	4.94	6.42	2 % , 14%, 10% for C.S, ST.S and F.S resp.	0.3% PEG is optimum for M40. Slump increases with the increase in PEG.
[12]	Mohammed noorulla	Behavior under acid attack	OPC-43{3.15} FA-2	10% to 50% replace	90th day after	---	---	---	---	---	---	---	---	----	20% replacement of pumice stone give more strength after

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			{2.58} CA-20mm {2.56} H2SO4 Pumice stone {0.84}	ment of pumice stone (LWA)	acid attack										90 days of acid attack.
[13]	Akanksha Anantrao Patil	Comparison of normal and self-cured concrete under sorpitivity and acid attack test.	OPC-53 {3.15} FA—2{2.60} CA-16mm {2.9} Silica fumes{2.38} Super plasticizers	Concure WB Masterkure 107i	28th day	M70	0.47	68.40	---	---	60.60 56.72	---	---	Strength decreases upto 10% and 15%	When membrane is adopted durability isnot much affected.
[14]	Stella Evangeline	Comparison of mechanical properties between normal and self-cured concrete (polyvinyl alcohol)	OPC-53 {3.15} FA-2 {2.6} CA-20mm {2.63}	0.03% 0.06% 0.12% 0.24% 0.48% PVA	28th day	M25	---	32.1	4.30	5.8	33.7	4.94	8	4.9%, 14.8% and 37.9% for C.S, ST.S and F.S	0.48% of POLYVINYL ALCOHOL is optimum for better result.
[15]	Mohanraj.A Rajendran.M Ramesh.A.S	Comparison between self-cured and normal concrete for various grades.	OPC-53 {3.15} FA-2 {2.76} CA-20mm {2.8}	0.3% of PEG	3rd, 7th and 28th days	M20 M30 M40	0.49 0.43 0.35	---	---	---	---	---	---	----	Self-cured concrete gives more strength than normally cured concrete.
[2]	K.Vedhasakthi M.Saravanan	Normal and high strength self-curing concrete using PEG and SORBITAL	PPC-43 {3.20} FA-3 {2.58} CA-20mm {2.75} Silica fumes {2.20} Super plasticizer	0.3% of PEG 0.3% of SORBITOL	3rd, 7th and 28th days	M20 M30 M40 M60 M70 M80	0.5 0.4 0.4 0.3 0.29 0.29	26.33 35.02 45.43 71.11 79.25 84.50	--- --- --- --- --- ---	--- --- --- --- --- ---	26.92 35.53 46.02 72.45 80.49 87.20	--- --- --- --- --- ---	--- --- --- --- --- ---	2.2% 1.4% 1.2% 1.8% 1.5% 3.1%	O.3% is optimum for both normal and high strength self-curing concrete HSC self-curing concrete produces with 15% replacement of silica fumes.
[4]	Patel Manish kumarDahyabhai	Study of various % of PEG in M20	PPC-53 {3.14} FA-2 {2.69} CA-20mm {2.7}	0% 0.5% 1.0% 1.5% 2% of PEG	7th, 14th and 28th days	M20	---	---	---	---	---	---	---	---	1% is optimum for M20.
[6]	NISA group 2014	Compressive strength of self-cured concrete for various % of PEG	OPC-43 {3.15} FA-2 {2.89} CA-20mm {crushed 2.69}	0.5% 1.0% 1.5% 2.0% of PEG	7th, 14th and 28th days	M20	0.53	26.88	---	---	28.44	---	---	5.8%	1.5% is optimum for high compressive strength in self-cured concrete. Slump increases with increase in PEG.
[3]	M.V.Jaganadakumar M.Srikanth K.JagannaDaRao	Comparison of mechanical properties of self-cured and normal concrete in M20 and M40	OPC-53 {3.15} FA-3 {2.89} CA-20mm {2.89} PEG {1.120}	0.5% 1.0% 1.5% 2.0% of PEG	7th, 14th and 28th days	M20 M40	0.55 0.35	26.60 46.65	1.81 2.42	3.50 4.62	28.49 47.23	2.02 2.50	3.80 4.75	7.1%, 11.6%, 8.5% 1.2%, 3.3%, 2.8% for C.S, ST.S and F.S resp.	1% is optimum for M20 0.5% is optimum for M40 Slump value increases with increase in % of PEG

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		for various % PEG													
[7]	Patel Manish kumarDahyabhai	Comparison of compressive strength of self-cured concrete using SAP molecules PEG 600 and PEG 1500	OPC-53 {3.14} FA-1 {2.64} CA-20mm {2.72}	0.5% 1.0% 1.5% 2.0% of PEG 600 and PEG 1500	7th ,14th and 28th days	M25	0.5	27.15	---	---	33.77	---	---	24.3%	Strength increases by 37% and 33.9% in self-cured concrete for PEG 600 and PEG1500 respectively. 1% of PEG600 and PEG1500 is optimum.

TABLE: 3[10]

YEAR	AUTHORS	EXPERIMENTS CONDUCTED	MATERIALS USED/ ADMIXURES	TESTING DATE	GRADE	INFERENCE
1990	Swamyet, al	50MPa strength concrete by self-curing and adding slag	Ordinary materials and replacing 50% of cement by slag. PEG	28th day	---	50% replacement of slag and self-curing reached nearly 90% of target strength in 28 days.
1996	Dhiret	Comparison of self-curing concrete at low and high dosage of PEG	PEG (low dosage) PEG (high dosage)	---	---	Good strength, improved permeability, low determinal effect on concrete, high compressive strength
1998	Hansw. Reinhardt	High strength self-curing concrete	Partial replacement of normal weigth aggregate by light weigth aggregate	One year	---	Strength gains upto 25% after one year.
2001	Gowripalan	Mechanism of self-curing concrete	POLY ETHYLENE GLYCOL		---	The polymer added in the mix mainly form hydrogen bonds with water molecules and reduces the chemical potential of the molecule which in turn reduces the vapor pressure. This reduces the rate of evaporation from the surface."self-curing concrete is the newly emerging trend in the construction industry."
2006	TarunR.Naik	Influence of microstructure on the physical properties of self-cured concrete.	Ordinary materials with Light weight aggregate and 1% of PEG	28th day	---	Better thermal properties, better fire resistance, improved skid resistance, reduced autogeneous shrinkage, reduced chloride ion penetration, improved thawing and freezing durability, less micro-cracking, better elastic compatibility, improved contact between aggregate and cement matrix.
2008	N.Yazdani	Accelerated normal curing of silica fumed concrete	Cementitious materials+ silica fume	28th day	---	Dehydration takes place and causes shrinkage problems.
2011	Ravi kumar M	Study on high strength concrete with kiln ash replacement with and without self-curing method	Kin ash PEG600		---	High strength concrete with kiln ash replacement by self-curing gives high results than without self-curing agents.
2012	Raghavendra	Comparison of normal concrete and membrane cured concrete	Silica fumes Super plasticizers Concure WB Masterkure 107i	28th day	---	Membrane curing doesnot give much difference with the normally cured concrete.
2012	Vilas	Self-curing concrete using polyvinyl alcohol as shrinkage reducing agent	POLYVINYL ALCOHOL	7th , 14th and 28th day	----	Provides higher water retention, better hydration with time when compared to conventional concrete.
2013	Sathyanahan	Study ofself-curing concrete with addition of PEG	POLYETHYLENE GLYCOL (PEG 4000)	7th , 14th and 28th day	---	PEG increases the durability and reduces shrinkage when compared to conventional concrete.
2012	MateusWyrzykowski	Analysed the modeling of water migration during internal curing with SAP	Super absorbent polymer- PEG		---	SAP uniformly distributed in the concrete and act as internal water reservoir. By SAP it is possible to provide water curing in low w/c ratio.
2014	Magda I Mousa	Comparison of mechanical properties of self-curing concrete using PEG and PVA	Ordinary materials with PEG(poly ethylene glycol) PVA(polyvinyl alcohol)	7th , 14th and 28th day	M25	Self-curing concrete with PEG gives higher mechanical properties than self-curing concrete with PVA
---	Aielstein Rozario, Dr.Freeda Christy, Hannah angelin	Permeability of chemicals in self-curing concrete	Ordinary materials + fly ash + PEG	---	---	Permeability of concrete decreases with increase in replacement of cement with fly ash and n addition of the dosage.
---	Nagesh	Usage of polyvinyl alcohol as self-curing agent	POLYVINYL ALCOHOL (PVA) 0.03% 0.06% 0.12% 0.24% 0,48%	28th day	---	0.48% of PVA is optimum and efficiency of self-curing concrete increased by 92.5% than conventional concrete.

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11. COMPARATIVE STUDY:

a. WATER RETENTION*:*

The weight loss with time due to the moisture evaporation was found to be less for the self-curing mixes than that for the conventional mixes by A.S. El-Dieb in Construction and Building Materials 21 (2007)

1282-1287 [1]. This indicates better water retention for self-curing mixes. The weight isloosed with time for all the mixes. The weight loss for the concrete mixes with w/c ratio 0.4 was greater than that for the concrete mixes with w/c ratio 0.3 for both cement contents. Also, the weight loss for the concrete mixes with cement content 450 kg/m3 was slightly higher than that for concrete mixes with cement content 350 kg/m3.

A.S. El-Dieb shows the internal relative humidity for the self-curing and conventional concrete with time. The cement content and the w/c ratio have a significant effect on the internal relative humidity of the concrete whether self-curing or conventional mixes, this confirms with the findings previously concluded for conventional concrete mixes. For the concrete mixes with the cement content 350 kg/m3, the internal relative humidity for the self-curing mixes was slightly higher than 85% after 91 days, and below 85% for the conventional mixes. For the concrete mixes with cement content 450 kg/m3, the internal relative humidity was below 85% for the self-curing mixes while was below 80% for conventional mixes. This shows that the self-desiccation is more pronounced for the conventional mixes compared to the self-curing mixes which could have direct impact on thehydration of the cement.

b. HYDRATION:

The non-evaporable water measured on unsealed specimens (under drying condition) at different times for self-curing and conventional concrete mixes. A.S. El-Dieb found that self-curing concrete with its ability to retain water resulted in higher non-evaporable water which in turn imply higher degree of hydration [1]. The effect is affected by the mix proportions as found from the result of the measurement of the weight loss and internal relative humidity

c. MIX RATIO:

The following table 4 gives details about the quantity of materials required for per cubic meter of M20 [3], M25 [9] and M40 [3] graded concrete with inclusion of PEG %.

TABLE: 4

S.NO	MIX	CONCRETE (kg)	FINE (kg) AGGREGATE	COARSE (kg) AGGREGATE	WATER (kg)	PEG (kg)			
						0.05%	1.00%	1.50%	2.00%
1.	M20	340	610	1330	187	0.17	3.4	5.1	6.8
2.	M25	362.3	817	1128	140	0.18	3.6	5.4	7.2
3.	M40	440	520	1220	154	0.2	4.4	6.6	8.8

d. SLUMP TEST:

The result of the slump test for M20 [3], M25 [9] and M40 [3] are represented in the table 5 and the graphical representation is shown in fig 2. As % of the PEG increases theslump value is also found to be increase for M20[3], M25[9] and M40[3] grade concrete that that of the conventional concrete

TABLE: 5

S.NO	PEG(%)	M20	M25	M40
1.	0.00%	80	72	45
2.	0.05%	92	84	65
3.	1.00%	112	104	95
4.	1.50%	140	135	130
5.	2.00%	175	---	160

FIGURE: 2

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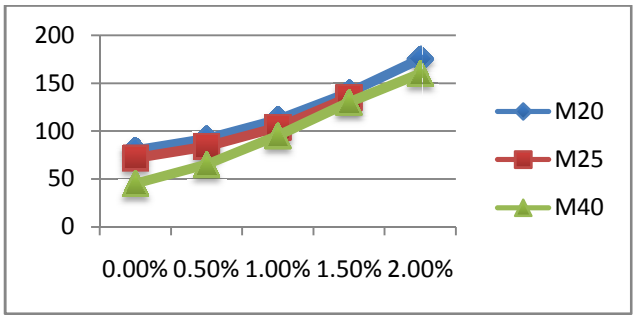


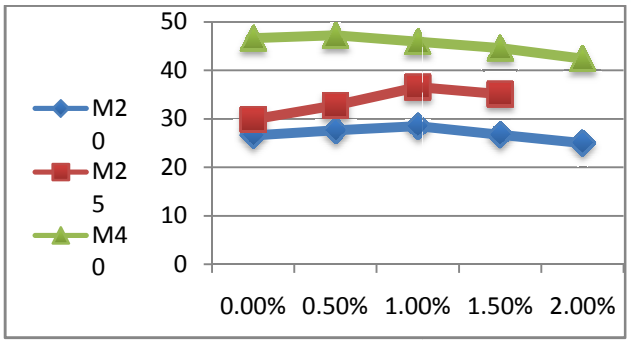
e. COMPRESSIVE STRENGTH:

The result of the compressive strength for M20[3], M25[9] and M40[3] are represented in the table 6 and the graphical representation is shown in fig 3 . The compressive strength was found to be increase upto 1% of PEG and then decreases for M20[3] and M25[9] grade concrete while the compressive strength was found to be increase upto 0.5% for M40[3] grade concrete. The compressive strength was increased upto 7.23% and 22.2% at 1% of PEG for M20[3] and M25[9] when compared with the conventional concrete while increase is 1.24% at 0.5% of PEG in case of M40[3] grade of concrete.

TABLE: 6

S.NO	PEG (%)	M20	M25	M40
1.	0.00%	26.60	29.89	46.65
2.	0.50%	27.61	32.81	47.23
3.	1.00%	28.49	36.55	45.93
4.	1.50%	26.74	35.11	44.62
5.	2.00%	25.03	----	42.44

FIGURE:3



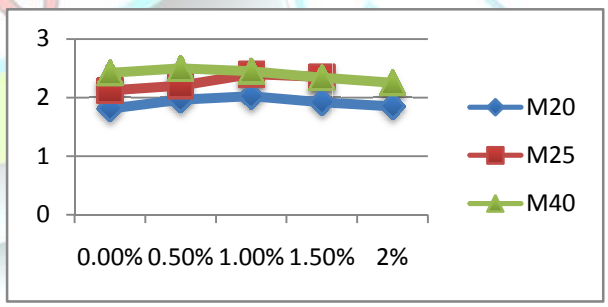
f. SPLIT TENSILE STRENGTH:

The result of the split tensile strength for M20[3], M25[9] and M40[3] are represented in the table 7 and the graphical representation is shown in fig 4 . The split tensile strength was found to be increase upto 1% of PEG and then decreases for M20[3] and M25[9] grade concrete while the split tensile strength was found to be increase upto 0.5% for M40[3] grade concrete. The split tensile strength was increased upto 11.60% and 13.2% at 1% of PEG for M20[3] and M25[9] when compared with the conventional concrete while increase is 3.30% at 0.5% of PEG in case of M40[3] grade of concrete.

TABLE: 7

S.NO	PEG(%)	M20	M25	M40
1.	0.00%	1.81	2.12	2.42
2.	0.50%	1.96	2.2	2.50
3.	1.00%	2.02	2.4	2.45
4.	1.50%	1.92	2.35	2.34
5.	2.00%	1.85	----	2.25

FIGURE:4



g. FLEXURAL STRENGTH:

The resultof the flexural strength for M20[3], and M40[3] are represented in the table 8 and the graphical representation is shown in fig 5. The flexural strength was found to be increase upto 1% of PEG and then decreases for M20[3] grade concrete while the flexural

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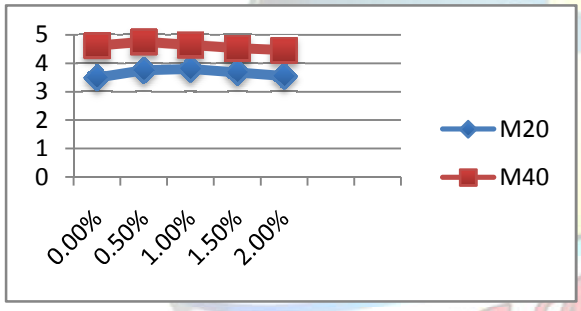
strength was found to be increase upto 0.5% for M40[3] grade concrete. The flexural strength was increased upto 8.57% at 1% of PEG for M20[3] when compared with the conventional concrete while increase is 2.81% at 0.5% of PEG in case of M40[3] grade of concrete.

TABLE: 8

S.NO	PEG(%)	M20	M40
1.	0.00%	3.50	4.62
2.	0.50%	3.75	4.75
3.	1.00%	3.80	4.64
4.	1.50%	3.68	4.53
5.	2.00%	3.55	4.46

FIGURE: 5



12. CONCLUSION:

Based on the literature review, the following could be concluded from the study inspite of the scattering of test results:

i. Water retention for the concrete mixes incorporating self-curing agent is higher compared to conventional concrete mixes, as found by the weight loss with time.[1]
ii. Self-curing concrete su□ered less self-desiccation under sealed conditions compared to conventional concrete.
iii. Self-curing concrete resulted in better hydration with time under drying condition compared to conventional concrete.[1]
iv. Water transport through self-curing concrete is lower than air-cured conventional concrete.[1]
v. Slump value increases with increase in the quantity of PEG.[6] [3]
vi. It was studied that the strength increases at different proportions of PEG i.e, 1% is optimum for M20 and M25 grade 0.5% for M40 grade and 0.3% for high strength self-curing concrete.

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