AN EXPERIMENTAL STUDY ON MECHANICAL PROPERTIES OF CONCRETE MADE WITH RECYCLED AGGREGATES AND POLYETHYLENE GLYCOL- 400 AS SELF CURING AGENT

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Abstract

The imagination of a world without concrete is impossible. It is a soul of infrastructures. Concrete is necessary to gain strength in structures. Conventional concrete, which is the mixture of cement, fine aggregate, coarse aggregate and water, needs curing to achieve strength. So, it is required to cure for a minimum period of 28 days for good hydration and to achieve target strength. Lack of proper curing can badly affect the strength of concrete. Self-curing concrete is concrete, which cure itself by retaining water (moisture content) in it. The use of POLYETHYLENE GLYCOL in conventional concrete as an admixture helps better hydration and hence the strength of concrete. As water is becoming a scarce commodity day-by-day, there is an urgent need to do research work pertaining to conserve water in producing concrete for constructions. Curing of concrete is maintaining satisfactory moisture content in concrete during its early stages in order to develop the desired properties. Curing of concrete plays, a major role in developing the concrete microstructure and pore structure and hence improves its durability and performance. The use of self-curing admixtures is very important from the point of view that saving of water is a necessity everyday (each $1m^3$of concrete requires $3m^3$of water in a construction, most of which is used for curing).This project focuses on self-curing of concrete, keeping importance to this, an attempt has been made to develop self-curing concrete by using water-soluble Polyethylene Glycol as self-curing agent. The function of self-curing agent is to reduce the water evaporation from concrete, and hence it increase the water retention capacity in concrete. The present investigation involves the use of self-curing agent viz., polyethylene glycol (PEG) of molecular weight 400 (PEG-400) for dosages of 0%, 0.5%,1%, 1.5% and 2% by weight of cement added to mixing water in the concrete. Comparative studies were carried out for compressive strength, tensile strength and flexural test for conventional and self-cured concrete mixture of M20, M30 and M40 grades at standard ages (7, 14,28 and 56 days).

Keywords: Concrete, Self curing agent, Polyethylene Glycol,

1. INTRODUCTION

Concrete has been and will be, for a considerable number of years the most versatile materials used in construction. Concrete most importantly has an edge over other construction materials because of its unique ability to take any shape in various applications whether it is produce on the site or whether it is made in a factory as a pre-cast product. During the last two decades, concrete technology has been undergoing rapid improvements. The imagination of world without concrete is impossible. Concrete is a soul of infrastructures. Concrete is necessary to gain strength in structures. Conventional concrete, which is the mixture of cement, fine aggregate, coarse aggregate and water needs for the formation of binding paste to achieve required strength. Water is required to cure for a minimum of 28 days for good hydration and to achieve target strength. Lack of proper curing can badly affect concrete. As water is becoming a scarce material day-by-day, there is an urgent need to perform research pertaining to conserving water in preparing concrete in constructions. Cure of concrete place a major role in acquiring strength, hardness, durability and performance of concrete. Curing of

concrete is maintaining satisfactory moisture content in concrete during its early ages in order to develop the desired properties .Because after mixing cement with water the process of hydration takes place which required water for cooling purpose. If water is not provided then shrinkage of concrete may occur which results in cracking. Therefore, it is necessary to provide water as curing for some fixed duration. Practically good curing is not achievable in many cases due to non-availability of good quality water and many other practical difficulties.

Methods of self curing

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 poly-ethylene glycol (PEG) which reduces the evaporation of water from the surface of concrete and also helps in water retention

1.1Materials for Internal Curing (IC)

The following materials can provide internal water reservoirs:

Lightweight Aggregate (natural and synthetic, expanded shale)

Super-absorbent Polymers (SAP) (60-300 nm size)

Polyethylene-glycol-400

1.2SCOPE AND OBJECTIVE

The scope of the paper is to study the effect of polyethylene glycol (PEG-400) on strength characteristics of Self-curing concrete

The objective is study the mechanical characteristics of concrete such as compressive strength, split tensile strength and flexure by varying strength the percentage of PEG from 0% to 2% by weight of cement for both M20 , M30and M40 grades of concrete.

2. LITERATURE REVIEW

- **Patel Manish KumarDahyabhai, Prof. JayeshKumarPitroda** studied on "introducing the self-curing concrete in construction industry". Compressive strength of self-curing concrete is increased by applying self-curing admixtures. The compressive strength of concrete mix increased by 37% by adding 1.0% of PEG400 and 33.9by adding 1.0% of PEG1500 as compared to the conventional concrete. The optimum dosage of PEG600 for maximum compressive strength was found to be 1% of weight of cement for M25 grade of concrete. The optimum dosage of PEG1500 of maximum compressive strength was found to be 1% of weight of cement for M25 grade of concrete. Self-curing concrete is the best solution to the problem faced in the desert region and faced due to lack of proper curing.
- **MohanrajRajendran M** Studied on "self-curing concrete incorporated with polyethylene glycol". The compressive strength of cube by compression testing machine for Self-cured concrete is higher than of concrete cured by full curing and sprinkler curing. The split tensile strength of self-cured cylinder specimen is higher than that of the conventionally cured specimen. Self-cured concrete is found to have less water absorption values compared with concrete cured by other methods. Self-cured concrete thus has a fewer amount of porous. The success of the initial studies highlights the promise of additional work. In planned studies the mix design will be optimized for self-curing agent in concrete mix
- **Basil M Joseph** Studied on self-curing concrete and PEG400 were used as a self-curing agent in concrete. M20 grade of concrete is adopted for investigation. He added 0-1.5% of PEG400 by weight of cement for M20 grade concrete from that he found 1% of PEG400 by weight of cement was optimum for M20 grade of concrete for achieve maximum strength. He also found that if percentage of PEG400 gets increased as well as compaction factor also increased.
- **Mohammed ShafeequeSanofar.P.B, Praveen.K.P.Jitin Raj, Nikhil.V.P, Gopikrishna** has used PEG600 as a self-curing agent in concrete. M20 and M25grade of concrete are adopted for investigation. They added 0-2% of PEG600 by weight of cement for M20 and M25 grade concrete. From that they found 1% of PEG600 by weight of cement was optimum for M20 and M25 grade of concrete for achieve maximum strength.
- **ShikhaTyagi** Studied on self-curing concrete and had use PEG400 as a self-curing agent in concrete. M25 and M40 grade of concrete are adopted for investigation. She added 1-2% of

PEG400 by weight of cement for M25 and M40 grade concrete. She was concluded that the optimum dosage of PEG400 for maximum Compressive strength was to be 1% for M25 and 0.5% for M4O grades of concrete.

- **Sathanandham T *et. al.*** (Nov 2013, 2014) 23 preliminary studies of self-curing concrete with the addition of polyethylene glycol (PEG) were done by them. They studied due excess of hydration in plain concrete shrinkage occurs which affect the durability hence introduced shrinkage reducing admixture polyethylene glycol (PEG 4000) which results in self-curing and helps in better hydration and hence good strength.

3 MATERIALS AND PROPERTIES

3.1 Cement

Cement plays vital role in concrete. One of the important criteria tricalcium aluminates (C_3A) content, tricalcium silicate (C_3S) content, dicalcium silicate (C_2S) content etc. It is also necessary to ensure the compatibility of chemical and mineral admixtures with cement.

This study, Ultratech53 grade Ordinary Portland Cement conforming to IS: 12269–1987 was used for the entire work. The cement was purchased from single source and was used for casting of all specimens. The physical properties of cement are furnished in Table

Table No: 3.1 properties of cement

S.No.	Characteristics	Value
1	Specific Gravity	3.17
2	Normal Consistency	31%

3.2 Fine Aggregate

Fine aggregate are basically sands won from the land or the marine environment. Fine aggregates generally consist of natural sand or crushed stone with 90% particles passing through a 9.5mm sieve. As with coarse aggregates these can be from Primary, Secondary or Recycled sources. The selection of fine aggregate is also on important factor as it directly affects the strength of concrete with the varying utilization of water. Fine aggregate with harsh surface requires high amount of water, so fine aggregate with smooth surface and rounded shape is being used as it requires low amount of water and hence produces high strength concrete. Fine aggregate, those fractions from 4.75 mm to 150 micron are termed as fine aggregate. The river sand is be used in combination as fine aggregate conforming to the requirements of IS 383- 1970. The river sand is washed and screened, to eliminate deleterious materials and over size particles. Specific gravity, water absorption and gradation of sand (FM) test were carried out as per IS 2386 (part I and Part III) - 1963. Physical test for specific gravity, water absorption, bulk density were carried out for coarse aggregate as per IS -2386 (I, II & IV) 1963 Properties of the fine aggregates given in Table

Table: 3.2. Properties of Fine Aggregate

S.No.	Physical Properties	Fine Aggregate
1	Size and Zone	4.75 mm down
2	Specific gravity	2.55
3	Water Absorption	1.4%
4	Moisture Adsorption	2%
5	Fineness modulus	3.95

3.3. Recycled Aggregates

The waste from the demolition of concrete structures are collected, aggregates are separated as recycled aggregates. The proposed recycled aggregates are used in the concrete mix for this project. The recycled aggregates are conformed by means of grading. As per specification 20 mm angular recycled aggregates are selected for partial replacement.

Figure- 3.1 Recycled Aggregate

3.3.1Applications of Recycled Aggregates

Nowadays, the applications of recycled aggregate in construction areas are wide. The applications are different from country to country

1) Aggregate Base Course, or the untreated aggregates used as foundation for roadway pavement, is the underlying layer which forms a structural foundation for paving.

2) Ready Mix Concrete -It is used for residential slab and foundation; walk and curb residential street; commercial slab and foundation and concrete paving per aggregate approval.

3) Pipe Bedding: Recycled concrete can serve as a stable bed or firm foundation in which to lay underground utilities.

Table 3.3 Physical properties of Coarse Aggregate

S.No.	Physical Properties	RCA
1	Water absorption (%)	7.63
2	Specific gravity	2.60
3	Bulk Density (kg/m^3)	1469.8

3.4 Water

Water used for mixing and curing shall be clean and free from injurious quantities of alkalies, acids, oils, salts, sugar, organic materials, vegetable growth (or) other substance that may be deleterious to bricks, stone, concrete, or steel. Potable water is generally considered satisfactory for mixing.

Water acts as a lubricant for the fine and coarse aggregates and acts chemically with cement to form the binding paste for the aggregate and reinforcement. Less water in the cement paste will yield a stronger, more durable concrete; adding too much water will reduce the strength of concrete and can cause bleeding. Impure water in concrete, effects the setting time and causing premature failure of the structure.

To avoid these problems quality (potable) water must be proffered in construction works and PH value of water should be not less than 6. And also Quantity of water to be taken is important.

3.5 Self-Curing Agents (Peg-400)

The polymers added in the mix mainly form hydrogen bonds with water molecules and reduce the chemical potential of the molecules of water which in turn reduces the vapour pressure, thus reducing the rate of evaporation from the surface. The physical and chemical properties of PEG-400 are shown in Table 3.4. Polyethylene Glycol (PEG), also known as Polyethylene Oxide (PEO) or Polyethylene (POE), is the most commercially important polyether used as self-curing agent. Polyethylene glycol is a condensation polymer of ethylene oxide and water with the general formula

H(OCH2CH2)nOH, where n is the average number of repeating ox ethylene 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 nature. Polyethylene glycol is non-toxic, odorless, neutral, lubricating, non-volatile and non-irritating and is used in a variety of pharmaceuticals

3.4 MIX PROPORTIONS

Table: 4.2 Mix Proportion of M20 with Peg-400

Mix	PEG 400 % of cement	PEG (Kg/m^3)	Cement (Kg/m^3)	Fine aggregate (Kg/m^3)	Coarse aggregate (Kg/m^3)	Water (lit/m^3)
CC	**0%**	0	383	585.65	1168.5	191.59
Mix-1	**0.5%**	1.9	383	585.65	1168.5	191.59
Mix-2	**1.0%**	3.8	383	585.65	1168.5	191.59
Mix-3	**1.5%**	5.7	383	585.65	1168.5	191.59
Mix-4	**2.0%**	7.6	383	585.65	1168.5	191.59

Table: 4.5 Mix Proportion of M30 with Peg-400

Mix	PEG 400 % of cement	PEG (Kg/m^3)	Cement (Kg/m^3)	Fine aggregate (Kg/m^3)	Coarse aggregate (Kg/m^3)	Water (lit/m^3)
CC	**0%**	0	438	610.47	1127.84	197.16
Mix-1	**0.5%**	2.1	438	610.47	1127.84	197.16
Mix-2	**1.0%**	4.3	438	610.47	1127.84	197.16
Mix-3	**1.5%**	6.5	438	610.47	1127.84	197.16
Mix-4	**2.0%**	8.7	438	610.47	1127.84	197.16

Table: 4.8 Mix Proportion of M40 with Peg-400

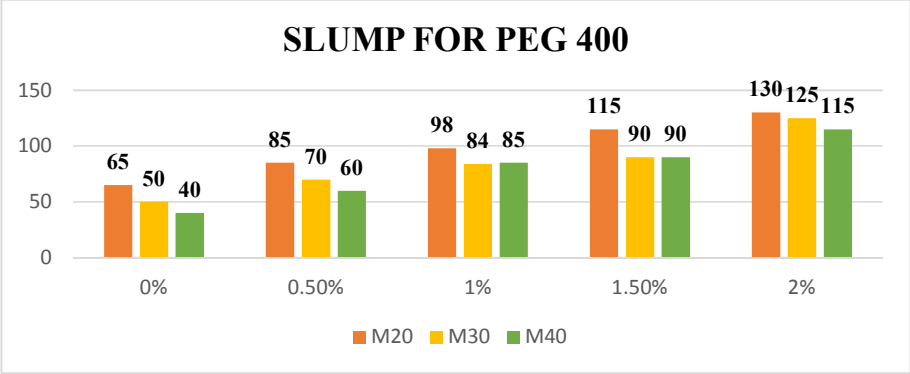
Mix	PEG 400 % of cement	PEG (Kg/m^3)	Cement (Kg/m^3)	Fine aggregate (Kg/m^3)	Coarse aggregate (Kg/m^3)	Water (lit/m^3)
CC	**0%**	0	421	804.4	1064.0	151.81
Mix-1	**0.5%**	2.1	421	804.4	1064.0	151.81
Mix-2	**1.0%**	4.2	421	804.4	1064.0	151.81
Mix-3	**1.5%**	6.3	421	804.4	1064.0	151.81
Mix-4	**2.0%**	8.4	421	804.4	1064.0	151.81

4 RESULTS AND DISCUSSIONS

4.1 Slump Test

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 are Slump cone and tamping rod.

Graph: 4.1. Slump Cone Test Results PEG 400

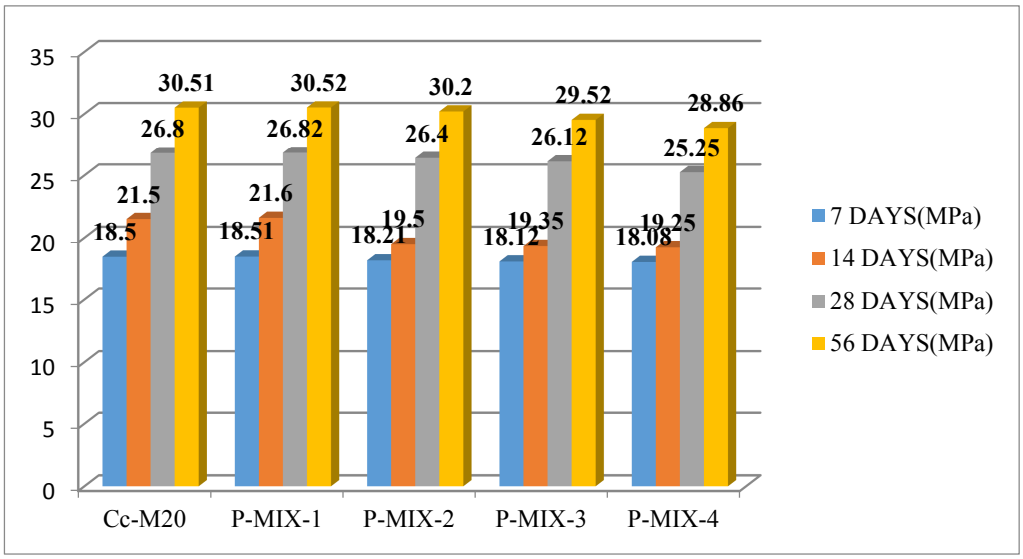


4.2 COMPRESSIVE STRENGTH TEST

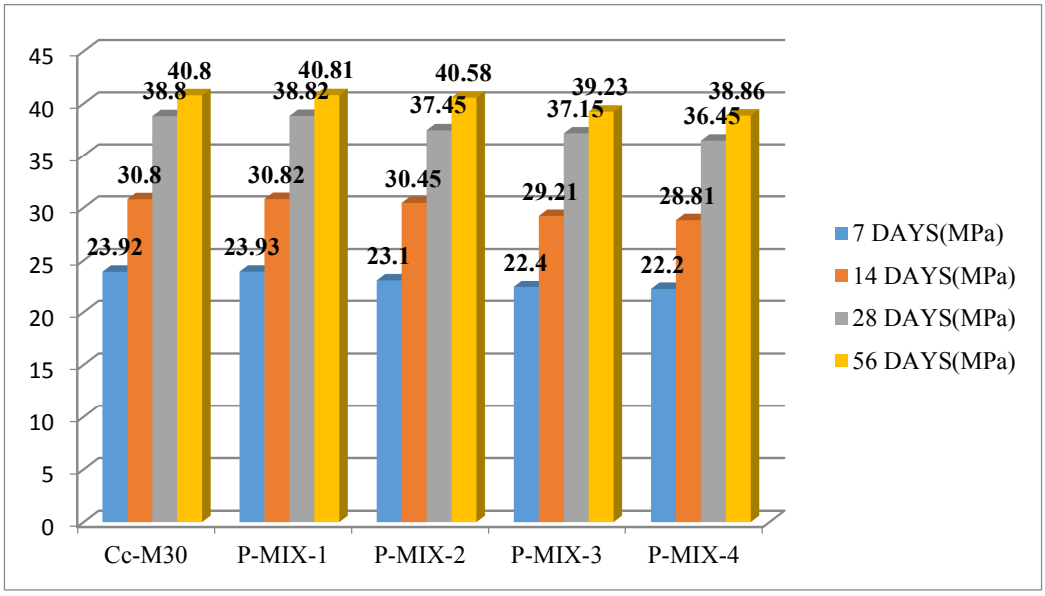
Compressive strength depends on loads of factor such as w/c ratio; cement strength, excellence of concrete material and excellence control during manufacture of concrete. These cubes are tested by compression testing machine after 7 days, 14 days or 28, 56 days curing. The sample is placed centrally on the base plate of machine and the load have to be apply gradually at the rate of 140 kg/cm^2 per minute till the specimen fails. Load at the failure separated by area of sample gives the compressive strength of concrete. The sample to increased load breaks down and no greater load greater load can be constant. The maximum load applied to specimen shall then be recorded and any unusual value noted at the time of failure brought out in the report.

The cube compressive strength, then f_c=P/A N/mm^2

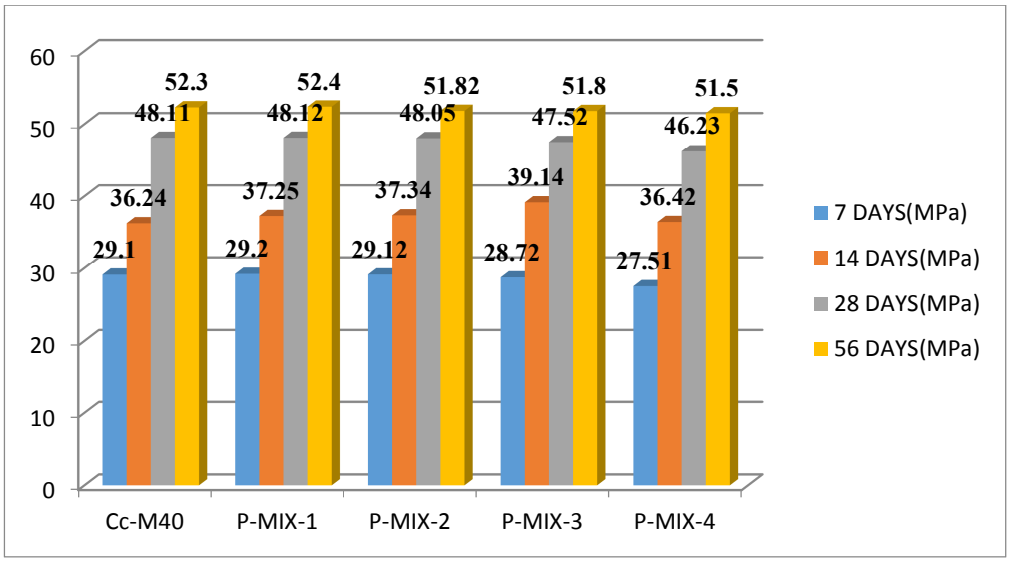
Graph: 4.2. Compressive strength of concrete with mix design of M20 (PEG)



Graph: 4.3Compressive strength of concrete with mix design of M30 (PEG)



Graph: 4.4Compressive strength of concrete with mix design of M40 (PEG)



4.2 SPLIT TENSILE STRENGTH TEST

The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack.

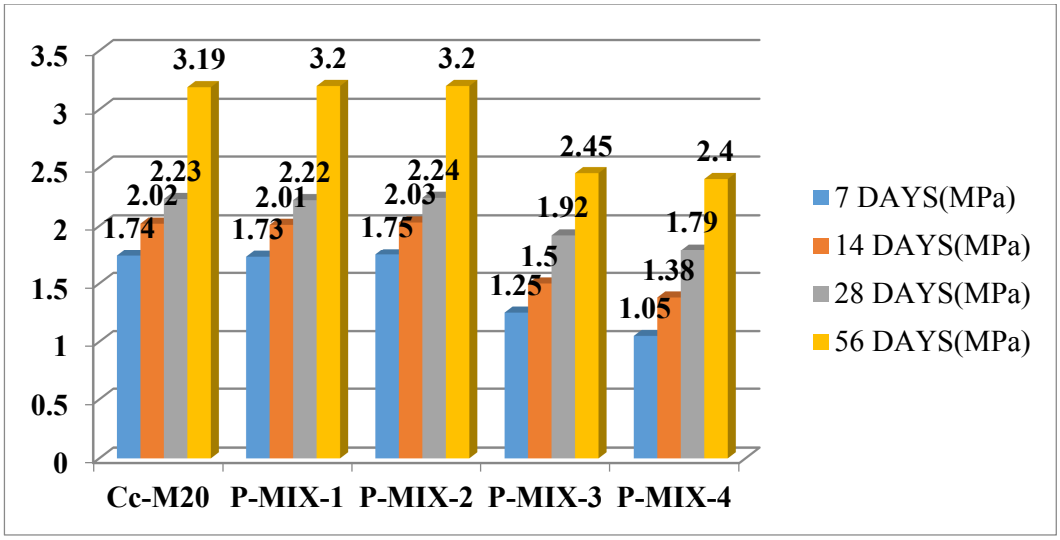
Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. Split tensile strength test was conducted by using the method prescribed by IS5816-1999. Cylinders of 150mm×300mm were used for this test. The specimens was tested for 7, 14, 28 days the cylinder specimen was placed in horizontal direction on the testing machine.

The splitting of cylinder is shown in figure. The following relation is used to find out the spilt tensile strength of cylinder

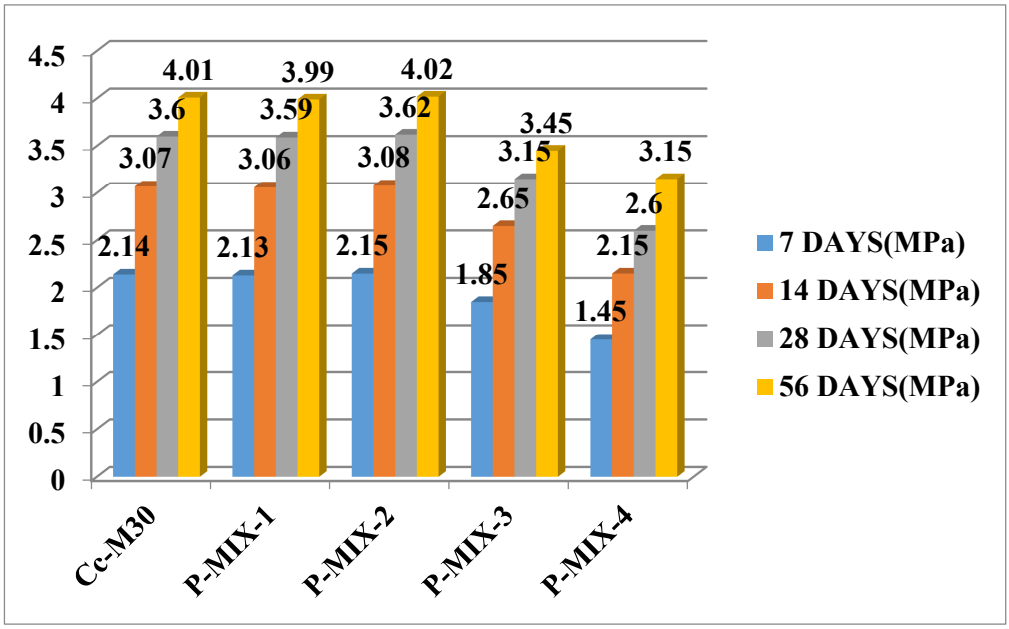
$$f_t = \frac{2P}{\pi DL}$$

Where Ft is split tensile strength,
P= Ultimate load in KN
L = Length of the cylinder in mm, D = Diameter of the cylinder in mm.

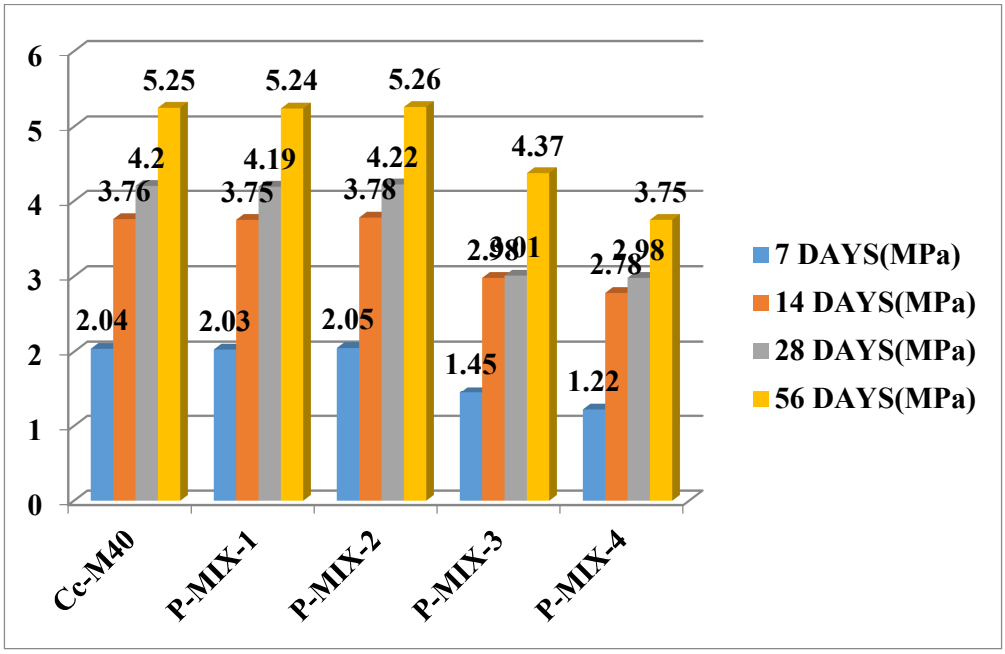
Graph: 4.5 Split tensile strength of concrete with mix design of M20 (PEG)



Graph: 4.6 Split tensile strength of concrete with mix design of M30 (PEG)



Graph: 4.7 Split tensile strength of concrete with mix design of M40 (PEG)

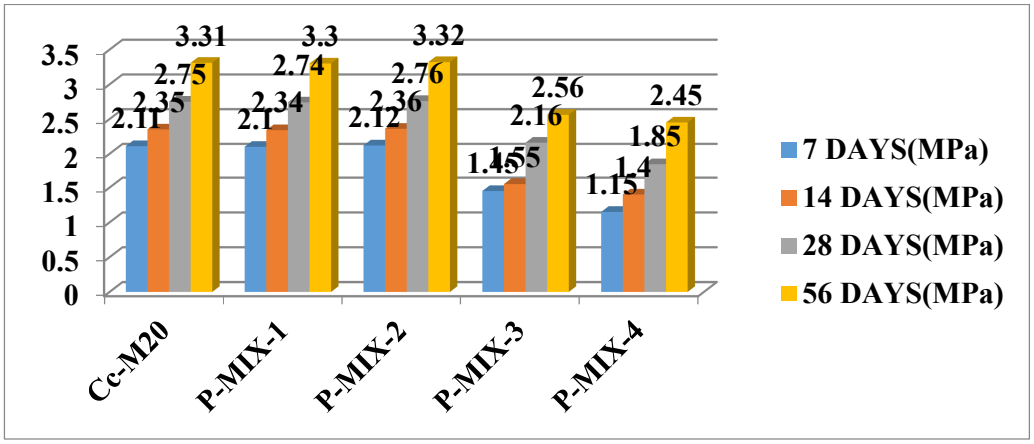


4.3 FLEXURE STRENGTH TEST

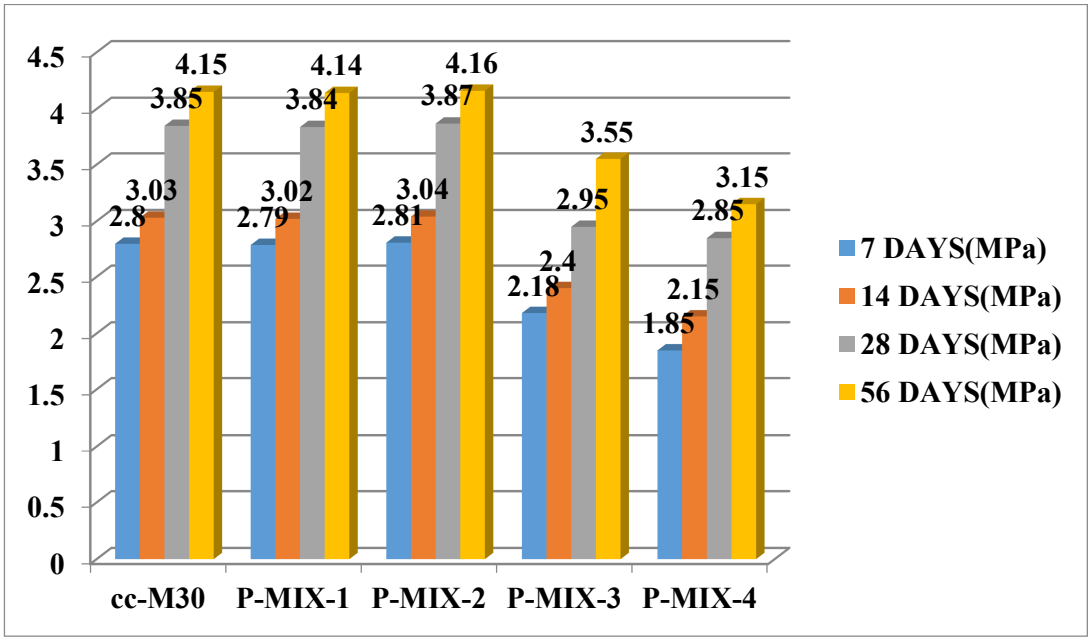
Flexural strength test concrete beam to determine the strength of concrete. Flexural strength test was conducted by using the method prescribed by IS 516 – 1959. Beams of dimension 700mm×150mm×150mm were used for this test, the test specimen is placed in the machine at the bearing surfaces of the supporting and loading rollers. So that the load shall be applied without shock and increasing continuously at a stress increases at approximately 7 kg/sq mm that is at a rate of loading 400 kg/min for the 150 mm specimens. The load shall be increased until the specimen fails, and the maximum load applied to the specimen during the test shall be recorded.

Where, Modulus of rupture $f = PL/BD^2$

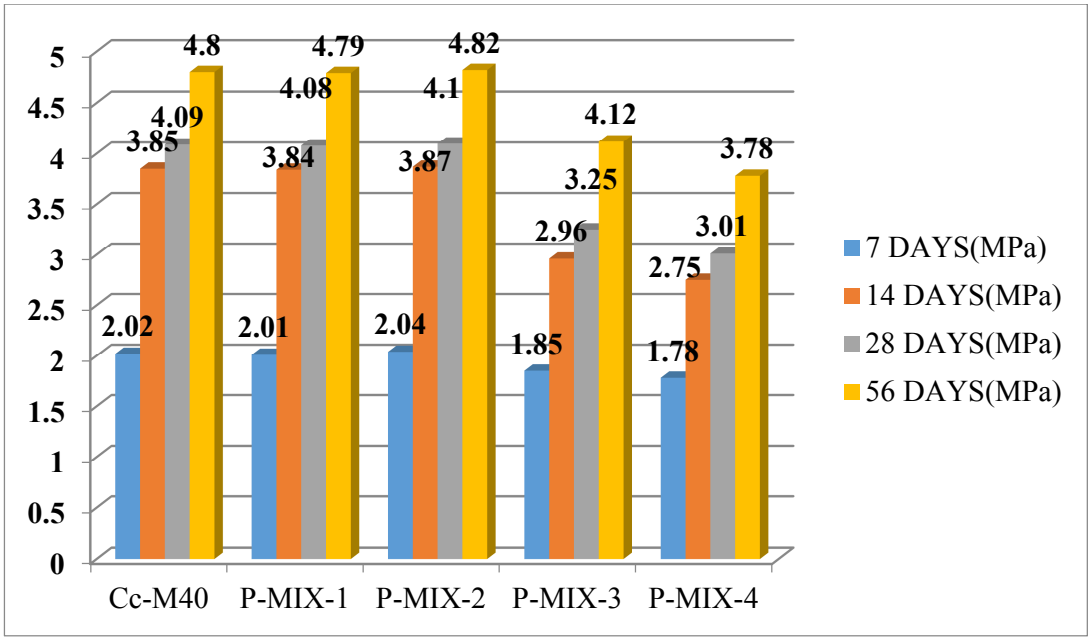
Graph: 4.8 Flexural strength of concrete with mix design of M20 (PEG)



Graph: 4.9 Flexural strength of concrete with mix design of M30 (PEG)



Graph: 4.10. Flexural strength of concrete with mix design of M40 (PEG)



5 CONCLUSIONS

The self-curing agent PEG-400was found to be effective. It was found that every grade of concrete has same optimum percentage of dosage for a given type of mechanical property. The results can be summarized as follows:

1. Compressive strength of self-cured concrete for dosage of 0.5% was higher than water cured concrete.
2. Split tensile strength of self-cured concrete for dosage of 1.0 % was higher than water cured concrete.
3. Flexural Strength of self-cured concrete for dosage of 1.0 % was lower than water cured concrete

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