

AN EXPERIMENTAL INVESTIGATION ON INTERNALLY CURED CONCRETE

Submitted in partial fulfillment of the requirements

For the degree of

Bachelor of Engineering

By

Mr. Bhadki Safwan Mohd.Hanif (11CE10)

Mr. Bodale Ahamad Mahd. Ashraf (13CE66)

Mr. Sayyad KaleemSaleem (13CE65)

Mr. Ulde Nuh Naeem (11CE60)

(Guided by)

Prof. Mohammed Junaid Siddiqui



Department of Civil Engineering

School of Engineering and Technology

Anjuman-I-Islam's Kalsekar Technical Campus

Plot No. 2 & 3, Sector – 16, Near Thana Naka, Khandagaon,
New Panvel, Navi Mumbai. 410206

2015-2016

AN EXPERIMENTAL INVESTIGATION ON INTERNALLY CURED CONCRETE

Submitted in partial fulfillment of the requirements

For the degree of

Bachelor of Engineering

By

Mr. Bhadki Safwan Mohd.Hanif (11CE10)

Mr. Bodale Ahamad Mahd. Ashraf (13CE66)

Mr. Sayyad KaleemSaleem (13CE65)

Mr. Ulde Nuh Naeem (11CE60)

(Guided by)

Prof. Mohammed Junaid Siddiqui



Department of Civil Engineering

School of Engineering and Technology

Anjuman-I-Islam's Kalsekar Technical Campus

Plot No. 2 & 3, Sector – 16, Near Thana Naka, Khandagaon,
New Panvel, Navi Mumbai. 410206

2015-2016



CERTIFICATE

This is to certify that the project entitled “*An Experimental Investigation on Internally Cured Concrete*” is bonafide work of *Mr. Bhadki Safwan Mohd. Hanif (11CE10)*, *Mr. Bodale Ahamad Mahd. Ashraf (13CE66)*, *Mr. Sayyad Kaleem Saleem (13CE65)*, *Mr. Ulde Nuh Naeem (11CE60)* submitted to the University of Mumbai in partial fulfillment of the requirement for the award of the degree of **Bachelor of Engineering**.

Prof. Mohammed Junaid Siddiqui
Guide

Dr. Rajendra Magar
H.O.D

Dr. Abdul Razak Honnutagi
Director

Project Report Approval for B. E.

This project report entitled “*An Experimental Investigation on Internally Cured Concrete*” by *Mr. Bhadki Safwan Mohd. Hanif (11CE10)*, *Mr. Bodale Ahamad Mahd. Ashraf (13CE66)*, *Mr. Sayyad Kaleem Saleem (13CE65)*, *Mr. Ulde Nuh Naeem (11CE60)* is approved for the degree of “**Bachelor of civil Engineering**”.

Examiners

1 _____

2 _____

Supervisors

1 _____

2 _____

Director

Date:

Place:

Declaration

We declare that this written submission represents our ideas in our own words and where others ideas or words have been included; we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

Mr. Bhadki Safwan Mohd.Hanif (11CE10)

Mr. Bodale Ahamad Mahd.Ashraf(13CE66)

Mr. Sayyad Kaleem Saleem (13CE65)

Mr. Ulde Nuh Naeem (11CE60)

Date:

Acknowledgement

It is our privilege to express our sincerest regards to our project guide, Prof. Mohammed Junaid Siddiqui for his valuable inputs, able guidance, encouragement, whole-hearted co-operation and constructive criticism throughout the duration of our project. We deeply express our sincere thanks to our Head of the Department Dr. Rajendra Magar and our Director Dr. Abdul Razak Honnutagi for encouraging and allowing us to present the project on the topic “**AN EXPERIMENTAL INVESTIGATION ON INTERNALLY CURED CONCRETE**” at our department premises for the partial fulfillment of the requirements leading to the award of Bachelor of Engineering degree. We take this opportunity to thank all our professors and non-teaching staff who have directly or indirectly helped in our project, especially Prof. Dada Patil, Prof. Shafi Mujawar. We pay our respects and love to our parents and all other family members for their love and encouragement throughout our career. Last but not the least we express our thanks to our friends for their cooperation and support.

Sincere thanks are extended to

AIM Cement Agency, Panvel for providing all materials.

BASF India Ltd., Turbhe for providing Master Glenium SKY8233.

Abstract

As water is becoming a scarce material day-by-day, there is an urgent need to do research work pertaining to saving of water in making concrete and in constructions. 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. Curing of concrete plays a major role in developing the concrete microstructure and pore structure and hence improves its durability and performance. Keeping importance to this, an attempt has been made to develop internal-curing concrete by using Poly Ethylene Glycol (PEG-400). In this experimental investigation the strength characteristics of Normal Strength Concrete and high strength concrete, cast with the self-curing agent PEG-400 have been studied and compared with the corresponding conventionally cured concrete. IS method of mix design was adopted, for the normal strength internal curing concrete of grade M20 and for M50 grade of concrete is design on trial and error basis. For producing internal-curing concrete trial dosage of 1%, 2% and 3% of PEG-400 by weight of cement was used and tested. It was observed that after implementation of new technique the water consumption for curing was significantly reduced by 100%.

Index Terms – Internally cured concrete, self-curing concrete, self-curing agent, PEG-400.

Chapter 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 improvement. 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 curing to achieve required strength. So it 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 modern concrete, which cure itself by retaining water (moisture content) in it.

As water is becoming a scarce material day-by-day, there is an urgent need to do research work pertaining to saving of water in making concrete and in constructions. Curing of concrete place a major role in developing the strength and hardness of concrete, which lead to improvement in durability and performance. Curing of concrete is maintaining satisfactory moisture content in concrete during its early ages in order 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 occurs which results cracking. Therefore it is necessary to provide water as curing for some fix duration. Practically good curing is not achievable in many cases due to unavailability of good quality water and many other practical difficulties.

In the past few decades internal curing of concrete has gained popularity and its steadily progressing from laboratory field of practice. Internal curing refer to the process by which the Hydration of cement occurs because of availability of additional internal water that is not part of the mixing water; “INTERNALCURING” is often also referred as self-curing.

Internally cured concrete can be achieved by adding SELF CURING AGENTS. The concept of internally cured agents is to reduce the water evaporation from the concrete and hence increasing the water retention capacity of the concrete. But it is necessary to give some brief explanation about different water retaining methods which are as follows.

1.1 Types of Curing:

The following are the types of curing:

1.1.1 Water Retaining Techniques:

Water retaining techniques include Membrane forming curing compound, plastic sheeting.

1.1.1.1 Curing compound:

Various types of curing compound are available in the market, mainly includes water-based, resin solvent based, chlorinated rubber, wax based etc. Water based curing compound shown in figure 1.1 is most used curing compound world-wide.



Fig1.1: spraying of curing compound

1.1.1.2 Plastic Sheet

Plastic sheets shown in figure 1.2 such as polyethylene film are used to cure concrete. Polyethylene films are lightweight, impervious hence prevent the moisture movement from the concrete and can be applied to simple as well as on complex shapes. Major disadvantage of this type of curing is that it causes patchy discoloration especially if the concrete contains calcium chloride.



Fig 1.2: Plastic sheet curing

1.1.2 Water adding techniques

Water adding techniques include Pounding or immersion, spraying or fogging and saturated wet covering.

1.1.2.1 Ponding or immersion:

Ponding or immersion shown in figure 1.3 is a curing method wherein the flat concrete surfaces such as slabs and pavements are cured by ponding of water around the perimeter of the surface with the help of sand dikes. It is an effective method as it maintains a uniform temperature in the concrete and also prevents the loss of the moisture from the concrete.



Fig1.3: Curing of concrete by Ponding

1.1.2.2 Fogging or Sprinkling:

Fogging or Sprinkling shown in figure 1.4 is a curing method wherein a fine fog mist is frequently applied on the surface of the concrete through a system of sprayers or nozzles. It is an effective method of curing when the humidity is low or the ambient temperature is well above the freezing point. This method requires ample of water and a proper supervision.



Fig 1.4: Curing by sprinkling method

1.1.2.3 Saturated Wet Curing

Saturated wet covering shown in figure 1.5 is most often used curing method in the construction industry. In this method moisture retaining fabrics such as burlap cotton mats and rugs are used as wet covering to keep the concrete in a wet condition during the curing period, the water will be absorb from the wet covering . Alternative cycles of wetting and

drying during the early period of curing will cause cracking of the surface. The major disadvantage of this method is discoloring of concrete



Fig 1.5: saturated wet curing

1.2 Aim and Objective of the Project:

- The aim and objective is to study the effect of polyethylene glycol (PEG 400) on strength characteristics of concrete.
- The objective is to study the mechanical characteristic of concrete i.e. compressive strength by varying the percentage of PEG from 0% to 3% by weight of cement for both M20 and M50 grade of concrete.

1.3. Scope of the work:

Based on the aim and objective mentioned in the preceding sections, the scope of the present investigation is outlined as under:

- Curing is the important Process as far as concrete structure is concern it requires 28 days of watering under congenial atmosphere. This is good in the sub-urban region like Mumbai but issue enhanced in the arid region where there is scarcity of water.
- This issues leads to research on curing process which requires less or no water for curing without compromising with its compressive strength.
- Thus above challenge can be overcome with the help of internally cured concrete which can be achieved by adding self-curing additives such as PEG-400.

- Hence, the scope of the work or research is to study the mechanical characteristics of concrete such as compressive strength, by varying the percentage of PEG-400 from 0% to 3% by weight of cement for M20 and M50 grade of concrete.

1.4 Internally Cured Concrete:



Fig 1.6: Internally Cured Concrete Cubes

Primary requirement of fast-track construction is high early strength in concrete. Early age concrete strength without costly heat treatment is of greater significance in the construction industry. The mechanism of self-curing can be explained as follows: Continuous evaporation of moisture takes place from an exposed surface due to the difference in chemical potentials (free energy) between the vapour and liquid phases. The polymer added in the mix mainly form hydrogen bonds with water molecules and reduce the chemical potential of the molecules which reduces the vapour pressure and retention in physical moisture occurs. This reduces the rate of evaporation from the surface. Internal-Curing concrete is the newly emerging trend in the construction industry. Water soluble alcohols are general used as self-curing agents. With conventional ingredients it is possible to design reasonably good fast track concrete mixture using admixture.

1.4.1 Advantages of Internally Cured Concrete:

- Each one cubic meter of concrete requires about 3m³ of water (K.vedhsakthi et. al. IJERT volume: 03 Issue 10 Oct 2014) for construction most of which is for curing. As internal curing concrete will not require water for curing, there will be enormous saving of water.
- Internally cured concrete is a good solution for the water scarcity region.
- As there is no requirement of labour for curing so it reduces the cost of labour required for curing.
- It is a good solution for the high rise buildings and complicated structure where curing is difficult.
- It is good solution for the external curing deficiencies generated due to many practical difficulties or by human during the initial hours when curing is required the most.
- Eliminates largely autogenous shrinkage.
- In case of large structure improper curing can be prevented using internally cured concrete.
- As it achieves strength of 28 Days in 7 Days only so it can be used for highways Construction, as highways construction demands early openings of the pavements.

1.4.2 Limitation of Internally Cured Concrete:

- Proper and Accurate supervision is needed while adding self-curing agent.
- Adding excess amount of Self-Curing agent may decrease the strength of concrete.
- Trails and Error is only method found till yet in deciding the dosage of Self-Curing agent
- It might take time in selecting the optimum dosage of Self curing agent as there is no IS method till yet in selecting the dosage of Self-curing agent.

Chapter 2

Literature Review

There are numerous studies that have been reported in the literature in respect of internally cured concrete. Some of the significant contributions are briefly mentioned in the literature.

Swamy *et. al.* (1990)²⁵ presented a simple method to obtain a 50MPa 28-day strength concrete having 50 and 65 percent by weight cement replacement with slag having a relatively low specific surface. The compressive and flexural strengths and the elastic modulus of these two concretes as affected by curing conditions are then presented. Without any water curing, concrete with 50 percent slag replacement reached nearly 90 percent of its target strength of 50MPa at 28 days 14 and continued to show modest strength improvement up to 6 months. The results emphasized that even 7day wet curing was inadequate for high levels of slag replacement, and that continued exposure to a drying environment can have adverse effect on the long-term durability of inadequately cured slag concrete.

Dhir *et. al.* (1996)⁴ reported that during the development of internally cured concrete, it was found that one particular self-curing admixture produce a number of effects with respect to particular physical properties and powder X-RAY diffraction characteristics. Two computer models, at low dosages, good strength and improved permeability characteristics were observed. At high dosages it appears that the admixture has a detrimental effect on the concrete's compressive strength due to an alteration of the natural of calcium hydroxide and the C-S-H gel structure was alter beneficially producing a highly impermeable concrete it is

Suggested that although a lowering of strength did occur at high dosage, a much lower permeability of given strength could be obtained.

Hans W. Reinhardt *et. al.* (1998)⁶ they demonstrated on self-cured high Performance concrete that a partial replacement of conventional weight aggregates by pre-wetted lightweight aggregates leads to an internal water supply for continuous hydration of cement. Despite water loss by evaporation there is continuous strength gain up to 25% more strength after 1 year compared to standard compressive testing after 28 days. Normal weight aggregate concrete reached considerably less strength at the same storage condition. Application of such concrete in practice means that no curing due to bad workmanship would not impair the concrete, i.e., it would be robust during construction. Current research deals with transport properties (diffusion, permeability) and long term strength.

Roland Tak Yong Liang, Robert Keith Sun (2002)²² carried work on internal curing composition for concrete which includes a glycol & a wax. The invention provides for the first time an internal curing composition which, when added to concrete or other cementitious mixes meets the required standards of curing as per Australian Standard AS 3799.

Cano Barrita *et. al.* (2004)² evaluated high performance concrete mixtures that can be used successfully in hot dry climates. In this research magnetic resonance imaging(MRI) was used to measure the effectiveness of extending the moist curing period by incorporating some saturated light weight aggregates into a concrete mixture being placed in hot dry climatic conditions. A series of concrete mixtures were prepared and moist cured for 0, 0.5, 1or 3 days, or by using a curing compound, followed by air drying at 38°C and 40% relative humidity. To accomplish this, 11% by volume of the total aggregate content was replaced with lightweight aggregate. Type I white Portland cement and quartz aggregate plus the lightweight aggregate were all selected for their low iron content to minimize adversely affecting the MRI measurements. The concrete mixtures were low strength concrete (W/C=0.60), self-consolidating concrete (W/C=0.33 containing 30% fly ash), and high strength concrete (W/ C=0.30 containing 8% silica fume).

Ole Mejlhede Jensen (2006)¹⁹ describe a new concept for the prevention of desiccation in hardening cement-based materials using fine, super absorbent polymer (SAP) particles as a concrete admixture. The SAP will absorb water & form macro inclusions & this leads to water entrainment i.e. the formation of water-filled macro pore inclusions in the fresh concrete. Consequently, the pore structure is actively designed to control self-desiccation.

Tarun R. Naik et. al. (2006)²⁶ Influence of microstructure on the physical properties of self-curing concrete has been studied. The Potential benefits from concrete using lightweight aggregate include: Better thermal properties, Better fire resistance, improved skid-resistance, reduced autogenous shrinkage, reduced chloride ion penetrability, improved freezing and thawing durability, an improved contact zone between aggregate and cement matrix and less micro-cracking as a result of better elastic compatibility.

EI-Dieb (2007)⁵ investigated water retention of concrete using water-soluble polymeric glycol as self-curing agent. Concrete weight loss & internal relative humidity measurements with time were carried out to evaluate the water retention of self-curing concrete. Water transport through concrete is evaluated by measuring absorption %, permeable voids %, water sorptivity & water permeability. The water transport through self-curing concrete is evaluated with age. The effect of the concrete mix proportions on the performance of self-curing concrete were investigated, such as cement content & water/cement ratio.

Md. Safiuddin et. al. (2007)¹⁵ carried out experiments to study the effect of this types of curing on the properties of Micro silica Concrete (Micro silica was used as a 10% weight replacement of cement) with a water binder ratio of 0.35. Dry-air curing produced 15.2%, 6.59% and 3.36% reduction in compressive strength, dynamic modulus of elasticity and ultrasonic pulse velocity respectively, this was owing to the early drying of concrete which virtually ceased hydration of the cement because the relative humidity within capillaries drop below 80% (**Neville 1996**) and thus the formation of major reaction product Calcium silicate hydrate the major strength providing and porosity reducer stops before the pores are adequately blocked by it. Also, it caused 12.4% and 46.53% increase in initial surface absorption after 10 and 120 minutes respectively. This might be due to micro cracks or shrinkage cracks resulting from the early drying out of the concrete (**Fauzi 1995**)

Pietro Lura(2007)²⁰ The main goal of his study was to reach a better comprehension of autogenous shrinkage in order to be able to model it & possibly reduce it. Once the important role of self-desiccation shrinkage in autogenous shrinkage is shown, the benefits of avoiding self-desiccation through internal curing become apparent.

N.Yazdani et. al. (2008)¹⁸ presented a study on accelerated curing of silica fume concrete. It is a common addition to high-performance concrete mix designs. The use of silica fume in concrete leads to increased water demand. For this reason, Florida Department of Transportation (FDOT) allows only a 72-h continuous moist cure process for such mixed concrete. Accelerated curing has been shown to be effective in producing high-performance

characteristics at early ages in silica-fume concrete. Hence dehydration takes place, which may cause shrinkage problems. An experimental study was undertaken to determine the feasibility of steam curing of FDOT concrete with silica fume in order to reduce precast turnaround time. Various steam-curing durations were utilized with small laboratory specimens. The concrete compressive strength, surface resistivity, and shrinkage were determined for various durations of steam curing. Results indicate that steam cured silica-fume concrete met all FDOT requirements for the 12, 18, and 24 h of curing periods. The steam-cured specimens displayed low to very low and very low chloride ion permeability at 28 and 364 days of age, respectively. Greater surface resistivity indicates lower chloride ion permeability and increased long-term durability of concrete; all steam cured samples demonstrated excellent durability up to 1 year of age. It was recommended that FDOT allow 12 h steam curing for concrete with silica fume.

C.Selvamony et. al. (2010)³ investigated on self-compacted self-curing Concrete using limestone powder and clinkers. In this study, the effect of replacing the cement, coarse aggregate and fine aggregate by limestone powder (LP) with silica fume(SF), quarry dust(QD) and clinkers respectively and their combinations of various proportions on the properties of SCC has been compared. Fresh properties, flexural and compressive strength and water absorption of concrete were determined. The use of SF in concrete significantly increase the dosage of super plasticizer (SP). At the same constant SP dosage (0.8%) and mineral additives content (30%), LP can better improve the workability then that of control and fine aggregate mixture by (5% to 45%). However the results of this study suggested that certain QD, SF and LP combination can improve the workability of SCCs, more QD, SF and LP alone. LP can have influence on the mechanical performance at early strength development while SF improved aggregates matrix bond resulting from the formation of a less porous transition zone in concrete. SF can better reducing effect on total water absorption while QD and LP will not have the same effect at 28 days.

Ravi Kumar M.S. et. al. (2011)²¹, an experimental investigation was conducted to make a comparative study on the properties of High Performance Concrete with kiln ash (25% and 50% replacement) and without kiln ash (control concrete) in conventional and aggressive environment using self-curing instead of water curing. It is concluded that high performance kiln ash internally cured concrete performs well both in normal and aggressive condition when compared to control cement concrete without kiln ash.

Wen-Chen Jau (2011)²⁷ stated that self-curing concrete is provided to absorb water from moisture from air to achieve better hydration of cement in concrete. It solves the problem when the degree of cement hydration is lowered due to no curing or improper curing by using self-curing agent like poly-acrylic acid which has strong capability of absorbing moisture from atmosphere & providing water required for curing concrete.

Mateusz Wyrzykowski et. al. (2012)¹³, analyzed the modeling of water migration during internal curing with superabsorbent polymers. The SAP are supposed to be uniformly distributed in the concrete and act as internal water reservoirs, which first absorb water during mixing and release it to the surrounding cement paste. By adding SAP, it is possible to provide water curing in low water-to-cement ratio (w/c) mixtures.

John Roberts et. al. (Jan, 2013)⁷ demonstrated internal curing improves flexural and compressive strength of pervious concrete. The internally cured sections did not receive poly protection or any special curing, other than internal. The use of LWAS improved the flexural strength by 150% and the compressive strength by 200%. The LWAS used was preconditioned and meets ASTM C330 and C33 (except for gradation). Replacements were 50, 100, and 150 pounds of LWAS per cubic yard, and only the control slab received standard curing with a 6 mil poly covering for 14 days. The characteristics desired in Pervious Concrete used in infiltration systems is optimized with the choice of materials, the execution of procedures, and the proper treatment and curing of the concrete. They provided the procedure for ascertaining the proper amount of saturated LWAS to use to bring improved flexural and compressive strength in pervious concrete.

Nirav R Kholia et. al. (2013)¹⁷ the properties of hardened concrete, especially the durability, are greatly influenced by curing since it has a remarkable effect on the hydration of the cement. The advancements in the construction and chemical industry have paved way for the development of the new curing techniques and construction chemicals such as Membrane curing compounds, Self-curing agents, Wrapped curing, Accelerators, Water proofing compounds etc. With the growing scale of the project conventional curing methods have proven to be a costly affair as there are many practical issues and they have been replaced by Membrane curing compounds and Self-curing agents up to some extent as they can be used in inaccessible areas, Vertical structures, Water scarce areas etc. It is most practical and widely used curing method. In this review paper effort has been made to understand the working and efficiency of curing methods which are generally adopted in the construction industry and compared with the conventional water curing method. Conventional water curing is the most

efficient method of curing as compared to Membrane curing, Self-curing, Wrapped curing and Dry air curing methods. Using Membrane curing and Self-Curing methods one can achieve 90% of efficiency as compared to Conventional Curing method. Self-Curing method is most suitable for high-rise buildings especially in columns and inaccessible areas. Membrane curing compounds are most practical and widely used method it is most suitable in water scarce area. Wrapped curing is less efficient than Membrane curing and Self-Curing it can be applied to simple as well as complex shapes. Dry-Air curing should be avoided at the construction sites because designed design strength is not achieved by this method. The average efficiency of the curing compound increases with curing age initially by reduces at later age. Application of the curing compound is significantly dependent on the time of application of the compound.

Amal Francis k et. al. (2013)¹ the scope of the research included characterization of super absorbent polymer for use in self-curing. Experimental measurements were performed on to predict the compressive strength, split tensile strength and flexural strength of the concrete containing Super Absorbent Polymer (SAP) at a range of 0%, 0.2%, 0.3%, and 0.4% of cement and compared with that of cured concrete. The grade of concrete selected was M40.

Nirav R Kholia et al (2013)¹⁶ found out the effect on concrete by different curing method and efficiency of curing compounds. Primary requirement of fast-track construction is high early strength in concrete. Early age concrete strength without costly heat treatment is of greater significance in the construction industry (**Cangiano et. al, March 2009**). **Gowripalan et. al. (2001)**, the mechanism of self-curing can be explained as follows: “Continuous evaporation of moisture takes place from an exposed surface due to the difference in chemical potentials (free energy) between the vapour and liquid phases. The polymer added in the mix mainly form hydrogen bonds with water molecules and reduce the chemical potential of the molecules which in turn reduces the vapour pressure. Physical moisture retention also occurs. This reduces the rate of evaporation from the surface” Self-Curing concrete is the newly emerging trend in the construction industry. Water soluble alcohols are general used as self-curing agents. With conventional ingredients it is possible to design reasonably good fast track concrete mixture using admixture. (**Vilas et al 2012**). **Nagesh** carried out an experimental study to investigate the use of water soluble polyvinyl alcohol as a self-cutting agent. He concluded that Concrete mixes incorporating self-curing agent has higher water retention and better hydration with time as compared to conventional concrete. Use of 0.48% of polyvinyl alcohol by the weight of cement as a self-curing agent provides higher compressive, flexural as well as tensile strength than the strength of conventional mix.

With increase in the percentage of polyvinyl alcohol there is a reduction the weight loss of concrete. Efficiency of the self- cured concrete is 92.5% as compared to the conventional standard water curing method (**Raghavendra et. al. 2012**), Using Membrane curing and Self-Curing methods one can achieve 90% of efficiency as compared to Conventional Curing method. Self-Curing method is most suitable for high-rise buildings especially in columns and inaccessible areas. Membrane curing compounds are most practical and widely used method it is most suitable in water scarce area. Wrapped curing is less efficient than Membrane curing and Self-Curing it can be applied to simple as well as complex shapes. Application of the curing compound is significantly dependent on the time of application of the compound Curing of concrete is mostly governed by two parameters Temperature and Period

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.

Magda I. Mousa et. al. (2014)¹¹ the mechanical properties of concrete containing self-curing agents are investigated in his paper. In this study, two materials were selected as self-curing agents with different amounts, and the addition of silica fume was studied. The self-curing agents were, pre-soaked lightweight aggregate (LECA) and polyethylene-glycol PEG (CH). The result shows that concrete used polyethylene-glycol as self-curing agent, attained higher values of mechanical properties than concrete with saturated LECA.

Ya Wei et al (2014)²⁸ investigated on internal curing efficiency of prewetted LWFAS on Concrete Humidity and Autogenous Shrinkage development. To better utilize internal curing technology for durable concretes, this study investigates the microstructure and the Desorption properties of sintered fly ash and expanded shale LWFAs. The influences of these two types of LWFAs on autogenous shrinkage and internal RH development were experimentally evaluated in concrete with w/c of 0.3 and 0.4.

Siddiqui M. Junaid et. al. (2015)²⁴ presented the use of shrinkage reducing admixture i.e. polyethylene glycol (By adding 1% & 1.25% of PEG-4000 by weight of cement) in M40 grade of concrete (Grade ratio =1:2.23:3.08) which helps in self-curing with better hydration which reduces shrinkage cracks and hence increases strength and is compared with that of conventional cured concrete of the same grade.

2.1 Self Curing Agents (PEG-400):

Polyethylene Glycol (PEG), also known as Polyethylene Oxide (PEO) or Polyoxyethylene (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 $H(OCH_2CH_2)_nOH$, 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 nature. Polyethylene glycol is non-toxic, odorless, neutral, lubricating, non-volatile and non-irritating and is used in a variety of pharmaceuticals. The behavior of Polyethylene glycol is shown in Fig 2.1.(a)

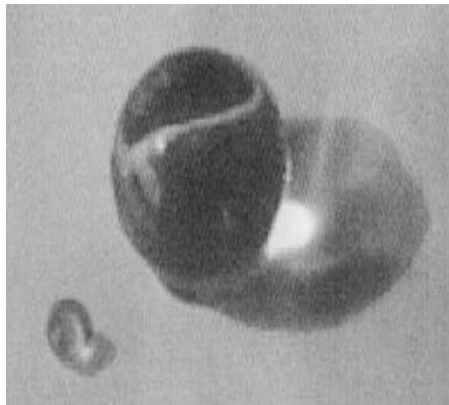


Fig (a)



Fig (b)

Fig 2.1 (a) & (b): PEG-400

2.1.1 Properties:

- Molecular weight: 380-420
- Hydroxyl value : 265-295
- Specific gravity : 1.12-1.13
- Appearance : clear liquid
- Nature : water soluble
- Molecular formula : $HO(C_2H_4O)_nH$

Where n is a average number of repeating oxyethylene groups

- Shelf life : 5years
- pH value: 6-7 at 10g/l at 23°C
- Density : $1.125g/cm^3$

2.1.2 Behavior of PEG in Concrete:

When water is mixed with dry concrete it starts reacting with the cement and heat of hydration takes place due to which exothermal heat is generated. This causes shrinkage cracks at its early stage. At the same time evaporation of water takes place and that's why cracks are formed.

When PEG is added to concrete it forms a shell around water particles and water is entrapped between these shells. These shells are formed on every water particle present in the concrete. The thicknesses of these shells are around 2nm. Due to formation of this shell water is not able to evaporate from concrete this reduces rate of evaporation and water is always available at the time period when heat of hydration is going on. Due to this early age shrinkage cracks will not form. As evaporation does not take place there is no need of water as curing for a particular period and ultimately water is saved.

2.2 Summary:

The literature shows that there are also various methods of producing an internally cured concrete. Various other methods of internal curing concrete are such as: 1) Self-curing/Internally cured concrete by light weight aggregate (LWA) 2) Self-curing/Internally cured concrete by super absorbent polymers (SAP) 3) Self-curing/Internally cured concrete by chemical admixture poly-acrylic acid 4) Use of polyvinyl alcohol by weight of concrete as internal curing agents 5) Use of plasticizers with LWA 6) Use of PEG 4000 with LWA and some more. As various other methods of internal curing or self-curing mentioned above were already been used hence referring such literature a unique attempt was adopted to use PEG-400 as the only curing agent as a admixture as no works on PEG-400 is been found yet. PEG-400 is also a liquid state agent which makes it different from PEG-4000 which is a powder form admixture. The molecular weight of PEG-400 is also less than the molecular weight of PEG 4000 so the comparison of both the methods, its cost and other aspects was also done with this experiment which results in a useful and beneficial conclusion.

So effort is made in this investigation to produce an internally-cured concrete and comparing it with the conventional cured concrete by adopting a water retaining curing technique using self-curing agent "polyethylene glycol 400" as the only admixture by varying the dosage of PEG 400 by 1%, 2%, 3% weight of cement for M20 and M50 grade of concrete which results in internal curing and in better hydration.

Chapter 3

Methodology

3.1 Experimental Programme:

The experimental program was designed to investigate the strength of internally cured concrete by adding polyethylene glycol PEG-400 @ 1%, 2% and 3% by weight of cement to the concrete. The experimental program was aimed to study the compressive strength. In this investigation cube compressive strength of conventionally cured normal strength and high strength concrete has been compared with normal strength and high strength internal cured concrete for this experimental program mixes of M20 GRADE and M50 GRADE as normal strength and high strength respectively were considered.

3.2 Mix Design Tests:

The test done on the materials for the mix design:

1. Sieve Analysis of fine Aggregates (IS: 2386 Part I 1963)
2. Specific Gravity of Sand (IS: 2386 Part III 1963)
3. Water Absorption of aggregates (IS: 2386 Part III 1963)
4. Specific Gravity of Coarse Aggregate (IS: 2386 Part III 1963)

3.2.1 Sieve Analysis:

Sieve analysis helps to determine the particle size distribution of the coarse and fine aggregates. This is done by sieving the aggregates as per IS: 2386 (Part I) – 1963. In this we use different sieves as standardized by the IS code and then pass aggregates through them and thus collect different sized particles left over different sieves.

Table 3.1: Sieve Analysis Observations

Sieve	Average Weight (gm.)	Percentage retained	Cumulative % retained	Cumulative % passing	IS Requirements for		Remarks
					Zone I	Zone II	
4.75 mm	38.30	3.74	-	96.26	Zone I	Zone II	ZONE I
2.36 mm	87.83	8.57	12.31	87.69	90-100	90-100	
1.18 mm	307.92	30.03	42.34	57.66	60-95	75-100	
600 μ	311.43	30.37	72.41	27.59	30-70	55-90	
300 μ	221.20	21.5/7	94.28	5.72	15-34	35-59	
150 μ	47.20	4.60	98.88	1.12	5-20	8-30	

3.2.2. Specific Gravity, Absolute Gravity and Water Absorption Test For Fine Aggregates:

Table 3.2: Test Observations of F.A

Steps	1	2
a)Weight of sample taken	2000 gm	2000 gm
b)Weight of saturated and surface dry aggregate (C)	500	500
c)Weight of pycnometer + sample + water (A)	1.8	1.81
d)Weight of pycnometer + water(B)	1.49	1.50
e)Weight of over dry sample(D)	490	493
f)Specific gravity = $D/C-(A-B)$	2.57	2.59
g)Apparent sp. Gravity= $D/D-(A-B)$	2.72	2.69
h)Water absorption % of dry $C-D/D *100$	2.04%	1.42%

Average: 1)Specific gravity =2.58

2)Water absorption=1.73%

3.2.3. Specific Gravity and Water Absorption of Coarse Aggregates:

Table 3.3: Test Observations of C.A

Steps	1
a) Weight of sample taken	1000 gm
b) Weight of Vessel + sample + water [A]	2.680
c) Weight of vessel + water [B]	2.020
d) Wt. of saturated & surface dry sampler (D)	0.970
e) Weight of oven dry sample (D)	0.940
f) Sp.gravity = $D/C-(A-B)$	2.84
g) Apparent sp. Gravity= $D/D-(A-B)$	3.13
h)water absorption % of dry $C-D/D *100$	3.19%

3.3. Mix Design:

3.3.1. M20 Grade (as per IS: 10262-2009)

A) Properties of Material Required

a) Fine Aggregate (conforming to IS: 2386 1963):

1. Specific Gravity= 2.58
2. Water Absorption=1.73%
3. Moisture Present=2%

b) Coarse Aggregate (confirming to IS: 2386 Part 1963):

1. Specific Gravity=2.84
2. Water Absorption=3.19%

c) Cement (conforming to IS: 12269-1987):

1. Specific Gravity = 3.15
2. Compressive Strength After 28 Days = 53 N/mm²

B) Procedure:

Step 1: For M20 grade of concrete standard deviation=4 N/mm² (According to table no.1 clauses 3.2.1.2, A-3&B-3 IS 10262:2009)

Step 2: Target strength = $f_{ck} + 1.65 * S.D$

$$= 20 + 1.65 * 4$$

$$= 26.6 \text{ N/mm}^2$$

Step 3: Water cement ratio: **0.55**

Step 4: (According to IS 456:2000)(clause 6.1.2, 8.2.4.1, 9.1.2)

For Mild exposure condition: Maximum water cement ratio= 0.55

And minimum cement content = 300kg/m³

Step 5: For M20 grade of concrete, 20mm nominal size of aggregate, Sand conforming to zone 1, water cement ratio 0.55, Water content per m³ for concrete is 186kg. Sand as a percentage of aggregate by absolute volume is 35%. Since the water cement ratio is 0.55 and compacting factor is 0.85.

Table 3.4: correction for water content

Change in condition of water content	Percentage adjustment required	Sand in total aggregate
Decrease in water cement ratio 0.55-0.45 = 0.1	0	+1.5
Increase in compaction factor 0.8 to 0.85= 0.05	+1	0
Total correction	+1	+1.5

After applying the above correction, the required sand content as a percentage of the total aggregate the absolute volume is $35+1.5 = 36.5\%$. Also, the required water content is $186 + ((186+1)/100) = \mathbf{187.87L}$

Step 6: Determination of cement content: the water cement ratio as 0.55 and the water content as 187.87L, and the cement content as $187.87/0.55 = \mathbf{341.58kg}$.

Step 7: Check for cement content (According to IS 456:2000) (clause 6.1.2, 8.2.4.1, 9.1.2) for durability criteria the minimum cement content for mild exposure is 300kg/m^3 . Hence the worked out cement content satisfies the required condition, and we adopt the cement content of 341.58kg. This is also less than the maximum permissible limit of 450kg/m^3 .

Step 8: The percentage of entrapped air is 2% for nominal size of aggregate 20mm. So, the absolute volume of concrete is $1-0.02 = 0.98\text{m}^3$. (As per IS 10262 Table 3)

Step 9: Determination of CA and FA content: $V = [W+(C/S_c) + (1/p)*(F_a/S_{fa})]*(1/1000)$

$$0.98 = [187.87 + (341.58/3.15) + (1/0.365)*(F_a/2.58)]*(1/1000)$$

$$F_a = \mathbf{643.83kg}$$

$$V = [W+(C/S_c) + (1/ (1-p))*(C_a/S_{ca})]*(1/1000)$$

$$0.98 = [187.87 + (341.58/3.15) + (1/ (1-0.365))*(C_a/2.84)]*(1/1000)$$

$$C_a = \mathbf{1232.97kg}$$

Step 10: This proportion is now required to be corrected to suit the site condition. Correct for surface moisture carried by sand at 2%, and for absorption of water in the case of CA at 3.19%

a) Extra quantity of water to be added for absorption in the case of CA at 3.19% =
 $1232.97 \times 3.14\%$

$$= 38.71\text{L}$$

b) Quantity of water to be deducted for moisture present in sand at 2% = $643.83 \times 2\%$

$$= 12.88\text{L}$$

The actual quantity of water required to be added = $187.87 + 38.71 - 12.88 = \mathbf{213.7L}$

The actual quantity of sand required after allowing for the mass of free moisture =
 $643.83 + 12.88 = \mathbf{656.71kg}$

The actual quantity of CA = $1232.97 - 38.71 = \mathbf{1194.26kg}$

Fraction 1: (60% of 12.5mm to 20mm) = **716.55kg**

Fraction 2: (40% of 10mm to 12.5mm) = **477.70kg**

Table 3.5: Proportion by Weight M20.

CEMENT	WATER	SAND	CA (12.5 mm TO 20mm)	CA (10mm to 12.5mm)
341.58	213.7	656.71	716.55	477.70

Table 3.6: Proportion by Ratio M20

CEMENT	WATER	SAND	CA (12.5 mm TO 20mm)	CA (10mm to 12.5mm)
1	0.62	1.92	2.09	1.4

3.3.2: M50 Grade

A) Properties of Material Required

a) Fine Aggregate (confirming to IS: 2386 Part 1963):

1. Specific Gravity= 2.58
2. Water Absorption=1.73%
3. Moisture Present=2%

b) Coarse Aggregate (confirming to IS: 2386 Part 1963):

1. Specific Gravity=2.84
2. Water Absorption=3.19%

c) Cement (conforming to IS: 12269-1987):

1. Specific Gravity = 3.15
2. Compressive Strength After 28 Days = 53 N/mm²

d) Water Reducer:

1. MASTERGLENIUM SKY 8233

B) Procedure:

Step 1: For M20 grade of concrete standard deviation=4 N/mm² (According to table no.1 clauses 3.2.1.2, A-3&B-3 IS 10262:2009)

Step 2: Target strength = $f_{ck} + 1.65 * S.D$

$$= 50 + 1.65 * 5$$

$$= 58.25 \text{ N/mm}^2$$

Step 3: Water cement ratio by curve: **0.33**

Step 4: According to IS 456:2000 (clause 6.1.2, 8.2.4.1, 9.1.2)

For Mild exposure condition: Maximum water cement ratio by table= 0.35

And maximum cement content = 450kg/m³

Step 5: For M50 grade of concrete, 20mm max size of aggregate, Size of aggregate =180/m³ (As per Table No.5, IS: 10262). As the plasticizer is proposed we can reduce water content by 20%. Now water content =180*0.8 =144kg/m³

Sand as a percentage of aggregate by absolute volume is 25%. Since the water cement ratio is 0.35 and compacting factor is 0.85.

Table 3.7: Correction for Water Content

Change in condition of water content	Percentage adjustment required	Sand in total aggregate
Decrease in water cement ratio 0.45-0.35 = 0.1	0	+1.5
Increase in compaction factor 0.8 to 0.85= 0.05	+1	0
Total correction	+1	+1.5

After applying the above correction, the required sand content as a percentage of the total aggregate the absolute volume is $25+1.5 = 26.5\%$.

Step 6: Determination of cement content: the water cement ratio as 0.33 and the water content as 144L, and the cement content as $144/0.33 = 436.36\text{kg/m}$.

Step 7: Check for cement content (According to IS 456:2000) (clause 6.1.2, 8.2.4.1, 9.1.2) for durability criteria the maximum cement content for mild exposure is 450kg/m^3 . Hence the Worked out cement content satisfies the required condition, hence we can adopt the cement content of 436.36kg/m

Step 8: The percentage of entrapped air is **2%**. So, the absolute volume of concrete is $1-0.02 = 0.98\text{m}^3$. (As per IS 10262 Table 3)

Step 9: Determination of CA and FA content: $V = [W + (C/S_c) + (1/p) * (F_a/S_{fa})] * (1/1000)$

$$0.98 = [181.83 + (436.36/3.15) + (1/0.265) * (F_a/2.58)] * (1/1000)$$

$$F_a = 452.24\text{kg}$$

$$V = [W + (C/S_c) + (1/(1-p)) * (C_a/S_{ca})] * (1/1000)$$

$$0.98 = [181.83 + (436.36/3.15) + (1/(1-0.265)) * (C_a/2.84)] * (1/1000)$$

$$C_a = 1380.75\text{kg}$$

Step 10: This proportion is now required to be corrected to suit the site condition. Correct for surface moisture carried by sand at 2%, and for absorption of water in the case of CA at 3.19%

- a) Extra quantity of water to be added for absorption in the case of CA at 3.19% =
 $1380.75 \times 3.19\% = \mathbf{44.046L}$
- b) Quantity of water to be deducted for moisture present in sand at 2% = $452.24 \times 2\%$
 $= \mathbf{9.0448L}$

The actual quantity of sand required after allowing for the mass of free moisture
 $= 452.24 + 9.044$

$= \mathbf{461.28kg}$

The actual quantity of CA = $1380.75 - 44.046 = \mathbf{1336.704kg}$

Fraction 1: (60% of 12.5mm to 20mm) = $\mathbf{802.2kg}$

Fraction 2: (40% of 10mm to 12.5mm) = $\mathbf{534.68kg}$

Proportion of Water Reducer: 0.4% BY WEIGHT OF CEMENT.

Table 3.8: Proportion by weight M50

CEMENT	WATER	SAND	CA (12.5 mm TO 20mm)	CA (10mm to 12.5mm)
436.36	144	461.28	802.02	534.68

Table 3.9: Proportion by ratio M50

Cement	Water	Sand	CA (12.5 mm to 20mm)	CA (10mm to 12.5mm)
1	0.33	1.05	1.84	1.22

3.4: Casting Details:

- Casting was done in an iron cube moulds
- The size of each cube is 150 x150 x150 mm
- 12 No. of cubes of each type for both M20 & M50 GRADE were casted.
- All Cubes of Conventional concrete mix were kept for curing and tested as per IS at 3, 7, 14 & 28 days.
- Whereas all the Non-Conventional type of mix i.e. Internally cured concrete were not kept for curing at all and were instantly kept under dry condition after taking out from the moulds and tested as per IS at 3, 7,14 & 28 days respectively.

Table3.10: Details of specimens casted

Sr No.	Days	M20				M50			
		CC	PEG 400			CC	PEG 400		
			1%	2%	3%		1%	2%	3%
1	3days	3	3	3	3	3	3	3	3
2	7days	3	3	3	3	3	3	3	3
3	14days	3	3	3	3	3	3	3	3
4	28days	3	3	3	3	3	3	3	3

*CC: Conventional Concrete

3.4.1: Moulds:



Fig 3.1: Moulds

Metal moulds preferably steel or cast iron thick enough to prevent distortion are required. They are made in such a manner as to facilitate the removal of the casted specimen without damage and are so machined that when it is assembled ready to use the dimensions and internal faces are required to be accurate within the following limits. The size of mould is 150X150X150mm. As shown in figure 3.1.

3.4.2: Compaction:

The test cube specimens are made as soon as practicable after mixing and in such a way as to produce full compacting of the concrete with neither segregations nor excessive laitance. The concrete is filled into the mould in layers approximately 5cm. Each layer is compacted either by hand or vibration. As shown in figure 3.2 & 3.3 respectively. After the top layer has been compacted the surface of the concrete is brought to the finish level with the top of the mould using a trowel.



Fig 3.2: Manual Compaction



Fig 3.3: Table Vibrator Compaction

3.4.3: Compressive Strength Test:

The test procedure was in accordance to IS: 516 - 1959. Compression test is the most common test conducted on hardened concrete partly because it is an easy test to perform and partly because most of the desirable characteristics properties of concrete are qualitatively related to its compressive strength. The test is performed on (CTM) compression testing machine As shown in figure 3.4.



Fig 3.4: Compression Testing Machine

3.4.4 Failure of Compression Specimen:

After desired duration the specimens are tested in compression testing machine. The specimen is placed in CTM and load is applied after the ultimate load the specimen is failed and load at which the specimen is failed are observed and recorded. The sample of an observed specimen is shown in figure 3.5. To get the strength at particular days the ultimate load is divided by the surface area of specimen.



Fig 3.5: Failure of Cube

Chapter 4

Results and discussion

4.1: Compressive Strength:

The various types of cubes of different mix were tested under compression testing machine (CTM) at 3 days, 7 days, 14 days & 28 days as recommended in IS code. the details of specimen tested are shown in table 4.1 and Some of the tested specimens are as shown in figure 4.1 & 4.2.

Table4.1: Details of specimens tested

Sr no.	Days	M20				M50			
		CC	PEG 400			CC	PEG 400		
			1%	2%	3%		1%	2%	3%
1	3 days	3	3	3	3	3	3	3	
2	7days	3	3	3	3	3	3	3	
3	14dayS	3	3	3	3	3	3	3	
4	28days	3	3	3	3	3	3	3	

*CC: CONVENTIONAL CONCRETE



Fig 4.1: Tested Specimen

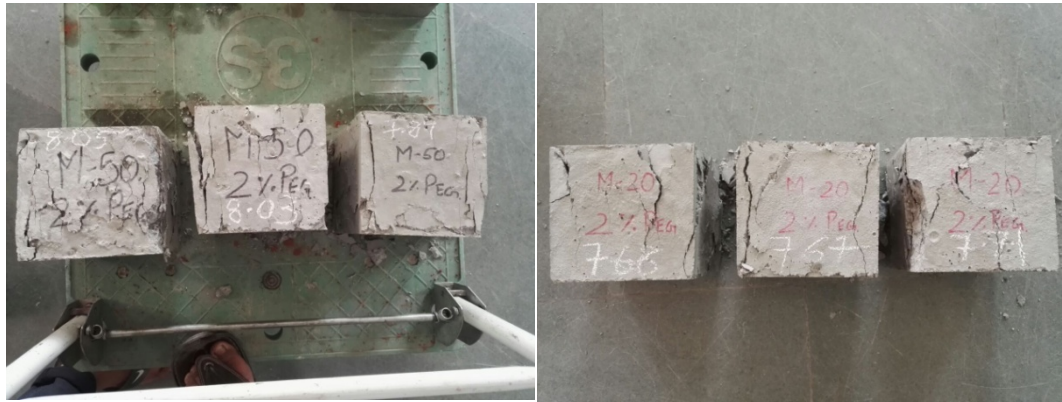


Fig 4.2: Specimen after Test

The average compressive strength of conventional cured and internally cured concrete work found out using compressive strength testing machine. The results are shown the following table.

Table 4.2: compressive strength results

Grade	Mix	Average compressive strength(N/mm ²)			
		3 days	7days	14days	28 days
M20	CC	14.56	15.82	18.32	24.53
	1% PEG	19.43	20.46	22.8	25.93
	2% PEG	14.66	18.8	21.10	23.13
	3% PEG	12.33	14.53	17.23	20.96
M50	CC	31.96	35.02	40.39	51.13
	1% PEG	34.02	42.24	46.29	53.20
	2% PEG	35.09	47.15	50.42	56.98
	3% PEG	31.81	38.13	43.52	52.23

4.2: Graphs:

Graphical representation of all the above results with respect to different dosage of PEG-400 and conventional concrete are as follows:

4.2.1: M20 Grade: Graphs plotted for 3, 7, 14, 28 Days are shown in figures below.

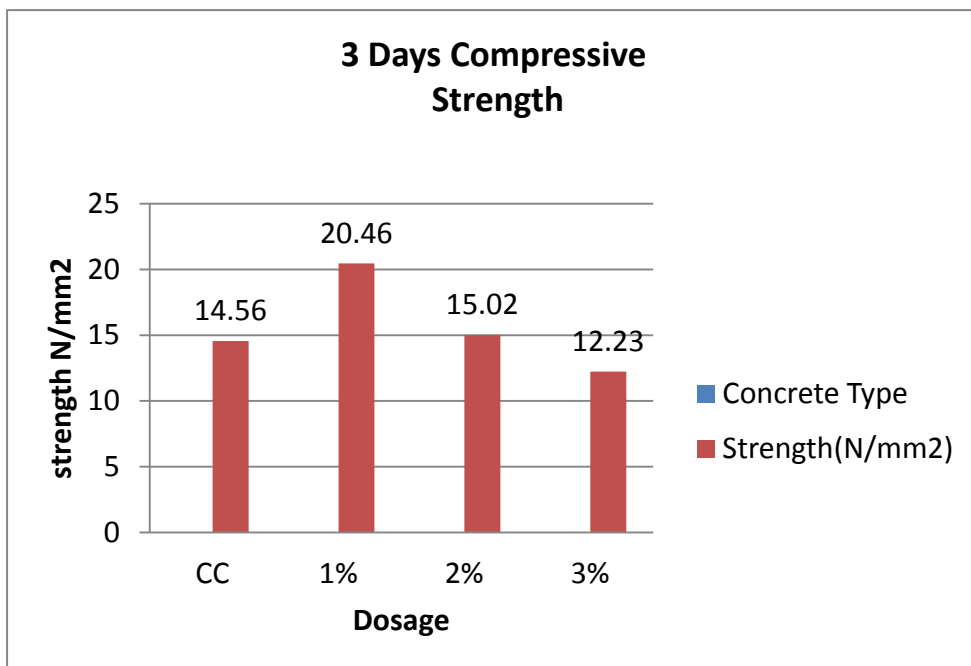


Fig 4.3: 3 Days Test Results

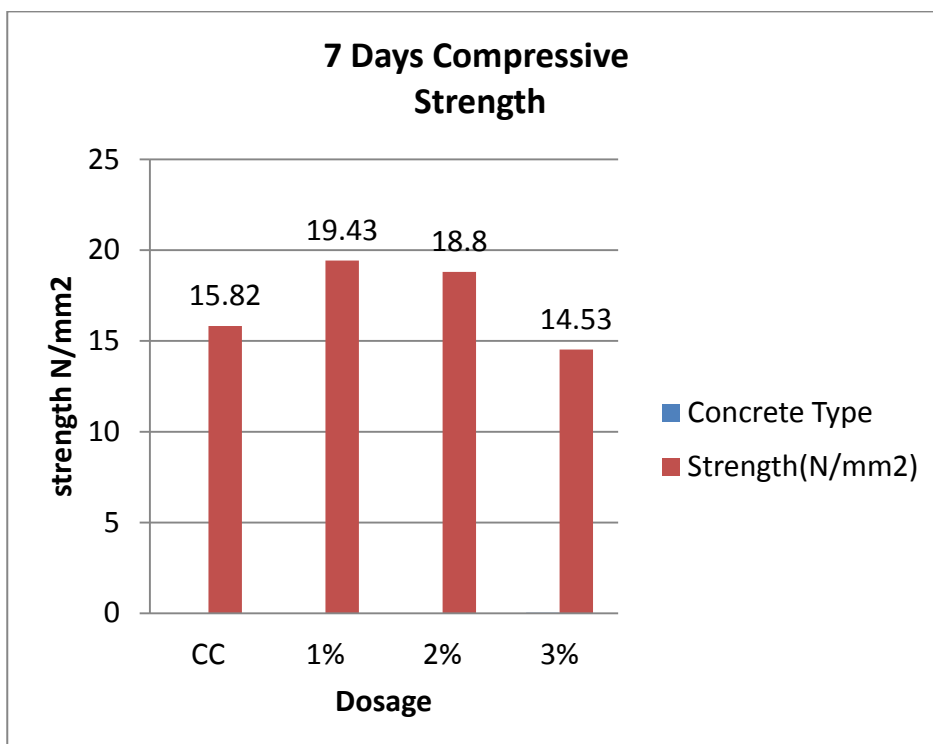


Fig 4.4: 7 Days Test Results

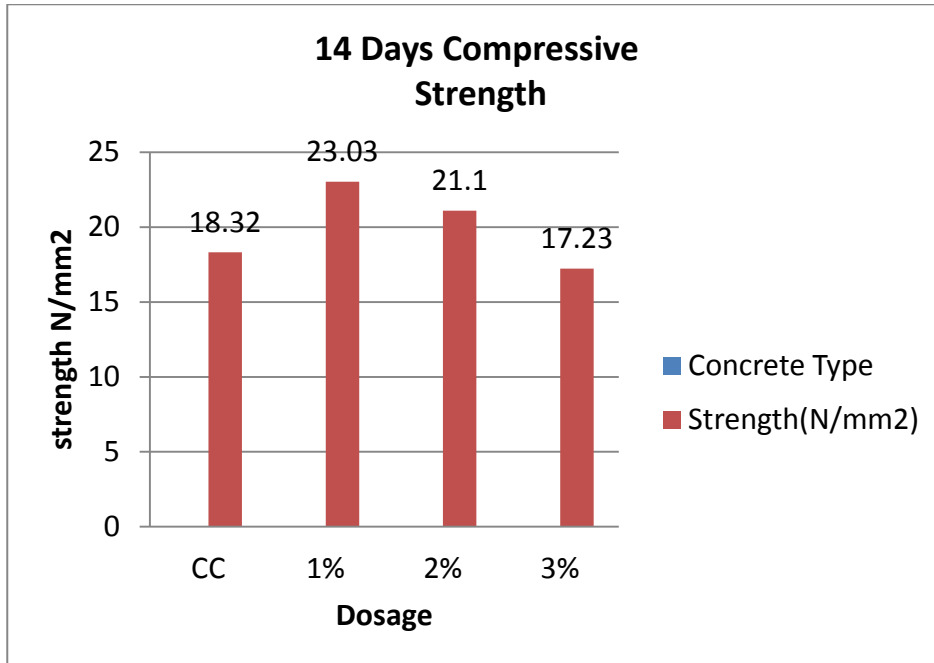


Fig 4.5: 14 Days Test Results

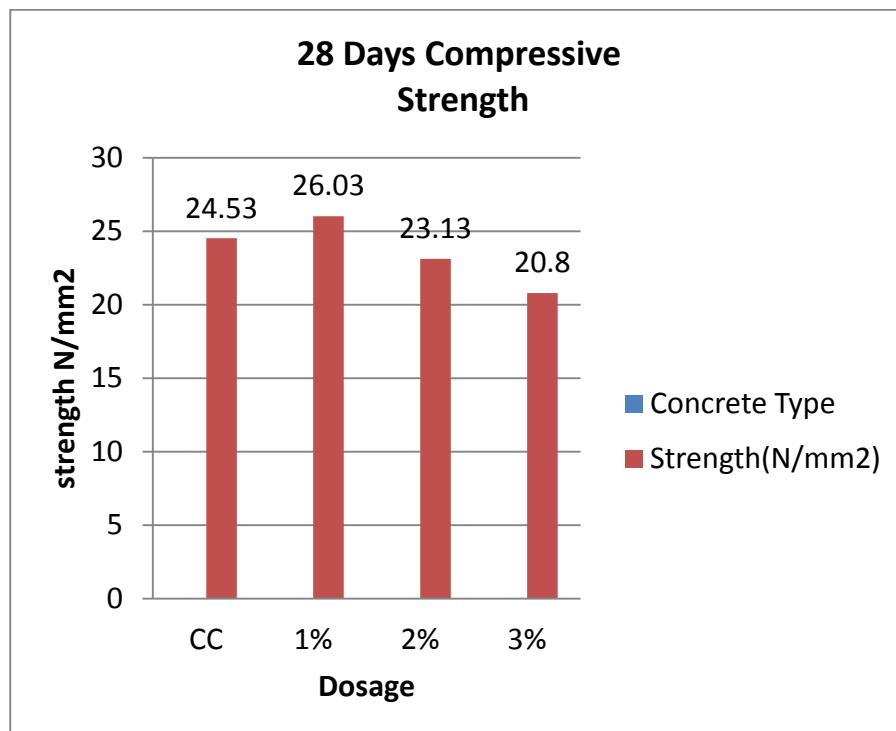


Fig 4.6: 28 Days Test Results

4.2.2: M50 Grade: Graphs plotted for 3, 7, 14, 28 Days are shown in figures below.

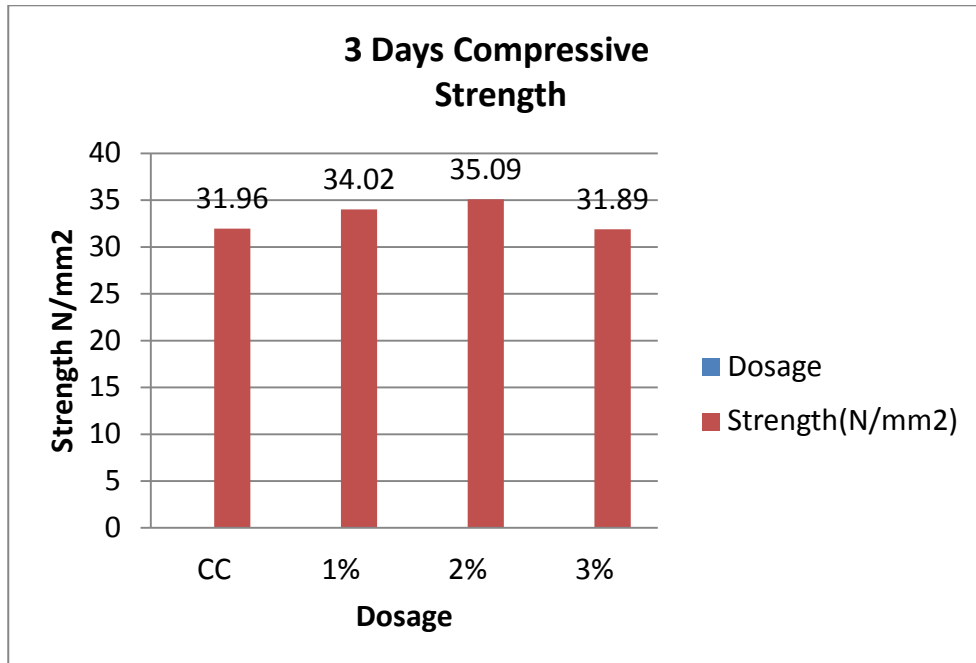


Fig 4.7: 3 Days Test Results

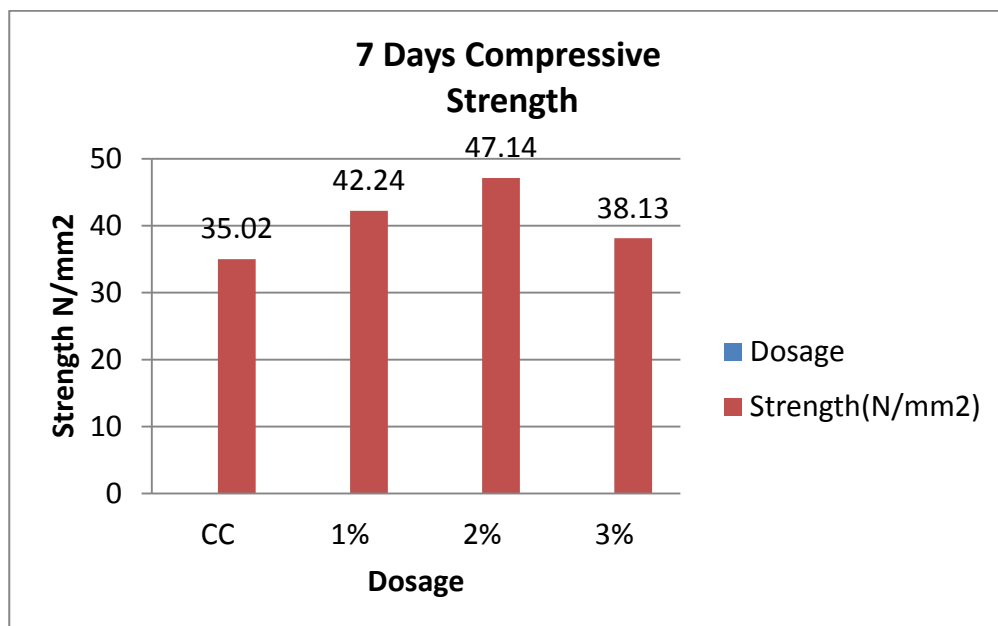


Fig 4.8: 7 Days Test Results

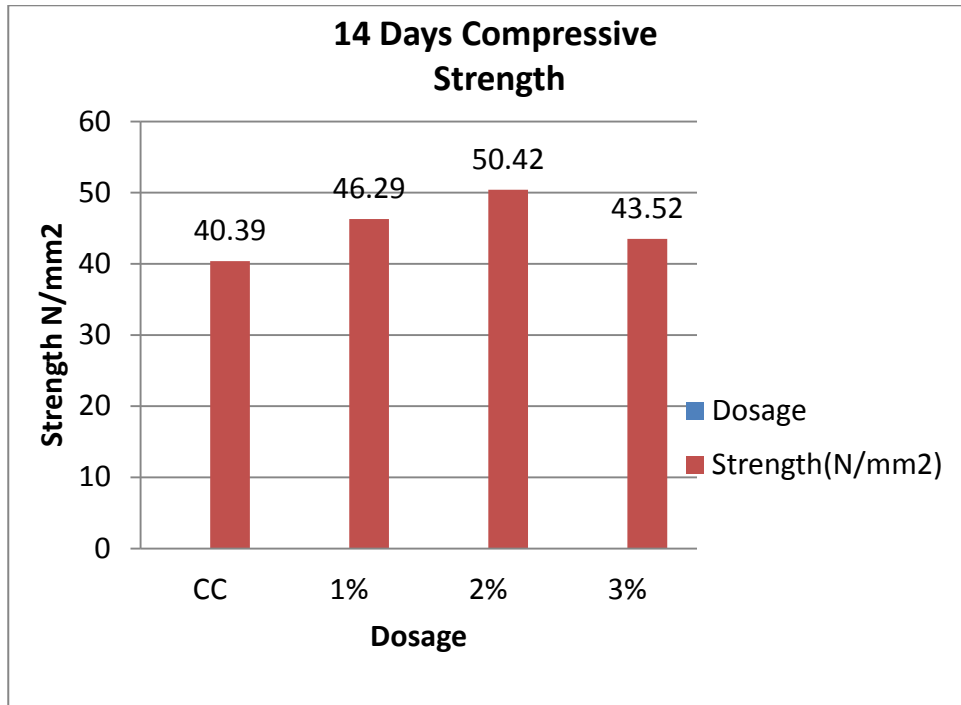


Fig 4.9: 14 Days Test Results

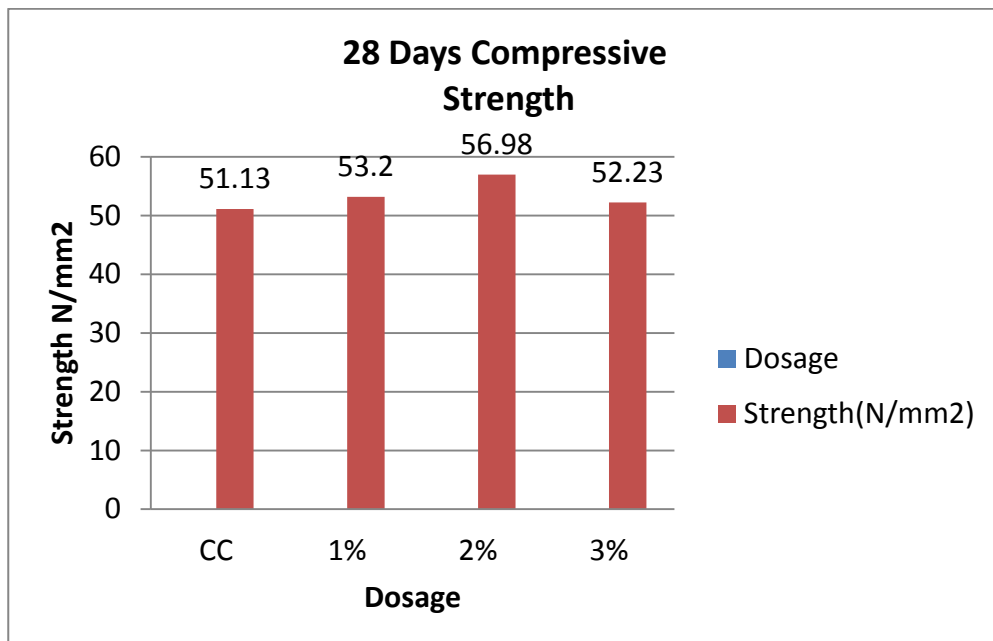
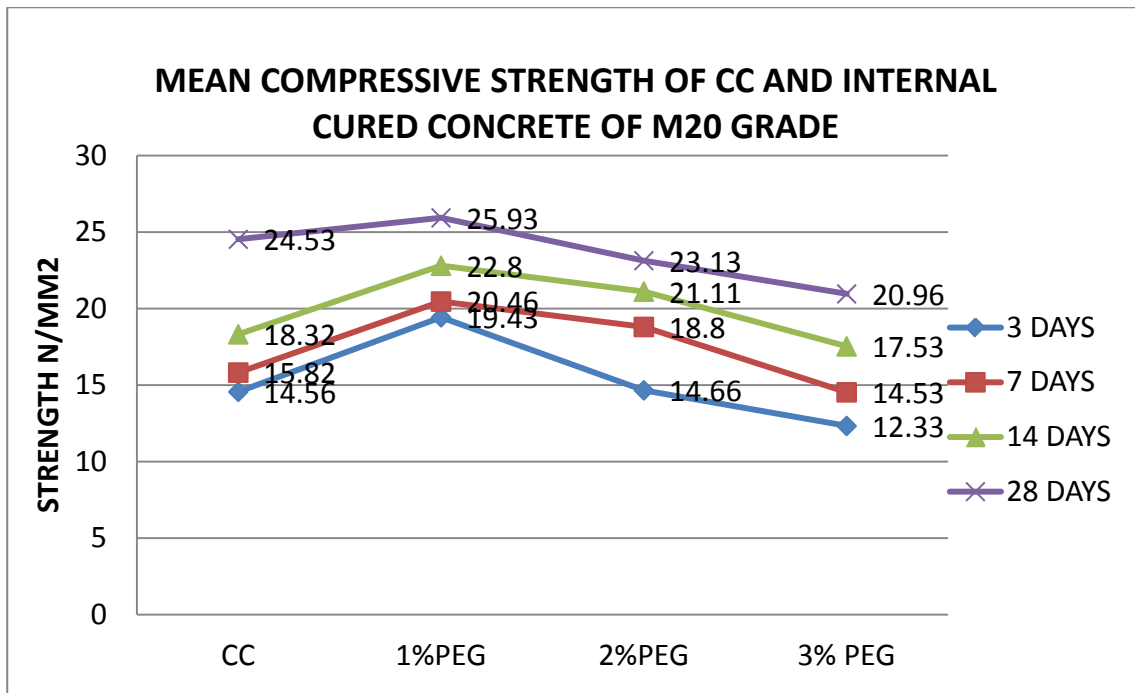
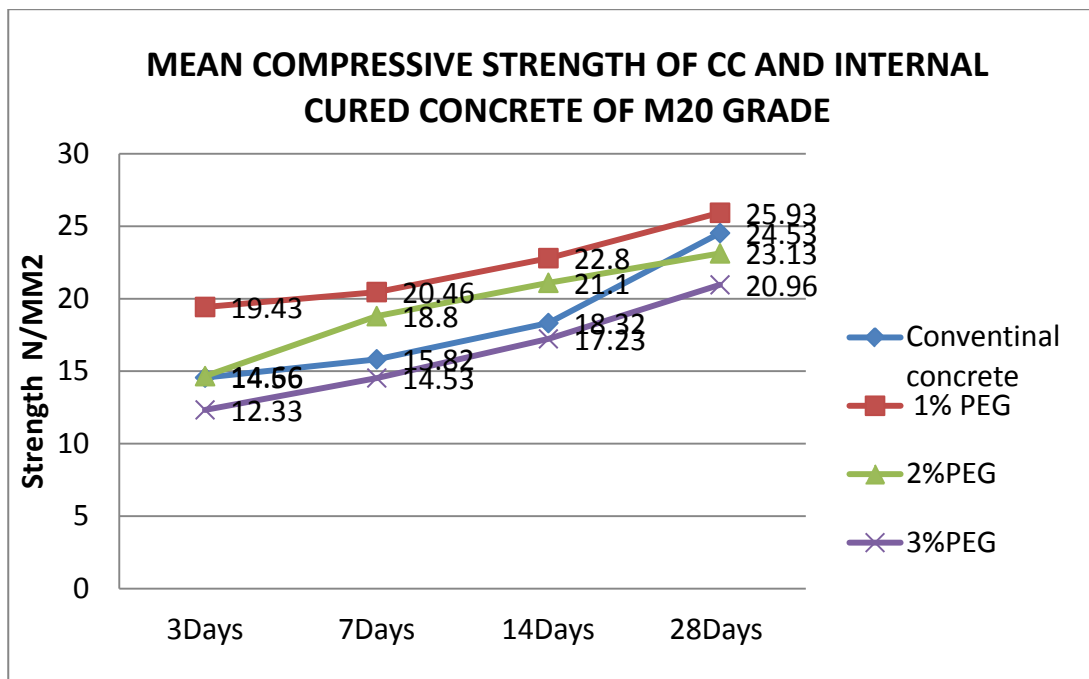


Fig 4.10: 28 Days Test Results

4.3: Average Results Of All Days for M20 and M50 are shown in figure 4.11 & 4.12.

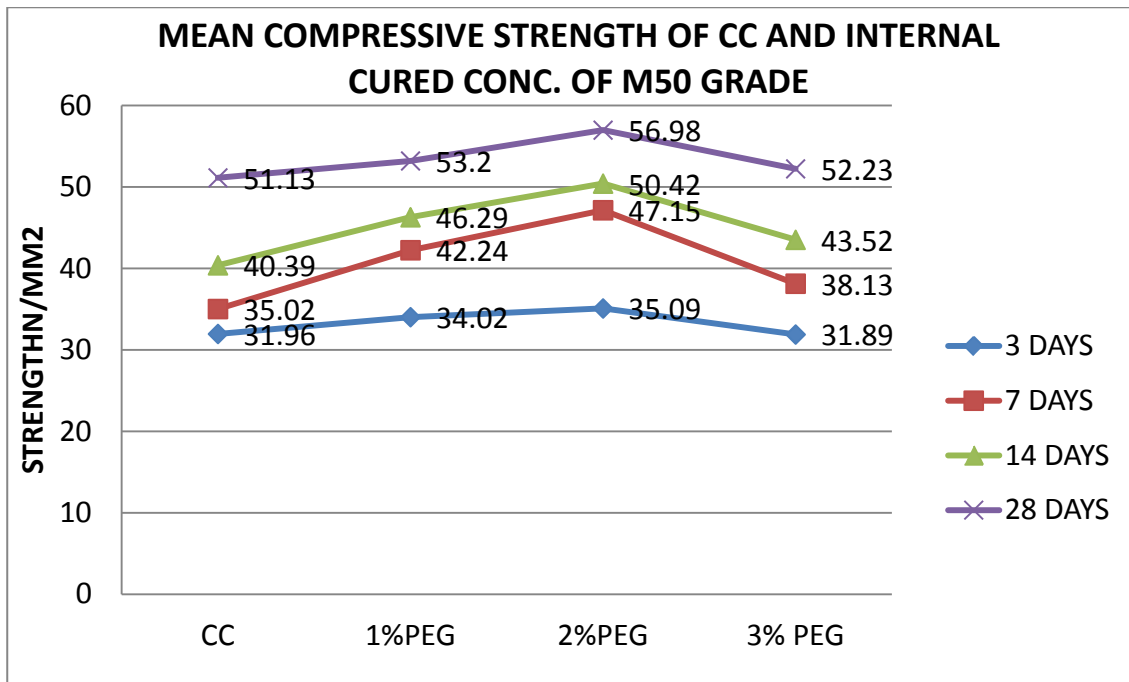


Graph a

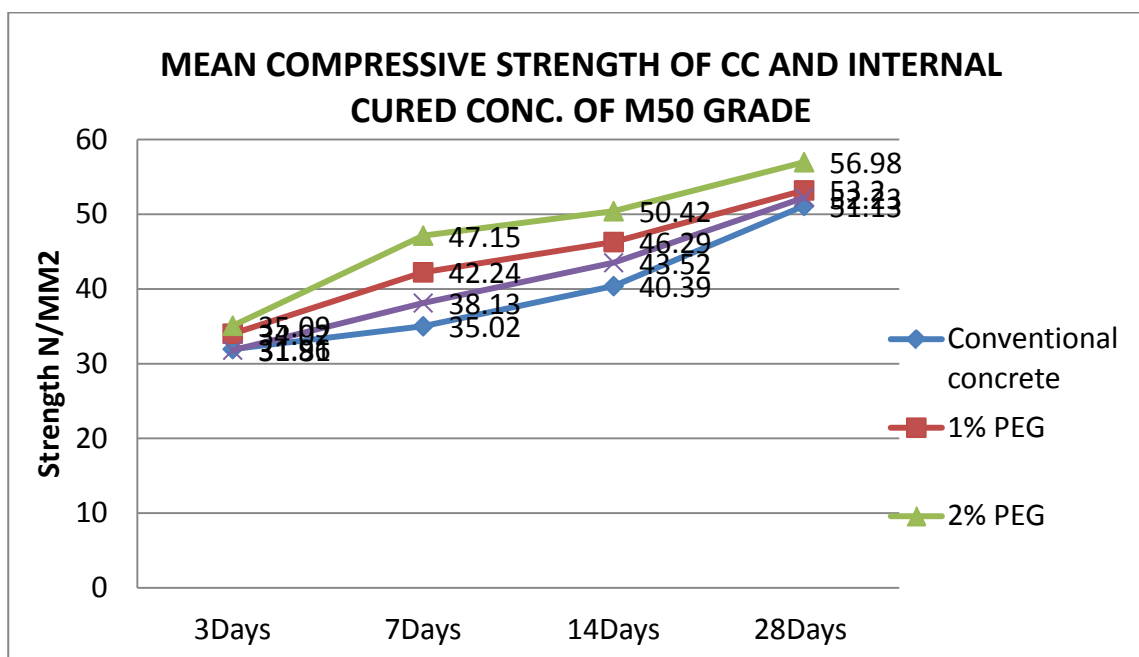


Graph b

Fig 4.11: Average Test Results for M20 Graph a & b:



Graph a



Graph b

Fig 4.12: Average Test Results for M50 Graph a & b:

- Referring to this above graphs it was observed that the maximum strength achieve in case of M20 grade was by 1% of PEG-400 and in case of M50 it was by 2% of PEG-400.

4.4: Rate Analysis & Cost Comparison:

Talking about the actual site conditions, Conventional concrete which requires water for external curing as well as an extra labor to apply the water to the concrete for a minimum durations of 7days whereas with the formation of internally cured concrete the amount of water applied for external curing and its labor cost can be saved as there no such requirement of curing in case of internal cured concrete.

So the attempt was also made to find out the rates and comparison of their cost between the conventional concrete and internal concrete including the cost of water require for curing and an labor which is needed in case of conventional concrete for it.

Table 4.3: Cost of Conventional Concrete

Grade	Requirements	Quantity	Analysis	Amount(Rs.)
M20	Concrete	6m ³	6 x 8360	50160
	Water	18m ³	18000 x 0.50	9000
	Labour	8hrs/day	400 x 7	2800
	TOTAL=61960			
M50	Concrete	6m ³	6 x 8860	53160
	Water	18m ³	18000 x 0.50	9000
	Labour	8hrs/day	400 x 7	2800
TOTAL=64960				

*cost of water is for Mumbai region

Table 4.4: Cost of Internal Cured Concrete 1%PEG

Grade	Materials	Quantity	Analysis	Amount(Rs.)
M20	Concrete	6m ³	6 x 8360	50160
	PEG-400	3.50L x 6	21 x 544	11424
	TOTAL=61584			
M50	Concrete	6m ³	6 x 8860	53160
	PEG-400	4.25L x 6	25.5 x 544	13872
TOTAL=67032				

Table 4.5: Cost of Internally Cured Concrete 2%PEG

Grade	Materials	Quantity	Analysis	Amount(Rs.)
M20	Concrete	6m ³	6 x 8360	50160
	PEG-400	7L x 6	42L x 544	22848
				TOTAL=73008
M50	Concrete	6m ³	6 x 8860	53160
	PEG-400	8.5L x 6	51L x 540	27744
				TOTAL= 80904

Table 4.6: Cost of Internally Cured Concrete 3%PEG

GRADE	MATERIALS	QUANTITY	Analysis	AMOUNT(Rs.)
M20	Concrete	6m ³	6 x 8360	50160
	PEG-400	10.5L x 6	63L x 544	34272
				TOTAL=84432
M50	Concrete	6m ³	6 x 8360	53160
	PEG-400	12.75L x 6	76.5L x 544	41616
				TOTAL=94776

Results: As Gujarat sand was used in this investigation which is the superior quality sand in India, therefore the cost of concrete is higher than the usual. Hence it is found that there is no much difference in cost between internally cured concrete conventional concrete. This factor might have come different, if locally available sand would have been used.

CONCLUSION:

Table No. 5.1: Compressive strength results

Grade	Mix	Average compressive strength(N/mm ²)			
		3 days	7days	14days	28 days
M20	CC	14.56	15.82	18.32	24.53
	1% PEG	19.43	20.46	22.8	25.93
	2% PEG	14.66	18.8	21.10	23.13
	3% PEG	12.33	14.53	17.23	20.96
M50	CC	31.96	35.02	40.39	51.13
	1% PEG	34.02	42.24	46.29	53.20
	2% PEG	35.09	47.15	50.42	56.98
	3% PEG	31.81	38.13	43.52	52.23

- The self-curing agent PEG-400 was found to be effective.
- It was found that every grade of concrete has one optimum percentage of dosage which it requires to give the maximum strength.
- It was found that PEG at an optimum dosage gives a better results whereas adding it in excess may decreases the strength of concrete
- Also it was found that the optimum dosage for M20 was 1% and for M50 it was 2% so with this we can conclude that with the increase in grade of concrete it is required to increase the dosage of self-curing agent for better results.
- Compressive strength of concrete with 1% and 2% PEG-400 dosage gives higher compressive strength as compared to conventionally cured concrete.
- As the dosage of PEG-400 increases the strength of concrete reduces.
- The compressive strength of conventional concrete at 28 days can be obtained in 7 days and 14 days by adding 1% and 2% PEG-400 respectively with conventional concrete.
- By the use of PEG-400 it is observed that the workability of concrete also increases and concrete becomes flowable.
- We conclude that use of PEG-400 is a better option to form an internally cured concrete which does not require any external curing water without compromising with its strength.

- 100% curing water can be saved as there is no need of curing process required for internally cured concrete.
- It has been observed during testing, internally cured concrete (conventional mix + PEG-400) shows lesser cracks than the conventional concrete.
- It is observed that price of PEG-400 is 544Rs/kg whereas PEG-4000 is 800Rs/litre hence PEG-400 is more economical self-curing agent.
- The cost of conventional concrete was same as internally cured concrete.
- As Gujarat sand was used in this investigation which is of superior quality, therefore the cost of concrete is higher than the usual hence this factor might have come different if locally available sand would have been used.

5.1 FUTURE SCOPE OF INTERNALLY CURED CONCRETE by PEG400:

- It can become a new practice in construction field of replacing conventional concrete with internally cured concrete to skip curing process.
- It can be used for normal as well as high strength concrete.
- More of research can be done such as self compacted internally cured concrete.
- Research on internally cured concrete in hot and cold weather condition can be done.
- Many other properties of concrete can be study such as chemical and physical properties.
- Taking present scenario, saving water should be given more priority than money so with the same economic factors of concrete of both conventional and internally cured concrete, we should start adopting internally cured concrete technique in construction field.

REFERENCES

- [1] Amal Francis k, Jino John, “Experimental investigation on mechanical properties of self-curing concrete”, *International Journal of Emerging* Vol.2,Issue3, pp 641-647, 2013.
- [2] Cano Barrita, B.J. Balcom, T.W. Bremner, M.B. MacMillan, W.S. Langley “Moisture distribution in drying ordinary and High performance concrete cured in simulated hot dry climate”, *kluwer academic Publishers* October 2004
- [3] C. Selvamony, M. S. Ravikumar, S. U. Kannan and S. Basil Gnanappa, “Investigations on self-compacted self-curing concrete using limestone powder and clinkers”, Vol.5, No.3 *ARPJ Journal of Engineering and Applied*, 2010.
- [4] Dhir, R.K., Hewlett, P.C., Lota, J.S., and Dyer, T.D.,(1996), “Influence of Microstructure on the Physical properties of Self-Curing Concrete,” *ACI Materials Journal*, Vol.93(5), pp. 465-471.
- [5] El-Dieb .A.S, “Self-curing concrete: Water retention, hydration and moisture transport”, *Construction and Building Materials* 21 (2007), pp. 1282–1287.
- [6] Hans W. Reinhardt and Silvia Weber, (1998), “SELF-CURED HIGH PERFORMANCE CONCRETE ”, *journal of materials in civil engineering* November 1998.
- [7] Hoff, G.C., “Internal Curing of Concrete Using Lightweight Aggregates,” Theodore Bremner Symposium, Sixth CANMET/ACI, International Conference on Durability, Thessaloniki, Greece, June 1- 7 (2003).
- [8] John Roberts and Ron Vaughn, (2013), "INTERNAL CURING IMPROVES FLEXURAL AND COMPRESSIVE STRENGTH OF PERVIOUS CONCRETE", Northeast Solite Corporation Saugerties, New York.
- [9] Kovler , K., Souslikov , A., and Bentur, A., “Pre-soaked lightweight aggregates as additives for internal curing of high-strength concretes,” *Cement, Concrete and Aggregates*, Vol. 26, No. 2, 2004, CCA12295, pp. 131-138.

- [10] K.vedhsakthi¹,M.saravanan²,Development of normal and high strength self curing concrete using sap and comparison of strength characteristics, international journal of engineering research & technology (IJERT) volume :03 Issue 10 Oct 2014.
- [11] Magda. Mousa, Mohamed G. Mahdy, Ahmed H. Abdel-Reheem, Akram Z. Yehia, (2014), " MECHANICAL PROPERTIES OF SELF-CURING CONCRETE (SCUC) ", Housing and Building National Research Centre HBRC Journal.
- [12] Mangaiarkarasi, V.; Damodarasamy, S.R., "Self-curing concrete today's and tomorrow's need of construction world," INCRAC & CT 2005–Proc Intl Conf on recent advances in concrete and construction technology. 7-9 December 2005, Chennai. Vol.2.
- [13] Mateusz Wyrzykowski; Pietro Lura; Francesco Pesavento; and DariuszGawin, (2012), "Modelling of Water Migration during Internal Curing with Superabsorbent Polymers ", journal of materials in civil engineering © ASCE / AUGUST 2012.
- [14] Mather, B., "Self-curing concrete, why not?" Concrete International, Vol. 23, No.1, 2001, pp. 46-47.
- [15] Md. Safuddin,S.N. Raman and M.F.M. Zain ,2007,"Effect of Different Curing Methods on the Properties of Microsilica Concrete" , Australian Journal of Basic and Applied Sciences, 1(2): 87-95, ISSN 1991-8178.7.
- [16] N.Gowripalan, R Marks and R Sun., Early age properties of self-cured concrete, Proceedings of Concrete Institute of Australia, Perth 2001, pp 655-662.
- [17] Nirav R Kholia, Prof. Binita A Vyas, Prof. T. G. Tank, (2013), " EFFECT ON CONCRETE BY DIFFERENT CURING METHOD AND EFFICIENCY OF CURING COMPOUNDS ", *international journal of advanced engineering technology*/Vol. IV/ Issue II/April-June, 2013.
- [18] N. Yazdani, F.ASCE; M. Filsaime; and S. Islam, (2008), "Accelerated Curing of Silica-Fume Concrete ", *journal of materials in civil engineering* © ASCE / AUGUST 2008.
- [19] Ole Mejlhede Jensen and Pietro Lura,,,"Techniques and materials for internal water curing of concrete", Materials and Structures, vol.39, pp.817–825, 2006.
- [20] Pietro Lura and Ole Mejlhede Jensen, „Experimental observation of internal water curing of concrete“, Materials and Structures. vol.40, pp.211-220, 2007.
- [21] Ravi Kumar M.S., Selvamony. C., Kannan S.U., Basil Gnanappa .S, (2011), "SELF-COMPACTED / SELF CURING / KILN ASH CONCRETE ", international journal on design and manufacturing technologies, Vol. 5, No.1, January 2011.

- [22] Roland Tak Yang Liang, Robert Keith Sun, "Compositions And Methods for curing concrete ",Also published as CA2308237A1, Australian Standard AS 3799. 22 October 2002
- [23] Sathanandham. T, Gobinath. R, Naveen Prabhu. M, Gnanasundar. S, Vajravel.K, Sabariraja.G, Manoj kumar.R, Jagathishprabu.R, (2013), "Preliminary Studies of Self Curing Concrete with the Addition of Polyethylene Glycol", international journal of engineering research & technology (IJERT) Vol. 2 Issue 11.
- [24] Siddiqui Mohd. Junaid, Sheikh Saddam, Khan Yusuf, Shaikh Abu Huzaifa, Mansuri Junaid (2015) Study the use of shrinkage reducing admixture (PEG4000) for M40 grade concrete which attained more strength than conventional cured concrete .journal of civil engineering and environmental technology (JCEET) Vol.2,number,6 April 2015.
- [25] Swamy, R. N. and Bouikni, A, "Some Engineering Properties Of Slag Concrete As Influenced By Mix Proportioning And Curing", *ACI Materials Journal*, Vol. 87, No. 3, pp. 210-220. (1990)
- [26] Tarun R. Naik and FethullahCanpolat, (2006), "SELF-CURING CONCRETE ", A *CBU report department of civil engineering and mechanics college of engineering and applied science THE UNIVERSITY OF WISCONSIN-MILWAUKEE*.
- [27] Wen-Chen Jau, "Methods for self-curing concrete", IFI CLAIMS patent Services,16 August 2011
- [28] Ya Wei; Yaping Xiang; and Qianqian Zhang, (2014), "Internal Curing Efficiency of Prewetted LWFAs on Concrete Humidity and Autogenous Shrinkage Development ", *journal of materials in civil engineering* © ASCE / MAY 2014.