Experimental study on improving the strength of concrete by using self-curing technic with Polyethylene glycol and super absorbent polymer

Podeti Anil¹, V. Bhikshma²

¹Research scholar, Department of Civil Engineering, University College of Engineering, Osmania University, Hyderabad, India.
²Professor, Department of Civil Engineering, University College of Engineering, Osmania University, Hyderabad, India.

Corresponding author’s email address: anilpodeti@gmail.com

Abstract. Increase in infrastructural projects demands the need for workable concrete in the 21st century. With the technological advancement there is a need for looking into an alternate solution to the current day problems in the construction sector. Shortage of water is also a concern in some of the places which demands for the utilization of a better substitute to water in concrete. Internal curing agents like Polyethylene Glycol (PEG400), ceramic and Super Absorbent Polymer are used extensively which would be beneficial for engineering and construction applications. Day by day increasing of waste from disposable diapers will give increase the waste generation and requires large space dumping. To overcome this diapers which are primarily worn by infants, and by children who are not yet potty trained or who experience bedwetting are used in the present study as a self-curing agent along with PEG 400. In this present study, influence of PEG and diaper polymer on the workability and compressive strength of the concrete was investigated. M40 grade of concrete has been adopted for the entire study. Compressive strength at 3, 7, 28 and 90 days was calculated for 150mm X 150mm X150mm cubes with the 1%PEG as a control mix and 1% PEG + varying ratios of 1% to 10% of diaper polymer with 5% interval. It was observed that workability increased with the addition of diaper polymer and the strength decreased.

Key words: Self-curing Concrete, Diapers, PEG400, compressive strength.

1. Introduction

Day by day construction activities are increasing with the use of different grades of concrete with natural and artificial ingredients. The huge development in construction industry have contributed immensely for new construction chemicals, which effect the property such as strength and durability of concrete. Performance of concrete can be increased when durability is higher. During construction in spite of supervision proper care is not taken in curing and other operations and also, curing leads to usage of large amount of water. Instead of water curing, there are other methods available including polymer curing, membrane curing etc. Curing is the process of avoid moisture loss from concrete during the hydration process. Strength of concrete to the required level can only be attained by using a proper curing technique. Proper curing of concrete structures is important to meet performance and durability requirements. In conventional curing this is achieved by external curing applied after mixing, placing and finishing. Self-curing or internal curing is a technique that can be used to provide additional moisture in concrete for more effective hydration of cement and reduced self-desiccation. Curing cannot be properly supervised due to difficulty or some inaccessibility in construction sites. In recent studies many alternatives available (such as coal bottom ash (CBA), fly ash, used engine oil and etc.) which are taken from waste products and
are utilized to replace commercially available materials. The impact of waste from disposable diapers on the environment has been over-looked. Disposable diapers produce 1.5% of solid waste, the percentage of waste is increasing year by year. Disposable diapers occupying 5 to 40 % land fill space [8] and they contain cancer causing agents like dioxin and dyes which can be danger if released in to environment [7]. Once the initial free water has been consumed, the water absorbed by the self-curing agent will be gradually released to maximize the heat of hydration and also improve the quality of concrete compare to conventional curing. To avoid concrete not achieved the maximum strength, improper curing or dry-air curing should be seriously concern because designed strength is not achieved by this method. Expected result will probably solve two problems which are while use the disposable diapers polymer to reduce amount at dumping area and also producing the eco-friendly concrete for construction which are used self-curing method.

1.1. 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.

1.2. Mechanism of Internal Curing

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 in the mix mainly form hydrogen bonds with water molecules and reduce the chemical potential of the molecules which in turn reduces the vapor pressure, thus reducing the rate of evaporation from the surface.

1.3. Curing

Curing is the maintenance of a satisfactory moisture content and temperature in concrete for a period of time. The need for adequate curing of concrete cannot be overemphasized. Curing has a strong influence on the properties of hardened concrete; proper curing will increase durability, strength, water tightness, abrasion resistance, volume stability, and resistance to freezing and thawing and deicers. When Portland cement is mixed with water, a chemical reaction called hydration takes place. The extent to which this reaction is completed influences the strength and durability of the concrete. Freshly mixed concrete normally contains more water than is required for hydration of the cement; however, excessive loss of water by evaporation can delay or prevent adequate hydration. With proper curing, concrete becomes stronger, more impermeable, and more resistant to stress, abrasion, and freezing and thawing.

The function of Internal curing agent is to serve as internal storage for curing water. For this reason, internal curing agents are usually very porous materials with weak mechanical properties. The effects of internal curing on the mechanical properties and durability of concrete are to minimize these effects remain the subject of research interest [9]. The main application of internal curing agent will help to improve concrete strength with high risk of early age cracking.

1.4 Polymer as an inner Curing Agent
Several methods have been proposed to mitigate autogenously shrinkage and the internal stress that might be induced. Expansive Additives (EXA) based on calcium sulfoaluminate or free lime[1,2], drying Shrinkage- Reducing Admixtures (SRA)[2,3] super- absorbent polymer particles inclusions[4], as well as high belite or low heat Portland cement[1,2] have been successfully and extensively used in mitigating shrinkage. According to [5] result Self-Consolidating Lightweight Concrete at [6] and 28 days ages when incorporating with SAP show that reducing the compressive strength. The coarser SAP resulted, however, in slightly lower reduction than the fine SAP. With the advantages it brings in extreme weather conditions as well as its reduction in water usage on sites, this makes Internal curing a topic which will garner more attention as water usage shoots upwards in the construction industry [10]. Super Absorbent Polymer (SAP) have behavior like super-swelling behavior, chemistry, and designing the variety of final applications. SAP have same features that can give a big impact to internal-curing concrete. Therefore, this project is to introduce the self-curing concrete containing significant material like waste from diapers polymer as additional material since a few researches give positive result, and there is very limited research.

1.5 Potential Materials 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)
- SRA (Shrinkage Reducing Admixture) (propylene glycol type i.e. polyethylene-glycol)

1.6 Polymer in Concrete

As per Assmann et al. [11], polymer used is a gel polymerized type of SAP. It was a development product supplied by BASF Construction Chemicals, Germany. Gel polymerized SAP is typically crushed from larger pieces and has an irregular shape. The median diameter of the dry particles ranges between 60 and 125 μm. The fluid absorption capacity was 24 g/g. It should be noted that the SAP was “salt insensitive” which means that it was developed for the special use in high alkaline environment such as cementitious suspensions. The concrete was chosen such that should maintain 60 to 70 MPA after 28 days. There may be some results drawn from the experimental investigation on concretes with two water-to-cement ratios. Two mixes were compared which had the same water content whereby one contained entrained water by SAP. The strength for both mixture was almost the same after 28 days. Mixture with SAP showed a significantly less autogenously shrinkage. SAP modified concrete had approximately 50% less tensile creep. Also the tensile creep of SAP modified concrete had different strengths and different paste volumes. While in [12] research the study on pre-soaked SAP effect, show the properties of self-consolidating lightweight concrete. From result, the mixture contained of commercially ASTM type II cement will improve workability by use silica fume and a polycarboxylate-based on super plasticizer.

1.7 Advantages of Internal Curing

Internal curing (IC) is a method to provide the water to hydrate all the cement, accomplishing what the mixing water alone cannot do.

- Provides water to keep the relative humidity (RH) high, keeping self-desiccation from occurring.
- Eliminates largely autogenously shrinkage.
- Maintains the strengths of mortar/concrete at the early age (12 to 72 hrs.) above the level where internally & externally induced strains can cause cracking.
- Can make up for some of the deficiencies of external curing, both human related (critical period when curing is required in the first 12 to 72 hours) and hydration.
2. METHODOLOGY

i. Normal methodology followed for coarse aggregates and fine aggregate

ii. For fineness of cement 50-micron sieve is used. For mixing the proportions conventional strategies are followed.

iii. While we use the diapers with blended proportions initially there can be a risk of excessive absorption of water. Better to use earlier than casting of concrete.

iv. PEG400 added to the concrete mix uniformly.

v. Normal techniques are followed in compressive and tensile power assessments.

| Table 1Mix Proportioning as per 10292-2009 |
|------------------------------------------|
| Type | Mix no. | Target Grade of concrete (kg/m³) | Cement (kg/m³) w/c (%) | PEG (%) | Self-Curing Agent (Disposable Diapers Polymer) (%) | Coarse aggregate (kg/m³) | Fine aggregates (kg/m³) |
|------|---------|----------------------------------|------------------------|---------|-----------------------------------------------|------------------------|------------------------|
| Control Mix | 1 | 40 | 398 | 1 | 0 | 1254 | 670 |
| | 2 | 40 | 390 | 1 | 1 | 1254 | 670 |
| Polymer | 3 | 40 | 382 | 1 | 5 | 1254 | 670 |
| | 4 | 40 | 362 | 1 | 10 | 1254 | 670 |

2.1 Sample Preparation

Self-curing implemented by using room temperature. The optimum self-curing agent using disposable diapers was determined by using four mixes for each type of curing with one mix as a control. All the sample prepared for testing concrete fulfilled the standard requirement which is 10292-2009. This standard is method for determination of compressive strength of concrete cubes. The dosage was referring [Table 1] by weight of the cement.

2.2 Clean Concrete take a look at / Workability

Fresh concrete properties were determined by conduct a slump test. Slump test in this study was conducted according to 10292-2009.

2.3 Test Procedures

2.3.1 Concrete Mixing

Concrete is a composite material contain of water, aggregate, and cement. Often, an additive is included in the mixture to achieve the desired physical properties of the finished material. In this study, super plasticizer is used to increase workability as there is a reduction to 30% in water-cement ratio. As these ingredients mixed together, a fluid mass is formed and it is easily molded into shape and avoid segregation.

2.3.2 Slump Test

One of method to determine workability of concrete is a slump test. Slump test conduct to indicate water content that has been used in the mix and also shown the stiffness of the concrete. Function of stiffness in the concrete mix should be matched to the requirements for the finished product quality.

2.3.3 Compressive Strength Test

This research, sample size 150 x 150 x 150mm was tested by Destructive test on hardened concrete using compressive test machine to get the strength. Testing followed American
Society for Testing Materials ASTM C39/C39M standard. Three samples per day (3, 7, 28 and 90 days) has been tested. Testing start from day 3 because from that, we can see the changes of strength due to hydration more accurately. Compressive strength unit in MPa will show the weather have an effect in term of strength while add a self-curing agent into a concrete mix.

3. Results and Discussion

Experimental investigation was carries out to study the workability and strength characteristics of control mix+1%PEG and mix with 1% PEG+ varying percentages of diaper polymer.

3.1 Workability

Addition of Diaper Polymer in concrete mixture can have a considerable effect on concrete workability since it will absorb some amount of water content. From Figure 1, it can be seen that there is an increase in workability of concrete with diapers polymer as self-curing agent. Figure 1 shows the variation of slump value for 1% PEG and 1% PEG with varying percentages of diaper polymer. All concrete mixes have slump value in the range of 10mm-40mm which indicates that the degree of workability is low. It is observed that the increase in percentage of diaper polymer marginally enhanced the slump value for a constant water cement ratio. Concrete mix with 10% diaper polymer resulted in maximum slump value due to the presence of additional water in the form of liquid gel, which eases the flowable characteristics of the mix. The slump value for control mix with 1% PEG and mix with 1% PEG + 1% diaper polymer are almost same as the contribution from liquid gel present in diaper to the overall concrete mix is very less.

3.2 Compressive Strength Result
From Figure 2, the compressive strength of concrete decreases with increase in diaper polymer percentage. This is because the water in the form of gel present in diaper will increase the water content in the mix which decreases the strength properties of the mix. Reduction of compressive strength due to addition of Diapers Polymer can differ which depends on the dosage of diapers and w/c ratio used in the mixture. Higher dosage of diaper and water will reduce the compressive strength compare to control mix without Diapers Polymer. Higher dosage of diapers will also increase the voids in the mix which is also one of the main reasons attributing to strength reduction. The result shows a 30% reduction in compressive strength with 1% of SAP added at age of 3 days, 20% reduction at age of 7 days, 15% reduction at age of 28 days (Figure 2). At early ages of 3 days, 7 days the hydration process of concrete will not be completely done and henceforth the corresponding strengths at 3 days, 7 days are less. Similar strength values are observed for 1% and 5% of diapers and there is a significant reduction in strength for 10% diaper.

When the hydration process occurs, the polymer can transfer the water to all part of the concrete and to the hydration point it results the early age cracking can be preventing and promotes maximization of cement hydration, potentially contributing to increase the strength and the fluid transport coefficients can be reduced. Compared to the conventional curing, the water can penetrate only a few millimeters from outside into inside the concrete. But in the internal curing, the water in the polymers already inside the concrete and it make the water be more easily to penetrate into the concrete and transfer it uniformly. Once concrete sets, chemical shrinkage continues in the cement paste as hydration progresses and creates partially-filled pores within the microstructure of the concrete. These unfilled pores in the cement paste create capillary stress, which causes shrinkage. Internal curing provides readily available additional water throughout the concrete, so more of the pores remain water-filled, minimizing stress and strain development. The goal of internal curing is to provide additional water in the proper amount with a proper spatial distribution so that the entire three-dimensional microstructure of hydrating cementitious paste remains saturated and autogenously stress free.

4. Conclusion

From the investigation it can be concluded that the internal curing help to improve the hydration process and workability. Higher percentages of diapers polymer even though acts as a self-curing agent has a limitation due to its strength reduction which might reduce the life time of the strength considering the serviceability. Concrete with 1% of the diapers polymers has the optimum result in terms of workability and strength and the same can be adopted in practice.

5. References
[1] Hori A, Morioka M, Sakai E, Daimon M. JCI (Japan Concrete Institute), Hiroshima, June 13-14, 1998 1999 Jan 28 (p. 187). Taylor & Francis.

[2] Ito H, Maruyama I, Tanimura M, Sato R. Journal of Advanced Concrete Technology. 2004;2(2):155-74.

[3] Tazawa E, Miyazawa S. Magazine of Concrete Research. 1997 Mar;49(178):15-22.

[4] Jensen OM, Hansen PF. Cement and Concrete Research. 2002 Jun 1;32(6):973-8.

[5] Allsopp M, Stringer R, Thornton J, Costner P.. Greenpeace International; 1994.

[6] Fauzi M.. Ph.D. Thesis, Kyushu University, Japan; 1995.

[7] Municipal solid waste in the United States; Facts and Figures for 2010. US EPA Office of Solid Waste; 2010.

[8] Rathje WL, Murphy C. Rubbish: the archaeology of garbage. University of Arizona Press; 2001.

[9] Zhutovsky S, Kovler K. Cement and concrete research. 2012 Jan 1;42(1):20-6.

[10] Colón J, Mestre-Montserrat M, Puig-Ventosa I, Sánchez A.. Waste management. 2013 May 1;33(5):1097-103.

[11] Assmann A, Reinhardt HW.. Cement and Concrete Research. 2014 Apr 1;58:179-85.

[12] Bentz DP, Lura P, Roberts JW.. Concrete international. 2005 Feb 1;27(2):35-40.