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Self-curing Concrete using Baby Diapers Polymer

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Abstract

Quality of the construction project is very crucial issue nowadays. Sometimes works are carried out in place where there is acute shortage of water and the application of water curing is not possible for reasons of economy. There are several papers studied on internal curing agent and effect to the concrete such as from Polyethylene Glycol (PEG400), ceramic and Super Absorbent Polymer that make them beneficial for engineering and construction applications. Year by year, increasing of waste from disposable diapers will give impact to dumping area. Internal curing agent that used in this research is new diapers contain of super absorbent polymer, which becomes a gel-like substance when wet and absorb the water. Diapers are primarily worn by infants, and by children who are not yet potty trained or who experience bedwetting. In this research, it will be analyzed by investigating the workability and compressive strength impact to the concrete. Design Mix with size of cube 100 x 100 x 100mm has been testing day 3, 7, 28 and 90 days with the ratio from 0% as a control and 1%, 2%, 3%, 5% and 10%. From the result that had obtained, 1% of diapers polymers can conclude that the internal curing process can help to improve the hydration process. 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.

Keywords: Compressive Strength, Diapers, Polymer, Self-curing Concrete, Workability

1. Introduction

The advances in construction industry have contributed tremendously for the new developments in construction chemicals. Application of several chemicals in concrete that effect their properties such as strength and durability. Higher that durability of concrete can increase the performance and satisfactorily in the working environment. Due to the massive construction activities, application of different grades of concrete with natural and artificial ingredients are in use. It is observed during construction even though supervision is given importance proper care is not taken in the curing and other operations. As an alternative to water curing, different other methods are also available including membrane curing, polymer curing etc. Curing is the process of avoid moisture content

loss from concrete during the hydration process. Desired strength of concrete can only achieve by a proper curing techniques. In the actual construction sites, improper curing techniques occasionally occur due to difficult or far places, some inaccessible, where curing cannot be properly supervised. These factors may lead to the lower performance of concrete. Recently, a lot of waste are being utilized to replace the commercially available materials such as coal bottom ash (CBA), fly ash, used engine oil and etc.

The impact of waste from disposable diapers on the environment has been over-looked. Concerning about the current environment issues, solid waste from disposable diapers produce 1.5%. This amount has been increased over the year¹. Surveyed conducted estimated between 5 to 40 percent that disposable diapers occupied

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somewhere of landfill space². Disposable diapers contain of dioxin and dyes which is one of cancer agent that it will be danger if released into the environment. That toxin can accumulate in humans and animals³. Avoid from effect to environment, few studies have been done which involved of Super-Absorbent Polymer with concrete. 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 method⁴. 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 Background on Diapers and Waste

In disposable pampers, one of the material is super-absorbent gel to absorb wetness and keep baby dry. That material also help baby feel comforts, avoid diapers rash and keep baby skins healthy. According to the U.S. Environmental Protection Agency (EPA) (2015), about 20 billion disposable diapers are dumped in landfills each year, accounting for more than 3.5 million tons of waste⁵. From that data show that, waste diapers also contribute impact to dump area and that numbers increase year by year. Although the way to decompose disposable diapers need to be exposed to oxygen and sunlight, they do not degrade well in a landfill. Actually, to decompose disposable diapers need to take about 500 years. Also have another problem come from disposable diapers which is viruses excreted in a baby's feces could end up leaking into local water supplies. Decomposing diapers also can release methane into the air. High concentrations of the gas can be explosive and flammable. Most dangerous of the Methane when we are breathing in because it replaces oxygen.

1.2 Curing Process

Curing function is a to avoid from moisture content loss or hydration of the cement. Curing process is a control of temperature and moisture movement from concrete and into the concrete⁶. Strength and impermeability of concrete will not achieve if Improper curing process⁷.

Effect from curing has a strong influence on the properties of hardened concrete such as will increase the durability, strength, volume stability, abrasion resistance, impermeability and resistance to freezing and thawing⁸. 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 interest⁹. The main application of internal curing agent will help to improve concrete strength with high risk of early age cracking.

1.3 Polymer as an Internal Curing Agent

Several methods have been proposed to mitigate autogenous shrinkage and the internal stress that might be induced. EXpansive Additives (EXA) based on calcium sulfoaluminate or free lime^{10,11}, drying Shrinkage-Reducing Admixtures (SRA)^{11,12} super-absorbent polymer particles inclusions¹³, as well as high belite or lowheat Portland cement^{10,11} have been successfully and extensively used in mitigating shrinkage. According to³ result Self-Consolidating Lightweight Concrete at 7 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 industry¹⁵.

Super Absorbent Polymer (SAP) have behaviour like super-swelling behaviour, 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.

1.4 Baby Diapers Polymers

Disposable diapers contain of an absorbent layer of cellulose pulp and hydrophilic polymers, an outer plastic film, and a layer nearest to the skin. The hydrophilic polymer is usually a Na⁺ polyacrylate and it is estimated

that over 130Gg of polyacrylates is used annually in diapers¹⁶. In the process of using SAP for land reclamation, the role of pure hydrophilic polyacrylate polymers is to enhance plant growth by increasing the water-holding capacity of soils¹⁶ and by supplying the cation present when this is a plant nutrient, such as K⁺ or NH₄⁺. Another attempt to recycle used baby diapers taken by¹⁷, trying to manufacture composting out of used diapers yard waste which were composed together using bioreactors. Previous researcher used recycle baby diapers in the experiment contained urine from 0-2 years-aged babies collected from a sector in Mexico City. The results show the possibility of introducing used diapers in the compositing with no negative effects on the process. Parameters used in the study (pH, CO₂ production, temperature, C/N ration and moisture content) had very similar values with or without diapers for bioreactors. The feasibility of biological recycling of urine-contained diapers had been confirmed in this study¹⁷. For this research, Baby Diapers Polymer brand 'Mamy Poko' was selected. The priced consider medium ranged and selected because its familiar and easy to get in Malaysia market.

1.5 Polymer in Concrete

According to Assmann et al.¹⁸, 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. The specimen was divided into three groups to simulate different situations which are first group could dry from day 1 used for shrinkage measurements and they were not loaded, second group of specimen were wrapped in PolyEthylene (PE) foil which were loaded after 28 days and third group were sealed by an aluminum barrier foil where some of them tested in sealed condition and the rest unsealed and loaded. 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 autogenous 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 in¹⁹ 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 superplasticizer.

2. Methodology

The workability and compressive strength of the self-curing concrete after 90 days due to the additive added as a self-curing agent in the concrete mixture determined by conducted some testing. The procedures to produce the concrete sample for the tests are explained sequentially in order to achieve the objective of this study. Self-curing process conducted in Laboratory with room temperature 25°Celsius to 27°Celsius.

Table 1. Mix design

Type	Mix no.	Target Grade of concrete (kg/ m ³)	Cement (kg/m ³)	w/c (%)	Super plasticizer (%)	Self-Curing Agent (Disposable Diapers Polymer) (%)	Coarse aggregate (kg/m ³)	fine aggregates (kg/m ³)
Control Mix Polymer	1	40	400	30	2	0	1252	674
	2	40	396	30	2	1	1252	674
	3	40	392	30	2	2	1252	674
	4	40	388	30	2	3	1252	674
	5	40	380	30	2	5	1252	674
	6	40	360	30	2	10	1252	674

2.1 Sample Preparation

Self-curing implemented by using room temperature. The optimum self-curing agent using disposable diapers was determined by using six (6) 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 BS1881: Part 116:1983. 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 Fresh Concrete Test / Workability

Fresh concrete properties were determined by conduct a slump test. Slump test in this study was conducted according to BS EN 12350-2:2000.

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 indicates 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 100 x 100 x 100mm 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 (3) sample 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 whether have an effect in term of strength while add a self-curing agent into a concrete mix.

3. Experimental Result

3.1 Workability

Addition of Diapers Polymers in concrete mixture can have a considerable effect on concrete workability since it will absorb some of water content of the mixture. As a results of that (Figure 1), there has an increase workability of concrete with self-curing agent Diapers Polymer. From this result, we can notice that the slump test value decreased by almost 70% when adding 0.4% relative to cement of Diapers Polymer to concrete mixture. As shown in Figure 1, all concrete mixes have slump value in the range of 10mm-40mm which indicates that the degree of workability is low. The control mix and mix concrete 1, mix concrete 2 and concrete mix 3 has the same slump which is 30mm. The concrete mix 4 had increased the slump that is 31mm and the concrete mix 5 has the more slumps that are 41. This might be due to the addition of Diapers Polymer into the concrete mix that increases the workability even though the water cement ratio is just the same. The concrete mix 5 has the higher percentages of using the polymer that are 10% the percentages had affect the slump test due to the mix be more loose and freely to move because it contains more liquid gel in it. This might be due to increment of the amount of Diapers Polymer as it acts as a self-curing agent that happen to be a water reservoir to the concrete and so it reduces the workability decreases, the addition of the Diapers Polymer in the low percentages does not affect the workability of the concrete when compare to the control mix. But from the result we can see the highest percentages helps the concrete cubes to have higher slump than the normal mix but still maintain in a low degree of workability which is fairly acceptable.

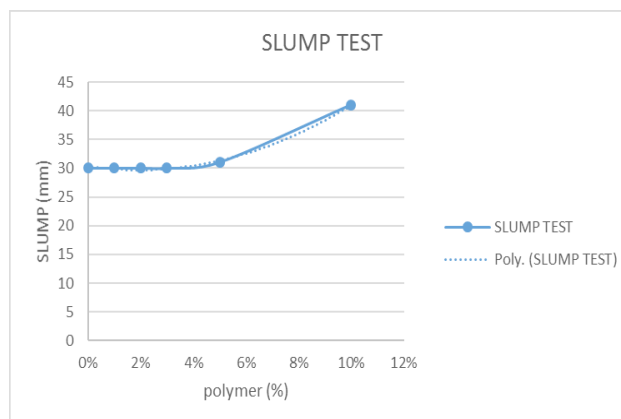


Figure 1. Workability result.

3.2 Compressive Strength Result

In general, addition of Diapers Polymer to the concrete mixture will be presented as a reduction in compressive strength of the concrete compared to a reference mixture without Diapers Polymer added which have been reported by most of publications especially at early ages of concrete. Reduction of compressive strength due to addition of Diapers Polymer can differ depends of their dosage and w/c ration used in the mixture. The higher dosage and water used, the higher reduction percentage in compressive strength compare to control mixture without Diapers Polymer added. In average, 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 (refer Figures 2 and 3).

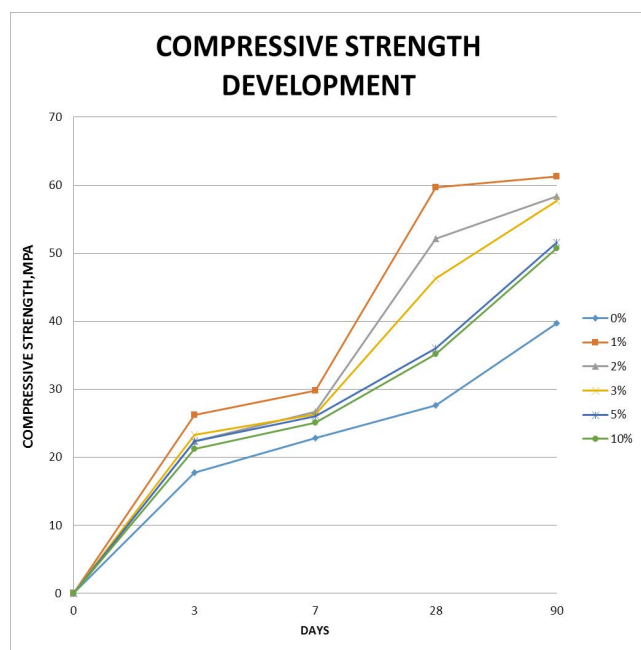


Figure 2. Compressive strength result.

3.2.1 Result for 3 Days of Curing

3 days of concrete curing is to check the workability of the concrete and the strength of the concrete. The compression has been done with the concrete with the different ratio of Diapers polymer that had been added. Based on the results that had been gain, at the 3 days of concrete curing the strength are low because of the hydration process are not fully done.

3.2.2 Result for 7 Days of Curing

Refer on the results, we can see the compressive strength test had been increased on the 7 days of curing. The trend of the graph is uniformly for all the mix. The concrete mix with added of the polymer 1% has the highest strength development for the 7 days curing this is because the polymer can be water reservoir when the hydration process and because of the amount of polymer that had been added are not in large amount, the void in the concrete are less that affect the strength of the concrete.

3.2.3 Result for 28 Days of Curing

The strength for the concrete for all concrete mix still increase in the 28 days of curing. On the 28 days of curing, normally the design grade of the concrete had been obtained. The concrete mix with added of the polymer 1% also has the highest strength. Refer to the results of the compressive strength test, all the mix had achieved the design mix strength except the control mix and the concrete mix 4 and concrete mix 5. For the concrete mix 4 and concrete mix 5, this due to the void occurs in the concrete. The concrete mix 4 and concrete mix 5 has more void compare to others because of the highest percentage of use polymer. When the hydration process, the liquid in the polymer had been absorb and the polymer will shrinkage and it will leave a void between inside it and it affect the strength of the concrete. The concrete with a more void will give a less strength.

3.2.4 Result for 90 Days of Curing

Based on the results that had been gain, at the 90 days of concrete curing the strength are still increased. Its show that hydration process gives a good impact when add with Diapers polymer. When the hydration process, the liquid in the polymer had been absorb and the polymer will shrinkage and it will leave a void between inside it and it affect the strength of the concrete. The concrete with a more void will give a less strength. From the correlation in Figure 3, we can see the concrete mix for 1% has the highest f'_{cu} and compare to others. This is due to the void inside the concrete.

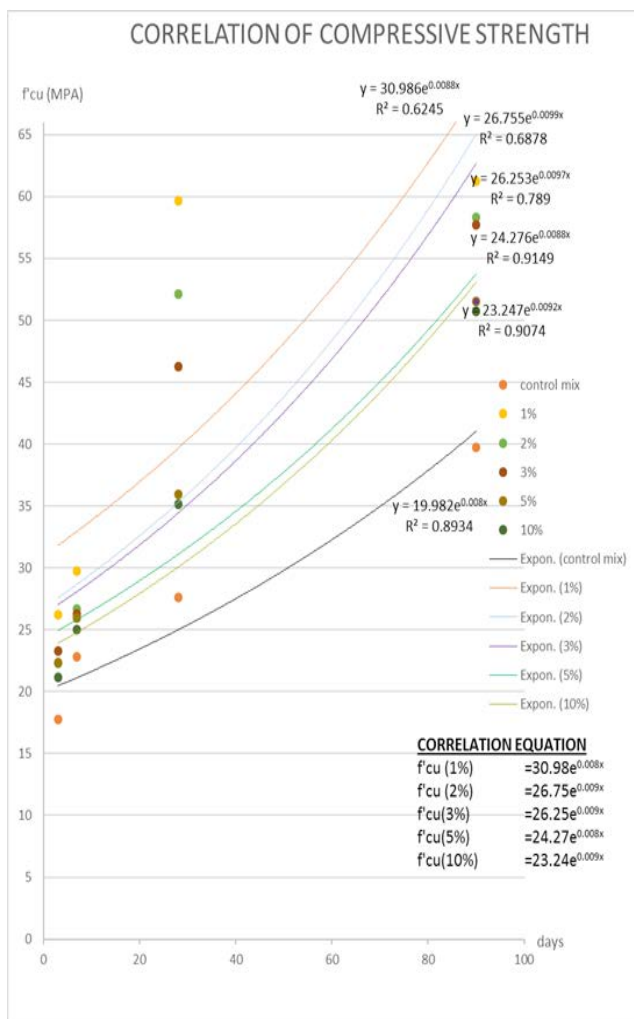


Figure 3. Correlation of Compressive strength.

4. Conclusion

The result that had obtained can conclude that the internal curing help to improve the hydration process. 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 autogenous stress free²⁰. Findings that concrete cube with added of the 1% of the baby diapers polymers has the optimum result. The hydration for the internal curing increased and it gives the positive result and have a highest strength and a good durability.

5. Acknowledgement

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