Journal of Engineering and Applied Sciences 12 (20): 5312-5316, 2017
ISSN: 1816-949X

The Use of Polymer in Concrete as Water Blocker in Rigid Pavements

[1]Khaled Z. Ramadan and [2]Moayyad Al-Nasra
[1]Department of Civil Engineering, Faculty of Engineering, University of Petra, P.O. Box 961343, Amman, Jordan
[2]College of Engineering, American University of Ras Al-Khaimah AURAK, Ras Al-Khaimah, United Arab Emirates

Abstract: The super absorbent polymer is a chemical that has the capability of absorbing water up to 500 times of its own weight at the same time its volume increases substantially. This polymer if used in concrete, fills the voids left during the process of the cement chemical reaction and also during the process of concrete drying. Rigid pavements are subjected to sever wetting and drying cycles especially, if this process is associated with a substantial temperature fluctuation. The freezing-thawing cycle can damage the concrete in an accelerated rate due to the water expansion, creating large hydraulic pressure. This hydraulic pressure is usually large enough to create cracks in the concrete. These cracks can also be filled with water during the cycle of wetting and drying, allowing the water to penetrate deeper into the rigid pavement. The process is very fast, causing substantial damage to the rigid pavement. This damage is relatively costly to repair and also it is inconvenient. The polymer concrete especially if applied at the upper layer of the concrete rigid pavement will prevent the penetration of water into the concrete by providing a sealing layer. The super absorbent polymer turns into gel when mixed with water at the same time expands substantially preventing the water to penetrate into the concrete rigid pavement. This study focuses on the effect of the use of super absorbent polymer in the concrete rigid pavement. Adding excessive amount of super absorbent polymer creates large amount of voids in the concrete. These extra voids reduce the concrete strength and jeopardize the concrete durability. Several samples will be prepared to study the concrete capability to block the water flow. Optimum value of the super absorbent polymer will be targeted to determine the most efficient concrete mix design. The effect of adding super absorbent polymer to the concrete mix on the concrete strength is also one of the main objectives of this study.

Key words: Internal curing, rigid pavement, water blocker, super absorbent polymer, water tightness, temperature

INTRODUCTION

The main advantage of the super absorbent polymer is its ability to absorb water in the amount of several hundred times its own weight producing gel. The volume of the produced gel is proportional to the amount of the water absorbed. If the product is left to dry, the volume and the weight reduces by the amount of the evaporated water. This process is usually slow due the bonding of the absorbed water into the mass of the gel. This property came to be very useful in agricultural applications where watering the plants may be an issue. Holding large amount of water and releasing it slowly is proven to be very useful property of the super absorbent polymer. This property can be utilized in concrete especially when the volume of the gel increases filling every void and gap in the concrete mass and leaving no room for the water to penetrate into the concrete mass. This study focusses on the ability of the concrete top layer of the rigid pavements to block the flow of water. Several amounts of super absorbent polymer is used to determine the most efficient amount of super absorbent polymer to be used in rigid pavement.

Rigid pavements are subjected to wide range of applied loads including the environmental loads and the traffic loads. Several researchers studied the behavior of concrete slabs subjected to point loads (Al-Nasra and Wang, 1994). Punching shear is the main concern when the slab is subjected to point traffic load. Several studies focused on improving the slab behavior when subjected to large punching shear forces (Duweib *et al*., 2013). Special reinforcement were introduced to improve the punching shear strength (Al-Nasra *et al*., 2013). The deflected shape and the strain generated by the applied point loads on slabs are also covered in previous studies (Al-Nasra *et al*., 2013). The concrete slabs and the

Corresponding Author: Khaled Z. Ramadan, Department of Civil Engineering, Faculty of Engineering, University of Petra, P.O. Box 961343, Amman, Jordan

rigid pavements can be considered as either two dimensional elements or three dimensional elements depending mainly on the slab thickness.

The use of super absorbent polymer in concrete can be extended beyond its ability to absorb large quantity of water and filling up the voids in concrete. Al-Nasra (2013a, b) studied the effect of super absorbent polymer in concrete on the insulation value of concrete. He concluded that the super absorbent polymer has significant effect on improving the insulation characteristics of concrete.

Adding water to the concrete mix is an essential step to initiate the chemical reaction. This chemical reaction is necessary to develop bonds among the concrete ingredients. The workability of fresh concrete can be improved by increasing the water cement ratio but this will reversely affect the strength as well as the durability of the concrete. Adding the super absorbent polymer to the concrete mix in a very small amount, below 1% by weight of cement, absorbs some of the added water and converts it into gel. This gel releases water slowly to the chemical reaction which is a very useful process to keep the chemical reaction active. This process is called internal curing. This process is proven to increase the strength of concrete by prolonging the chemical process. The gel also occupies space in concrete. Excessive space due to the presence of the gel will reduce the strength of concrete. An optimum amount of super absorbent polymer is necessary to balance between the need for internal curing and the reduction in concrete strength due to excessive voids produced by the super absorbent polymer.

Researchers focused on how would the super absorbent polymer affect the strength and shrinkage of concrete (Jensen, 2013). The excessive shrinkage causes cracks in concrete in its both phases; the fresh concrete and the hardened concrete. Other researchers proved that adding super absorbent polymer is helpful to the concrete by reducing the potential cracks (Jensen and Hensen, 2001). Some researchers concluded that adding super absorbent polymer reduces the stress buildup in the concrete mass which is an essential factor to reduce concrete cracks (Jensen and Hensen, 2002).

Al-Nasra (2013a, b) studied the effect of the use of special kind of super absorbent polymer called Sodium/Potassium Polyacrylates. His study main focus was on the determination of the optimum value of the super absorbent polymer to be added to the concrete mix. Al-Nasra concluded that the optimum and the most effective amount of super absorbent polymer is about 0.11% of the Portland cement used by weight.

The super absorbent polymer can be very useful to the concrete when it comes to the concrete ability to resist freezing-thawing cycles. Water expands upon freezing by an amount of approximately 9%. Providing voids in the concrete mass absorbs the hydraulic pressure generated by the water expansion. The super absorbent polymer has the potential of providing the needed voids in the concrete mass. Rigid pavement are subjected not only to hydraulic pressure but it is also subjected to the osmosis pressure due to the use of salts at the top of the rigid pavement during the frigid conditions. The top of the rigid pavement is the part of the rigid pavement that is subjected to most sever conditions. In this study the top layer of the rigid pavement is the main focus of this study.

Several researchers studied the use of the super absorbent polymer as a sealing agent (Snoeck *et al.*, 2012). The concrete cracks due to its low strength in tension. These cracks if left without treatment may expand and become serious structural defect. The deterioration of concrete is exacerbated by the presence of water. Super absorbent polymer can be used as a mean to stop the water flow through these crack (Al-Nasra and Daoud, 2013, 2006). The gel produced by the super absorbent polymer expands when exposed to water and fill out the space produced by the cracks (Al-Nasra *et al.*, 2015, 1926). Filling out the space by the super absorbent gel has the potential of blocking the water flow though the concrete mass (Al-Nasra and Daoud, 2013, 2006). The amount of super absorbent polymer used in the concrete mix determines the concrete capability of blocking the water flow under pressure. The higher the water pressure requires larger amount of super absorbent polymer to be mixed with the concrete as an admixture.

The use of super absorbent polymer in the concrete in the rigid pavement can be useful in prolonging the live of the rigid pavement. The top layer of the rigid pavement is the focus of the study. The top portion of the rigid pavement can be mixed with an optimum amount of super absorbent polymer. This top portion will act as a sealing layer preventing the water to penetrate into the concrete lower layers. Also this top portion layer helps in reducing the damage caused by the freezing and thawing cycles.

MATERIALS AND METHODS

Super absorbent polymer: The super absorbent polymer tested in this study is the sodium salt of the polyacrylic acid. This polymer has the potential of absorbing water up to 500 times its own weight. It is negatively charged anionic Polyelectrolytes. Figure 1 shows the super absorbent polymer before adding water and after adding water.

Fig. 1: Sodium polyacrylate super absorbent polymer

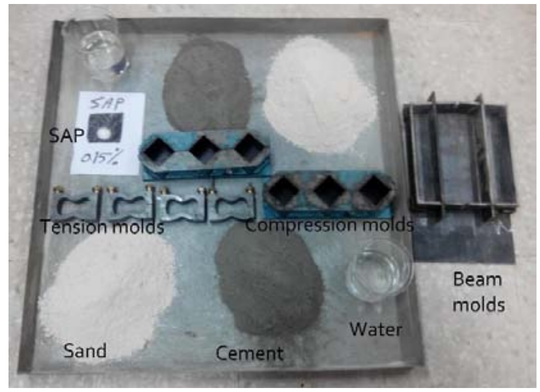

Fig. 2: Concrete ingredients

The sodium super absorbent polymer used in this study is made of several multiple chains of acrylate chemical compound. This compound has the capability to attract water-based fluid molecules. It absorbs water in a relatively faster rate. When this compound is subjected to drying process, it loses moisture in a much slower rate. This phenomena is very useful whenever there is a need for a continuous supply of water. That makes this compound very useful in plant that need continuous supply of water over long period of time. Also this phenomena became useful in concrete where internal curing is needed.

RESULTS AND DISCUSSION

Water tightness test: Two groups of samples were prepared in this study; the first group is prepared to test the concrete strength and the second group is prepared to test the concrete ability to block the water flow. The samples were prepared with at least two different amounts of super absorbent polymer in addition to the control sample which is prepared with 0% of super absorbent polymer. The 0% super absorbent polymer is used as the control sample. Figure 2 shows a tray of typical concrete ingredients used in this study. The figure shows two batches. The first batch is the plain concrete with no admixture. The second batch uses the same ingredients as in the first batch in addition to the super absorbent polymer used here as admixture. Three different groups of samples were prepared to test the concrete strength. The first group is to test the concrete strength by preparing concrete cubes of 5 cm side length. The second group is to test the tensile strength by preparing dog-bone samples. The third group is to test the flexural strength of concrete by preparing beams. Figure 3 shows the compressive strength of the plain concrete and the concrete mixed super absorbent polymer at a percentage

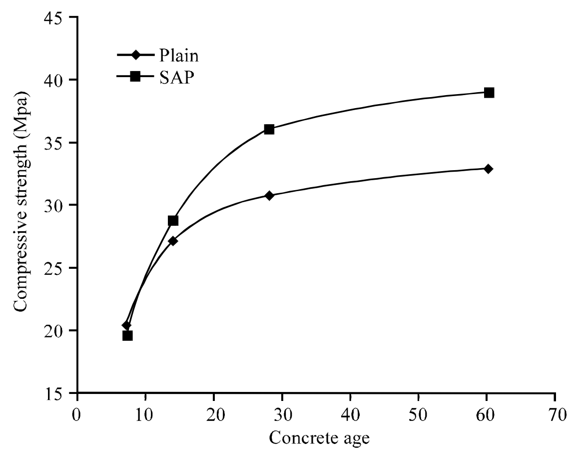

Fig. 3: Concrete compressive strength of plain concrete and concrete mixed with 0.1% SAP

Fig. 4: Flexural sample at failure

of 0.1% by weight of the Portland cement used in the concrete mix. The tensile strength results were very close among the plain samples and the samples prepared with the super absorbent polymer. Figure 4 shows the flexural mode of failure of the tested beams. The plain samples behavior is very similar to the one mixed with super absorbent polymer. The results of the tested samples were very close. The beam test results of the plain samples were very similar to the results of the samples prepared the super absorbent polymer.

Additional three more groups of samples were prepared to test the concrete ability to block the water flow through the concrete mass. Table 1 shows the concrete ingredients used in this study. The first group is prepared with no super absorbent polymer and it is used as control sample. The other two group of samples were mixed with 0.15 and 0.25% of super absorbent polymer by the weight of Portland cement used respectively. The water cement ratio used in these samples was fixed for all samples and is taken to be 0.52.

The water flow test samples were prepared as cylindrical solid samples then subjected to bending stresses to break across the diameter making almost two equal pieces. Figure 5 shows the sample ready to be placed in its chamber to be tested for water flow. The water flow sample is of 10 mm thickness and of 35 mm in diameter. The sample is of almost two equal pieces put together making an artificial crack. The sample is subjected to constant water pressure of 105 cm. The sample is placed in a sealed chamber allowing the water to flow only through the artificial crack.

The test is focused on measuring the volume water flowing through the induced artificial crack per time. The samples were prepared with different values of super absorbent polymer ranges from 0-0.25% of the cement used by weight. The water discharge is measured as follows:

$$D = F/t \quad (1)$$

Where:

D = The water discharge (mL/min)

F = The volume of water flowing through the induced crack (mL)

t = Time (min)

Figure 6 shows the water flow due to constant water pressure using different values of super absorbent polymer. The sample of 0% super absorbent polymer, which is called here plain concrete sample and is used as control sample, exhibited large flow rate that ranges from 26.8-28.5 mL/min. The amount of super absorbed polymer used plays significant role in determining the amount of flow. The flow reduces with time. The gel expands with time, making it possible for the crack to block the water flow completely with time. The sample of 0.25% super absorbent polymer by weight of cement was able to block the water flow completely in 112 min from the start of the test under constant water pressure of 105 cm.

Table 1: Ingredients used

Sample ID	Sand (g)	Cement (g)	SAP (g)
P-Plain	500	250	0.0
0.15-SAP	500	250	0.15
0.25-SAP	500	250	0.25

Fig. 5: Water flow sample broken into two pieces

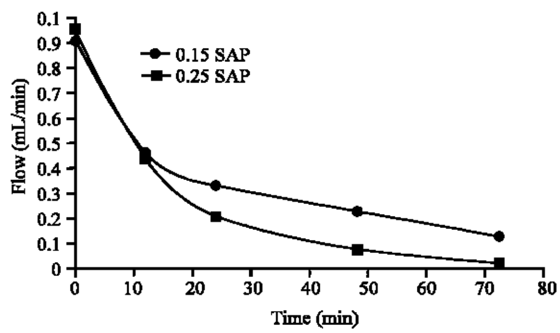

Fig. 6: Water flow results

CONCLUSION

The super absorbent polymer is found capable to block the water flow though the concrete cracks if used as admixture in the concrete mix. As the amount of the super absorbent polymer increases in the concrete mix the concrete capability of blocking the water flow increases. The water flow though the concrete mixed super absorbent polymer decreases with time as the volume of the gel produced by the reaction of the super absorbent polymer and the water increases, filling out the voids and spaces in the concrete mass. The super absorbent polymer has the potential to provide internal curing in the new concrete which in turn, helps to increase the concrete strength. Excessive amount of super absorbent polymer added to the concrete mix generate excessive voids. These voids reduce the concrete strength.

ACKNOWLEDGEMENT

The researchers would like to acknowledge the University of Petra for providing all kinds of support.

REFERENCES

Al-Nasra, M. and L.R. Wang, 1994. Parametric study of slab-on-grade problems due to initial warping and point loads. Struct. J., 91: 198-210.

Al-Nasra, M. and M. Daoud, 2006. Study of the ability of cracked concrete to block water flow, concrete mixed with super absorbent polymer. ARPN. J. Eng. Appl. Sci., 12: 274-281.

Al-Nasra, M. and M. Daoud, 2013. Investigating the use of super absorbent polymer in plain concrete. Intl. J. Emerging Technol. Adv. Eng., 3: 598-603.

Al-Nasra, M., 2013a. Concrete made for energy conservation mixed with sodium polyacrylates. Space, 3: 601-604.

Al-Nasra, M., 2013b. Optimizing the use of sodium polyacrylate in plain concrete. Intl. J. Eng. Res. Appl., 3: 1058-1062.

Al-Nasra, M., A. Najmi and I. Duweib, 2013. Effective use of space swimmer bars in reinforced concrete flat slabs. Intl. J. Eng. Sci. Res. Technol., 2: 195-201.

Al-Nasra, M., M. Daoudb and T.M. Abu-Lebdeh, 2015. The use of the super absorbent polymer as water blocker in concrete structures. Am. J. Eng. Appl. Sci., 8: 659-665.

Al-Nasra, M.M., I.A. Duweib and A.S. Najmi, 1926. The use of pyramid swimmer bars as punching shear reinforcement in reinforced concrete flat slabs. J. Civ. Eng. Res., 3: 75-80.

Duweib, I., M. Al-Nasra and A. Najmi, 2013. Investigating the use of swimmer bars as punching shear reinforcement of reinforced concrete flat plates. Intl. J. Eng. Res. Ind. Appl., 6: 127-139.

Jensen, O.M. and P.F. Hansen, 2001. Autogenous deformation and RH-change in perspective. Cem. Conc. Res., 31: 1859-1865.

Jensen, O.M. and P.F. Hansen, 2002. Water-entrained cement-based materials: II, Experimental observations. Cem. Conc. Res., 32: 973-978.

Jensen, O.M., 2013. Use of superabsorbent polymers in concrete. Concr. Intl., 35: 48-52.

Snoeck, D., K.V. Tittelboom, N.D. Belie, S. Steuperaert and P. Dubruel, 2012. The Use of Superabsorbent Polymers as a Crack Sealing and Crack Healing Mechanism in Cementitious Materials. In: Concrete Repair, Rehabilitation and Retrofitting III, Alexander, M.G., B. Hans-Dieter, D. Frank and M. Pilate (Eds.). CRC Press, Boca Raton, Florida, USA., pp: 58-59.