Kufa Journal of Engineering
Vol. 8, No. 2, June 2017, P.P. 42-52
Received 22 August 2016, accepted 30 November 2016

COMPRESSIVE STRENGTH OF CONCRETE CONTAINING WATER ABSORPTION POLYMER BALLS (WAPB)

Ikram Faraoun Ahmed[1]

[1] Instructor at Civil Engineering Dept./ University of Baghdad, Email: Ikram_f_mulla@yahoo.com

ABSTRACT:

Water absorbent polymers (WAP) are new component in producing building materials. They provide internal curing which reduces autogenous cracking, eliminates autogenous shrinkage, mortar strength increased, enhance early age strength to withstand strain, improve the durability, introduce higher early age compressive strength, have higher performance and reduce the effect of insufficient external curing. This research used different percent of polymer balls to choose the percent that provides good development in compressive strength with time for both water and air curing. The water absorption polymer balls in this research have the ability to absorb water and after usage in concrete they spill out the water (internal curing) and shrink leaving voids of their own diameter before shrinking, thus leads to have internal curing with air voids to reduce the samples weight .The required quantity of water for the mixes reduced due to the addition of water from the absorption polymers.

KEYWORDS: Water absorption polymers; Cellular concrete; Internal curing

مقاومة انضغاط الخرسانة الحاوية على الكرات البوليمرية الممتصة للماء

م. اكرام فرعون احمد

قسم الهندسة المدنية/ جامعة بغداد

الخلاصة :

البوليمرات الممتصة للماء هي اسلوب جديد في انتاج المواد البنائية التي تحتفظ بالماء اذ تقدم معالجة داخلية والتي تقلل التشققات الذاتية وتقلل الا نكماش الذاتي وتزيد قوة المونة والخرسانة وتزيد الانفعال المبكر وتزيد مقاومة الانضغاط المبكرة وبالتالي تحسن الاداء العام وتقلل من تاثير المعالجة الخارجية. هذا البحث يستخدم نسب مختلفة من الكرات البوليمرية لاختيار النسبة المثلى التي تعطي تطور جيد لمقاومة الانضغاط مع الزمن للنماذج المعرضة للمعالجة بالماء وبالهواء. ان الكرات البوليمرية (WAPB) المستخدمة في هذا البحث لها القابلية على امتصاص الماء وبعد وضعها في الخلطات الكونكريتية تطرح هذا الماء (تعطي معالجة داخلية) وتنكمش تاركة فراغات داخل الخلطة الخرسانية بقدر قطر هذه الكرات قبل انكماشها مما يقلل من وزن النموذج ان كمية الماء المستخدمة لاجراء الخلطات الخرسانية تم تقليلها بما يتناسب واضافة الكرات البوليمرية الماصة للماء وحسب كمية الماء الذي ستطرحه هذه الكرات البوليمرية.

مفاتيح البحث: البوليمرات الماصة للماء، الخرسانة الخلوية، المعالجة الداخلية

1. INTRODUCTION:

Different types of polymers are known to function as super- absorber, most of them are often poly acrylic acids which are used since their water absorption ratio (water absorption in relation to self-weight) is higher than other types of polymers (Aggarwal et al., 2007). The polymers are covalently cross linked by di-functional molecules. The swelling capacity of polymers is highly reduced in the presence of ions because they cause collapse the gel that cross linking the polymers (Sequera et al., 2015) this fact invented the use of saturation absorption polymers which are small spherical balls used in concrete and cement mortar. The addition of polymers to cement mortar and concrete enhances many properties such as the workability, increasing the flexural and compressive strengths, decreasing the water absorption, carbonation and chloride ions penetration and improve their characteristics to use for works in humid and industrial environments (Monnig, 2005). All the previous enhancements depends totally on the type of polymers to be added to mortar or concrete and their dosages (Jensen, 2013). Using water absorption polymer balls (WAPB) considered as sustainable material. Super-absorbent polymers came recently under investigation and it was expected that they perform as internal water sources. The polymers extract water after they have been added to mortar or concrete mixture (Sefton, 2013). They provide the absorbed water during hydration functioning as internal water source. These polymers can absorb up to hundreds of their own weight of pure water (Ganesh et al., 2003).Water Absorption Polymers (WAP) typically have a water absorption of 100 to 400 g/g dry, and they can be produced in almost any size and shape (Aggarwal et al., 2007). WAPs belong to the group of called “smart materials” (Monnig, 2005) that, significantly change their properties when exposed to water, they swell, and when subsequently subjected to drying, they reversibly shrink. These key properties can actively be used in relation to concrete (Hoff, 1972). Dry WAP addition can result in positive effect, including internal water curing, mitigation of autogenous shrinkage, and reduced susceptibility to damage due to freezing and thawing (Sefton, 2013). There are many characteristics of the polymer balls WAP such as low density, low coefficient of friction, good corrosion resistance, excellent surface finishing, can be produced with close dimensional tolerance, economical, have poor tensile strength, low mechanical properties, poor temperature resistance, different colours (Kearsely et al., 2001).

1.1. Aim of this research:

This research aimed to produce concrete with internal curing by using water absorbing polymer balls and study the compressive strength of different ratios of this type of polymers

2. MATERIALS AND SPECIMENS:

Ordinary Portland cement (Table 1) with natural sand graded (Table 2) and gravel of maximum size (5-15mm), absorption (0.49%) and SO_3 (0.06%) (Table 3) were used to produce five concrete mixes (Table 5) .The mix proportions were described in (Table 4) .The water absorption polymers (WAP) were added with percentages of (5%, 10%, 15% and 20%) by weight of cement. The mixes were designed according to the ACI 211 with target compressive strength for plain mix at 28 days of curing was (20 MPa) with w/c ratio 0.44.The water absorption polymer balls were immersed in water for 24 hours to absorb the water and enlarged in size, then they were added to the mixes with different percentages.

Table 1. Properties of cement.

Chemical properties of cement		
Oxides	Percentage	I.Q.S. No.5/1981
CaO	60	
SiO_2	20	
Al_2O_3	3.6	
Fe_2O_3	3.4	
SO_3	2.3	2.5(max.)
MgO	3	5 (max.)
Loss on ignition L.O.I	3.1	4 (max.)
Physical properties of cement		
Fineness (Blaine)m^2/kg	310	230 (min.)
Setting time		
Initial (minutes)	80	45(min.)
Final(hours)	5	10(max.)
Compressive strength (Mpa)		
3-days	19	15(min.)
7-days	25.8	23(min.)

Table 2. Grading and properties of sand.

Sieve size (mm)	% passing	% passing I.Q.S No.45/80(zone 3)
4.75	100	90-100
2.36	93.43	85-100
1.18	84.48	75-100
0.6	69.13	60-79
0.3	28.68	12-40
0.15	8.98	0-10
Fineness modulus	2.15	
Sp.gr.	2.63	
Sulfate SO_3	0.08%	
Dry rodded density (Kg/m^3)	1592	

Table 3. Grading and properties of coarse aggregate.

Sieve size (mm)	% passing	% passing I.Q.S No.45/80
14	100	100
10	98.9	85-100
4.75	17.4	0-25
Sp.gr.	2.69	

Table 4. Mix proportions for the used mixes

Contents	Mix content(kg/m^3)	Water absorption polymer ball%	Mix proportion	
Cement	300	5	% by weight	1:1.5:2.6
Sand	450	10	w/c ratio	0.44
Gravel	780	15		
Water	135	20		

Water absorption polymer balls (WAPB) are small spherical polymers have the ability to absorb water 102 times their own size. The dry water absorption polymer balls (WAPB) were immersed in water for one day then they will used in concrete as shown in Picture 1-a & b.

(a) Polymer balls after and before absorbing water (b) water absorption polymer ball

Picture 1. (a & b) Water Absorbent Polymer balls (WAP).

The mixes were poured in (100x100x100) mm cubes and half of the samples were cured in water then tested for compressive strength(three cubes for each age) at ages (28, 60, 90 &120) days Figs. 1, 3, 4, 5, 6 & 7**,** the other samples were cured in water for 7 days and then continued curing in air depending on the internal curing from the water absorption polymers (WAP) and then tested after ages (28, 60, 90 &120) days in air Figs. 2, 3, 4, 5, 6 & 7**.**

3. TEST RESULTS

All the results of this research were tabulated in (Table 5), the mixes mentioned were: mix 1 plain mix contains no water absorption polymer balls (WAP), mix 2 contains 5%, by weight of cement, water absorption polymer balls (WAP), mix 3 contains 10% water absorption polymer balls (WAP), mix 4 contains 15% water absorption polymer balls (WAP) and mix 5 contains 20% water absorption polymer balls (WAP). The w/c ratio were reduced as the water absorption polymer balls (WAP) were added to the mixes (each weight of WAPB is measured before and after immersed in water then we reduce the difference between the weights from the mix´s water). Obviously, control of water is important to concrete, this research gives an overview of some of the opportunities offered by the use of the water absorption polymer balls (WAP) for achieving that control. The compressive strength for samples cured in air were higher than those cured in water at any age Figs. 4, 5, 6 & 7 and except for mix 1(without water absorption polymer balls WAP) Fig. 3**.** This behavior leads to a conclusion that the water absorption polymer balls (WAP) developed compressive strength with time by internal curing.

Figs. 1, 3, 4, 5, 6 & 7, were cured in water then tested for compressive strength at ages (28, 60, 90 &120) days while Figs. 2, 3, 4, 5, 6 & 7 were cured in water for 7 days and then continued curing in air and then tested after ages (28, 60, 90 &120) days in air**.**

Table 5. Compressive strength (MPa) with time (Days) for mixes containing water absorption polymer balls (WAPB).

mixes	Curing type	Strength @28 days	Strength @60 days	Strength @90 days	Strength @120 days
Mix 1 (plain)	Air	12.3	16.6	17	17.5
	Water	20	26	28.5	29
Mix 2 (5%WAPB)	Air	21	24	29	29.6
	Water	18.5	19	19.6	20
Mix 3 (10%WAPB)	Air	20.8	22	28.64	29
	Water	15.2	17	20	21
Mix 4 (15%WAPB)	Air	21	23	26	26.5
	Water	15	16.3	18	18.2
Mix 5 (20%WAPB)	Air	16.7	17.4	18	19
	Water	15	16	17.4	18.7

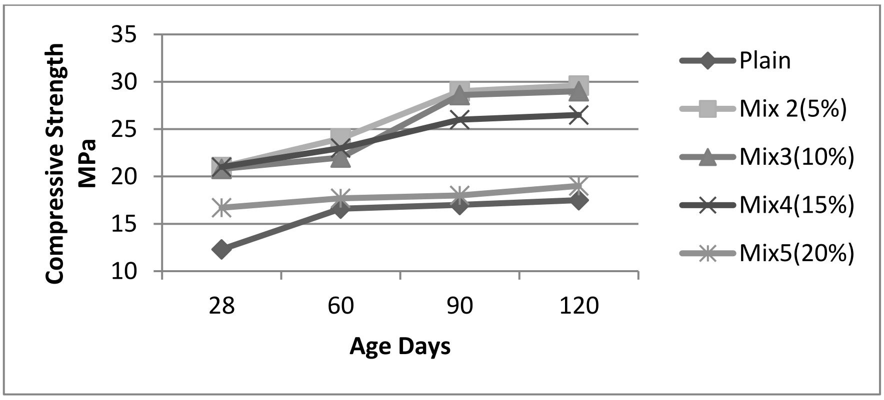


Fig. 1. Compressive strength with time in air curing for different mixes.

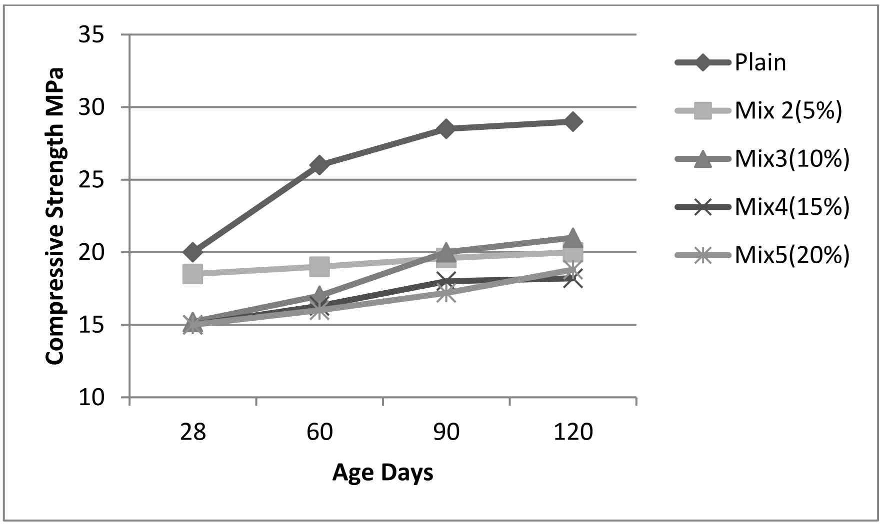


Fig. 2. Compressive strength with time in water curing for different mixes.

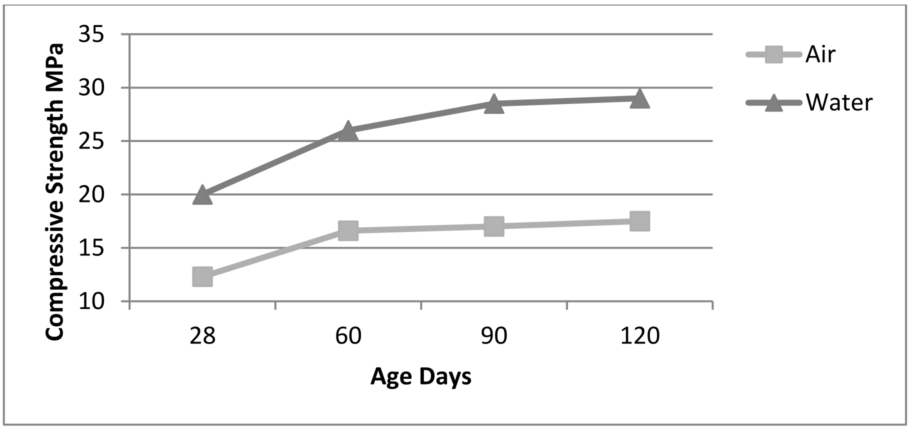


Fig. 3. Compressive strength for plain mixes with air& water curing.

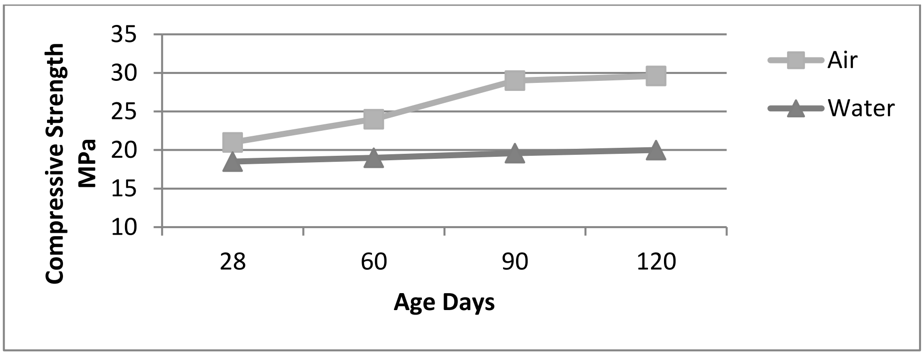


Fig. 4. Compressive strength for 5% WAP mixes with air& water curing.

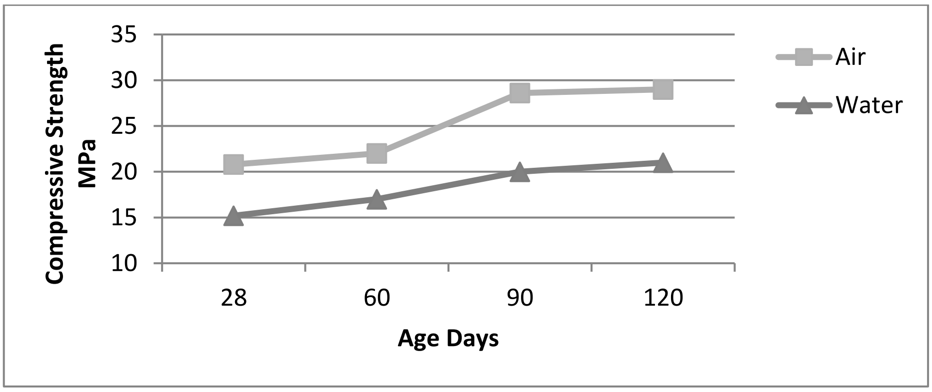


Fig. 5. Compressive strength for 10% WAP mixes with air& water curing.

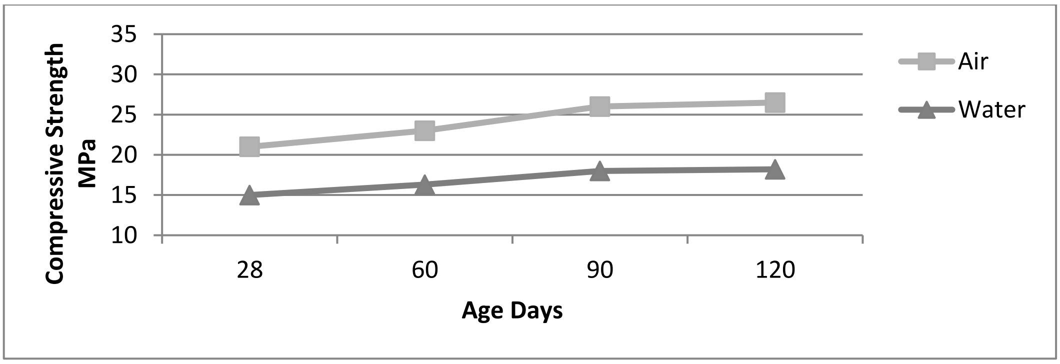


Fig. 6. Compressive strength for 15% WAP mixes with air& water curing.

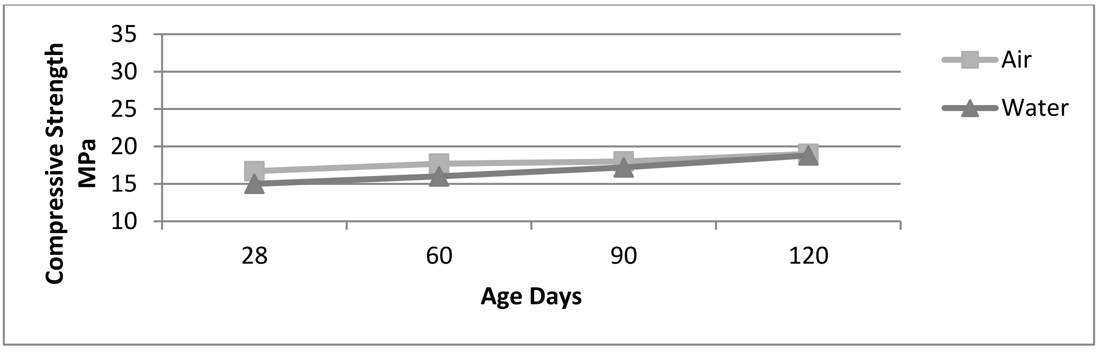
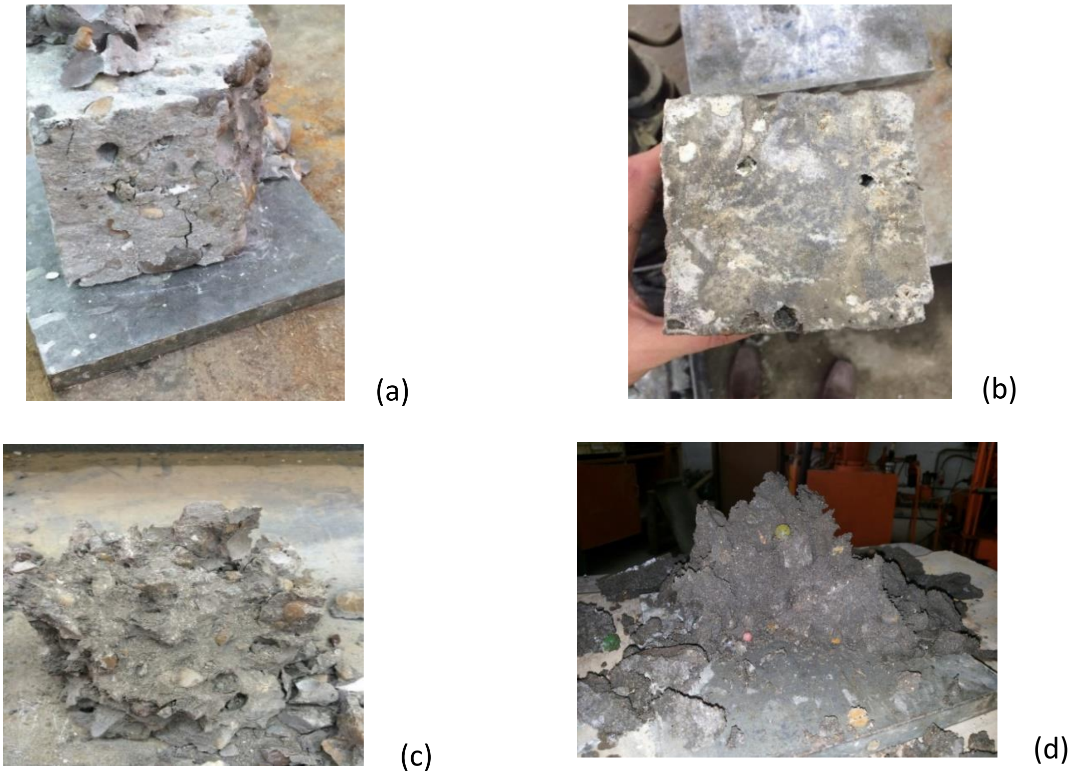


Fig. 7. Compressive strength for 20% WAP mixes with air& water curing.

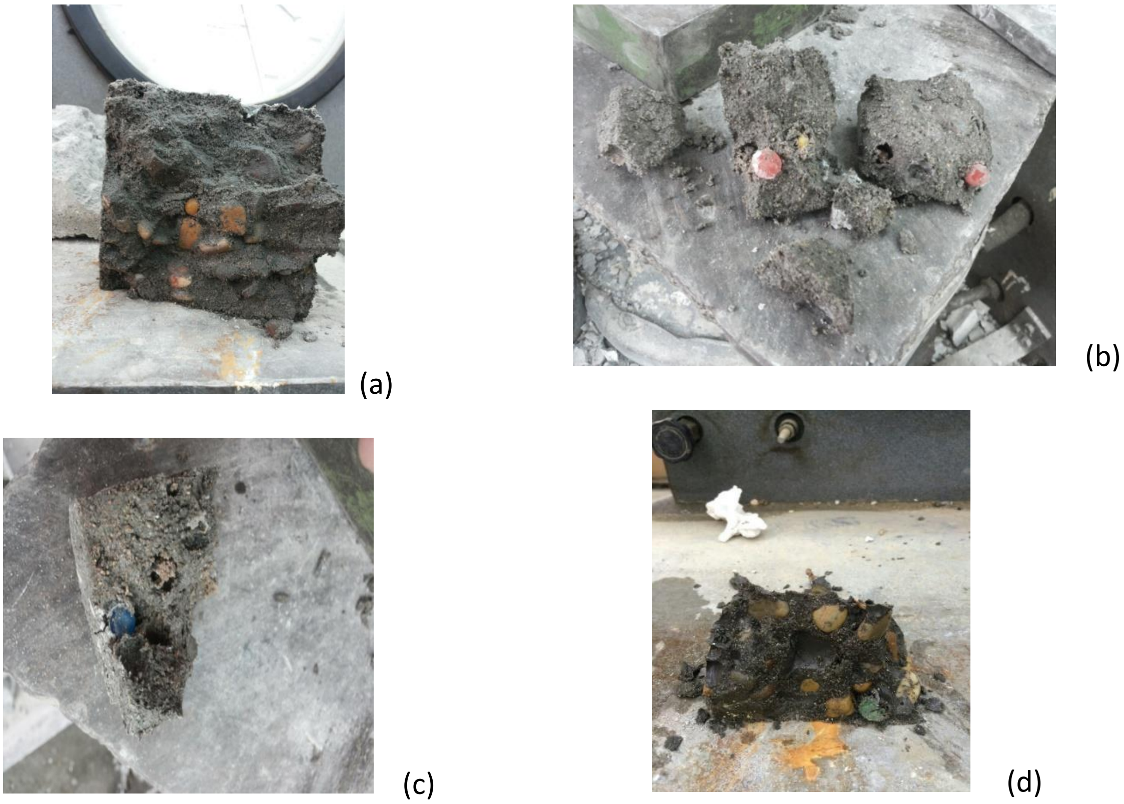
4. DISCUSSION

Water Absorption Polymer balls (WAPB) may enhance sustainability and durability normally caused by corrosion of reinforcing steel within concrete structure after abundant amount of water get absorbed. The polymers influence the concrete on two different ways, dependent on the way how they get added to the mixture. Firstly, in case of being dryly inserted, they extract water from the fresh mix and by doing this the density of the matrix increases (Baozhen, 1987). Thereby they can consume such high amounts of water that their diameter increases dependent on their ability to consume water producing air pores with diameters of up to 14mm. Secondly, they provide the absorbed water during hydration and act as an internal water source (Baozhen, 1987). From Table 4 it can be noticed that the typical percentage of water absorption polymer balls (WAPB) addition was 5% by weight of cement and air curing provides higher compressive strength Picture 2-a, b, c & d since there is internal curing that keeps the hydration to be continue.

While in water curing the compressive strength reduced Picture 3 (a, b, c & d) because the balls continued absorbing water till they exploded (Picture 4) and create pores in the concrete structure that reduces the compressive strengths with time.



Picture 2. Samples containing (water absorption polymers) cured in Air: a-after 28 days b- after 60 days c- after 90 days d- after 120 days



Picture 3. Samples containing WAP (water absorption polymers) cured in water: a-after 28 days b- after 60 days c- after 90 days d- after 120 days

Picture 4. Polymer balls shrinks and exploded leaving pores in concrete.

5. CONCLUSION

1. Water Absorption Polymer balls (WAP) provide their absorbed water during hydration as internal water curing and can absorb up to 102 times of their own size.
2. From the behaviour of polymer balls it can be concluded that the compressive strength is reduced due to the pores caused by WAP.
3. The water percentage of concrete mixes reduces by the substituted percentage of water from the water absorption polymer balls WAP.
4. The compressive strength in air curing increased by 16% than that in water curing due to the internal curing provided with time.
5. With the development of water curing the water absorption polymer balls WAPs exploded since they absorbed water over their own bearings
6. Increasing the percentage of water absorption polymer balls WAPs leads to reduce the compressive strength of concrete as they provided more pores.
7. The typical percent of water absorption polymer balls WAP(Water Absorption Polymer balls) to be added to the concrete mix and provides good compressive strength was 5% by weight of cement.

6. REFERENCES

Aggarwal. L. K., Thapliyal P. C. and karad S. R., 2007 “Properties of polymer mortar using epoxy and acrylic emulsions”, Science Direct (ELSEVIER), construction and building materials, vol.21, pp. 379-383.

Babu K. Ganesh. and Saradhi D. Babu, May 2003 "Behavior of lightweight expanded polystyrene concrete containing silica fume", cement and concrete research, vol.33, issue 5,pp.755-762.

Baozhen S. and Erda S., September 1987 "Relation between properties of aerated concrete" proclaiment, France, p.p.232 -237.

Hoff G. C., 1972 "Porosity – strength consideration for cellular concrete", cement and concrete research, vol.2, p.p.91-100.

Kenneth Sequera, Raghu Naik and B. Pai, June 2015 "Use of superabsorbent polymer powder in internal cured concrete", Vol.2, international research journal of engineering and technology, p.p. 1593-1595.

Kearsely E. P. and Wainwright P. J., 2001 "Porosity and permeability of foamed concrete", cement and concrete research, vol.31, pp. 805-812.

Mejlhede O. Jensen, January 2013 "Use of superabsorbent polymers in concrete", concrete international.

Robert C. Sefton, 2013 "Concrete mixture containing expanded polystyrene and homogentizing agent", Applied science journal, vol.21, pp.1356-1360.

Sven Monnig, 2005 "Water saturated superabsorbent polymers used in high strength concrete", Otto-Graff Journal, vol.16.

ACI 211, 2002 "standard practice for selecting proportions for normal, heavyweight and mass concrete", reported by ACI Committee, 211.1-1 - 211.1-38.