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الخواص الديناميكية للخرسانة المطورة بالبوليمر والمعرضة لتأثير حامض النتريك

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الخلاصـــــة

في الوقت الحاضر هنالك اهتمام عالمي واسع في تكنولوجيا الخرسانة نحو تحسين ديمومة الخرسانة، ان احد واهم الطرق لتحقيق ذلك هو باستخدام المواد البوليمرية والتي اصبحت واسعة الاستخدام حول العالم. ان الهدف الرئيسي من هذا البحث هو لدراسة السلوك الديناميكي للخرسانة المطورة بالبوليمر والمعرضة لتأثير حامض النتريك المخفف. تم استعمال نوعين من المواد البوليمرية (مطاط الستايرين-بيوتادين وراتنج الايبوكسي) وتم اضافتهما بنسب (٥, ١٠, ١٥ %) كنسبة من وزن السمنت. وتم غمر النماذج كليا في محلول حامض النتريك المخفف (٠.٥، ١.٥، ٣ %) لحين أجراء الفحص.

تم فحص مقاومة الانضغاط ومعامل المرونة الساكن ونسبة بوسون والامواج فوق الصوتية ومعامل المرونة الديناميكي و مقاومة الصدم.

اثبتت النتائج بان اضافة المواد البوليمرية(مطاط الستايرين-بيوتادين وراتنج الايبوكسي) يؤدي الى تحسن مهم في مقاومة الانضغاط و ومعامل المرونة الساكن وصلابة الانثناء والامواج فوق الصوتية ومعامل المرونة الديناميكي و مقاومة الصدم مقارنة مع نماذج المرجعية وفي كافة الاعمار. ان نسب التحسن هذه تتناسب طرديا مع الزيادة في نسبة البوليمر|السمنت واستخدام راتنج الايبوكسي . وكذلك اظهرت النتائج أظهرت ان استعمال البوليمر|السمنت بنسبة ١٥ % يعطي تحسن ملحوظ في الخواص الميكانيكية والديناميكية وكذلك أداء جيد لتأثيرات حامض النتريك المخفف.

Dynamic Properties of Polymer Modified Concrete Subjected to Nitric Acid Attack

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Abstract

In the present a great world-wide consideration in concrete technology trends to improve the durability of concrete. One of the important ways to satisfactorily realize this objective is by using polymeric materials, which are widely used in the world. The main aim of this study is to investigate the behaviour of the polymer modified concrete under dynamic effect and exposed to diluted nitric acid solution.

Two types of polymeric materials (SBR and epoxy) are used as cement modifiers; these materials are added to the concrete mix in three percentages (5, 10, and 15%) by weight of cement. The specimens were totally immersed in three soultions percent (0.5, 1.5, and 3%) of diluted nitric acid until the time of test.

Compressive strength, static modulus of elasticity, Poisson's ratio, ultrasonic pulse velocity, dynamic modulus of elasticity and impact strength are investigated for reference, SBR, and epoxy modified concretes.

Results show that SBR and epoxy modified concrete exhibit significant improvement in compressive strength, ultrasonic pulse velocity, dynamic modulus of elasticity, and impact strength, compared with reference concrete at all ages. The results also showed that the improvements are directly proportional to the increase in P/C ratio and use of epoxy resin.

The results also indicated that the specimens containing P/C ratio of 15% have a noticeable improvement in dynamic properties and significant improvement in performance with diluted concentrations of nitric acid.

1. Introduction

Nowadays due to development in the different life branches many problems are reflected with adverse effect on the structural concrete behavior in complex manner. Day by day new concrete defects appears to be pragmatic. This effects can be noted in the dynamic effects which increase and are seen in various types such as machine vibration, impact, rocket, ballistic, explosions, heavy duty traffic of vehicle, wind load, earthquake and seismic.

One of the most important problems of the concrete durability is the attack of acidic solutions, where no Portland cement, regardless of its other ingredients, can withstand attack from water of high acid concentration [(1)].

The compensation effects of the two previous parameters (dynamic effect and deterioration) are harmful on concrete performance. In this connection, there has been a fresh demand for a newly developed concrete which will supplement the defects of the existing cement concrete. Polymer modified concrete is one of the favorable solutions to utilize the dynamic properties and increase concrete durability to aggressive solutions especially acidic ions. The use of polymer modified concrete is creating a balance in strength, durability, and cost.

Several investigations have been made about the effect of aggressive acidic solutions with different concentration on the durability of polymer modified concrete[2, 3].

As for the field of effect of polymer cement ratio on the dynamic properties, the results shows an improvement on the dynamic modulus of elasticity and impact resistance with raising the P/C ratio[4, 5, 6].

The main aim of this investigation is to find out the dynamic characteristics of the polymer modified concrete exposed to diluted nitric acid solutions.

2. Experimental Program

2-1 Materials

a- Cement

Type (I) ordinary Portland cement was used, the chemical and physical properties are conform to the Iraqi Specification No.5/1984.

b- Fine Aggregate

The fine aggregate used in this investigation was brought from Al-Ukhider region and it is conforms to requirements of the Iraqi Specification No.45/1984, zone (3).

c- Coarse Aggregate

Crushed gravel with (19 mm) maximum size brought from Al-Nebai region is used in this work. The grading, clay content, and sulfate content are determined. The test results show that these characteristics are within the limits specified by Iraqi Standard Specification No.45/1984.

d- Polymers

Two types of polymers are used, Styrene butadiene rubber (SBR) which is commercially named **SIKA LATEX EMULSION** and Epoxy resin which is commercially named (**QUICK MAST-108-ENGLAND**).

e- Nitric Acid

Nitric acid solution with the concentrations 0.5, 1.5, 3% was used in this study.

2-2 Mixes, Mixing and Preparation of Specimens:

Mix design is made in accordance with building design established method. Reference concrete mixture is designed to give at 28 days characteristic compressive strength of 40 MPa, the mix proportions are 1:1.54:3.59 (Cement:Sand:Gravel) with water cement ratio 0.45 and 75±5mm slump.

The mix proportion for polymer modified concrete is similar to that of reference concrete except the W/C ratio, were changed to maintain the same slump for all polymer/cement ratio. The P/C ratio for SBR or epoxy which used are 5, 10, 15%.

After the raw materials are mixed with water for 90 seconds up to the homogeneity of mix, then the polymer modifier (SBR or epoxy) is added during a mix period about 1 minute and mixed for about 30 seconds, adopted by 1 minute rest to avoid the air bubbles as recommended by ACI committee 548[7]. Finally the mixture is remixed for about 1 minute.

Concrete cube of 100mm were used for compressive strength and prisms of 100×100×400m were used to measure the ultrasonic pulse velocity according to ASTM C597-2003 and cylindrical specimens of 150×300m for Poisson's ratio according to ASTM C469-2003 and slab of 400×400×50mm for impact strength.

2-3 Curing:

Three types of curing (air dry, moisture, hybrid) methods had been investigated, the third method gave the best results, thus it has been considered in this research.

2-4 Experimental Test:

a- Impact Strength:

A drop weight test was used to determine impact resistance of specimens, it is considered good and simple test method [8, 9]. Impact test was performed on slabs supported on four side frame. A steel ball of 567gm positioned at a predetermined height 1200nm was dropped at the center of the slab.

For the first blow; the maximum transient central deflection (total deflection) and the residual central deflection was measured. The depth and diameter of creature at impact zone with respect to number of blows was measured also.

Number of blows that caused first crack, initial scabbing, complete scabbing and perforation were observed and recorded. The total scabbing was measured by using plano meter apparatus.

b- Dynamic Modulus of Elasticity:

Indirect method is adopted to find the dynamic modulus of elasticity by applying the equation (1) below:

Concrete Type	Symbol	P/C ratio	W/C ratio to	Compressive strength (MPa)

$$v = \sqrt{\frac{Ed(1-\mu)}{\rho(1+\mu)(1-2\mu)}} \quad \text{..........(1)}$$

Where:

v: Ultrasonic pulse velocity (m/s)

Ed: Dynamic modulus of elasticity (GPa)

ρ: Density of concrete (kg/m^3)

μ: Poisson's ratio

3. Results and Discussion

3-1 Compressive Strength:

The development of the compressive strength of reference and various types of polymer modified concrete (SBR and epoxy) with age is presented in Table (1).

The test results show that the compressive strength of Polymer modified concrete (SBR and epoxy) is higher than that of reference concrete at all test periods and the percent increase decreases with the increase in P/C ratio. This behavior may be due to that the, W/C ratio is low in polymeric mixture compared with reference concrete, and the partial filling of the pores with the polymer particles reduces the porosity of the polymer modified concrete(9).

Table (1) Compressive strength of (100 mm) cubic specimens of reference and various types of polymer modified concrete specimens

				Age(days)				
				7	28	56	90	180
Reference concrete	R	0	0.48	23.1	39.5	42.0	42.8	43
SBR concrete	S5	5	0.42	36.6	51.4	53.3	54.0	56.7
SBR concrete	S10	10	0.35	31.0	46.6	48.9	50.0	52.0
SBR concrete	S15	15	0.33	44.7	47.8	48	48.1	49.3
Epoxy concrete	E5	5	0.43	55.0	65.5	68.7	70.0	72.1
Epoxy concrete	E10	10	0.37	45.2	53.0	57.1	59.0	60.2
Epoxy concrete	E15	15	0.35	50.0	53.0	54.8	56.0	56.5

3-2 Ultrasonic Pulse Velocity:

Fig (1) illustrates the relationship between the Ultrasonic pulse velocity of reference and various types of polymer modified concrete (SBR and epoxy) and age.

Test results show that the velocity of ultrasonic waves transmitted through polymer modified concrete is faster than that of reference concrete and the increasement increases with the increase in P/C ratio and the use of epoxy resin at all test periods.

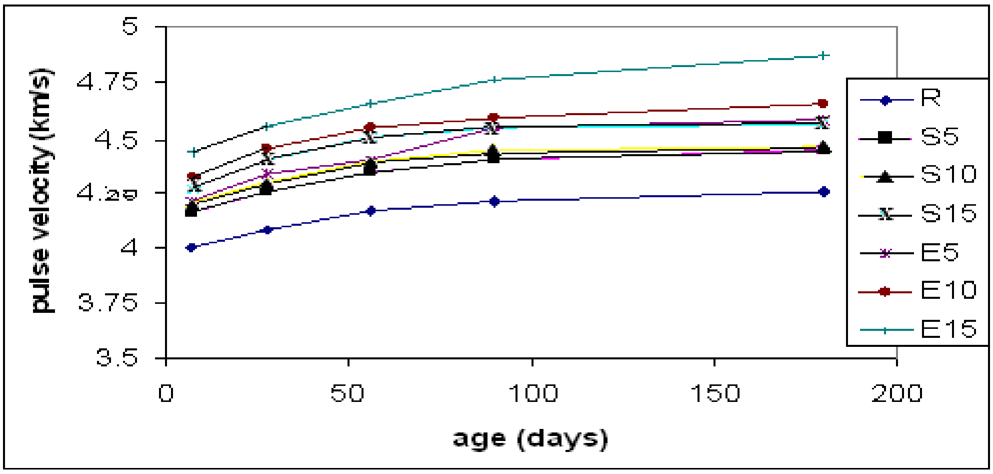


Fig (1) Ultrasonic pulse velocities of reference and various types of polymer concrete

From Figure (2) it can be seen that the ultrasonic pulse velocities for all specimens increase continuously up to exposure age of 90 days after that decrease up to age of 180 days. It can be seen that the ultrasonic pulse velocities for reference and various types of polymer modified concrete after exposure to 3 % of diluted nitric acid decrease with the increase in age exposure.

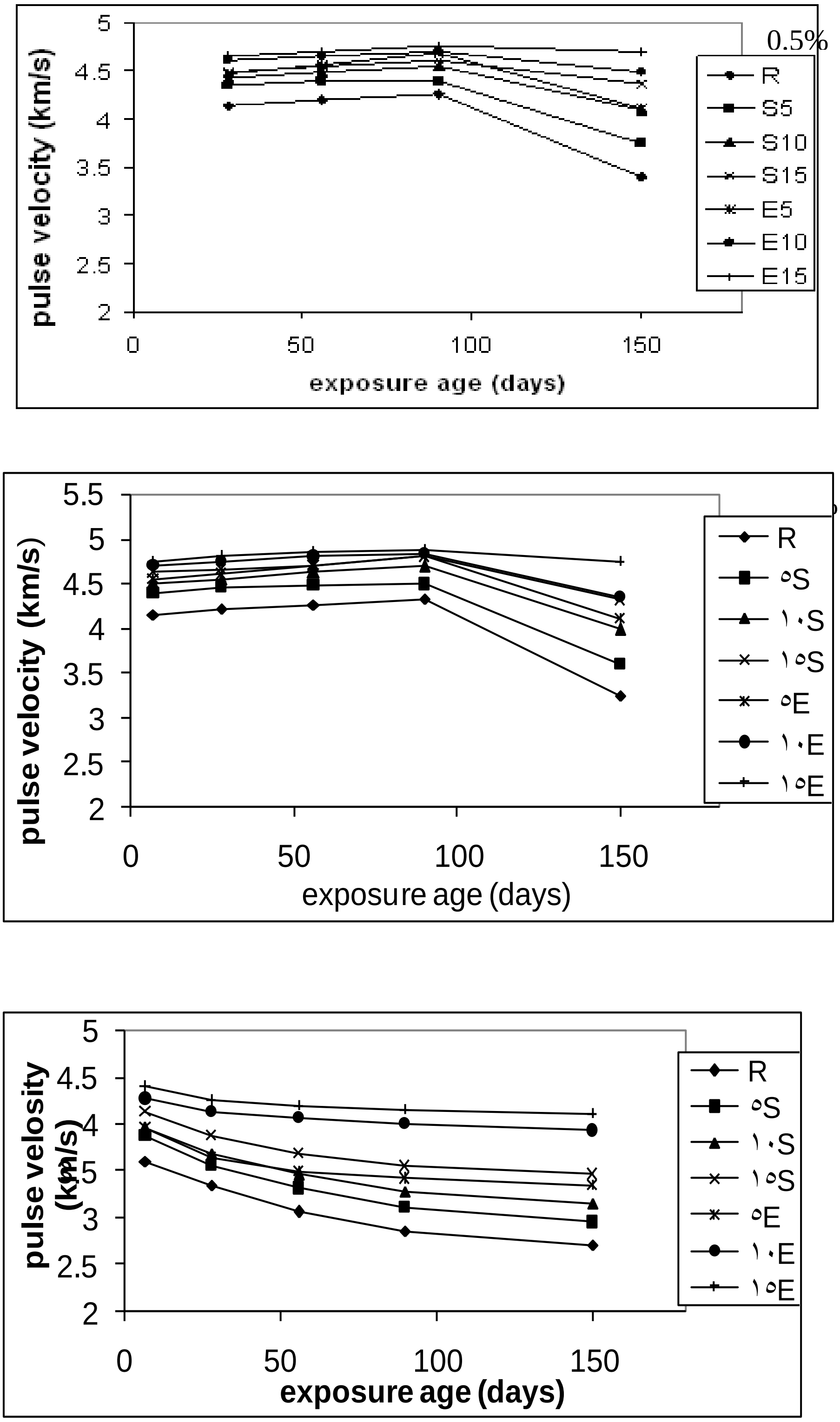


Fig (2) Ultrasonic pulse velocities of reference and various types of polymer concrete after exposure to diluted nitric acid

3-3 Static Modulus of Elasticity and Poisson's Ratio:

Static modulus of elasticity and Poisson's ratios for polymer modified concrete at age of 28 days are shown in Table (2), the static modulus of elasticity of polymer modified concrete (SBR and epoxy) is higher than that of reference concrete.

The result also shows that the epoxy modified concrete develops a static modulus of elasticity in rate larger than that of reference concrete and SBR-concrete. It can be seen that the Poisson's ratio of polymer modified concrete is less than that of reference concrete**.**

Table (2) Static modulus of elasticity and poisons ratio of reference and various types of polymer modified concrete at age of 28 days

Concrete Type	Symbol	P/C Ratio %	Static modulus of elasticity (GPa)	Poisson's ratio
Reference concrete	R	0	25.9	0.164
SBR concrete	S5	5	38.2	0.136
SBR concrete	S10	10	34.9	0.142
SBR concrete	S15	15	34.5	0.148
Epoxy concrete	E5	5	43.4	0.133
Epoxy concrete	E10	10	39.0	0.136
Epoxy concrete	E15	15	37.2	0.144

3-4 Dynamic modulus of elasticity:

The dynamic modulus of elasticity of reference and various types of polymer modified concrete (SBR and epoxy) with age is illustrated in Fig (3)**.** The Fig. shows that the polymer modified concrete has dynamic modulus of elasticity higher than that of reference concrete and the rise increases with the increase in P/C ratio. Epoxy modified concrete exhibits dynamic modulus of elasticity in a rate larger than that of reference and SBR-modified concrete.

The effect of 0.5, 1.5% and 3% diluted nitric acid solutions on the dynamic modulus of elasticity of reference and various types of polymer modified concrete is shown Fig (4). It can be seen that the increase of dynamic modulus of elasticity of all specimens is slight up to exposure age of 90 days then it decreases up to 150 days. Polymer modified concrete exhibits a good behavior where it keeps a high level of dynamic modulus of elasticity compared with reference concrete and an excellent rate occurs when epoxy resin is used. It can be also seen that the specimens exposed to 3% diluted nitric acid exhibit significant decrease in their dynamic modulus of elasticity.

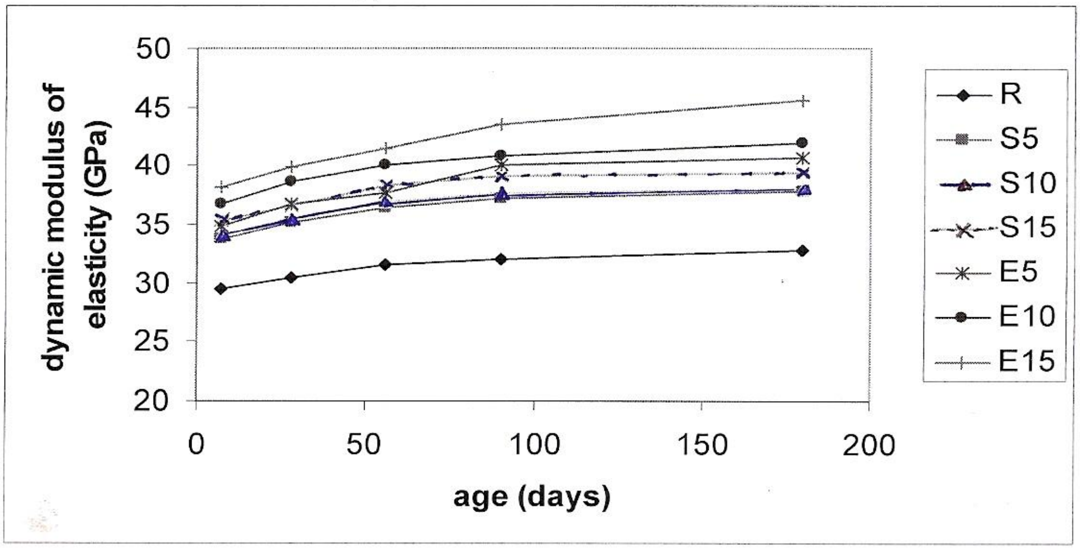


Fig (3) Dynamic modulus of elasticity of reference and various types of polymer concrete

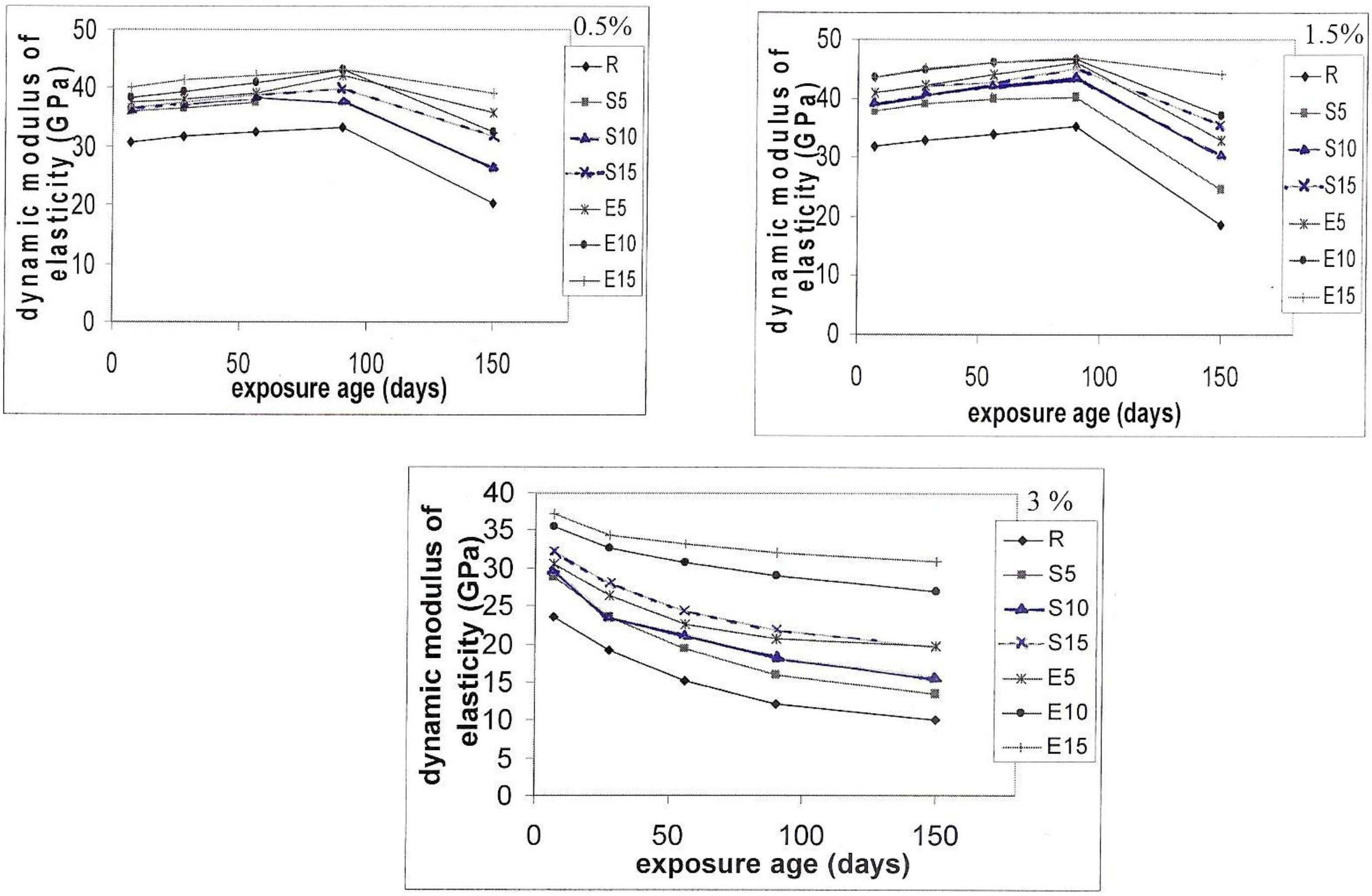


Fig (4) Dynamic modulus of elasticity of reference and various types of polymer concrete after exposure to diluted nitric acid

3-5 Impact Strength:

3-5-1 Initial Cracks, Scabbing, and Perforation:

The number of blows required to cause initial cracks, scabbing, and perforation for reference and various types of polymer modified concrete are plotted in Figs (5) to (7). The test results illustrate that: the number of blows or the energy required to cause initial cracks, scabbing, and perforation (failure) for various types of polymer specimens is higher than that of reference concrete. This is because the polymer specimens absorb a large quantity of energy before the failure when compared with reference concrete, and the energy absorbed increases with the increase in the P/C ratio. The logical explanation of this behavior is: first the nature of polymer materials has high elasticity and a high level of the transition zone. Second the damping property of the polymer materials, where the polymers during the colloids duration will participate in receiving the impact energy [10] within the concrete mass that will reduce the impact intensity. The Figs. also show that the specimens containing epoxy (10, 15%) exhibit higher impact strength improvement compared with the specimen containing SBR. That may be due to fact that the bond strength of the epoxy resin is larger than that of SBR latex which leads to good adhesion properties between the concrete constituents and epoxy resin.

The effects of the diluted nitric acid solutions (1.5 and 3%) on the impact strength of various types of polymer modified concrete are indicated in Figs (8) and (9) below. It be seen that the impact strength (no of blows) of all specimens exposed to 1.5% diluted nitric acid increases with the increase of the exposure duration up to age of 90 days. Then the impact resistance decreases gradually up to exposure age of 150 days.

Polymer modified concrete (SBR and epoxy) has superior impact strength compared with the reference concrete. All specimens exposed to 3% diluted nitric acid suffer reduction in the impact strength (no of blows) with the progress of the age of exposure.

3-5-2 Area of Scabbing:

The results of the area of scabbing for various types of polymer modified concrete is illustrated in Fig(10). The results show that, the area of scabbing for all specimens decreases with the age progress. Polymer modified concrete exhibits good impact strength in this state (especially the epoxy modified concrete)**,** due to the effect of the polymer film which acts as three dimensional network which eliminates the microcracks diffusion and prevents the surface rupture from the specimens at colloids. Also the rate of utilization increases with the increase in the P/C ratio at all test periods. The effect of the polymer content on the area of scabbing of polymer modified concrete after exposure to 0.5, 1.5 and 3% diluted nitric acid is indicated in Fig.(11). The results exhibit a reduction in area of scabbing with the increase in the exposure age up to 150 days for acid solutions of 0.5 and 1.5% compared with that of specimens without exposure, while the Fig show continuous increase in area of scabbing of reference and various types of polymer modified concrete specimens exposed to 3% diluted nitric acid with the age**.**

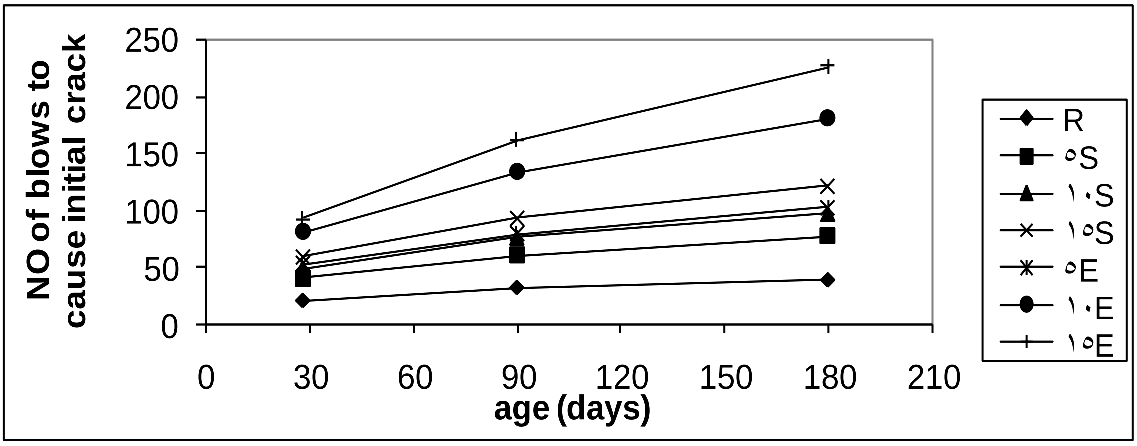


Fig (5) No of blows to cause initial crack for reference and various types of polymer modified concrete

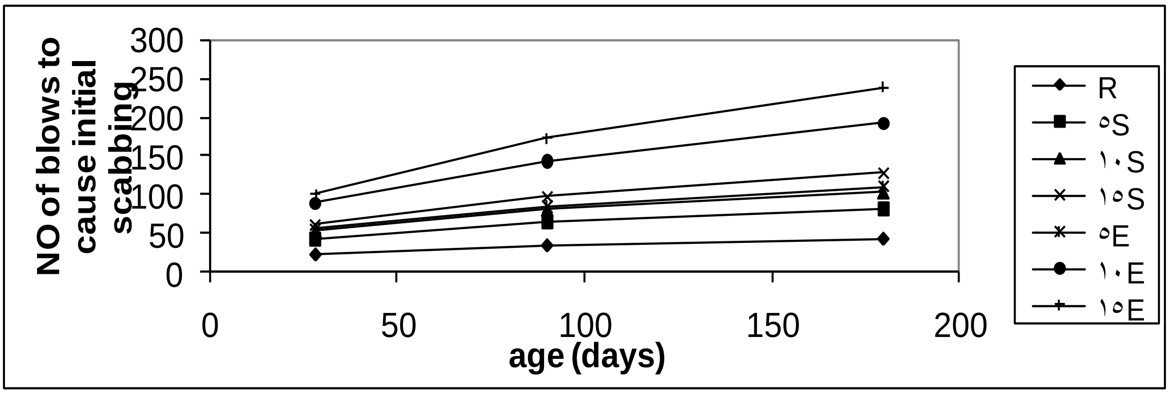


Fig (6) No of blows to cause initial scabbing for reference and various types of polymer modified concrete

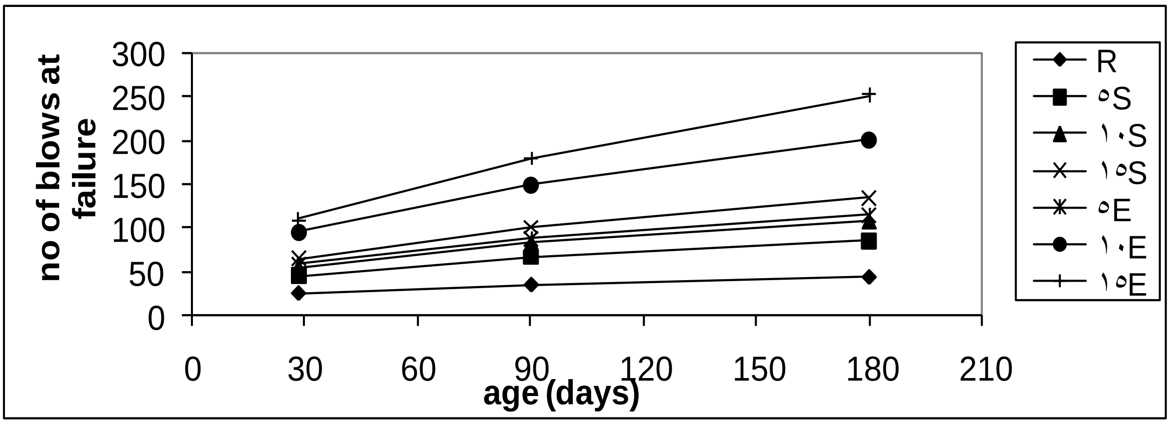
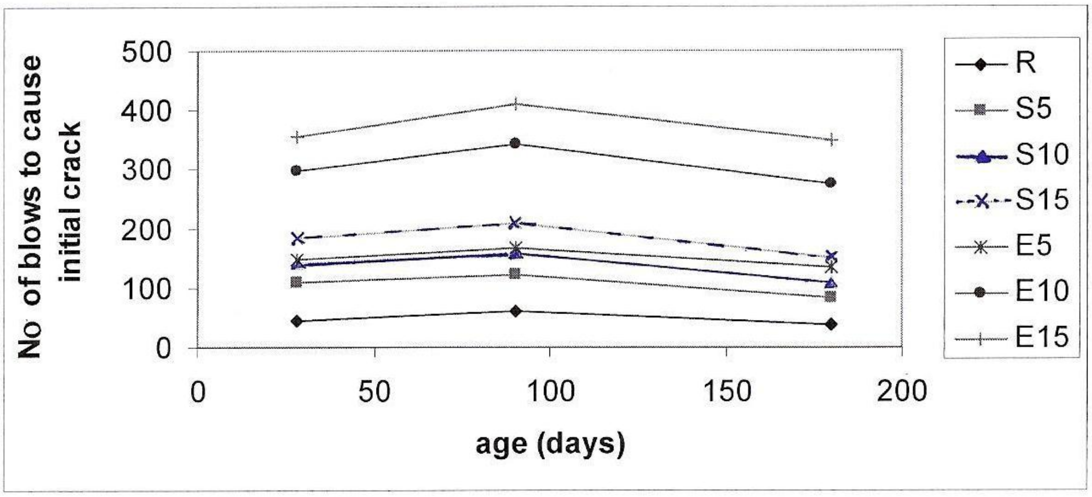
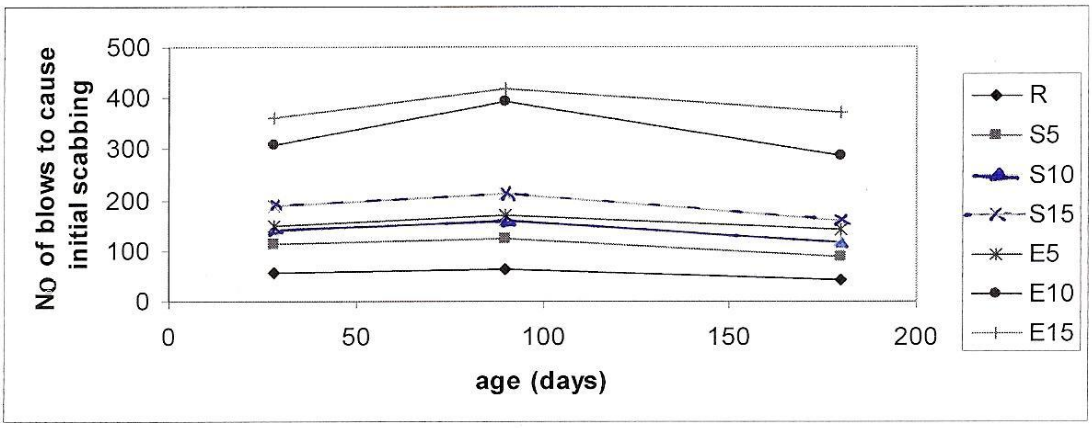


Fig (7) No of blows to cause perforation for reference and various types of polymer modified concrete





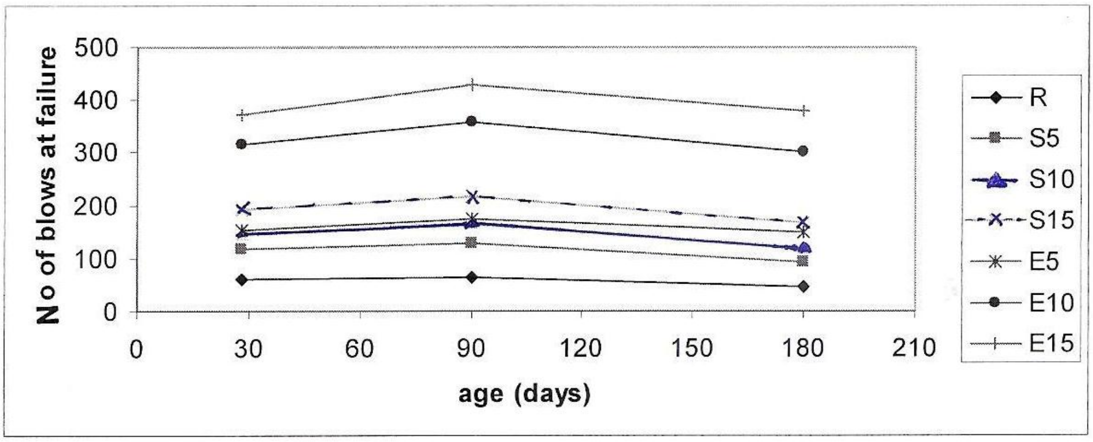
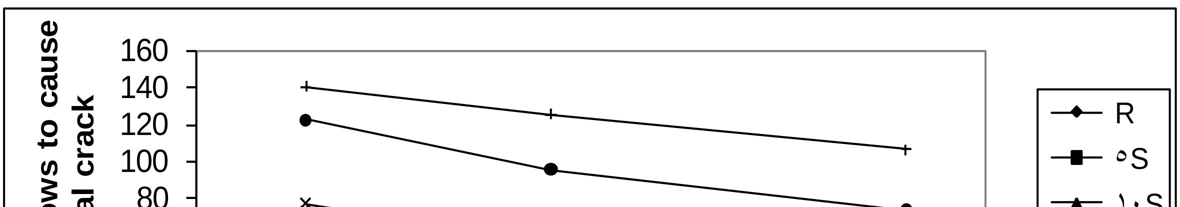
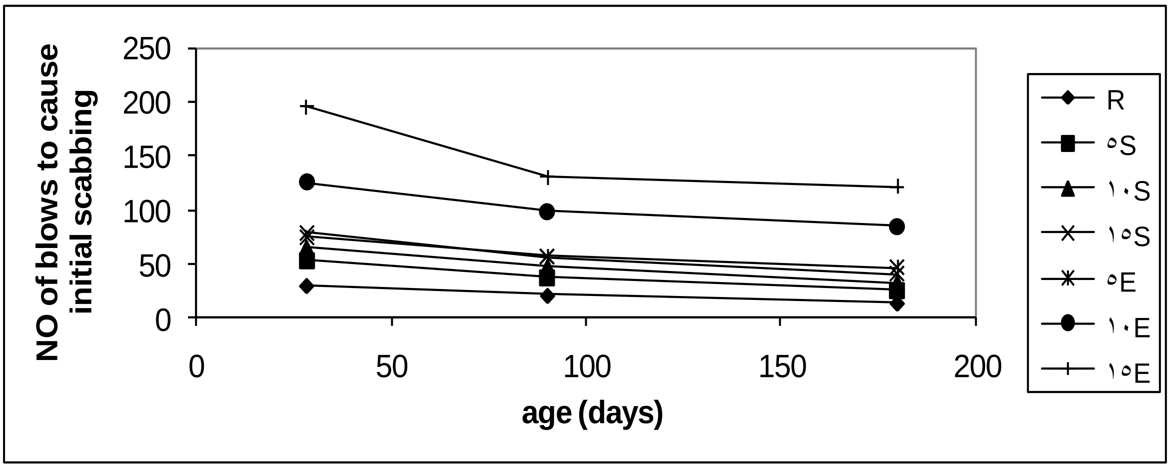


Fig (8) No of blows to cause initial crack, scabbing and perforation for reference and various types of polymer modified concrete after exposure to 1.5% nitric acid





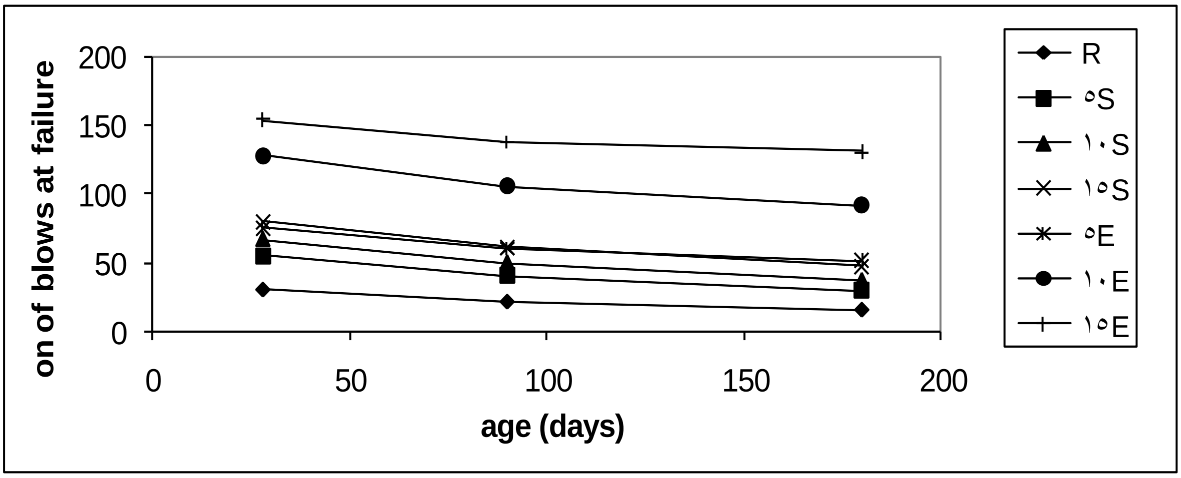


Fig (9) No of blows to cause initial crack, scabbing and perforation for reference and various types of polymer modified concrete after exposure to 3% diluted nitric acid

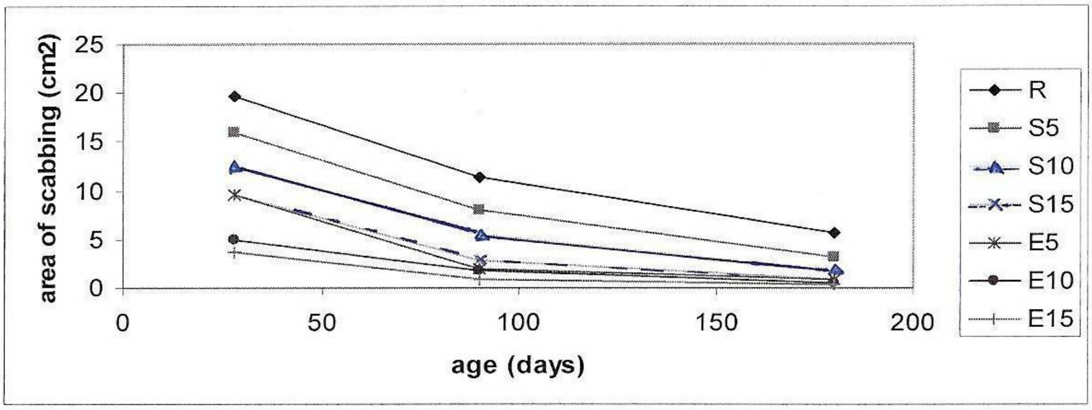


Fig (10) Area of scabbing for reference and various types of polymer modified concrete

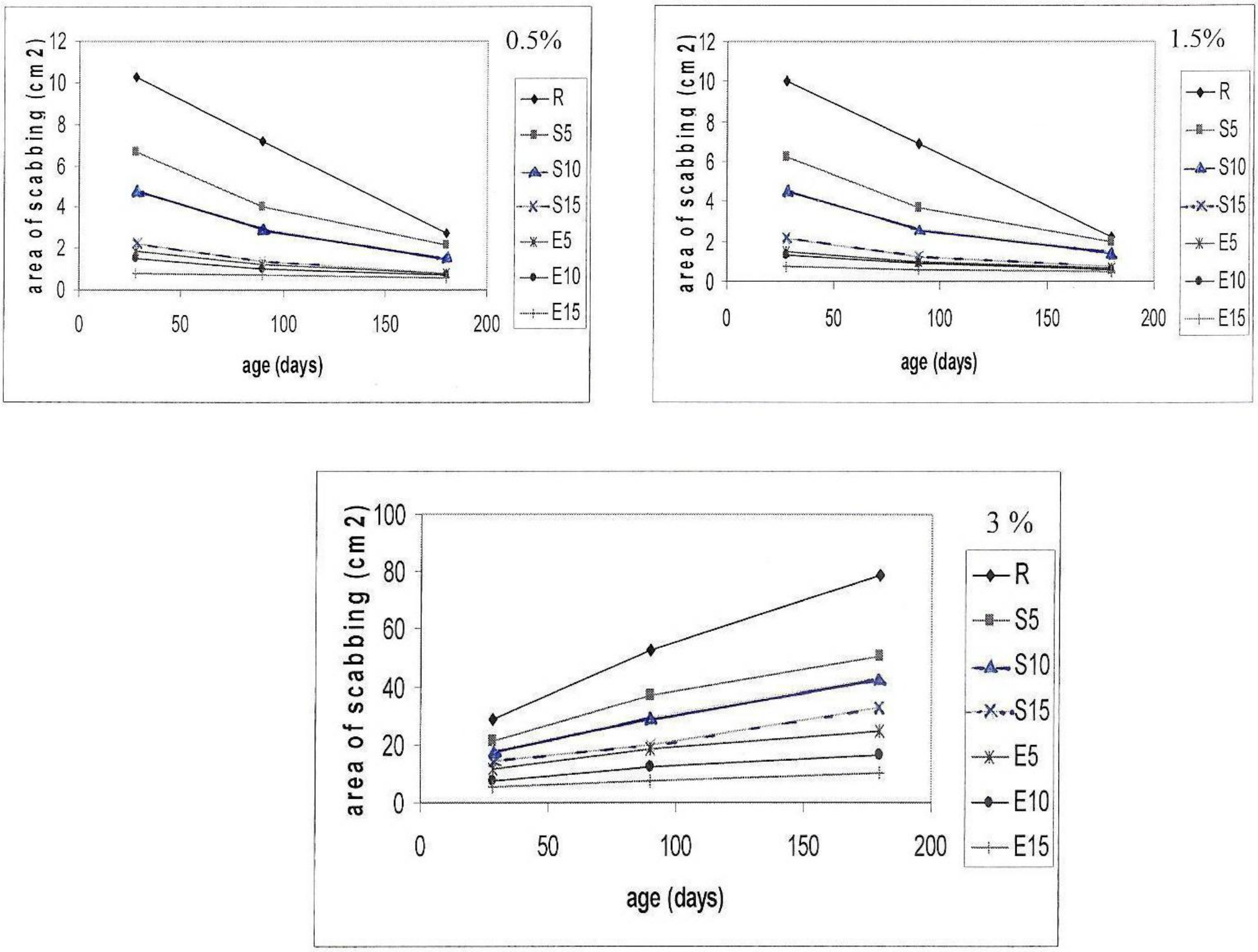


Fig (11) Area of scabbing for reference and various types of polymer modified concrete after exposure to diluted nitric acid

3-5-3 Deflection:

The mid span total and residual deflections of reference and various types of polymer concrete are presented in Figs (12) and (13), the results show that the total and residual deflection of all specimens decreases with the increase in the specimens age. It can be also seen that polymer modified concrete develops dynamic behavior better than reference concrete, where the total central deflection is higher than that of reference concrete and it increases with the increase in the P/C ratio and use of epoxy resin, while the residual central deflection is less than that of reference concrete this is because of the high extensibility, good adhesion properties, good network connecting, and good transition zone strength properties of polymer modified concrete.

The residual central deflection of all specimens exposed to 0.5, 1.5 and 3% diluted nitric acid is shown in Figs (14) to (16) . It can be also noted that the total and residual deflections decrease with the increase in the exposure duration up to 90 days. Then the deflections increase up to 180 days, while polymer modified concrete suffer an increase in the total and residual central deflection after exposure to 3%.

3-5-4 Depth and Diameter of Crater:

From the Figs (17) to (20) the followings observation can be made:

1- For the same age, the number of blow required to cause the same depth and diameter of crater increases with the use of polymer materials and increase in P/C ratio.

2- Epoxy modified concrete has lower depth and diameter of crater compared with SBR-concrete for the same conditions.

3- 3% diluted nitric acid solution considers more aggressive than the other nitric acid solutions (0.5, 1.5%).

4- For the same specimens, the number of blow that required to causing the same depth and diameter of crater at 1.5% diluted nitric acid solution is larger than that of 0.5% diluted nitric acid in same age.

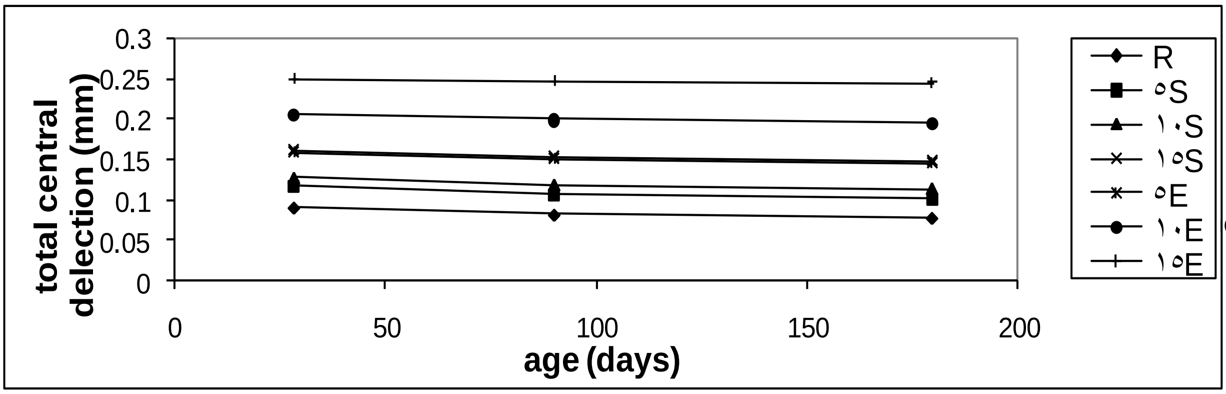


Fig (12) Total deflection of the first blow for reference and various types of polymer modified concrete

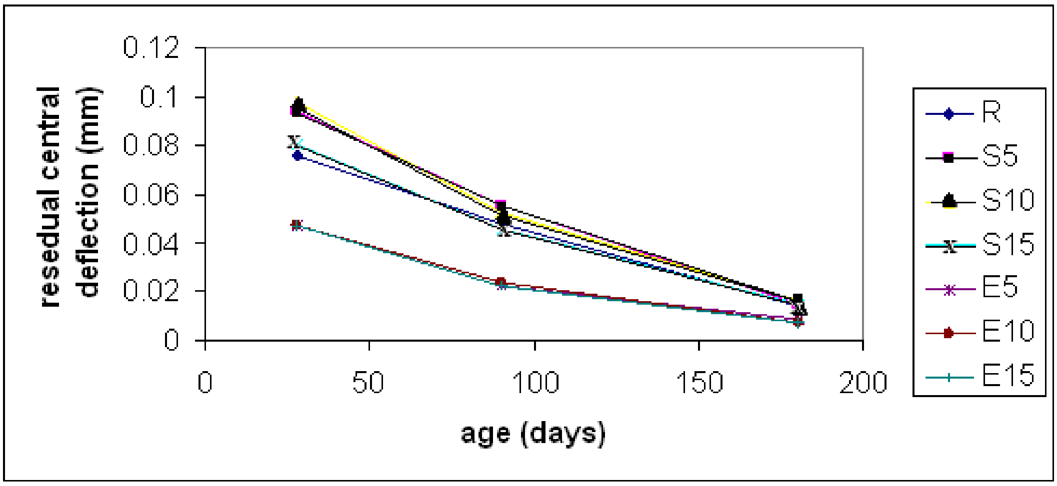
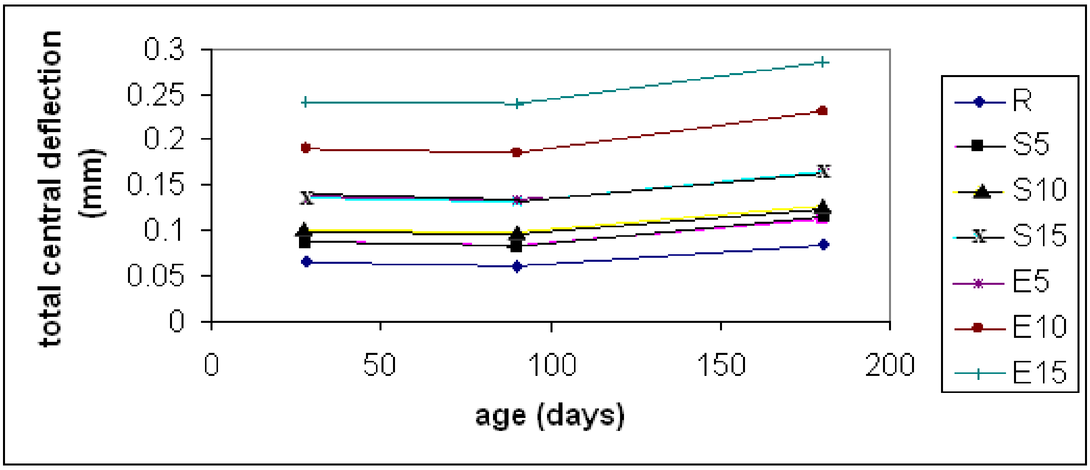


Fig (13) Residual deflection of the first blow for reference and various types of polymer modified concrete



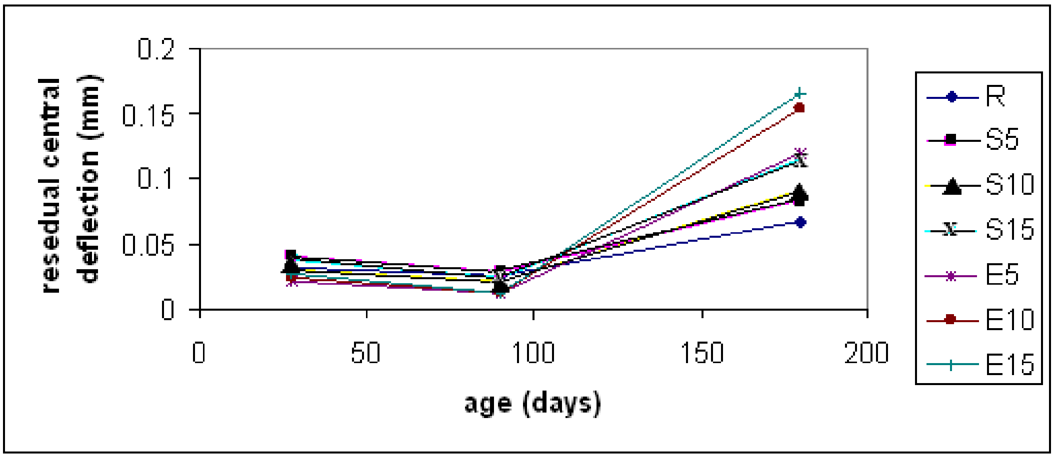


Fig (14) Deflection of the first blow for reference and various types of polymer modified concrete after exposure to 0.5% nitric acid

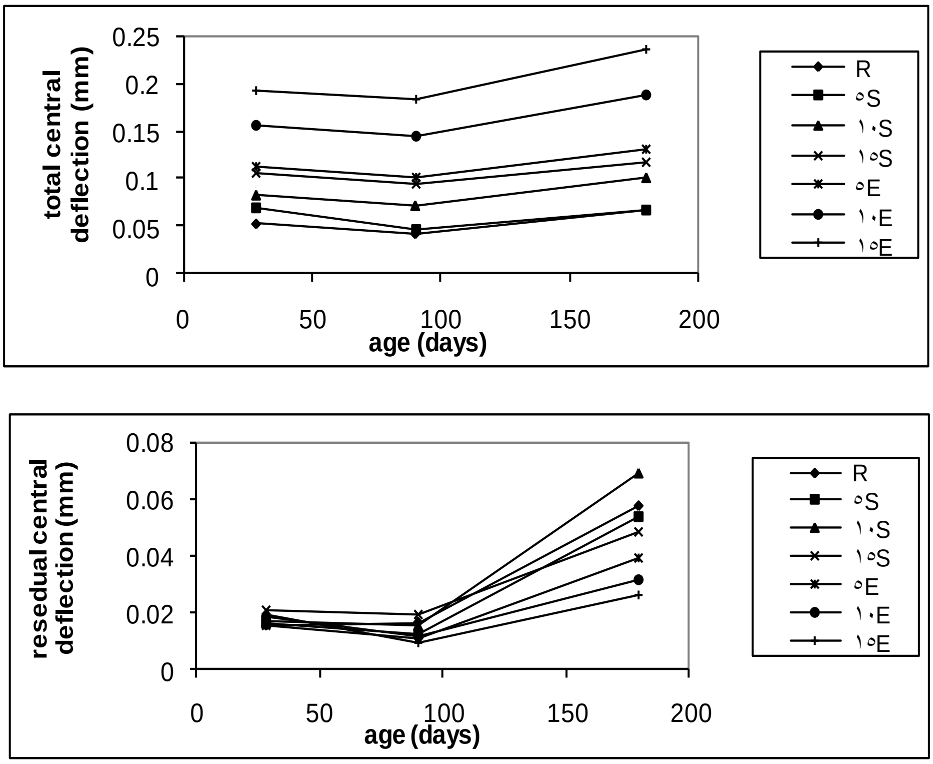


Fig (15) Deflection for first blow of reference and various types of polymer modified concrete after exposure to 1.5% diluted nitric acid

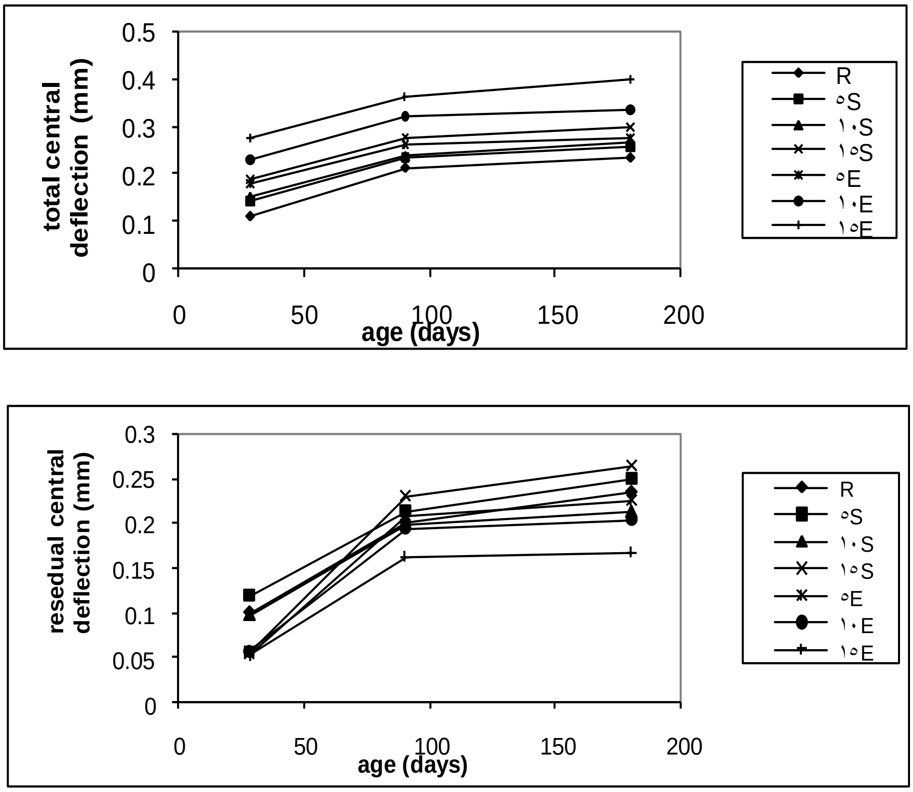


Fig (16) Deflection for first blow of reference and various types of polymer modified concrete after exposure to 3% diluted nitric acid

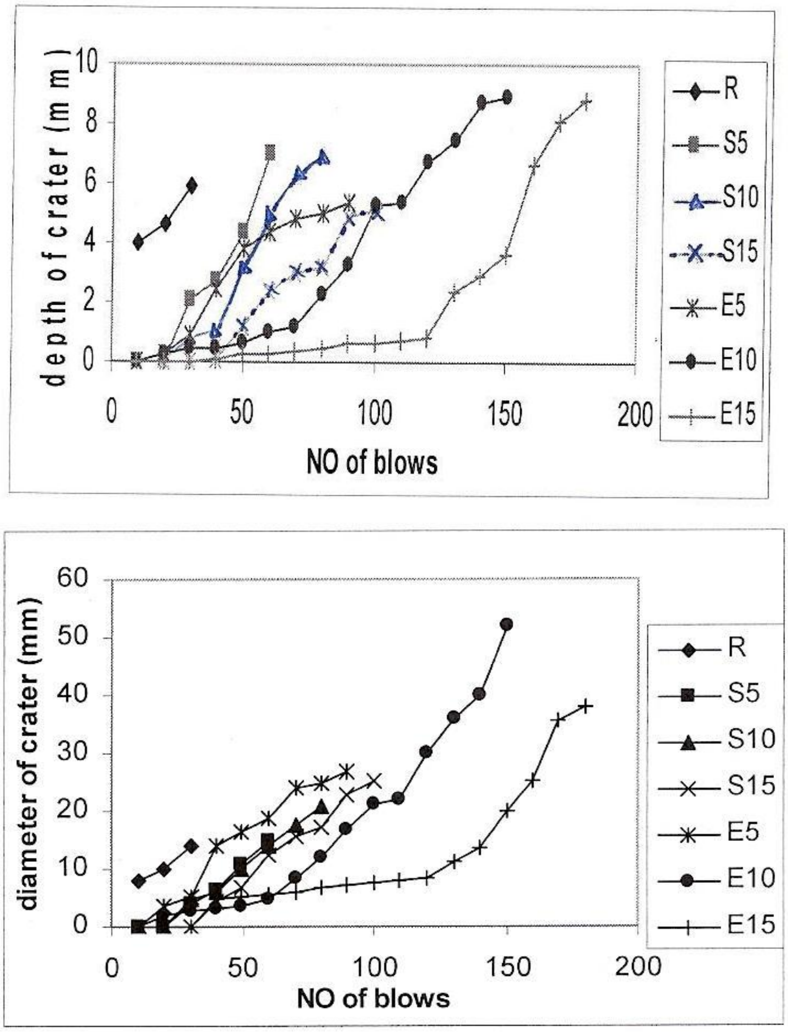


Fig (17) Depth and diameter of crater of reference and various types of polymer modified concrete at 180 days

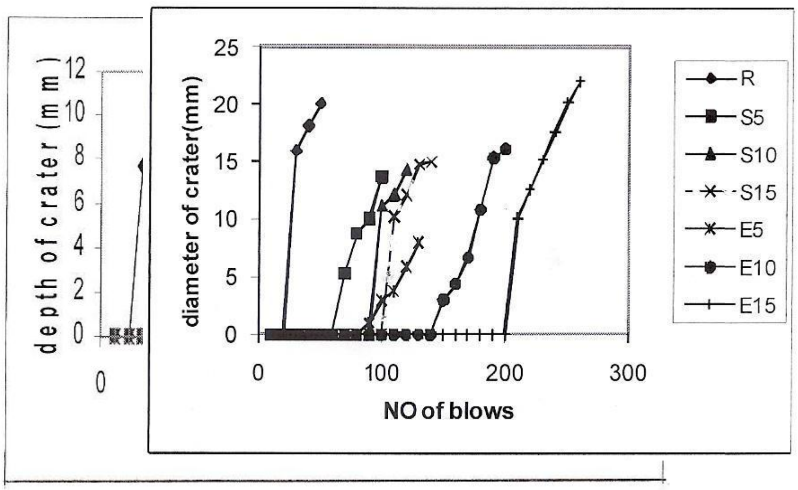
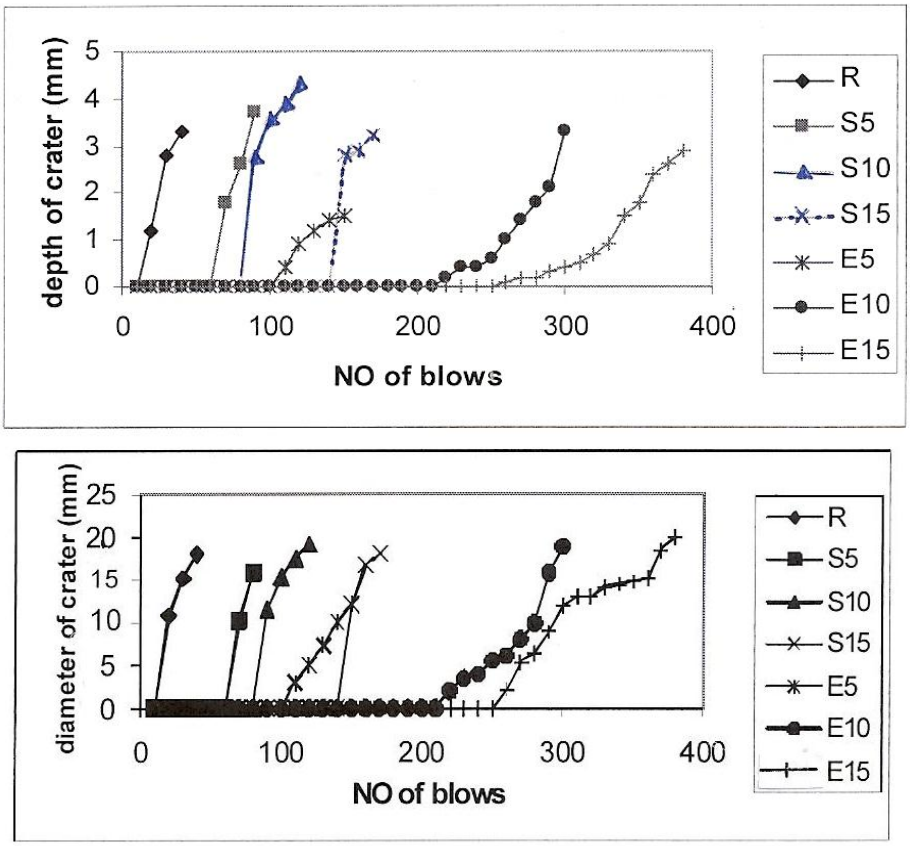


Fig (18) Depth and diameter of crater of refe polymer modified concrete at 180 days after ex acid



(19) Depth and diameter of crater of reference and various types of polymer modified concrete at 180 days after exposure to 1.5% diluted nitric acid

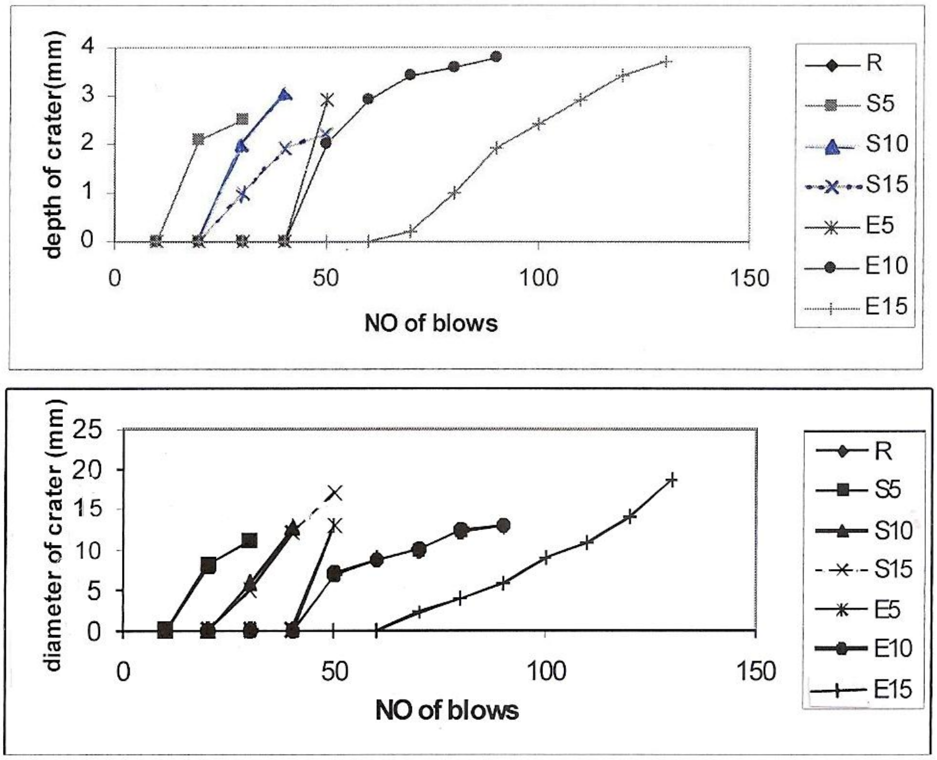


Fig (20) Depth and diameter of crater of reference and various types of polymer modified concrete at 180 days after exposure to 3% diluted nitric acid

4. Conclusions

Based on the results and discussions, the following conclusions can be drawn:

1- The compressive strength of polymer modified concrete (SBR and epoxy) is higher than that of reference concrete at all ages, but it decreases with the increase in P/C ratio. The Epoxy modified concrete is developing high compressive strength compared with SBR-concrete at the same ages.

2- A significant improvement is demonstrated in the velocity of the ultrasonic waves transmitted through SBR and epoxy modified specimens, where the ultrasonic pulse velocity is increased with the increase of P/C ratio at all ages. On the other hand the ultrasonic pulse velocity of all specimens decreases if they are exposed to diluted nitric acids.

3- Dynamic modulus of elasticity of Epoxy modified concrete is higher than that of reference and SBR-concrete at the same ages. The dynamic modulus of elasticity of all specimens decreases when exposed to 0.5, 1.5, and 3% diluted nitric acid.

4- Good improvement occurs in the impact strength of concrete exposed to the effect of diluted nitric acid solutions if polymeric materials (SBR and epoxy) are added.

5- With respect to reference concrete there is a noticeable drop in area of scabbing of specimens containing polymer modifier materials (SBR and epoxy) at all ages.

6- Polymer modified specimens showed superior elastic behavior under dynamic impact loads; because they posses highest central total and least central residual deflections compared with reference specimens with and without acid exposure and at all ages.

5. References

1. Mindess, S., and Young, J. F., "***Concrete***", Prentice-Hall, New Jercy, 1981, pp.1.

2. Ohama, Y., Kobayashi, T., Takeuchi, K., and Nawata, K, "***Chemical Resistance of Polymethyle Methacrylate Concrete***", The International Journal of Cement Composite and Light Weight Concrete, vol. 8, No. 2, May. 1986, p.p. 87-91.

3. Rizwan, S. A., hammed, A., and Ahmed, K., "***Latex Modified High Performance Concrete***", 6-th International Symposium in Utilization of High Strength-High Performance Concrete, ACI Proceedings, June. 2002, pp. 1313-1323.

4. Lee, H. S., Lee, H., Moon, J. S., and Jong, J. W., "***Development of Tire Added Latex Concrete*** ", ACI Materials Journal, Vol. 95, No. 4, Jul-aug. 1998, pp.356-364.

5. Al-Gasani, Q. K., "***Impact Resistance of Plain and Steel Fiber Reinforced Polymer Modified Concrete***", M.Sc. thesis, Al Mustansiriya University, April. 2004, pp. 45-97.

6. Al-Hadithi, A. I., "***Flexural, Impact, and Thermal Properties of Polymer Modified Concrete***", Ph.D. thesis, Al Mustansiriya University, March. 2005. pp. 93-107.

7. ACI Committee 548-1999, "***Polymer Modified Concrete***", ACI Manual of Concrete Practice, Part 5, 548-3R, 1999.

8. Nataraja, M.C., Dhang, N., and gupta, A.P., "***Statically Variations in Impact Resistance of Steel Fiber Reinforced Concrete Subjected to Droop Weight Test"***, Cement and Concrete Research, Apr. 1999, pp.989-995.

9. Sujjavanich, S., and Lundy, J.R., "***Development on Strength and Fracture Properties of Styrene-Butadiene Copolymer Latex Modified Concrete***", ACI Materials Journal, vol. 95, No. 2, March-April. 1998, pp. 131-143.

10. H. Thomas courteny, "***Mechanical Behavior of Materials***," 2003, pp. 44-84.