BEHAVIOUR OF RUBBERIZED PLAIN AND REINFORCED CONCRETE UNDER IMPACT

سلوك الخرسانة المطاطية العادية و المسلحة المعرضة لإجهادات صدم

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خلاصة

ان الانتفاع بمنتجات مخلفات الإطارات المطاطية فى الخرسانة قد جذب الانتباه بسبب مشاكل البيئة المتصاعدة من حرق هذه المخلفات. و قد أصبحت الخرسانة الآن من المواد التى يمكن أن تمتص الطاقة فى تطبيقات التشييد و التى قد تتعرض لتأثيرات التصادم مثل توظيفها كحواجز صدم فى الكبارى و الطرق. فى هذا البحث، تم دراسة الخرسانة المطاطية و ذلك باستخدام نسب مختلفة من مسحوق المطاط فى الخلطة الخرسانية بعمل إحلال جزئى للرمل بنسب حجمية مختلفة (٠%-١٥%-٣٠%-٥٠%-١٠٠%). وقد جهز لهذا البحث عشرون كمرة خرسانية (١٠X١٠X ٧٠سم) من الخرسانة العادية والمسلحة و التى خصصت لاختبارات مقاومة الصدم. تم حساب مقاومة الصدم باستخدام الطاقة الحركية التى تنتج من سقوط كتلة قدرها ١٥ كجم من ارتفاعات مختلفة تدريجية و بانتظام حتى يحدث الكسر.

تم تجهز العينات من المكعبات و الإسطوانات و الكمرات لدراسة إجهادات الضغط و المتانة و الصدم للخرسانة المطاطية. أظهرت النتائج ضعف فى نتائج إجهادات الضغط عن الخرسانة العادية (بدون مطاط)، فى حين أن شكل الكسر كان اقل قصافة بكثير و أكثر ممطولية من الخرسانة العادية (بدون مطاط) كما أن الخرسانة المطاطية لها القدرة على إمتصاص كمية كبيرة من الطاقة عند تعرضها لإجهادات الصدم.

ABSTRACT

Utilization of rubber tire waste products in concrete has attracted attention because of energy crisis and the environmental problems. The concrete are postulated to be a potential material especially for construction applications, which are subjected to impact effects such as crash barriers, bridges and roads. In this study, an analysis of rubberized concrete was done by using various proportions of crumb rubber as a replacement of sand by volume [0 %, 15%, 30%, 50% and 100%]. The slump for five different mixes was measured. On the other hand twenty plain and reinforced concrete beams with dimensions (10 x 10 x 70 cm) were prepared for impact resistance test. The impact resistance was measured as a kinetic energy, which generated by falling of a load (15 kg.) from variable distances until the failure occurs.

Cubes, cylinders and beams were prepared to study the compressive strength, toughness and impact for rubberized concrete. The concrete mixtures exhibited lower compressive strength than normal concrete, however the samples did not has a brittle failure but it has a ductile failure, and has the ability to absorb large amount of plastic energy under impact strength. On the other hand the results showed that the impact resistance of rubberized concrete was higher.

Keywords: Concrete beams, rubber tire aggregate, workability, slump, compression, impact.

Accepted October 30, 2005.

INTRODUCTION

In some applications of concrete, it is desired that concrete should have lower unit weight, high toughness and impact resistance (Eldin 1993). On the other hand, a wide variety of waste materials has been suggested as additives to cement-based materials (Soroushian 2003) . Although concrete is the most commonly used construction material, it does not always fulfill these requirements (Abbas 1995). To improve elastic properties of concrete and recycle the waste materials recently new applications have been realized. One of these applications is the utilization of discarded tires to replace a part of the aggregate (Toutanji 1996). For this purpose, many researches have been done to investigate the physical and selected mechanical property of the concrete incorporating pieces of scarab tires (Topçu 1997). Topçu 1995, reported that most of the concrete properties could be improved by incorporating different kinds of industrial wastes. He observed the properties for the rubberized concrete in terms of both size and amount of rubber chips.

The purpose of using rubber tires as aggregate is to increase concrete's flexibility, elasticity, and capacity to absorb energy (Avcular 1997). (Mindess 1987) observed that the fracture toughness values under impact loading were much higher than those obtained in static tests. There was also dramatic increasing in the fracture energies under impact loading.

In this research, twenty plain and reinforced concrete beams with dimensions (10 x 10 x 70 cm) were prepared for impact resistance test. Ten beams are reinforced with 2 ∅ 8 bottom mild steel. The percentages of rubber were (0, 15, 30, 50, and 100 %). The impact resistance was measured as a kinetic energy, which was generated from the falling of a load (15 kg.) from variable distances until the failure occurs.

The objective of this research is to investigate the behavior of rubberized concrete with and without steel reinforcement under impact loads. Also, to determine the optimum percent of rubber as fine aggregate in order to meet the different applications of rubberized concrete.

CONCRETE MIX DESIGN

Normal 300-kg/cm^2 non-air-entrained concrete mix was proportioned according to ACI Method using Portland cement, 25 mm gravel, 2.66 specific gravity, sand of 2.4 finesse modulus, and a water cement ratio of 0.5 to give a slump of 10 cm. Table 1 shows the proportion of 1 m^3. This mixture was made as a control mix and the sand of this mix was replaced by crumbed scarab tires. Fig. -1 shows the sieve analysis of the crumbed rubber used for mixes with rubber/sand replacement [15%, 30%, 50%, and 100%] by volume.

The rubber used in this research is produced by MARSO factory at 10th of Ramadan City- Egypt. The rubber was mechanically ground, it is free from steel fibers or any foreign materials in the component of the rubber tire. Table (2) shows the chemical components of the used rubber . The unit weight of the rubber used is 400 kg/m^3.

EXPERIMENTAL PROGRAM

Slump Test

The slump test was recorded for each mix to measure the consistency of the concrete mixes, as it is the most widely used method both in the field and in the laboratory. Slump test was recorded according to E.S.S. test method for slump.

Compressive Strength

Cubic samples 15x15x15 cm and cylinders 15x30 cm were prepared to determine the compressive strength after 7 and 28 days for the tested mixes. All mixes were mixed in conventional blade-type mixer gravel, sand, cement, and rubber powder were loaded in the mixer for 5 minutes. Then water was added gradually to the mix for a period of about 2 minutes, followed by mixing for 5 minutes to have a uniform mix.

Impact

The test set-up for impact is shown in Plate (1). The impact resistance calculated as shown in Eqn.(1):

(Impactresistance)I.R=WxH (1)

Where, W = falling weight (15 kg), H = total falling height causing failure.

The initial distance of the falling load was 5 cm. The distance of the falling load is increased gradually by 5 cm (i.e. the distances were 5, 10, 15, 20... etc.). The initial crack energy and the failure load energy were recorded for each beam.

RESULTS AND DISCUSSION

Slump Test

Fig.-2 shows the slump values for all tested mixes. It is obvious from the results that the slump values decrease with increasing the quantity of rubber replacement in the mix. This reduction of slump values related to the high friction between the rubber surface and the mortar. The percentage of rubber replacement to give a suitable slump value ranges between (30%-50%), these percentages give slump values between (80-65) mm respectively, where the control mix gives 110 mm slump value.

Compressive Strength

Fig.-3 shows the effect of the rubber replacement on the compressive strength. The results show that a loss of compressive strength observed when the rubber content in the mix was increased. The losses of compressive strength after 7 days are 13%, 22%, 33%, and 54% for rubber replacement 15%, 30%, 50%, and 100% respectively. On the other hand, the results after 28 days give reduction of 15%, 30%, 50%, and 65% for rubber replacement 15%, 30%, 50% and 100% respectively. The losses of the compressive strength is related to the weak bond between the cement mortar and the rubber particles surfaces in additional to the weakness of the rubber to withstand the loads, so the particles of rubber may be assumed as a pores in concrete in case of compressive strength. Rubberized concrete to be used as structural elements should not have more than 30% rubber replacement, because this percent of rubber reduces the compressive strength by 30%.

Rubberized concrete with rubber percent more than 30% may be used for architectural applications, low strength concrete applications, and crash barriers around bridges and similar structures because of its high-energy absorption.

Impact Resistance

The plain control beams fail after 3 fallings of the load, where the beams with 50% rubber percent reach failure after 4 fallings. On the other hand, the beams with 100% rubber percent collapsed after 5 fallings. Plate (2) shows the modes of failure of typical tested beams. The impact resistance for plain concrete beams was about 5% of the resistance of the reinforced concrete beams. The results in Fig. -4 indicated that, the impact resistance of the reinforced concrete beams is improved when the concrete incorporate crumb rubber with a percentage up to 30%, after which the impact resistance begin to decrease. The rubber percent 50% gives the same results of the impact resistance for the control mix and any increases of rubber percent more than 50% decreases the impact resistance of the rubberized concrete than the control mix.

The impact resistance increases about 30% with adding rubber percent 30% where it increases for about 17% when the rubber percent is 15%. On the other hand, when rubber replacement is 100% the impact resistance decreases 50% of the control mix at failure.

Fig.-4 showed that the rubberized concrete has the ability to resist impact load better than the normal concrete because its high plastic energy and its high ductility. However the impact begin to decrease again for rubber percent more than 30% because of the weak bond between the excess rubber and the concrete paste, which leads to the low efficiency to resist the loads. Fig. -5 shows the relation between the compressive strength and the impact resistance of the tested samples. Fig. 6 and 7 indicates the initial and failure cracks strength for different amount of rubber. It is shown that the impact resistance of rubberized concrete increases with the decrease of compressive strength up to a certain value (220 kg/cm2) related to 30% rubber percent, then the impact resistance decreases. This is related to that with increasing the rubber content up to 30%, the compressive strength decreases where the impact resistance increases as shown in Fig. -4. However, if the rubber percent is more than 30% the impact resistance decreases with increasing the compressive strength so, the relation in these zones (220-325 kg/cm2) is directly proportion.

CONCLUSIONS

The following conclusions are based on the experimental test results performed in this study:

1- Compressive strength is reduced up to 65% when crumb rubber replaced sand.

2- Rubberized concrete did not exhibit brittle failure under compression, the specimens showed an ability to absorb a large amount of plastic energy under compression loading.

3- The impact resistance of rubberized concrete beams was improved by about 30% when adding crumb rubber percent 30%.

4- Workability of rubberized concrete was adequate.

5- Based on the properties measured, rubberized concrete with rubber percent more than 30% is suitable for: architectural applications (e.g. nailing concrete and interior construction because its light unit weight), low-strength-concrete applications (e.g. sidewalks, and selected road construction applications), and crash barriers around bridges (high plastic energy absorption).

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Table (1) Control Mix Proportions:

Material	Quantity kg/m^3
Gravel	1155
Sand	650
Cement	384
Water	192

Table (2) The Composition of a Tread Compound of Rubber Tire Used:

Ingredients	Content
Natural rubber (NR)	50
Butadiene rubber (BR)	10
Carbon Black	30
Zinc oxide	1.5
Stearic acid	0.3
Antioxidant	1.0
Paraffin wax	0.5
Processing oil	5.0
Accelerator	0.7
Sulphur	1.0

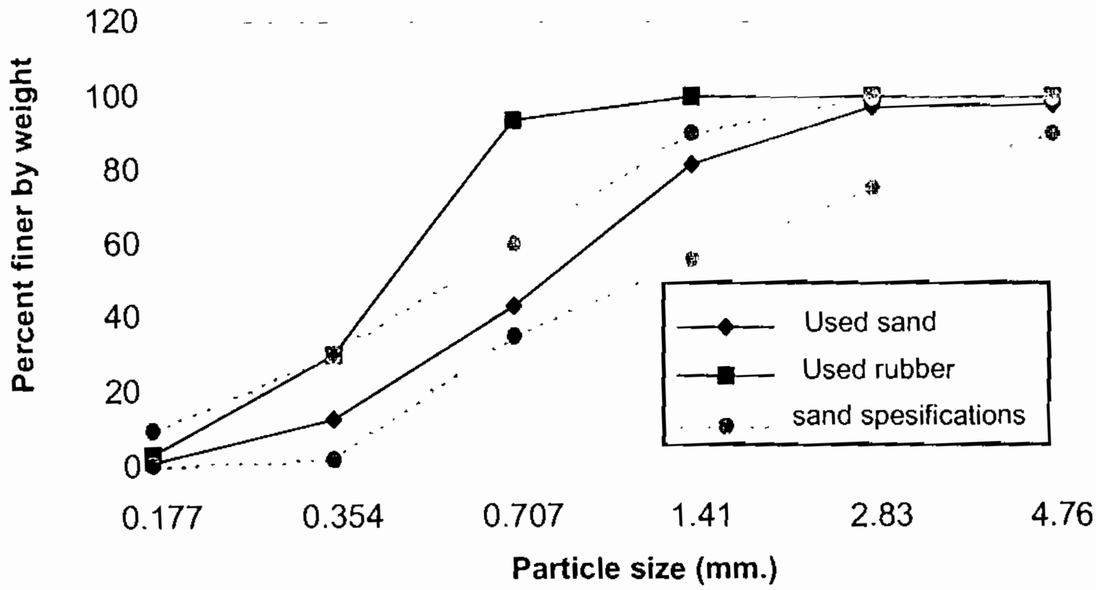

Fig. (1) Sieve Analysis Of Rubber And Sand

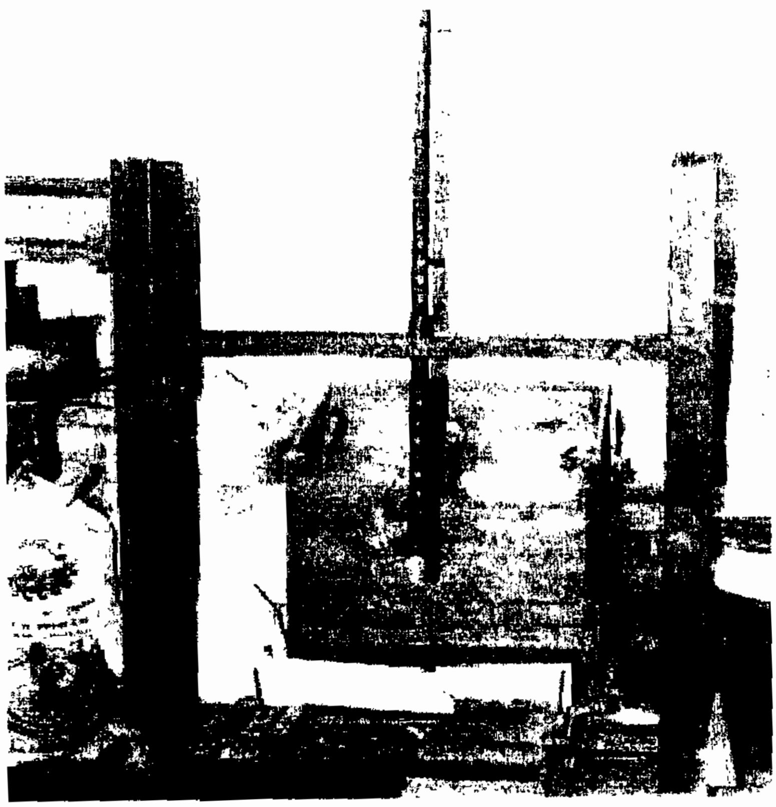

Plate (1) Test setup for impact

Plate (2) Crack pattern and failure modes

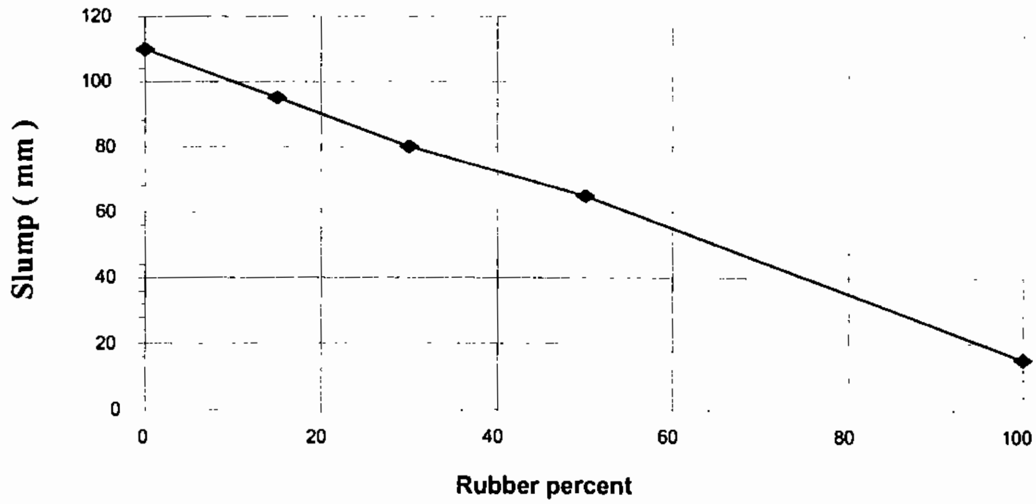

Fig . (2) Slump value for rubberized concrete mixes

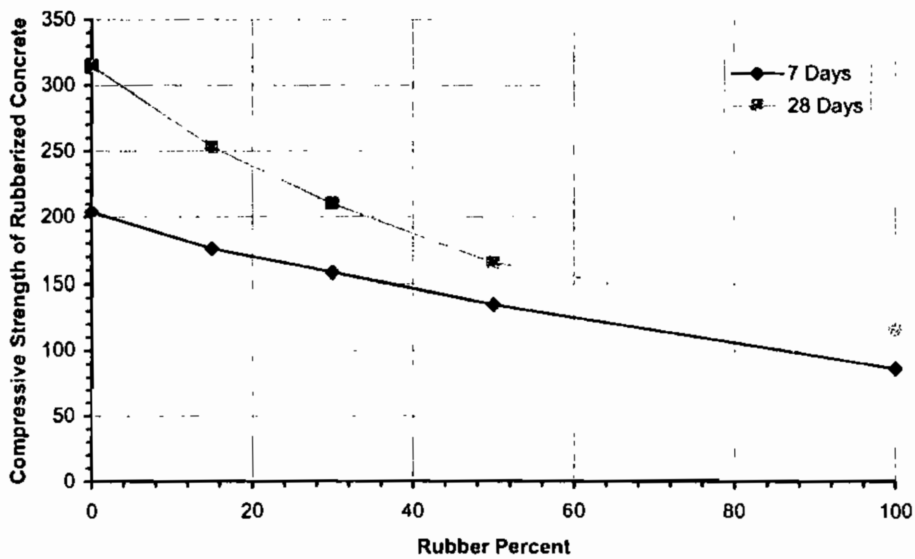

Fig. (3) Compressive Strength of Rubberized Concrete.

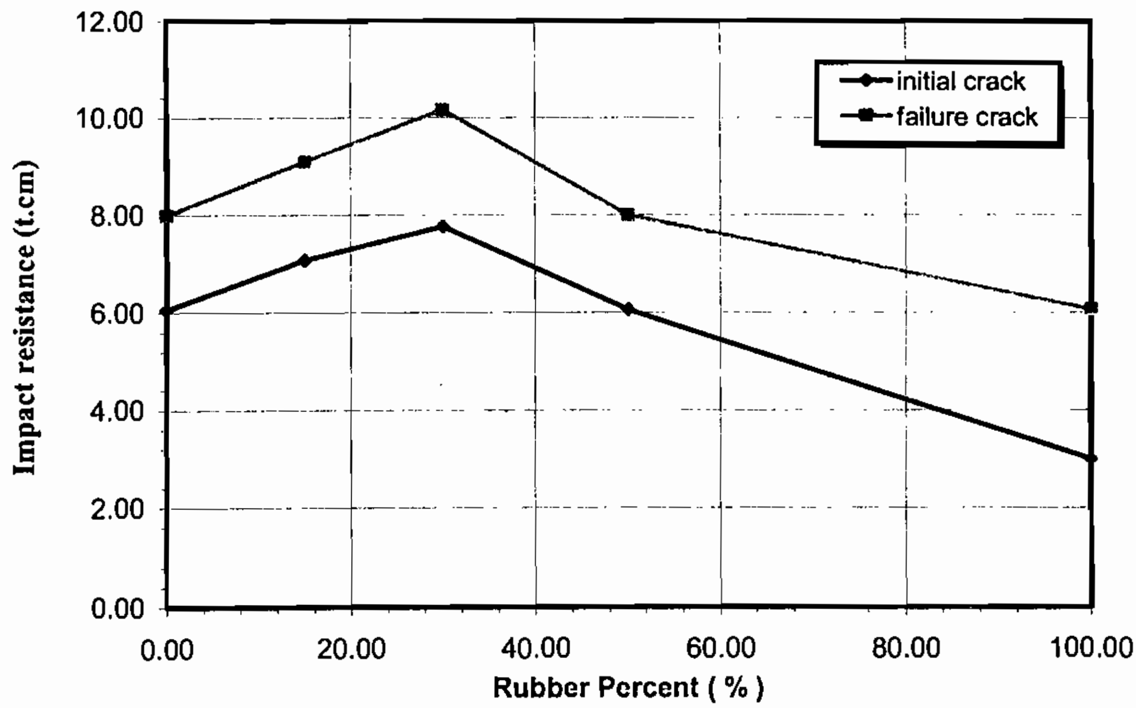

Fig. (4) Impact Resistance for Reinforced Rubberized Concrete.

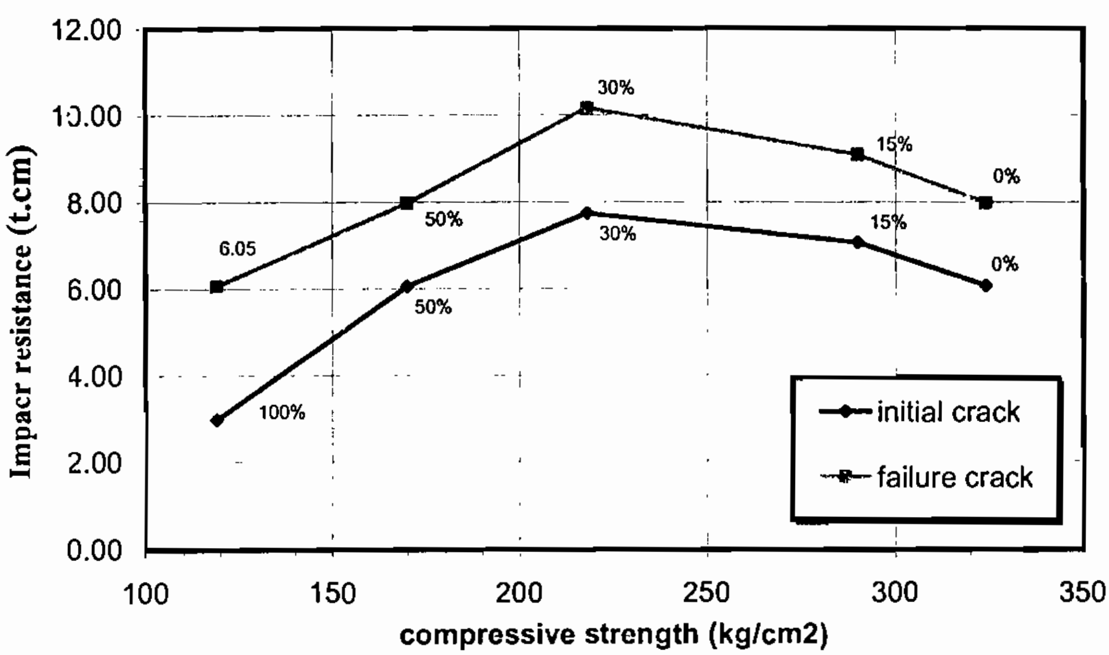

Fig. (5) Relation between compressive strength and Impact Resistance for Reinforced Rubberized Concrete.

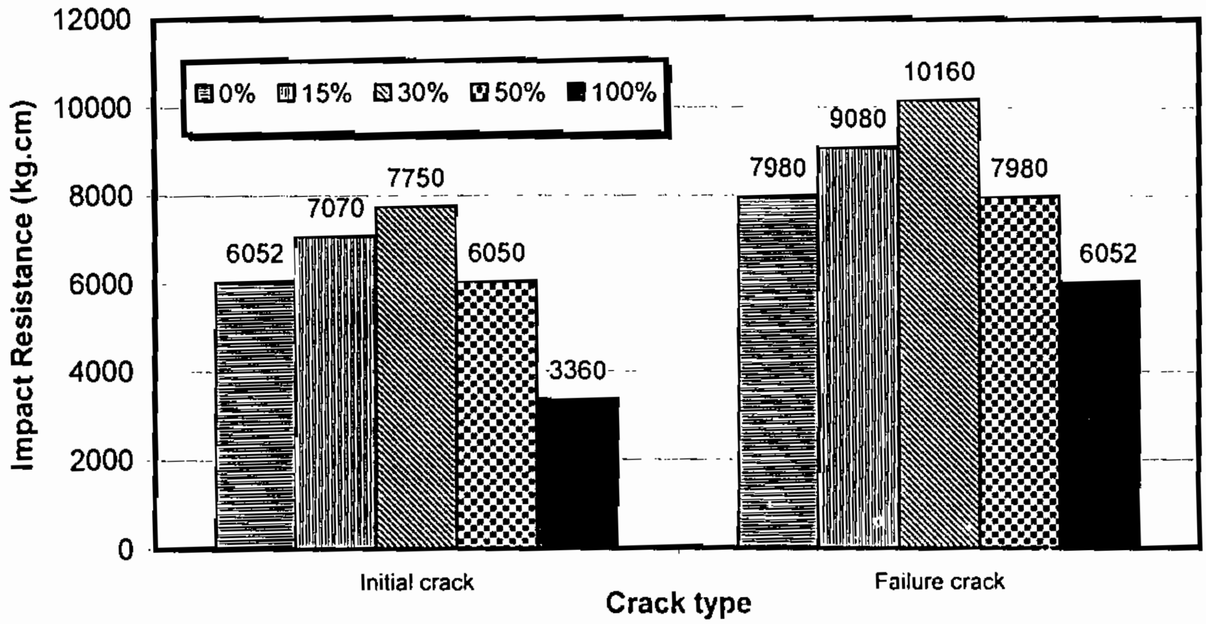

Fig. (6) Impact resistance for rubberized RC.

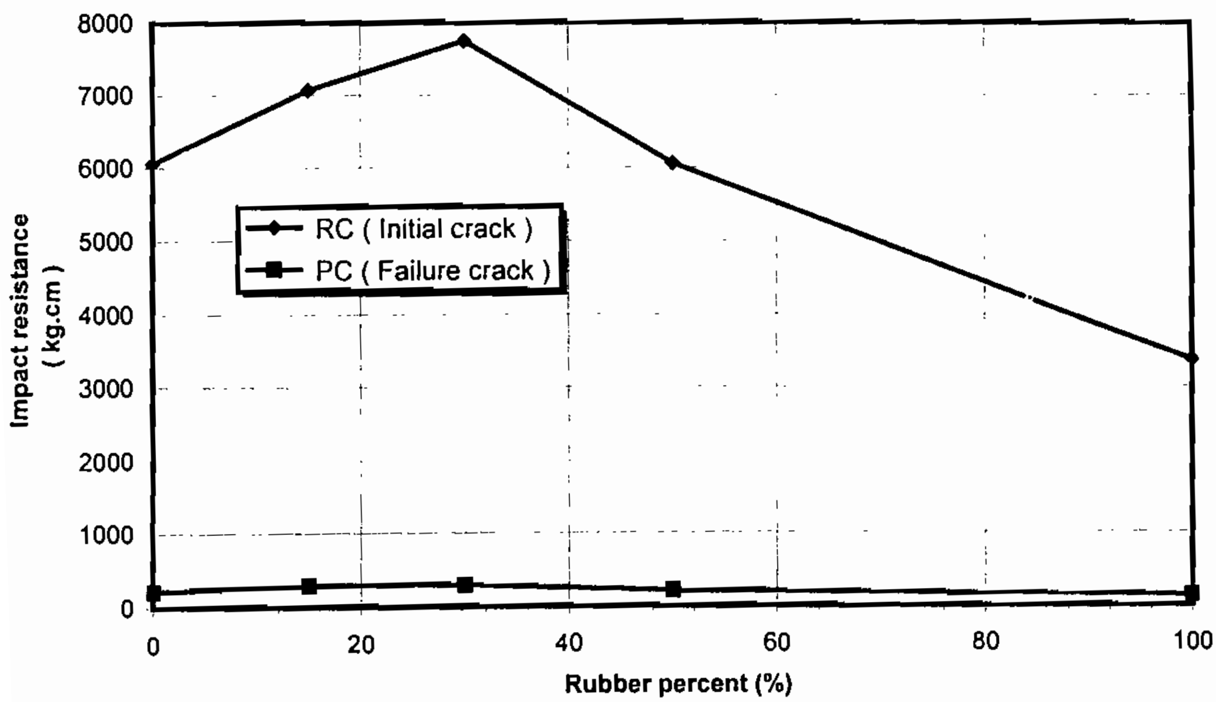

Fig. (7) Effect of rubbrr percent on the impact resistance.