THE EFFECT OF AGING OF CONCRETE AND RATE OF APPLIED LOADING ON ENERGY DISSIPATION OF PLAIN CONCRETE MEMBERS SUBJECTED TO STATIC CYCLIC LOADING

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الملخص

تم في هذه الورقة عرض نتائج الاختبارات المعملية لدراسة تأثير عمر الخرسانة وكذلك معدل التحميل على تبديد الطاقة الكامنة للكمرات الخرسانية حيث أظهرت النتائج أن امتصاص الطاقة الكامنة يتناقص مع زيادة عمر الخرسانة وأنها تتناسب تناسباً طردياً مع معدل التحميل وأنه عندما يكون الحمل المسلط على الكمرة يتزايد تدريجياً يعطي أقل هبوطاً للكمرة عندما منتصفها عن ذلك الهبوط الناتج عندما يكون الحمل ثابتاً.

ABSTRACT

This paper presents an experimental work, which was conducted to investigate the effect of concrete aging and rate of applied loading on energy dissipation. The obtained results indicated that the energy dissipation ratio decreases with increase in concrete age. The results also showed that the smaller rate of the applied loading the lesser the energy dissipation, and that applying that load gradually gave less permanent deflection than when the load is applied constant for all ages of concrete and for all rate of applied load which have been investigated.

KEYWORDS: Aging; Dissipation; Energy; Rate of Loading.

INTRODUCTION

Some structural members are subjected to special types of static loading. These loading are called cyclic loading. When concrete structures are subjected to these types of loading they tend to dissipate the generated energy which made by static loading. In the past there have been a few investigation on the energy dissipation properties of plain concrete elements. In 1987 [1] Jordan studied the effects of type of curing on energy dissipation, he concluded that the energy dissipated decreases as the moisture content of the specimen decreases, and also the same author studied the effect of the mix proportioning on the energy dissipation, and he concluded that, if a mix is weak it will show a higher value on energy dissipation than a stronger mix.

In 1986 [2] Flesch carried out a study to determine the effect of energy dissipation on tensile stress for reinforced concrete members.

In 1962 [3] Holand studied the energy dissipation of simply supported pre-stressed beams. His results indicated that the amount of energy dissipation present in a pre-stressed concrete member depended on loading history and on the displacement reduced. In 2000 [4] Alshebani and others studied the energy dissipation of masonry walls under cyclic biaxial compression, there conclusion was the masonry deteriorated under cyclic biaxial compression at two – third of peak (failure) stress. Recently Elazhari and others [5] studies the effect of aggregate size on energy dissipation and their conclusion was the smaller the aggregate size the lesser energy dissipation.

MATERIALS

The materials used in this study are ordinary Portland cement, coarse aggregates were imported from Misurata (200 km east of Tripoli) and fine aggregate (sand beach). These materials were widely used as local aggregates for construction, the physical and mechanical properties of these aggregates are given in Table (1).

Table 1: Properties of coarse aggregate type (I)

Property	Value	Specification Limit (BS812: Part 3: 1975)
Bulk specific gravity	2.65	2.50 – 2.80
Crushing value	28.60	$\leq$ 45 %
Impact value	17.00	$\leq$ 30 %
Water absorption	1.50	$\leq$ 3.44 %
Unit weight	1578.20	1400 – 1800 kg/m^3

SCHEME OF TEST

The experimental work is divided in two stages as shown in Figure (1).

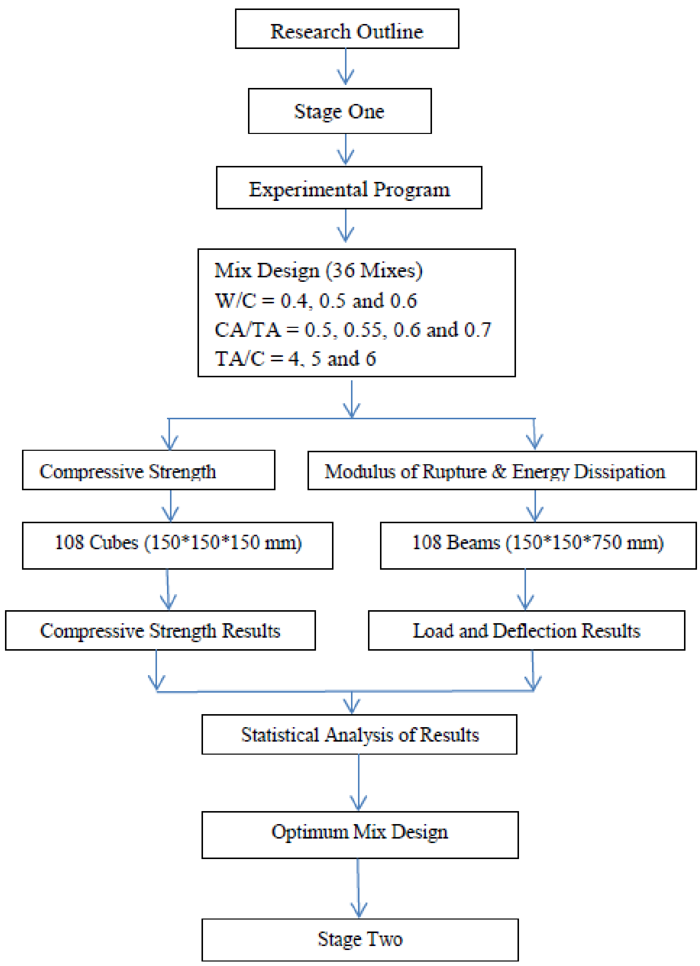

Figure 1: Experimental Plan Chart for Stage One

In the first stage a 36 concrete mixes are prepared, with various factors of water cement ratio (w/c), coarse aggregate to total aggregate (CA/CT), total aggregate to cement (TA/C). The main objective of first stage as presented in 2006 by Elazhari and others [6] in details was to develop the empirical relationships between concrete mix components and compressive strength, modulus of rupture and energy dissipation, then, the concrete mix which gives less energy dissipation, high strength and suitable workability will be investigated in the second stage, to determine the effect of concrete aging and rate of loading on energy dissipation as shown in Figure (2) and summarized as follows:

Nine beams to be tested at 28-days, 60-days, 90-days and 120-days (total number of samples to be tested 36 cubes and 36 beams)

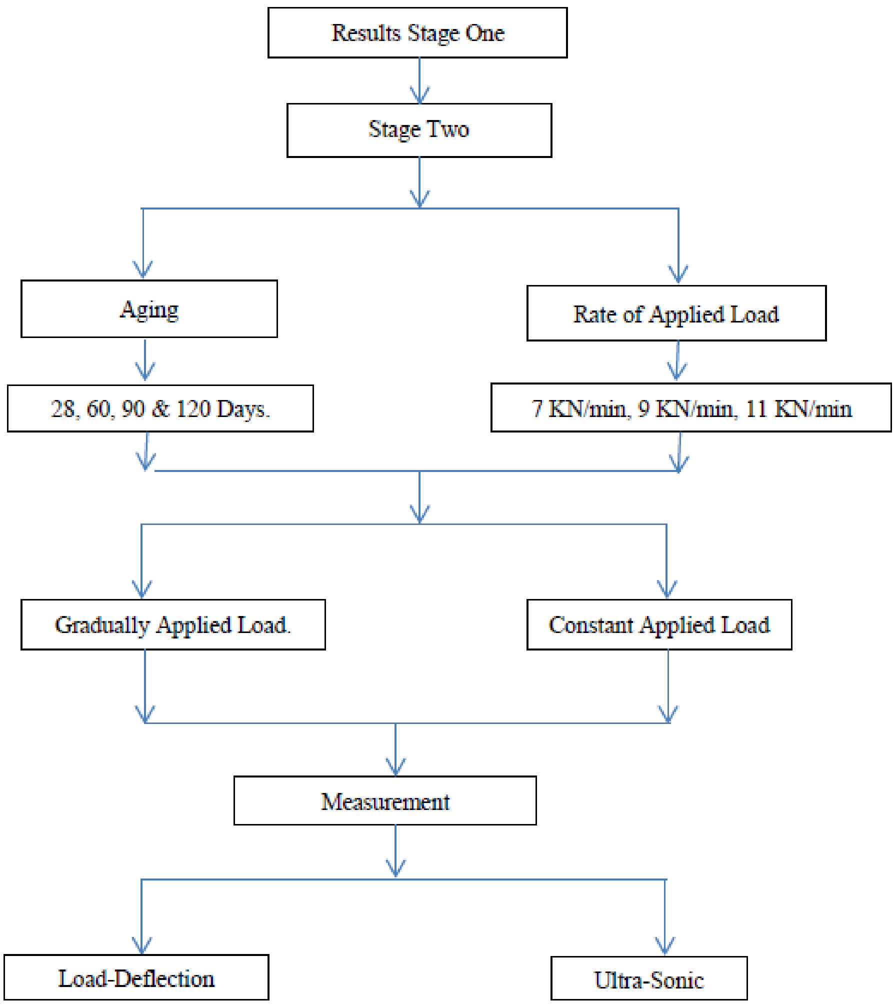

Figure 2: Flow Chart for Stage Two

METHODS OF MEASURING THE ENERGY DISSIPATION

In 2004, M.F Suleiman [7] discussed three methods of measuring energy dissipation, namely: Energy dissipation ratio, Rn that can be defined as the ratio of the energy dissipation per cycle to the total input energy. The second method used to measure the energy dissipation is to find the ratio of the area of each cycle to the area of the first cycle, in other word the energy dissipation is obtained by measuring the decrease in the area of each cycle with respect to the first cycle. The third method is called direct method in which the energy dissipation per cycle is represented by the area enclosed by loading-unloading loop of each cycle, and he concluded that the three methods were acceptable for representing (measuring the energy dissipation) since that Rn is the ratio of the energy dissipation to total energy, which will give clear picture about how much is the energy dissipation from the total energy input.

TYPE OF APPLIED LOAD

Two types of applied loads, constantly applied load or gradually applied load as show in Figure (3) were used in testing concrete beams using cycle loads.

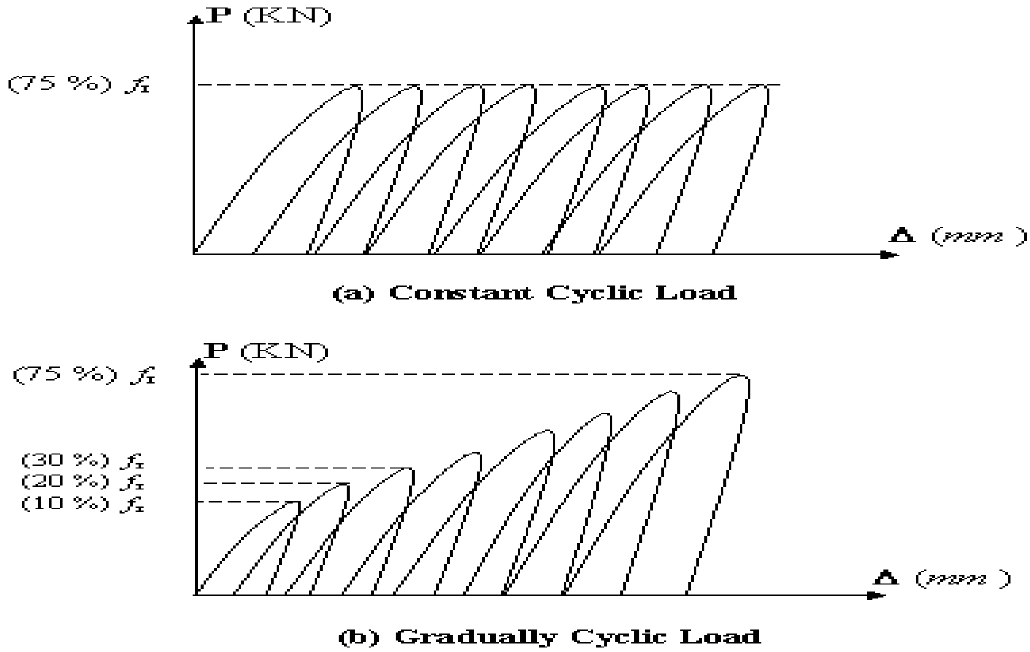

Figure 3: Types of applying loads

RESULT AND DISCUSSION

In general, when concrete is made from ordinary Portland cement and kept in normal curing condition will develop about 80 per cent of the final strength in the first 28 days, so the main objective of investigation to obtain more information about the effect of aging and rate of applied loading on energy dissipation.

The effect of type of applied load (constantly applied cyclic load or gradually increased cyclic load) on the behavior of the plain concrete beams is another objective of this investigation. The relation between the energy dissipation Rn and the number of cycles is shown in Figure (4) for testing period (28, 60, 90 and 120) days from the date of casting indicated that the energy dissipation ratio is decreasing with increasing the age of sample for the same mix. The relation between the total energy dissipation and concrete age for different applied loads is shown in Figure (5),

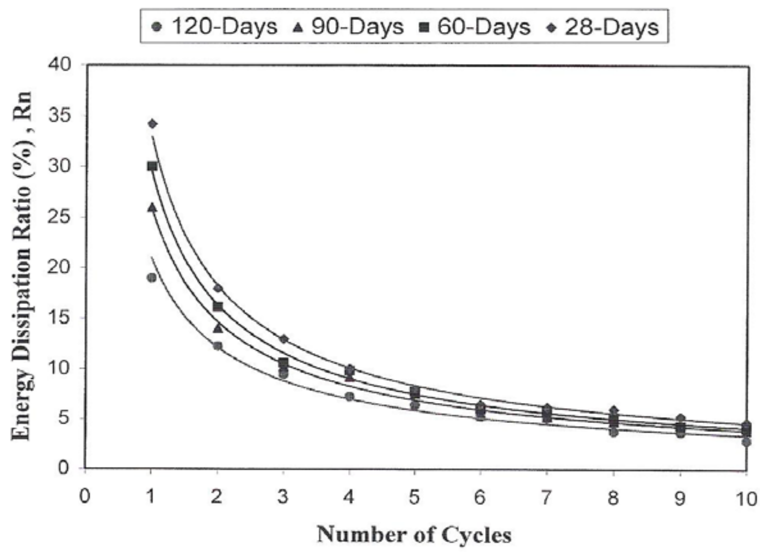

Figure 4: The effect of aging of plain concrete on the energy dissipation ratio with applied constant cyclic load. 12

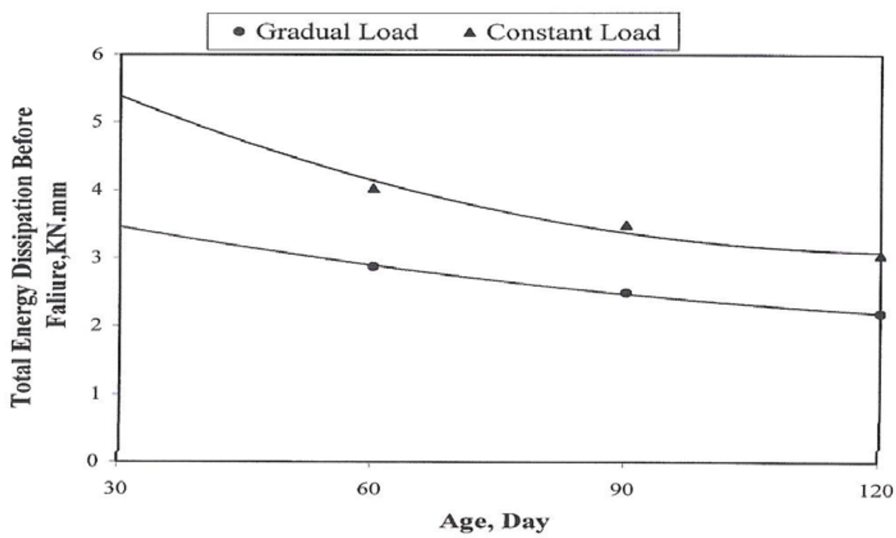

Figure 5: Total energy dissipation before failure versus aging

where one also can notice that by increasing the age of concrete the energy dissipation decreases for both constant and gradually applied loads, or for any concrete mix, the higher compressive strength, the less energy dissipation.

CRACK PROPAGATION

Figure (6) represent all curves for ultrasonic pulse velocity versus number of cycles for constantly and gradually applied load for 28 days age samples, and by comparing the ultrasonic results due to both constant and gradually applied cyclic load. One can concluded that if the cyclic load is applied gradually the cracks will be lesser than when the applied cyclic load is constant for all ages, and from Figure (7) one can conclude the older the age of concrete the higher the pulse velocity. The measured maximum permanent deflection for each cycle was plotted against the number of cycles for constant and gradual applied load respectively as shown in Figure (8) and Figure (9).

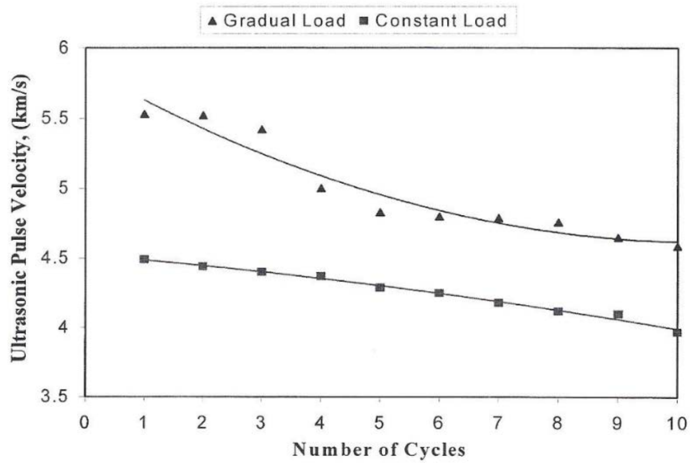

Figure 6: Pulse velocity versus number of cyclic loads for sample of 28-days of age.

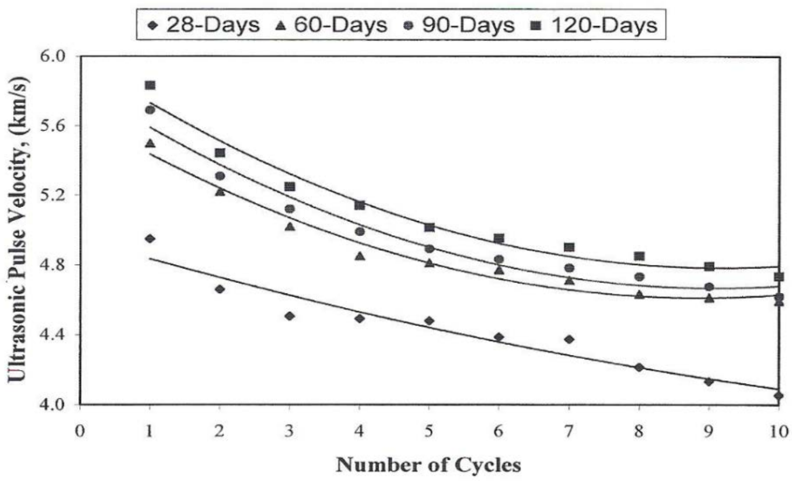

Figure 7: Pulse velocity for gradually applied cyclic load versus number of cyclic for different aging in days.

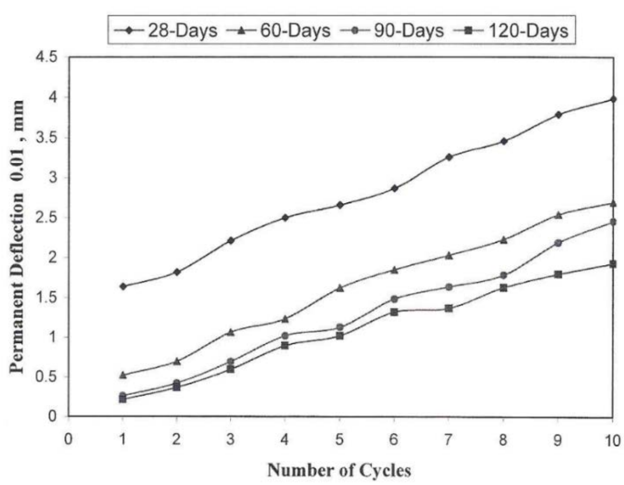

Figure 8: Permanent deflection for constant applied cyclic load versus number of cycles.

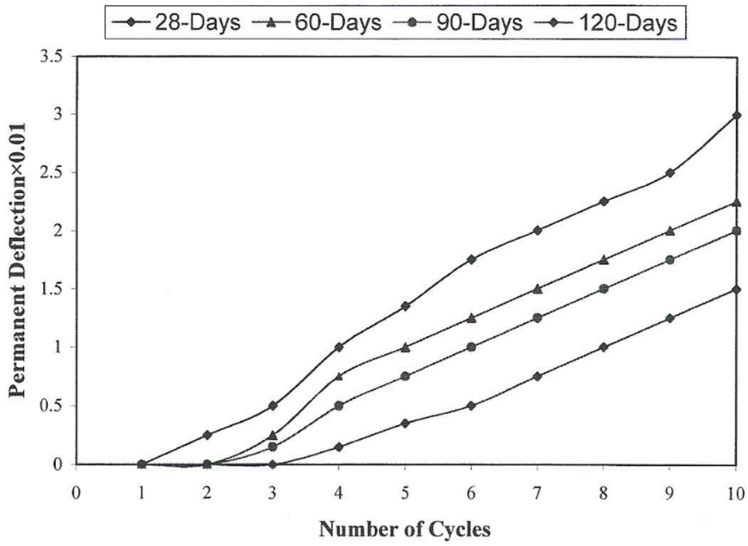

Figure 9: Permanente deflection for gradually applied cyclic load versus number of cycles.

It is clear from the curves that the measured permanent deflection for constant load more than that for gradual load. The reason behind that is during the gradual load, and within the first three cycles of load, the permanent deflection is back to the starting point see Figure (9) and that is because the concrete is still in the elastic range and therefore there is no clear deformation during the primary loading time, and it increases after that by gradually increasing the load, but for the constant load case, the deformation start from the beginning of the first cycle and increases in each successive cycle as by increasing the number of load cycles, an internal deformation occurs due to initiation and propagation of micro cracks, and hence this leads to a decrease in the stiffness of the beam (moment of internal of the section), which will increase the deflection just before failure. From Figure (10), one can conclude that the permanent deflection of the beam when it is subjected to gradually load is smaller than when it is subjected to constant load.

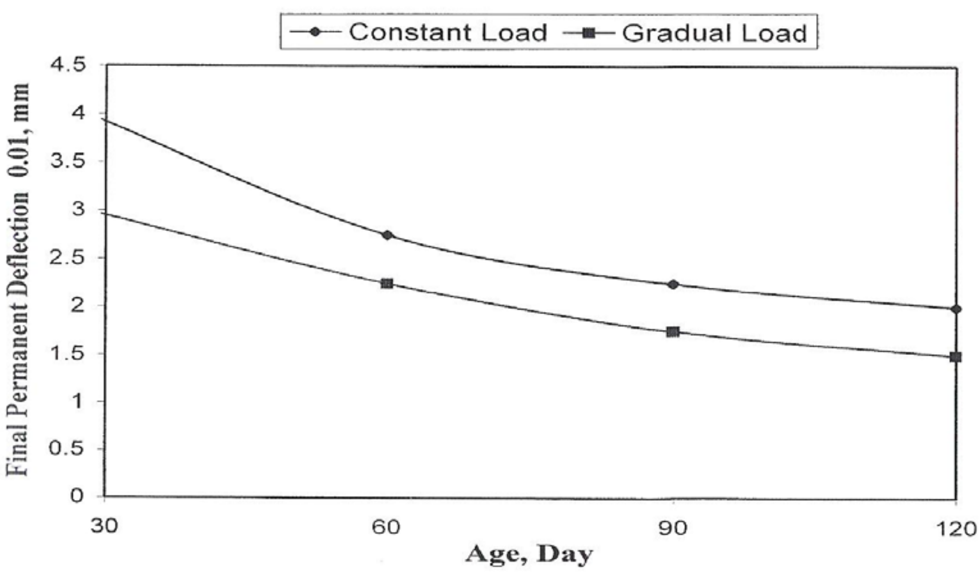

Figure 10: the relation between final permanent deflections versus age

The effect of changing the rate of applied cyclic load on behavior of plain concrete beams, is studied by taking the rate of applied load as (7, 9 and 11) kN/min the Figure (11) and Figure (12) represent the energy dissipation ratio (R_n) versus number of cycles with different rate of cyclic applied load and the ultrasonic pulse versus number of cycles with different rate of applied cyclic loading respectively.

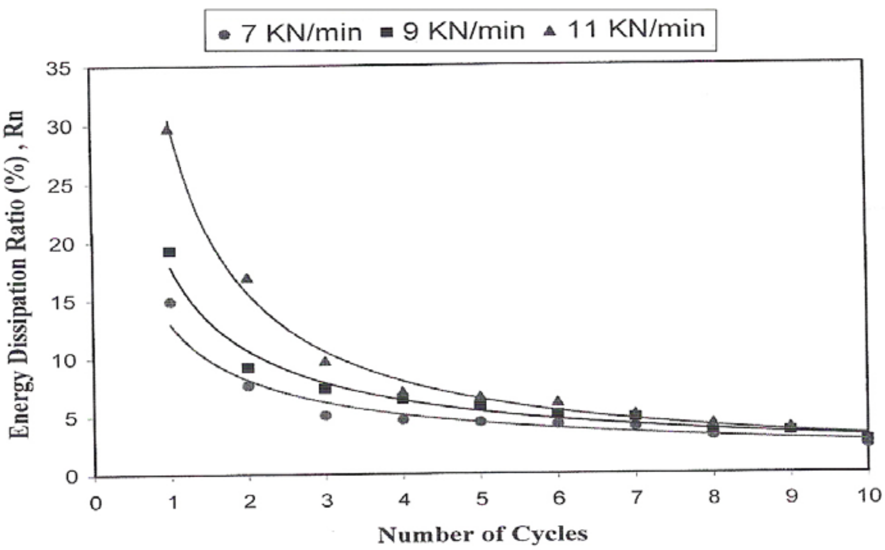

Figure 11: Energy dissipation ratio versus number of cycles with different rate of applied cyclic loading.

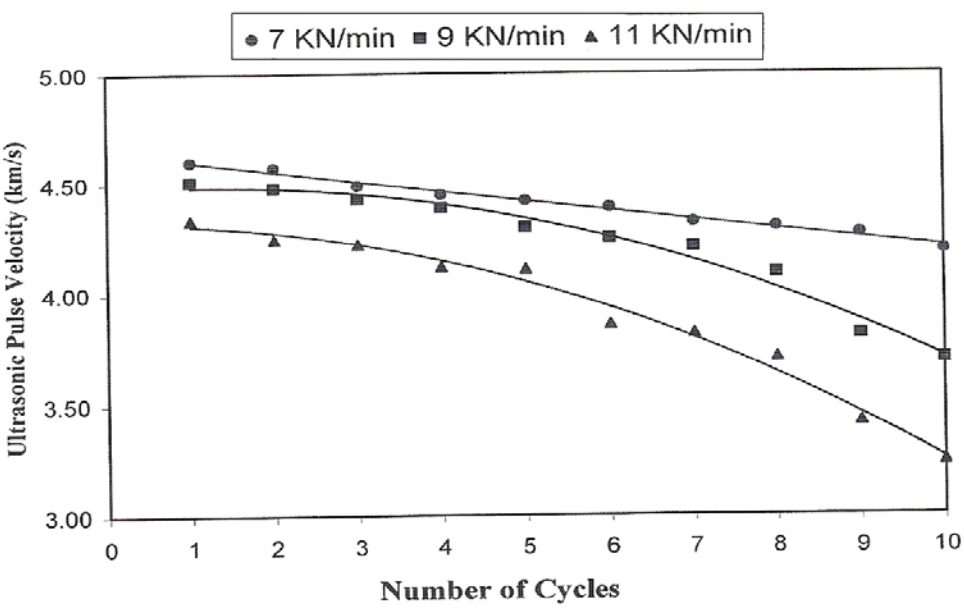

Figure 12: Pulse velocity versus number of cycles with different rate of applied cyclic loading

It is clear from these figures that when the rate of loading is low the deformation and the growth in the micro cracks is also low, then the energy dissipation ratio is low, and when the rate of loading is high, the energy dissipation ratio will be high, the cause behind that when the rate of loading is low the cyclic applied load will move static applied load than dynamic applied load, in this stage the crack is initiated and then propagates along weak interfaces between the aggregate and the cement paste will be increased.

Figure (13) shows relation between permanent deflection versus number of cycles with different rate of applied cyclic loading, one can observe from this figure that the deterioration due to high rate of applied loading is higher than the low rate of applied loading.

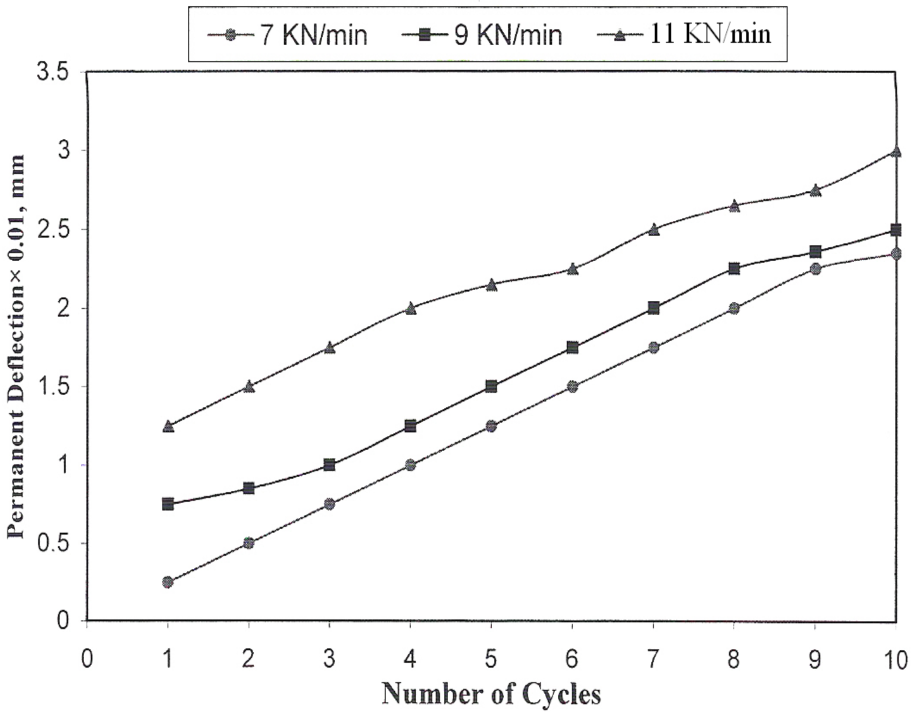

Figure 13: Permanent deflection versus number of cycles with different rate of applied cyclic loading.

CONCLUSION

A total of (36) cubes of (150 x 150 x 150) mm and (36) beams of (150 x 150 x 750) mm, were tested after (28, 60, 90 and 120) days and for rate of applied loading (7, 9 and 11) kN/min by subjected them to two types of applied cyclic loading test, the first is constant static cyclic load and other gradually increased static cycle load. The ultrasonic pulse velocity test was used to monitor the growth of micro cracks during the test, and based on the test results obtained from this experimental study, it can be concluded that:

The energy dissipation ratio decreased with increase in concrete age, the micro cracks are growth very fast during cyclic loading at 28-days more than 60, 90, and 120 days, that can be seen by using ultrasonic pulse velocity test, the growth of micro cracks for constant cyclic load is more than the gradual applied load.

From the results of the tested concrete beams, under three types of rate of applied load one can concluded that the energy dissipation decreases when the rate of applied load decreases, and the permanent deflection, increase in each cycle with increase in rate of applied load, and aging of concrete.

Ultrasonic pulse velocity in concrete decreases with the increase in the rate of applied loading. This decreased can be explained due to the formation of internal micro cracks in the concrete under the increased load.

REFERENCE

[1] Jordan, R. w "The effect of curing, mix and age upon the damping of concrete"Magazine of concrete reach vol. 32 No 113 pp. 195, 2001 December 1987

[2] Flesch, R. "The damping behavior of reinforced concrete element " International Association for Concrete Engineering report vol. 34, pp 83-98, 1981

[3] Holand, I "Energy dissipation and damping in simply supported presented beams "the Technical University of Norway, April 1962.

[4] Alshebani, M, M., and Sinha, S. N., "Energy dissipation of masonry under cyclic biaxial compressive" conference of structures under shock and impact, Wessex of Technology, UK, 427 - 436, 2000

[5] Elazhari, S. elal (The effect of aggregate size on energy dissipation subjected to static cycled loading). Twelfth international conference on advanced concrete technology and sustainability Prague Oct. 30-Nov.1/2012.

[6] Elazhari, S., Akkari, M. Suleiman, M. "The optimum mixed design "Local conference in 2006 Misrata – Libya

[7] Suleiman, F. M. "Experimental investigation of energy dissipation properties of plain concrete members "M S. Thesis in Civil Eng. Tripoli University 2004 Tripoli, Libya