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RE-USE OF WASTE TIRES RUBBER AS FINE AGGREGATE REPLACEMENT IN CONCRETE MIX APPLICATIONS

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ABSTRACT

Discarded waste tires are one of the important parts of solid waste which had historically been disposed of in to landfills also causing a serious environmental problem. Then this study explores the possibility of reusing discarded waste tires in concrete engineering applications through enhancing the properties of concrete mix as partial replacement with fine aggregate to produce ideal concrete mix. The percent of discarded waste tires substituted in to the concrete mix by weight (0%, 10%, 15%, and 20%) respectively. Two types of waste tires are used as (chips and grounded shape) applied at 68 experiments and tested their mechanical, physical and chemical properties with 260 test in order to determine the optimal enhancing replacement ratios of waste tires as (dry density, compressive and flexural strength, performing slump, and toughness indices) at curing ages of (3, 7, 28 and 56 days) for standard and improved concrete mix. The results for tests show a decline in compressive strength of the concrete in other hand an increase in their toughness with good approach properties and reduce the cost of additive materials, also solve a serious problem posed by waste tires.

KEYWORDS: Solid waste, recycling, waste tires, cleaner active technology, improvement of characteristic properties of concrete mix, applications.

INTRODUCTION

Many of the wastes produced today will remain in the environment for several years with larger grows accumulation with a waste disposable crisis, one of the active solution for this problem lies in recycling waste in to useful products with continuous decreasing the number of landfill materials by reusing them again [1,2].

Chips and grounded waste tires are different to other wastes materials with a potential for re-use because their production method is now well developed, the reuse of this material in concrete could have both environmental advantage and at the same time ensure economic viability with improvement the characteristic design properties of concrete mix [3-8].

Previous research has shown the use of waste tires particles in concrete mixes decreases the compressive strength of hardened concrete , also shown the improvement of mechanical properties according to several studies for different concrete mix design and their replacement type concentration and their civil engineering applications[9-12].

Tomas U. has been developed a concrete mix with a pelletized cut rubber tire as substituted to coarse aggregate for construction applications [13]. Malek K. use the crumb rubber in the developing strength of concrete mix[14], where Parveen et al has been studied the use of rubber waste as partial replacement of fine aggregate to produce rubberized concrete in M30 mix[15] . Nadim D. et al explores the possibility of reusing warn and damage vehicle tires in concrete mixture and develop their mechanical properties [16]. Mavronlidon M. et al , has been used rubber particles partially replace natural aggregate to increase the scarce of concrete [17], but Ahmed N. et al has been investigated the use of recycle tire products in several traditional civil engineering materials by use of both chips and crumb rubber[18], in other hand Ruiliun et al had recycled tires as coarse aggregate in concrete pavement mixtures in order to present the effect of low and high volume tire chips on fresh and hardened concrete properties[19] . Abrhamk S. had used the recycled rubber tires as partial replacement for coarse aggregate in concrete construction where a design and prepared

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concrete mix by use of DOE method [20]. Johnn B. have a utilization of recycled and waste materials various construction application by use of swine manure, animal fat, silica fume, roofing shingle, empty palm fruit bunch, citrus peels, cement kiln dust, fly ash, foundry sand, slag glass, plastic, carpet, tire scrap, in order to study the current practice of the use of waste and recycle materials in the construction industry [21].

Carme Carmen A. , have a modification of Portland cement concrete with scrap rubber by w/c ratios , then check their mechanical properties " compressive , indirect tensile strength, and flexural strength with difference wt. ratios of rubber wastes[22], and Oikonomon N. et al were studied the application addition of tire rubber in cement mixtures , road construction and geotechnical works[23], also Sara S. studied the use of rubber particles from recycled tires as concrete aggregate for engineering applications to improve their mechanical properties and workability , and air entrapment and compressive strength through use three types of scraps (ash rubber, crumb rubber and tire chips)[24] and Yunping X. et al were utilized of solid wastes (waste glass, and waste rubber particles) as aggregate in concrete[25] .

The aim of this research is to:

1. Design a standard concrete mix.
2. Replacement a fine aggregate of standard concrete mix with different weight ratios of scrap tires (both chips and ground rubber) as (0%, 10%, 15%, and 20%) respectively.
3. Check the physical, chemical, and mechanical properties for both standard and modification concrete mix.
4. Optimization which one of additive has excellent properties for civil construction applications.

Type the suitable application for optimum waste tire concrete mix.

EXPERIMENTAL WORK

Materials and mix design

Materials: The materials used in this study are as follows:

Cement: Type I Portland cement available was used in all types of aggregate content mixtures. The chemical and physical properties of the cement are presented in tables 1 and 2, respectively.

Table (1) Chemical composition of cement

Compounds	Abbreviation	% Weight
Lime	CaO	64.54
Silica	SiO_2	19.82
Alumina	Al_2O_2	5.23
Iron Oxide	Fe_2O_3	4.23
Sulfite	SO_3	2.4
Magnesia	MgO	1.69
Loss of ignition	L.O.I	2.61
Lime saturation factor	L.S.F	0.97
Insoluble residue	I.R	1.09

Main compounds (Bogue's equation) % by weight

Tricalcium silicate	C_3S	63.5
Dicalcium silicate	C_2S	8.92
Tricalcium aluminate	C_3A	6.69
Tetra calcium aluminoferrite	C_4AF	12.9

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Table (2) Physical Properties of cement

Physical properties	Abbreviation	Limits of cement
Finesse (m^2/kg)	-	320
Initial setting time (min)	I.S.T	4:00
Final setting time (h)	F.S.T	8:00
Soundness (%)	-	0.07
3 days age compressive strength (MPa)	C_s	29.50
7 days age compressive strength (MPa)	C_s	37.75
Tensile strength (MPa) (optional)	Ts	-

Fine aggregate: The fine aggregate was natural sand of 4.75mm maximum size. The properties of the fine aggregate were determined and table (3) presents the properties of the sand, where its gradation is presented in table (4).

Coarse aggregate: Natural crushed stone aggregate for maximum size 20mm and bulk density of 1594 Kg/m3 .

Table (3) properties of fine aggregate

Properties	Limit
Sulfate (%)	0.7
Finesse modulus	2.99
Absorption (%)	5.40
Max size (mm)	4.75
Density (Kg/m^3)	1588
Specific gravity	2.6

Table (4) Gradation of fine aggregate

Sieve size (mm)	Accumulated passing %
4.75	92.55
2.36	81.9
1.18	72.30
0.6	48.90
0.3	9.0
0.15	1.01

Waste tire rubber: Waste tires rubber presents the discarded automobile waste tires that are collected from the stockpiles of automobile waste tires. It consists of approximately 50% chips waste tires (13-100mm) size, and 50% grounded waste tires of (0.14-13m m) size. Briefly the waste tires rubber are shredded manually after collection, It was analyzed in terms of some physical properties such as density and sieve analysis and table (5) presents both physical and mechanical properties of waste tires rubber .

Table (5) Physical; and mechanical properties of waste tires rubber

Properties	Values
Compacted Density (Kg/m^3)	745
Shape of particles	It consists of approximately 50% chips waste tires (13-100mm) , and 50% grounded waste tires of (0.14-13mm)
Color	Black
Water absorption 24 h (%)	0.01
Compressive strength	Weak and poor
Tensile strength (PSi)	7000
Activity	Hydrophobic and Non active

Table (6) Physical; and mechanical properties of waste tires

Symbols	Materials					w/c or w/(c+wti)
	Cement (Kg/m^3)	Aggregate (Kg/m^3)	Sand (Kg/m^3)	Waste tires (Kg/m^3)	Waste tires %	
ti_1	666	956	533	0	0	0.3
ti_2	666	956	479.1	53.3	10	0.3
ti_3	666	956	453.1	79.95	15	0.3
ti_4	666	956	426.4	107	20	0.3

MODIFIED CONCRETE MIX

Referent concrete mixtures: Each mixture consisted of 666 Kg/m^3 cement, 533 Kg/m^3 sand , 956 Kg/m^3 aggregate , and W/C ratio of 0.3 these mixtures were of 0% waste tires ,and were cured for 3,7,28,and56 days .

Waste tires rubber concrete mixtures: These mixtures are presented in table (6) as ti_2, ti_3, and ti_4, corresponding to the 10%, 15%, and 20% addition of waste tires rubber as sand replacement, respectively.

PROPERTIES

- 68 cubes of concrete of 10x10x10mm were molded for compressive strength, and dry density tests.
- 64 prisms of 70x70x38mm were casted for flexural and toughness strength tests.

Density:
This test measured for the cubes taking from curing water basin just prior to compression strength, which represent the mean of dry density of 4 cubes of each curing age.

Compression:
The prepared concrete cubes were tested immediately after taken out of water while they were still wet by use of Forney Machine.

Flexural and toughness strength:
The prepared prism was tested by applied 10 KN load and proving ring capacity and 0.01 dial gage precision. Then flexural strength test and toughness indices implemented by applied the same load and conditions.

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RESULTS AND DISCUSSION

ICP measurement showed that the predominant elements composing the powder are calcium, carbon and fewer quantities of Al, Si and Sr. The estimation of these elements are presented in table 1. These compositions are in agreement with other results from the literature [11].

Slump test:-

Figure (1) represent the effect of waste tire content on slump of concrete , where slump values are decreasing with increasing content of waste tires and the same results get from decreasing ratios of slump and waste tire contents figure (2) with a sharply relation at 76% , 94.1%, and 100% of slump for ti2, ti3, and ti4 respectively.

This reduction can be reasoned to the fact that some particles are angular and others have nom-uniform shapes resulting in less fluidity , in other hand the reduction of slump have easy workability and suitable for use in precast and large site applications according to very low workability (slump = 0-25 mm) applied for vibrated concrete and large section high workability (slump = 100-180 mm) applied for congested reinforcement sections the concrete products with waste tires rubber almost zero , this means that no slump of concrete , then their utilized for roller compound concrete (RCC) or pavement construction applications [10].

Dry density tests:

The dry density tests for modified tires rubber concrete mixtures ti2, ti3, and ti4 are shown in fig. (3) And the decreasing ratios in the dry densities of those mixtures are presented in fig. (4). The dry densities at each curing age tend to decrease with the increase of waste tire rubber ratio in each concrete mixture but the dry densities tend to increase with time for each concrete mixtures at all curing ages. It is clear that at 56 days curing age, the lowest dry density (2370 kg/m3) exceeds the range of the dry density for structural light weight concrete. The use of modified tires rubber concrete for each curing age reduced the dry densities of all mixtures with increasing the waste tire rubber, because, the density of waste tire rubber lower than that of sand by (53.1) %[10,11].

Compressive strength tests:

The results of the compressive strength tests for developed waste tire rubber concrete mixtures are shown in fig. (5), while the decreasing ratios of all previous mixtures below the referent mixtures are shown in fig. (6). The results show a tendency for compressive strength values of waste tire rubber concrete mixtures to decrease below the referent mixtures with the increase of waste tire rubber ratio at each curing age. This trend can be attributed to the decrease in adhesive strength between the surface of the waste tires and cement paste, as well as particles size of the waste tire rubber increase, in addition waste tire rubber is a hydrophobic material, so this property may restrict the water necessary for cement hydration from entering through the structure of the concrete specimens during the curing period. All of the compressive strength values are higher than the minimum compressive strength required for structural concrete which is 17.24 □pa [10].

Flexural strength:

The results of the flexural strength tests for the waste tire rubber concrete mixtures ti2, ti3, and ti4 are illustrated in fig.(7), and the decreasing ratios in the flexural strength of the previous mixes below the plain mixtures are shown in fig(8). These results show that the flexural strength of waste tire rubber concrete mixtures at each curing age is become to decrease with the increase of the waste tire rubber ratio in these mixtures. This trend can be attributed to the decrease in adhesive strength between the surface of waste tire rubber particles and the cement matrix, as well as the hydrophobic nature of waste tire rubber which may limit the hydration of cement in concrete mixtures. Therefore the hydration developed slightly with time. The flexural strengths of the waste tire rubber concrete composites compared similarly with those of previous work [7].

Toughness indices tests:

The load-deflection curves of the referent mixtures (ti1) at all curing age 7, 28, and 56 days are illustrated in figure(9). This figure present the sudden failure of plain concrete under center-point loading on simple beams according to the brittle nature of concrete. The flexural load-deflection results for specimens were cleared for 10%, 15%, and20% waste tires additives at figures. (10-12), respectively. These figures present the arrest of the propagation of micro cracks by introducing waste tires rubber particles that have chips and grounded shape into concrete mixtures. Table

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(7) presents the toughness indices for waste tires rubber concrete at all curing ages. The toughness indices (I10/I5) for 7 days curing age of ti4 and toughness indices (I30/I10) for ti4 at the same curing age are negligible, they are 1.6 and 2.4, this difference the values of ti4 at 7 days curing age may be reasoned to the heterogeneity of shape of waste tires rubber particles. The toughness indices for ti4 concrete mixture at 28 and 56 days curing age, and the toughness indices for all other concrete mixtures at all curing ages reach the plastic behavior. This is behavior is desirable for many applications that require high toughness [10].

CONCLUSION

This research leads to several notifications:

1. The compressive strength values of all waste tires rubber concrete mixtures have a tendency to decrease below the values for the reference concrete mixtures with the increasing of waste tires rubber ratio at all curing age. This may be attributed to the decrease in the adhesive strength between the surface of the waste tires rubber and cement paste. At 56 days curing ages the concrete mixtures that made of 20% waste tires rubber has the lowest compressive strength, and the decreasing ratio of this mixture below the referent concrete mixture at the same curing age is 35.25%.
2. The flexural strength values of waste tires rubber concrete mixtures have a tendency to decrease below values for the referent concrete mixtures with increasing the waste tires rubber ratio. A concrete mixture made of 20% waste tires rubber has the lowest flexural strength at 56 days curing age. It has flexural strength of 17.6% value lower than that of reference concrete mixture at the same curing age.
3. The dry density values of waste tires concrete mixtures at each curing age tend to decrease below values for the reference concrete mixture. At 56 days curing age, the lowest dry density 2370 kg/m3 exceed the range of the dry density of structural lightweight concrete.
4. The slump values of waste tires rubber concrete mixtures tend to decrease below the slump of the referent concrete mixture, with the increase of this waste ratio. In spite of this decline in the slump of those mixtures, those mixtures are easy to work based on the fact that workability has a broad range from very low to high workability for different construction applications.
5. The load-deflection curves of concrete mixtures that contain waste tires rubber showed arrest of propagation of micro cracks by introducing waste tires rubber that has chips and grounded shop (I10/I5) and (I30/I10) reached the plastic behavior for ti2 and ti3 at all curing ages, but ti4 reached the plastic behavior at 28 and 56 days curing ages only.

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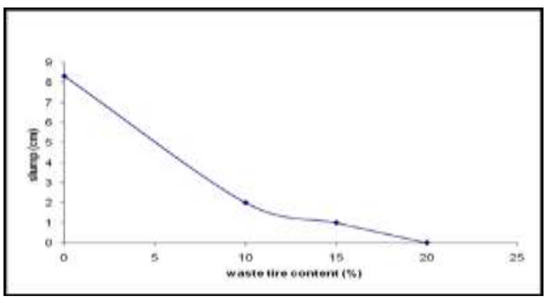

Figure (1) slump of waste tire concrete mix.

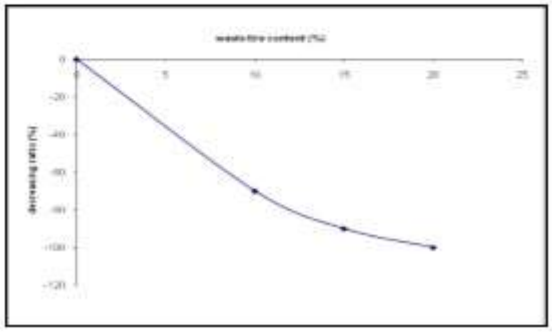

Figure (2) decreasing ratio in the slump of waste tire concrete mix.

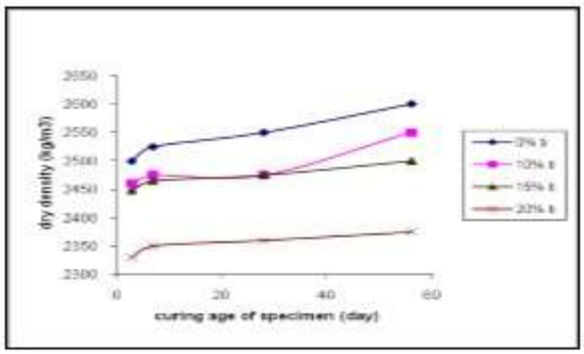

Figure (3) dry density of waste tire concrete mix.

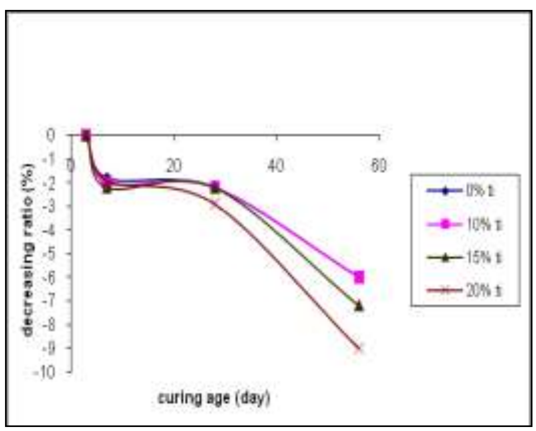

Figure (4) decreasing ratio in dry densities of waste tire concrete mix.

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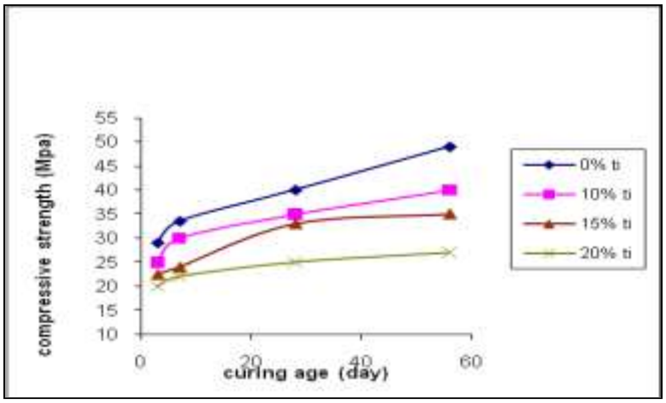

Figure (5) compressive strength of waste tire concrete mix.

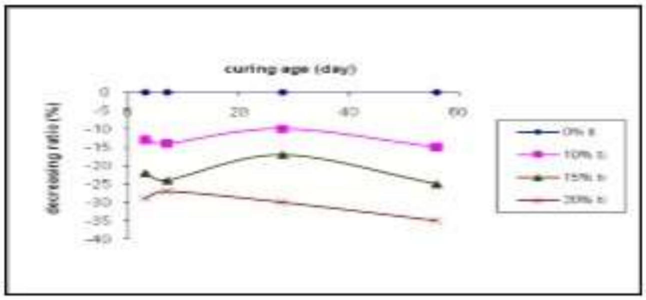

Figure (6) decreasing ratio in compressive strength of waste tire concrete mix.

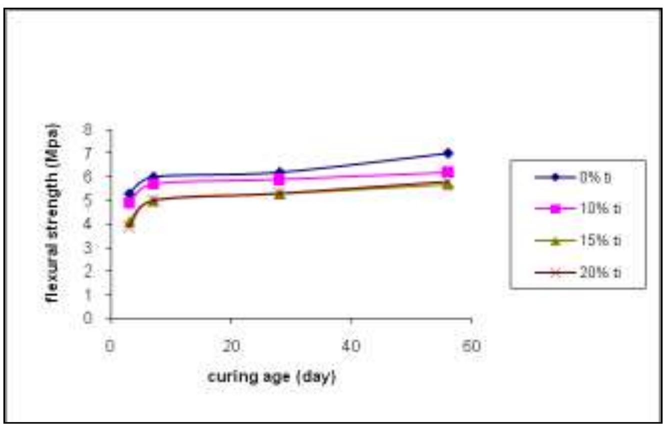

Figure (7) flexural strength of waste tire concrete mix.

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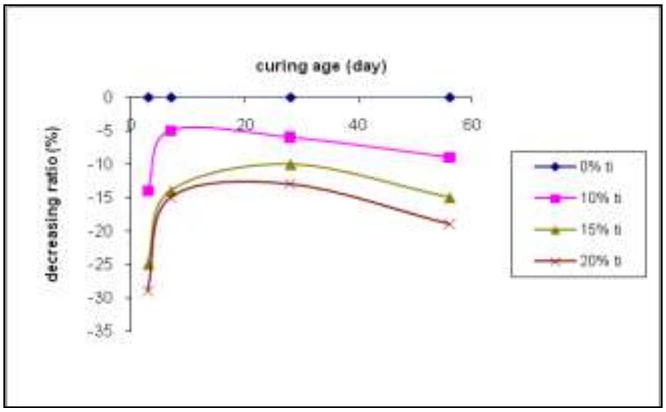

Figure (8) decreasing ratio in flexural strength of waste tire concrete mix.

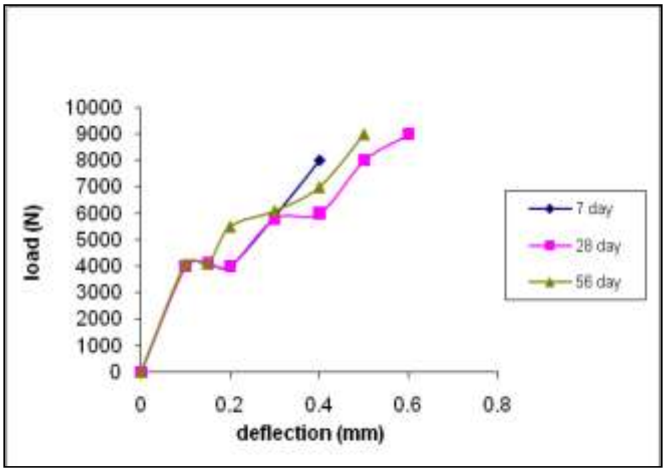

Figure (9) load-deflection curve of 0% waste tire concrete mix.

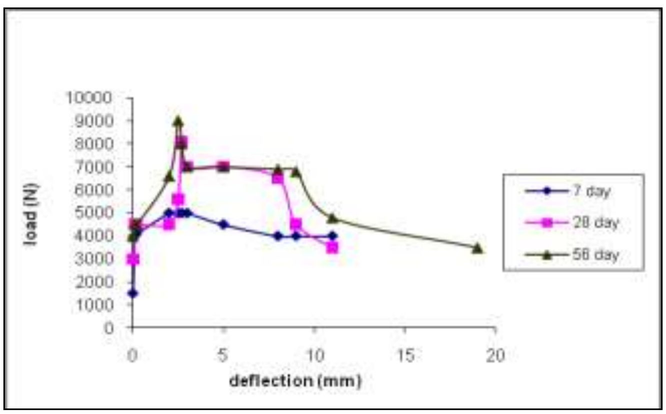

Figure (10) load- deflection curve of 10% waste tire concrete mix.

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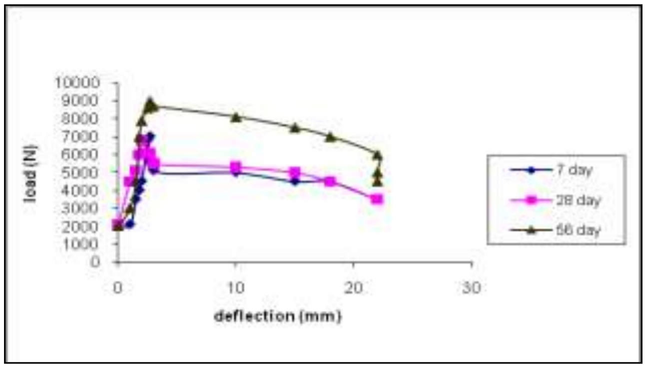

Figure (11) load –deflection curve of 15% waste tire concrete mix.

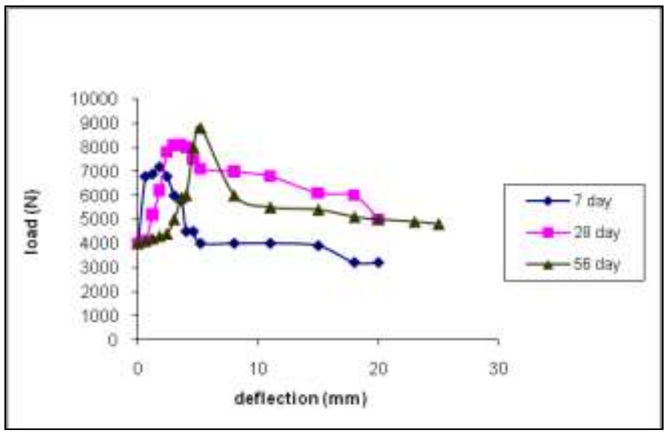

Figure (12) load- deflection curve of 20% waste tire concrete mix.

Table (7) toughness Indices.

Curing ages	7 days				
Indices / Mixtures	I_5	I_{10}	I_{30}	I_{10}/I_5	I_{30}/I_{10}
ti_2	3.12	6.15	17.36	2	3
ti_3	6.2	11.72	34.39	2	3
ti_4	6.1	9.8	23.74	1.6	2.4
Curing ages	**28 days**				
Indices / Mixtures	I_5	I_{10}	I_{30}	I_{10}/I_5	I_{30}/I_{10}
ti_2	5	10	54.95	2	5.5
ti_3	5.65	10.127	36.45	2	3.6
ti_4	6.7	15.44	45.9	2.31	3
Curing ages	**56 days**				
Indices / Mixtures	I_5	I_{10}	I_{30}	I_{10}/I_5	I_{30}/I_{10}
ti_2	5.7	11.35	44.37	2	4
ti_3	5.6	9.305	26.81	1.7	3
ti_4	5.3	13.4	51.19	2.54	3.8