SHREDDED WASTE TIRES AS A STABILIZING MATERIAL FOR UNPAVED ROADS

قطع الإطارات المتهالكة كمادة تثبيت للطرق غير المرصوفة

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خلاصة:

الغرض الأساسي من هذه الدراسة هو بحث إمكانية استخدام قطع الإطارات المتهالكة كمادة تسليح في إنشاء الطرق. وقد اختبر خليط من مادة الأساس للطريق (الرمل) وقطع الإطارات المتهالكة باستخدام كل من اختبار القص ثلاثي المحاور واختبار نسبة تحمل كاليفورنيا. وكانت العوامل المتغيرة في هذه التجارب هي نسب الخلط بالوزن وكذلك أحجام قطع الإطارات. وقد تم دراسة العوامل التالية لمعرفة تأثير قطع الإطارات على مقاومة القص ومقاومة الاختراق للخليط: الضغط المحصور , محتوى قطع الإطارات , حجم قطع الإطارات , كيفية وضع قطع الإطارات.

وقد خلصت الدراسة إلى ان قطع الإطارات المتهالكة تزيد من مقاومة القص ومقاومة الاختراق لطبقة الأساس . كذلك فإن محتوى قطع الإطارات المتهالكة وحجمها وكيفية إضافتها هي أهم العوامل المؤثرة على مقاومة القص والاختراق. وقد حدثت أفضل مقاومة قص عند نسبة قطع إطارات ٦% وحجم قطع إطارات ٥× ٥ مم , وأفضل مقاومة اختراق عند نسبة قطع إطارات ٣% وحجم قطع إطارات ٥× ٥ مم.

ABSTRACT:

The main objective of this study is to investigate the feasibility of using shredded waste tires as a reinforcing material in road construction. Triaxial and CBR tests were conducted on mixtures of base layer material (sand) and shredded waste tires. Sand-tire mixtures were prepared with different shred contents by weight and different shred sizes. These mixtures were subjected to identical laboratory tests to observe the influence of shredded waste tires on physical and engineering properties of sand-tire mixtures. The following parameters were studied to evaluate their influence on shear strength and resistance to penetration: confining pressure, shred content, shred size and order of adding shredded tires. Results indicated that generally, shredded waste tires increases the shear strength of sand and its resistance to penetration. Shred content, shred size and order of adding tire shreds are most significant characteristics of the mixes influencing shear strength and resistance to penetration The higher improvement in shear strength is achieved with shred content equal to 6% and shredded tire size of 5×5mm in case of Triaxial test while in case of CBR test, the higher resistance penetration achieved with shred content of 3% and shred size of 5×5mm

KEYWORDS: Shredded waste tires – Unpaved road – Soil stabilization – Environmental

INTRODUCTION:

Many traditional methods were adopted to eliminate waste materials that are associated with bad effect on environment. Several studies deal with how to use the waste materials as an alternative or solutions in some applications of civil engineering. These studies are introduced to the fieldwork as a result of increasing the cost of elimination or recycling these materials. One of these materials is the waste tire that can be used as a construction material in road construction as presented below The disposal of scrap tires has become a major environmental concern allover the world. The disadvantages associated with a large store of waste tires draw the attention to develop new ways of reuse or recycle waste materials. The process of recycling tire system is complicated and expensive. Furthermore, the wishing of consumers to new product is more than the recycled products because new tires have a long life cycle than recycled tires. Recent research indicates that shredded waste tires do not show any likelihood of being a hazardous waste material or having adverse effects on ground water quality [1]. Waste tires can be used in the field and applications of earthwork. Shredded waste tires are now being used as subgrade reinforcement for constructing roads over soft soils, as aggregate in leach beds for spetic systems, as an additive to asphalt, as a substitute for leachate collection stone in land fills and as sound barriers [2, 3]. A new design procedure for using shredded scrap tires as a lightweight fill material in highway construction was developed by Bosscher et al. [4]. They performed laboratory model test, field tests and numerical analyses to study embankments constructed using discarded shredded tires. The results of numerical analysis were showed that the FEM typically overpredicted the amount of displacement measured at the surface of the model test. Generally the results of this study supported the use of tire chips as an environmentally acceptable lightweight fill in highway applications of properly confined [4]. Tire shreds and soil-tire shred mixtures can be compacted using common compaction procedures. It is found that unit weight is primarily controlled by the amount of soil in the mixture, whereas compactive effort and molding water content appear to have little influence [2, 3, 5].

Direct shear tests were conducted on mixtures of outwash sand and tire shreds in a large-scale shear box. Edil and Bosscher [6] found that for dense outwash sand, adding 10% tire shreds by volume in a random arrangement resulted in greater strength than the pure sand. Fosse et al. [2] conducted direct shear tests on mixtures of dry sand and shredded waste tires. They reported that three significant factors affecting on shear strength were identified normal stress, shred content and sand matrix unit weight. The results of these tests ensure the adding shredded waste tires increased the shear strength of sand [2]. Also, the potential of tire rubber ash as a stabilizing agent for problematic soil material was investigated by Al-Homoud [7]. Soil-rubber ash mixtures were prepared with 0, 5, 7, 9, 11 and 20% by weight of both the natural and rubber treated soil. The following tests; Compaction, unconfined compressive strength, direct shear and free swell test were conducted on rubber ash admixtures to observe the influence of rubber on properties of the tested soils. Test results indicated that rubber ash is effective in stabilizing the soils and increase the shear strength of soil [7].

The main objective of the study described herein was to investigate the feasibility of using shredded waste tires as a means to enhance the stabilizing and performance of road construction. A series of Triaxial and CBR tests were conduct on mixture of sand and tire shreds to determine which faetors influence their strength. The parameters that were studied included confining pressure, shreds content and shreds size, confining pressure with size and content of shred tires and order of shreds tire.

MATERIALS:

The materials used in the present study are basically sand and shredded tires. The sand used in this research was brought from Giza area. It was used to simulate hase layer material in road construction. Primary tests were carried out to determine its physical and mechanical properties. Sand having particles size ranging from 0.1 to 2 mm, uniformity coefficient 2.85, and a specific gravity 2.63. The maximum dry density is 1.81 g/cm^3 and the optimum moisture content is 9.3%. The waste tires shreds used in this study were obtained from workshop for waste tires at Minia City. Shreds tire used was selected from sidewalk of whole tire because this part from the tire is free from wires. The tire shreds were divided into four groups based on size 5×5, 10×10, 20×20 and 30×30 mm. These sizes were used to study the effect of shreds tire size on the behaviour of randomly reinforced sand. Also, five different shreds tire content 1.5, 3, 4.5, 6 and 9 % by weight were used to study the effect of shreds content on the behaviour of reinforced sand.

EXPERIMENTAL PROGRAMME:

The testing programme consists of a series of Triaxial and CBR tests on pure sand and sand with inclusions of waste tire shreds. All tests were conducted at optimum moisture content and maximum dry unit weight. Modified compaction tests were carried out to determine the optimum moisture content and maximum dry density for pure sand and sand with inclusions of tire shreds Fig.1 to Fig.4 shows the compaction curves for pure sand and sand with different sizes and contents of waste tire shred. From these figures its clear that, an increase in shreds tire shreds content reduces maximum dry density and increases the optimum moisture content for all different size of shreds, these results agree with the result of Al-Homoud [7]. Typically behaviour can be observed with all different sizes of shreds tire used. The different parameters studied in CBR and Triaxial tests are confining pressure, shreds tire size, shreds tire content, order of shreds tire (random & sheets) and confining pressure with size and content.

Triaxial Tests

Triaxial tests with large size specimen having a diameter of 100 mm are conducted on pure sand and sand with shreds waste tire. A standard Triaxial apparatus was used, consisting of a motor-geared plated capable of moving vertically upwards or downwards at constant rate of loading 0.5 mm/min. The testing programme of this part of research involves the determining the difference between the behaviour of sand with and without shreds waste tire for identical samples at various test conditions (drained & undrained). Testing programme of Triaxial test is given in Table1.

Table 1: Experimental Programme of Triaxial Tests

Test No.	Test Condition	Confining Pressure KN/m^2	Size of waste tire (mm)	Content of Waste tire (%)	Order of Waste tire
A	drained	100, 200, 300, 500	--	--	--
B	drained	300	5×5, 10×10, 20×20, 30×30	6	random
C	drained	300	5×5	1.5, 3, 4.5, 6, 9	random
D Effect of confining pressure with size	drained	100, 200, 300, 500	5×5	3	random
		100, 200, 300, 500	30×30		
E Effect of confining pressure with content	drained	100, 200, 300, 500	5×5	1.5	random
		100, 200, 300, 500		6	
F	drained	100, 200, 300, 500	Tire Sheets	1.21 2.43 3.72 4.98	One layer Two layers Three layers Four layers
G	undrained	100, 200, 300, 500	–	–	--
H	undrained	300	5x5, 10×10 20×20, 30×30	6	random
I	undrained	100, 200, 300, 500	5×5 mm	1.5	random
		100, 200, 300, 500		6	

Tests were conducted on pure sand under four different confining pressures 100, 200, 300 and 500 kN/m^2. To study the effect of shreds tires size, tests were performed on samples mixed with different sizes of 5 × 5, 10 × 10, 20 × 20 and 30 × 30 mm under the same confining pressure of 300 kN/m^2 with shreds content of 6%. Also, tests were carried out on samples having shreds of 5 × 5 mm in size under constant confining pressure with different shreds contents of 1.5, 3, 4.5, 6 and 9% randomly mixed with sand. All tests are conducted at optimum moisture content and maximum dry density as mentioned before To investigate the effect order of shreds tire, shreds tire is cut to into disc shape element of approximately the same diameter as the Triaxial specimen and placed horizontally into the sand specimen.

CBR Tests:

Base layer material (sand) with or without shreds tire randomly mixed was placed in CBR mould in five layers and subjected to 56 blows per layer using 4.5 Kg weight with a drop of 450 mm, according to ASTM-D1557-70. A surcharge of 4.5Kg weight in the form of annular ring was placed in the top of the soil surface and 500-mm diameter standard CBR plunger was pushed through the annual steel ring into the soil at a constant rate of 1mm/min. In the soaked samples, the specimen is soaked for a period 96 hours with a surcharge weight 4.5Kg. The CBR values were determined at 2.5 and 5 mm for both top and bottom of the specimen. The testing programme of CBR tests involves the determining the difference between the resistance of sand penetration with and without inclusions of shreds tire for identical samples. All tests are carried out in both unsoaked and soaked samples having shreds tire with different sizes of 5 × 5, 10×10, 20×20 and 30×30 mm with different ratios of 1.5, 3, 4.5, 6 and 9%.

ANALYSIS OF TRIAXIAL TEST RESULTS:

The relationship between the deviator stress ($\sigma'_1 - \sigma'_3$) and axial strain ε % for pure sand are shown in Fig.5. From this figure, it can be observed that the effect of increasing the confining pressure is associated with an increase in deviator stress at any strain. As illustrated in testing programme, two test series **B** and **C** have been performed on sand with randomly distributed shredded tire elements. To study the effect of size and content of shredded waste tires four sizes and five contents have been used as mentioned before. It may be noted that by mixing the sand with a large number of shreds waste tire elements in a random manner, a new material is formed having properties different from these of the sand without additives.

Fig.6 shows the relationship between deviator stress and axial strain for pure sand and sand with different sizes (5×5, 10×10, 20×20 and 30×30mm) of shreds tire tested under constant confining pressure of 300 KN/m^2 and shreds tire content of 6%. It can be observed that the presence of shredded waste tires improves the stress-strain properties for all different sizes of shredded waste tire. . In all cases the maximum deviator stress occurs at a higher axial strain compared with the case of pure sand. Also, from this figure, one can notice that the maximum improvement in the deviator stress achieved with size 5x5mm compared to other sizes. Beyond this size, no much difference between the values of improvement in the deviator stress for all different sizes of shredded waste tires (10×10, 20×20 and 30×30 mm).

The percentage improvement in maximum deviator stress as a result of additive inclusions of shreds tire to the specimen can be compacted from the following relation:

$$PI = \frac{Max.\,deviatorsreess\,for\,sand\,with\,tire - Max.\,deviatorstress\,for\,pure\,sand}{Max.\,deviatorstress\,for\,\,pure\,sand}$$

The relation between percentage improvement in max. deviator stress against size of shredded waste tires are plotted in Fig.7. From this figure it is clear that, the best performance can be achieved in case of using size 5×5 mm with a value of 35%. Also, it can be noted that no much difference between the percentage improvement of maximum deviator stress for other sizes. Fig.8 shows the relation between deviator stress and axial strain for pure sand and sand with different contents (1.5, 3, 4.5, 6 and 9% by weight) of shreds tire tested under constant confining pressure of 300 KN/m^2 and constant size (5×5 mm). From this figure it can be seen that for all different contents of shreds tire, the deviator stress is higher for sand with shreds tires than pure sand especially at values of high strains. The relation between percentage improvement in max deviator stress against shreds tire content are shown in Fig.9. A greater improvement in stress-strain behaviour is achieved by increasing the shredded waste tire content until 6 % and then decreases.

Two series of tests **D** and **E** were conduct to study the effect of confining pressure with size and content of shreds tire as mentioned in testing programme. Series **D** was conducted on two different sizes of shreds waste tire content (5×5 mm and 30×30 mm) and constant shreds tire content of 3 % for all different confining pressure 100, 200, 300 and 500 KN/m^2. Series **E**, was performed on two different contents 1 5 and 6 % constant at constant shreds tire size of 5×5 mm for all different confining pressures. The relations between percentage improvement in max deviator stress against confining pressure are plotted in Fig 10 for case of shreds size effect and Fig 11 for case of shreds tire content. From these figures it is clear that higher percentage improvement in maximum deviator stress is obtained at lower confining pressure. Also, it can be observed that the increasing in percentage improvement in maximum deviator stress are achieved at size (5×5 mm) and shreds tire content of 6 %.

Series **F** were conducted on sand including horizontal circular tire sheets of approximately the same diameter of the triaxial test specimen as illustrated in testing schedule. Fig.12 shows the stress-strain relationship at constant confining pressure 300 KN/m^2 for pure sand and sand with one, two, three and four tire sheets located at equal distances between each layer which correspond to waste tire contents of 1.21, 2.43, 3.72 and 4.98 % respectively. Again presence of reinforcement in the sample increases the deviator stress especially at high values of strains. Also, it can be observed that the maximum deviator stress occurs at higher strain values compared with pure sand.

For a better illustration, the relation between the percentage improvement of maximum deviator stress against tire sheets layers .numbers are plotted in Fig.13. From this figure its clear that, the percentage improvement in maximum deviator stress increases with increase the number of tire sheets. For comparison between the behaviour of randomly reinforced and reinforced with parallel tire sheets, the relation between maximum deviator stress against percentage waste tire content for both tire sheets and randomly shreds tire with size (5×5 mm) is plotted in Fig.14. Noting that the tire sheet reinforcement tests were conduct approximately at the same waste tire content in case of randomly reinforcement. It can be seen from this figure that tire sheets gave better improvement compared to random reinforcement at the same waste tire content.

Triaxial Results under Undrained Tests:

Unlike drained Triaxial shear test, no volume change is allowed during axial loading in an undrained Triaxial shear test [8]. In our study the behaviour of sand under undrained conditions could be considered as a result of two reasons. Firstly, in case of earthquake condition, under the transient loading of an earthquake shock there is not enough time for even sand to dissipate pore water pressure by drainage and the undrained condition applies. The second reason, when the cross sectional of road covers with water (Saturation State) due to floods or rainfall. The sequence movements for wheels of vehicles or trucks over roads surface profile are consider a cyclic (dynamic) loading. So, under its loading movement, road layer soils has not enough time to dissipate pore water pressure by drainage. Therefore, the soil under this loading (dynamic) would be behaves undrained condition. Based on previous reasons, the stress-strain behaviour of base layer (sand) material in case of reinforced and unreinforced under undrained condition should be considered. The relationship between the effective deviator stress ($\sigma'_1 - \sigma'_3$) and axial strain ε % for pure sand under undrained condition for all different confining pressures are shown in Fig.15. From this figure, one can observe that, increasing confining pressure is associated with an increase in effective deviator stress at any strain value. Based on previous results of randomly reinforced sand with shredded waste tires under drained condition, the maximum improvement in stress-strain behaviour was obtained in case of 6 % tire content with tire size (5×5 mm) and the minimum improvement was obtained at 1.5 % tire content According to schedule of testing programme, series **G** was conducted on minimum and maximum contents (1.5 and 6 %) respectively with size (5×5 mm) for all different confining pressure to study the effect of shreds waste tire content under undrained condition.

Also, to study the effect of shredded waste tire size under undrained condition. Series H was conduct on the same previous sizes that are used in drained condition (5×5, 10×10, 20×20 and 30×30 mm) with constant tire content 6 % and constant confining pressure 300 KN/m^2. The relations between percentage improvement in max. deviator stress against confining pressure are plotted in Fig.16. From this figure it is clear that, the percentage improvement in maximum deviator stress decreases with increase the confining pressure for both drained and undrained tests. The percentage improvement in undrained condition is higher than drained condition for all different confining pressure. It can also notice that both samples tested under drained and undrained condition gave the same value of improvement. The trend of improvement in undrained tests is much pronounced than that in case of drained tests.
To illustrate the effect size of shredded waste tire on randomly reinforced sand under undrained condition, the relations between total deviator stress and axial strain are plotted in Fig.17. As observed before in stress-strain behaviour under drained condition, the maximum improvement was obtained with size (5×5 mm) and no much difference between other sizes. The relation between max. deviator stress against size of shredded waste tire for both drained and undrained condition is shown in Fig.18. It can be seen that there is no much difference between the shape of both curves for both drained and undrained conditions. The stress-strain behaviour of randomly reinforced in undrained is more significant than drained condition.

CBR Test Results

As mentioned before, the main purpose of this research is to assist the feasibility of using shredded waste tires as a reinforcement material in road construction. CBR tests were conduct on base layer (sand) material without and with different shredded waste tires for the same parameters mentioned for Triaxial tests. The main objective of CBR tests is to determine the penetration resistance for pure sand and sand with different inclusions of shredded waste tires and to investigate the effect of additives shreds waste tire to sand on the CBR value. As mentioned before four sizes (5×5, 10×10, 20×20 and 30×30 mm) and five contents (1.5, 3, 4.5, 6 and 9%) are used in this research. All specimens were tested in case of unsoaked and soaked condition. To study the effect of size of shreds tire, the relation between size of shredded waste tire against CBR value and percentage improvement in CBR are plotted in Fig.19 and Fig.20. From these figures it can be observed that, the higher improvement in CBR value are achieved at shreds size (5×5mm) and no much difference in (%) improvement in CBR values for other sizes for both soaked and unsoaked condition. Also, one can be noted that, the effect of shreds tire size agrees with results of Triaxial test. Fig.21 shows the relation between CBR values against shredded waste tires content at constant size of shreds tire size (5×5mm). It is clear that the CBR values increase with the increase of shreds tire content up to 3 % content in both soaked and unsoaked specimens. After 3% content the CBR value decreased with the increasing of shreds tire content. For a better illustration, the percentage improvement in CBR values against shreds content is plotted in Fig.22. It can be noted that the percentage improvement in CBR value in case of 3% content reaches the value of 36% and after this content the percentage improvement in CBR value decreased to reach approximately zero in case of 9% content. These results are consistent with other results of many researchers [9,10,11], although they used different types of reinforcing (stabilizing) material such as geogrid, geotextile, polymeric mesh elements. One can be say that, the higher improvement in CBR value for sand with inclusions of shredded waste tires was obtained at 3% content in case of size (5×5mm). Therefore 3% is consider the best content of shredded waste tires additives for increasing the CBR value for both soaked and unsoaked condition. These result can be explained the phenomena of decreasing the (%) improvement in CBR value after 3% content is related to the higher compressibility of sand-tire mixture beyond this percentage. Therefore, the resistance of penetration decreased with the increasing the compressibility of material.

CONCLUSIONS

Based on test results, the following conclusions are drawn:

1. An increase in shreds tire content reduces the maximum compaction dry density and increases the optimum moisture content for all different shreds size.
2. Increasing the confining pressure is associated with an increase the deviator stress at any strain in both drained and undrained condition.
3. The presence of shredded waste tires in sand improves the stress-strain properties for all different sizes and contents of shreds waste tire over that pure sand. The maximum deviator stress of randomly reinforced sand occurs at a higher axial strain compared to sand alone.
4. The maximum improvement in the deviator stress is achieved with size (5×5mm) and beyond this size, no much difference between the values of improvement on deviator stress for all different sizes. It may be said that, shreds tire size has no significant effect on shear strength expect size (5×5mm) in both drained and undrained condition.
5. A greater improvement in the stress-strain behaviour can be achieved by increasing the shreds tire content till 6 % after this content, the improvement in the stress-strain behaviour has no effect.
6. The higher improvement in stress-strain behaviour is obtained when the inclusions of waste tires (tire sheets) are placed horizontal directions compared to randomly reinforced sand with shreds tire at the same waste tire content.
7. The percentage improvement in maximum deviator stress decrease with the increase of the confining pressure for both drained and undrained tests.
8. The effect of randomly reinforced sample tested in undrained condition is more significant than drained condition for all different confining pressure expect higher confining pressure (500 KN/m²).
9. CBR values increases with the increase of shreds tire content up to 3 % content. After this content the increasing of CBR value decreases with the increase of shreds tire content in both soaked and unsoaked specimens.
10. The higher improvement in CBR value are achieved with tire size (5*5 mm) and no much difference in (%) improvement in CBR values for another sizes in both soaked and unsoaked tests. This result agrees with results of Triaxial test.
11. Shreds tire with 3% content and shreds tire size (5*5 mm) are consider the best output in the improvement of CBR value.

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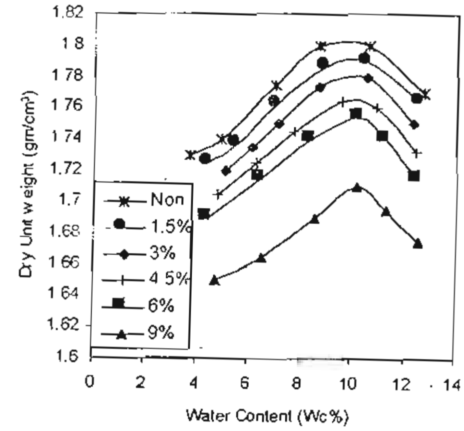

Fig.1. Modified Compaction Curve for Sand-Tire Mixture with shreds size (5*5mm) at different tire contents.

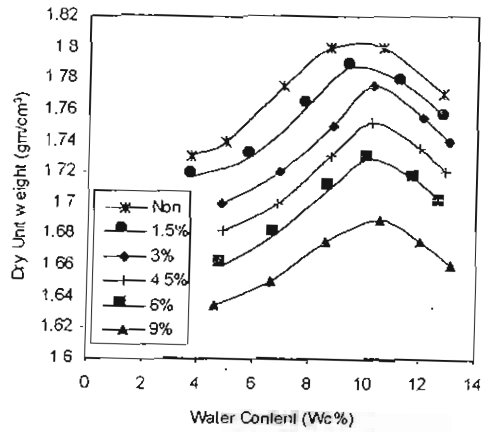

Fig.2. Modified Compaction Curve for Sand-Tire Mixture with shreds size (10*10mm) at different tire contents.

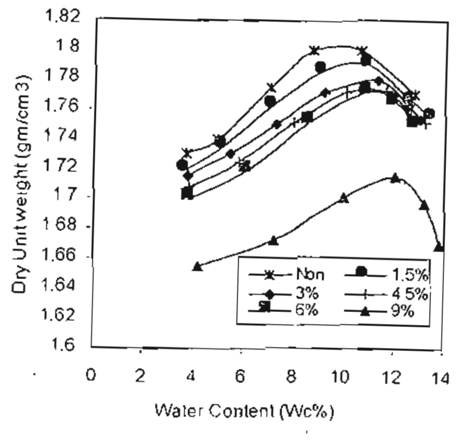

Fig.3. Modified Compaction Curve for Sand-Tire Mixture with shreds size (20*20mm) at different tire contents.

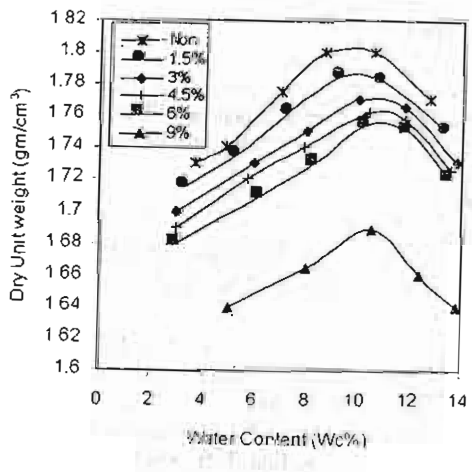

Fig.4. Modified Compaction Curve for Sand-Tire Mixture with shreds size (30*30mm) at different tire contents.

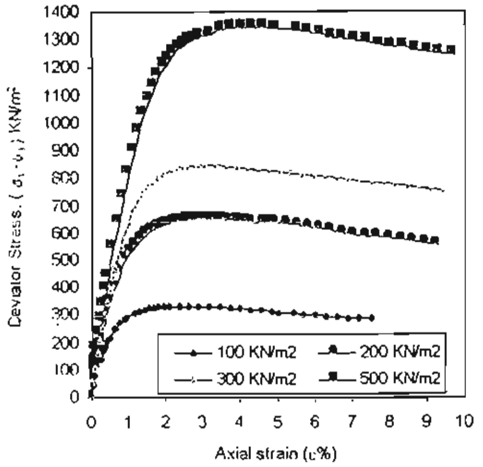

Fig.5. Relation between deviator stress and axial strain for pure sand at different confining pressure.

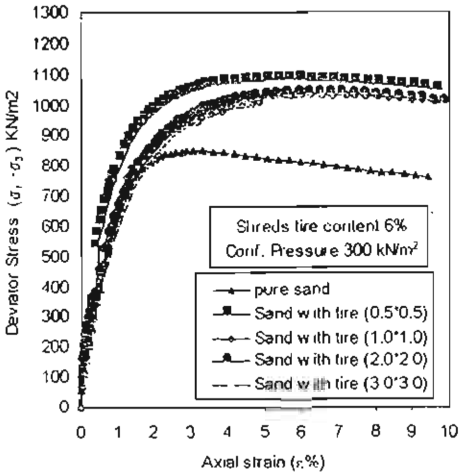

Fig.6. Relation between deviator stress and axial strain for pure sand and sand with different sizes of shred tires at constant confining pressure 300 KN/m2 and 6% shreds content

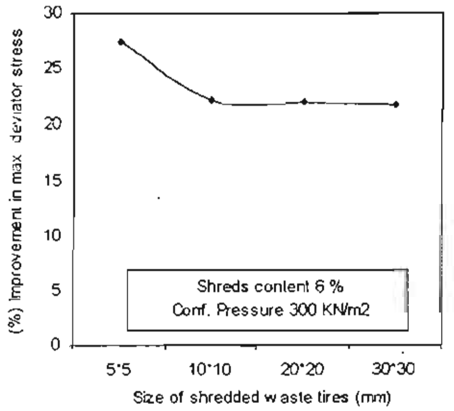

Fig 7. Effect of tire sizes on the (%) improvement of max. Deviator stress at constant confining pressure 300KN/m² and 6% tires content.

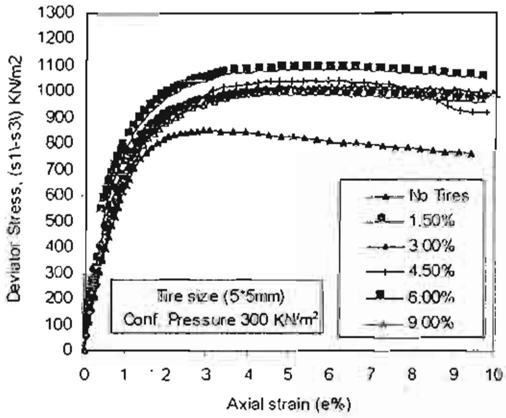

Fig.8. Relation between deviator stress and axial strain for pure sand and sand with different percentages of shred tires content for size (0.5*0.5) at constant confining pressure 300 KN/m.

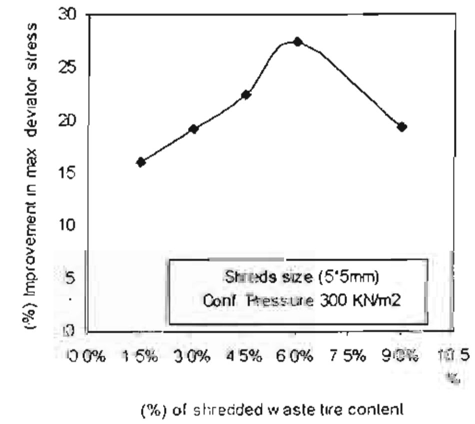

Fig.9. Effect of shreds tire content on the improvement of max. deviator stress at confining pressure 300KN/m² and tire size (0.5*0.5)

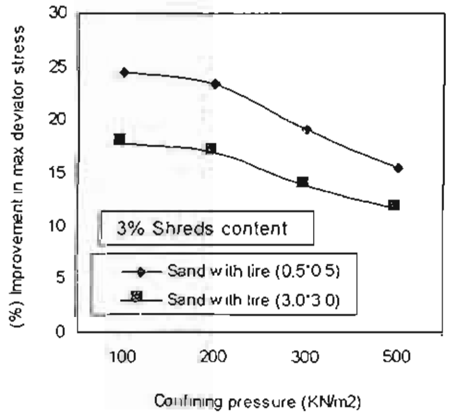

Fig.10. Effect of confining pressure with size of shredded waste tires.

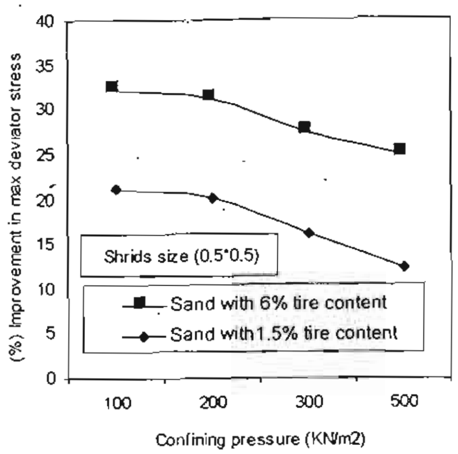

Fig 11. Effect of confining pressure with shreds waste tire content.

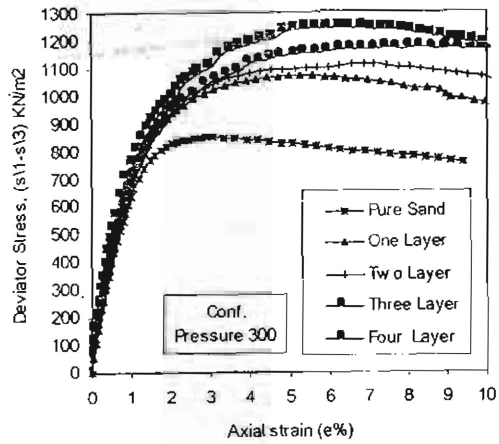

Fig.12. Stress-strain relationship for pure sand and sand with different sheets tire at constant confining pressure 300 KN/m².

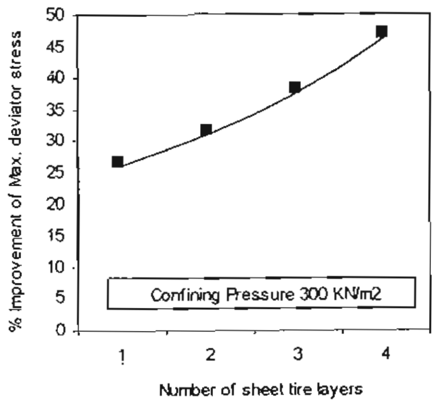

Fig.13. Variation of % improvement of max. deviator stress with number of tire layers.

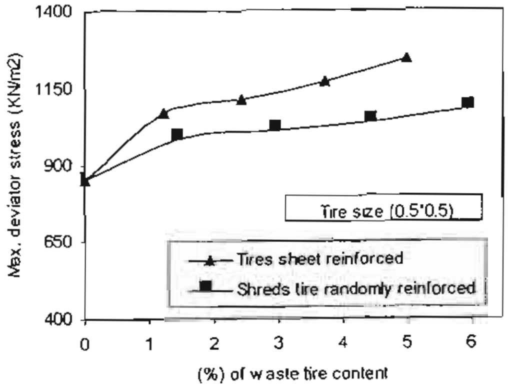

Fig.14. Variation between max. deviator stress and waste tire content in both sheet layer and randomly reinforced at 300 KN/m².

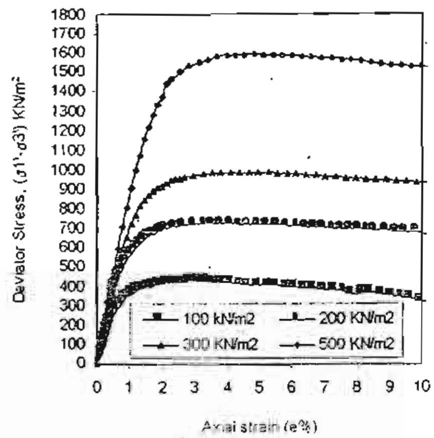

Fig 15. Stress-strain relationship for pure sand in undrained condition.

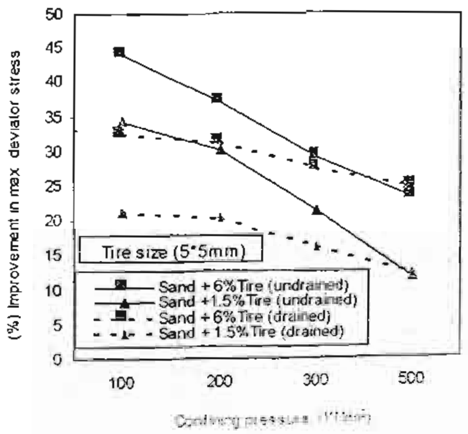

Fig 16. Effect of confining pressure with tire contents in both drained and undrained condition at constant tire size (5*5mm).

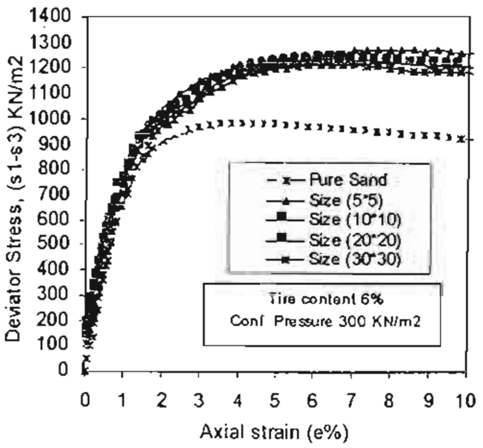

Fig.17. Stress-strain relationship for pure sand and sand with different sizes in case of undrained condition at constant 6% content.

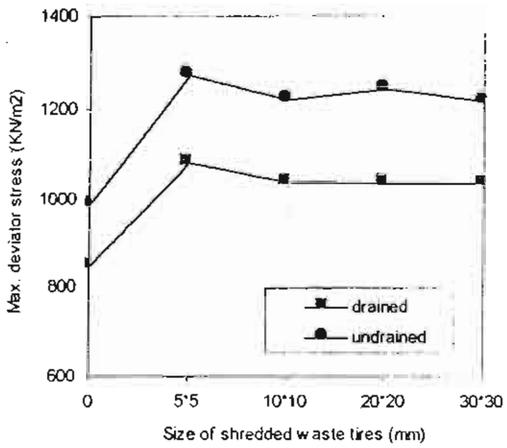

Fig.18 Effect of shreds size on the max. deviator stress at constant conf. pressure 300 KN/m²

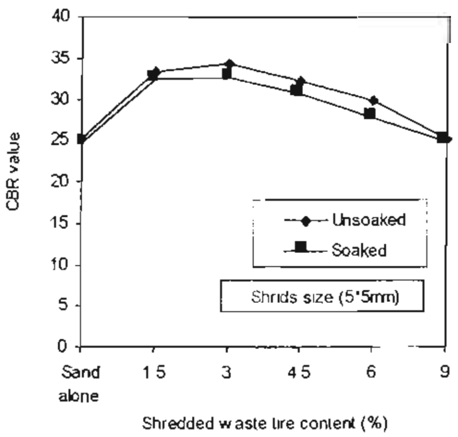

Fig.19 Effect of shred size on CBR values in both soaked and unsoaked.

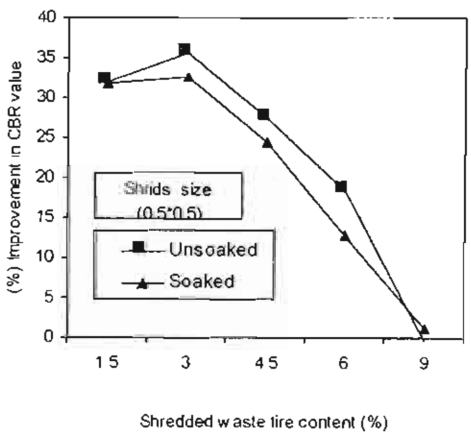

Fig 20 Effect of shreds size on the (%) improvement of CBR values.

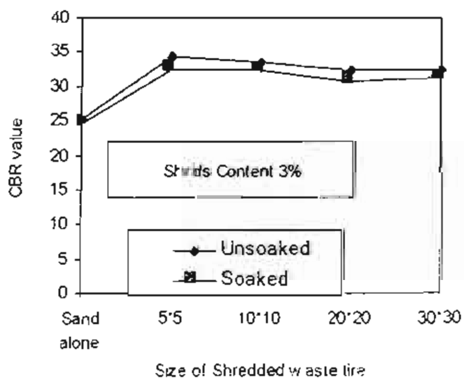

Fig 21 Effect of Shredded Waste Tire Content in the CBR values

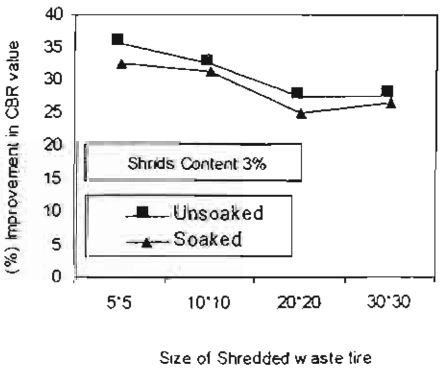

Fig.22. Effect of shred contents on the (%) improvement of CBR values.