Evaluation of Shear Strength Parameters of Sand-Tire Chips by Using Direct Shear and Triaxial Apparatus.

Write Author Name Here

Write Authors Affiliations here

KEYWORDS

Stress-Strain, Shear strength of sand-tire chips, Direct shear apparatus, Triaxial Shear Apparatus.

ABSTRACT

The devastation caused by the illegal dumping and burning of tires has been staggering. In civil engineering, the use of tires engineering properties has become a major concern. For this investigation, the research used locally sourced tire chips and sand. Use tire chips sand as an alternative backfill material that requires less pressure and has more improved properties than traditional backfilled. Four specimens were utilized in this experiment: pure sand and sand mixtures containing 20 percent, 30 percent, and 40 percent tire chips, respectively. Both the Direct Shear and Triaxial Apparatus, two of the most important geotechnical tools, were used to compare and evaluate soil and sand tire chip shear properties. 50, 100, and 150 kPa Confining pressure and normal stress have been utilized to maintain a consistent stress level. Direct shear apparatus had a circular shape with an area of 16.62 cm^2 and Triaxial shear apparatus had a height of 7.2 cm and a diameter of 3.2 cm. The stress-strain behavior of both apparatuses under ordinary loading and deviatoric stress was reported. The angles of internal friction (Φ') and cohesion (c') were measured for both equipment and specimens with and without tire chips, and the failure planes for direct shear and triaxial tests were reported. In both the direct and triaxial shear tests, 30 percent of the tire chips sand exhibit the best results, respectively. The toughness of soil may be significantly improved by the addition of tire chips.

1. Introduction

Environmentally beneficial uses for discarded tires were first pioneered by Civil Engineering applications in the early 1990s. Scrap tire stocks have environmental repercussions in many nations [1]. Both legal and illegal tire disposal pose a huge threat to our environment. It is challenging for land reclamation efforts to find recyclable scrap tires since they tend to ascend to the top of landfills [2, 3]. The rats and insects that thrive in discarded tires pose a health hazard. More dangerous are tire chips, which are very combustible and may start a blaze at any moment [4]. A rise in the return rate of waste tires owing to the ban on recycling scrap tires in landfills in certain developing nations has occurred lately. Increases in vehicle traffic also mean a rise in the annual amount of garbage generated by used tires [4]. Despite their strong technological advantages, civil engineering only utilises a small fraction of the waste tires created. Landfilled liners or covers; sub-grade fills and bottomed pads; retention walls and bridge abutments; leachate aggregate; asphalt additives for landfills; sound shield; bitumen-concrete combinations; and scrap tire pads are all examples of low-cost seismic foundation systems constructed from waste tires (STP) [3, 5].

Recycled tires have become a major environmental issue because of the explosive expansion of the automobile industry. If these pollutants are not properly disposed of, they may contaminate the atmosphere, start fires, and harm people's health. In Stanislaus, California, in 1999, for example, millions of waste tires unexpectedly detonated [6].

According to Cetin, Fener [7] tests on the use of tire chips-sand mixtures in civil engineering have just been completed. Tire chips and sand have many benefits over pure grit, including: low bulk density; chemical and physical strength; high tensile; shear; and permeability; cheap cost of production [5]. It is common for highway embankments to be made of porous or compressible soil, and rubber sand mixtures have already been widely used as a lightweight filler to overcome friction and seismic dynamic impacts and energy dissipation, as stated by Anvari, Shooshpasha [5], [7].

Rubber-sand mixes have been the subject of much research, which has yielded several significant discoveries and strongly supports their application in engineering. For direct shear experiments, the majority of past studies used either dry or slightly moist rubber-sand combinations [8]. They really cannot agree on how much rubber and sand should weigh together. Rubber pellets or tire chips have increased the sand mixture's shear strength. Rubber or tire chip shear strength is reduced by sand, according to research [9]. According to Gheni, Liu [10], the internal friction angle of the blends enhanced even though shear strength was unchanged by the 10% to 20% granulated rubber combinations. Edeskär [11] is considered to vary if the disparity between the internal friction angles changes Experiments using dry rubber and sediment mixtures indicated that when the volatility of waste tires grew, so did the volatility measure by direct shear [12].

As tire trash mounds have expanded, so has interest in finding innovative methods to utilize or recycle tires. By combining tire waste with earth, it may be utilized as a fertilizer [10]. The paucity of natural resources and rising disposal prices have led to an increase in the amount of tire trash used in embankment construction. Because of the low unit weight, high strength, and wide availability of tire trash, embankment structures on weak compressible soils are using it as a lightweight fill [13].

Particle form, particle size distribution, surface features, and mineralogy all influence the stress-strain response to sand at varying strain levels. Extrinsic variables correspond to the composition and general character of the sand particles themselves [14]. Every year, millions of worn tires accumulate as a result of population growth and an increase in the number of cars on the road. This issue necessitates a solution [15]. Due to the danger of fire and the expensive expense of sanitary disposal, the storage of worn tires is particularly unwanted. Because tires have a lengthy lifespan and are not biodegradable, avoiding them is a challenging task. It's possible to deal with unwanted tires in conventional ways like unlawful dumping or landfilling or by storing them, but these approaches are just short-term solutions. In order to avoid storing the enormous volume of old tires globally, recycling used tires is a vital duty [16].

Waste tire shreds and tire chips have been studied extensively for their effect on soil engineering parameters such shear strength, permeability, compressibility, compaction properties and the poison's ratio and modulus of elasticity in a variety of soil types [17]. According to them, tire chips may be used as a lightweight backfill for retaining walls and embankments. There are others who think that the aforementioned factors have an enormous impact on the serviceability of structures under normal and dynamic loads, and that the high damping behavior of rubber may minimize vibrations in structures [18]. Triaxial testing was used by Ahmed (1992) to evaluate the characteristics of sand-tire chips. As far as shear resistance factors are concerned, there is a significant influence on both tire chip % and confining pressure, according to his findings. The shear strength characteristics of sand were examined by Rao and Dutta (2006) using rectangular tire chips. They proposed that the highest shear strength of the sand-tire chips combination may be achieved if the length/width ratio of the tire chips is 2 and 20% tire chips are utilized by weight [19].

In the last several years, researchers have focused on the dynamic characteristics of rubber-sand mixtures. Furthermore, the study's findings might be contested by other researchers. Rubber chips or particles have been demonstrated to increase sand liquefaction resistance in certain experiments, whereas the contrary has also been shown in others. Experiments by Perez, Kwok [20] found that adding 10% tire chips to sand had no effect on liquefaction resistance [21]. Test results are inconclusive, according to the researchers. The liquefaction resistance of sand is significantly reduced when 30-40% tire chips are added. At a rate of 10% to 30%, tire chips may greatly increase the liquefaction resistance of a sand mixture. Senin, Shahidan [22] performed extensive torsional experiments to investigate tire chip combinations. According to the results, tire chips may be put to the sand at a rate of 10% to 25% to avoid liquefaction. Using direct shear and a triaxial apparatus, the shear strength of a sand mixture that contains tire chips will be studied.

A sand-tire chips combination reinforced with tire chips has an increased shear box () than unreinforced sand, according to Marto, Latifi [23]. A 20 percent weight increase in rubber chips is recommended to increase the sand's shear strength. There are a number of factors that affect the shear-resistance of sand and tire chips in combination, according to their research. Annadurai and Manoharan, Ravichandran [24] found that tire chips decreased the soil's MDD in the standard Proctor test when their percentage was increased. Because the chips are so light, they might be to fault [17]. The impact of tire chips on the shear strength properties of dune sand was studied by Yadav and Tiwari [25] using a shear box test. In accordance with the weight of sand, they used different quantities of tire chips at various points in the process. They determined that dune sand can be improved by adding tire parts (rd) are linked by Anvari and colleagues in their study of the sand-tire chips combination [26]. When tire chips content rose at high relative densities, a decrease in was observed. When tire chips content increases, it rises because of its low relative density. Grinded rubber was found to be the appropriate proportion at 5% [26]. Triaxial studies were carried out to assess the effect of tire chips content on and material stiffness, according to Feng, Li [27]. The results of the studies show that adding bigger tire shards to a mixture may increase the stiffness of a material. Researchers observed that as tire chips concentration increased to 20%, the cohesiveness intercept decreased, and that at this density, tire chips combined with sand had better distortion and shear strength properties, as reported by Rouhanifar, Afrazi [28] in their work published in 2020.

The shear strength of loose or thick dry soil has previously been studied in relation to tire chips. However, soil often holds water, suggesting that it hasn't dried up completely in most cases [28]. It will be interesting to see how the shear strength properties of tire chips/sand mixes are affected by direct shear and triaxial equipment. Moreover, the study is aimed at determining the shear strength characteristics of the tire chips sand combination using direct shear methods and triaxial equipment [21, 29].

2. Literature Review

Sand-tire chip (STC) mixtures are examined in this article for their optimal void ratio and shear strength, as per Bali Reddy, Pradeep Kumar et al. Sand and tire chips of various sizes, readily accessible in the area, are used at a more modest scale [30]. Tire chips (TC) comprise between 10% and 70% of soil-to-tire chip (STC) combinations, as well as sand with no TC and pure tire chips, are evaluated (100 percent TC). A variety of materials were tested for their specific gravity, mass, and shear strength. According to experimental data, the ideal percentages for tire chips of the required size are 30–40% by volume or 50-60% by weight. In geoengineering, the ideal ratio of STC mixes yields a lightweight material with a 20 percent reduction in unit weight, as well as increased strength and compressibility. Rezazadeh Eidgahee, Haddad [17] In structural engineering, also including geotechnical systems, rubber shreds may be employed in a cost-effective and ecologically beneficial method to expedite the waste tire processing step. On the other hand, engineering systems need knowledge about rubber grain strength characteristics, which may be gained by testing [31]. To assess the shear intensity characteristics within five rubber grain groups that ranged in gradation and size, this study performed tiny and broad direct shear tests. On the basis of these findings, we've been able to construct artificial neural networks and custom networks that better depict shear stress vs rubber strain in real life. A prediction model for shear energy and horizontal stress based on the multimodal algorithm is also included in the configuration of the Community data management system [32]. A correlation coefficient (R) and the current mean square error were used to evaluate the output and accuracy of the suggested models (MSE). Both the ANN and GMDH models have R-values of 0.9977 or 0.9994, respectively, for ANN models and 0.9862 or 0.9990 for GMDH models. Mathematical formulae for implementing the GMDH models are considered quite easy [33].

In this case, Tatlisoz, Benson [34] Waste pipes explored by Tatlisoz may be employed in land work projects like road retaining embankments or backfills by mixing these into structural filling systems. Tire or soil-tire chips must have the right mechanical and physical qualities for various purposes. The goal of this study was to determine the mechanical characteristics of fine and ground-grained soils and waste tire chips. The investigation was carried out with the use of large-scale laboratory measurement equipment [35]. Deformation, shear force and compressibility were all taken into consideration during testing. Sand, sandy silt, and clay backfill soils were put to the test. To a larger extent than soil, tire chips and soil-tire chip combinations act like soils, although they are more compressible and need a higher amount of strain to attain their maximum shear force. Backfilling with tire chips will result in a less unit weight and a higher shear intensity [35]. As with clay, the combined power of tire chips and clay equals, if not exceeds, that of clay on its own.The strength envelopes for sand-tire mixes could be nonlinear, with little or no intercept for cohesiveness. Sandy salty chip combinations are comparable to sand tire chip mixes in many respects due to the sheer cohesiveness intercept in the shear intensity envelope [36]. There is no difference in long-term compression behavior between sand-tire chips and sandy silt-tire chips. To test the shear strength of shredded rubber pneumatics, this research enlarges the pneumatics. The smooth, homogeneous sand was equally distributed and crushed at an angle of 2° of compaction. It was decided to make waste tire shreds with varied breadths: 2 cm, 3 cm, and 4 cm. Mixture included a 15 percent, 30 percent and 50 percent shreds content by volume ratio. Two possible combinations of shear intensities were explored utilizing sand-shrinking samples weighing between 15.5 kN/m^3 and 16.8 kN/m^3 [36]. The shear compressive strength of sand-shaken compressed mixes is affected by a number of variables, including the standard tension, sand weight, shred material, shred thickness, and tire shred aspect ratio. By modifying the aspect ratio, the starting friction angle (1 in degrees) is 1 to 67 with 113.5 percent of the desired shred width and compaction effort. In each experiment, increasing the friction angle by 25% was the consequence of altering the mixture's aspect ratio [37]. The average sample value was 37.5 percent for more compact samples and 17.2 percent for less compact samples of all widths and aspect ratios. Tire rectangular shreds must have at least a specified width in order to enhance the total friction angle of sand. This is the article's most significant contribution [38].

El Naggar and Zahran [26] Recycled tires have become an increasingly popular issue in the United States and around the globe after academics studied their environmental impact. Reverse filling in engineering uses tire-related aggregates because of this (TDA). Before it can be utilized in construction, the strength and stiffness of TDA must first be tested [39]. By studying backfill, researchers found that its particle size may influence its stiffness and strength. This study examined the effects of particle size on the results of five TDA samples varying in particle size from 19.05 to 25.4 mm, 38.1 to 50.8 mm, and 76.2 mm. When paired with draining, pressures of 50, 100, and 200 kPa were employed in the testing. Whenever the maximum particle size was raised, the TDA shear power rose, but the cohesiveness remained same. The particle's elastic modulus grew in proportion to its size [38].

Yang, Lohnes [40] The use of scrap tires in structural engineering applications as a means of recycling this hazardous waste is gaining popularity. This knowledge is necessary for the design of waste tire buildings, but it is not sufficient on its own. Tire chips were subjected to limited compression, direct shear, and triaxial testing in order to determine their mechanical properties [41]. Triaxial investigations were used to assess natural stress, direct shear power and confining pressure or initial tangent modulus, which allowed for the development of analytical correlations between these variables. For stress levels of zero to 90 kPa, shear strength is not influenced by molecular weight, and the resistance envelope is a power property. Confining pressure influences the initial tangent modulus through a quadratic equation; however, the lateral strain ratio is irrespective of the confining pressure.

Neaz Sheikh, Mashiri [42] Scrap tire recycling is a major environmental issue in many places because of the massive rise in the number of automobiles. Since scrap tire recycling or reusing has become a waste management strategy, researchers have done a lot of effort. Before tire sand doughnut (S-TC) mixes can be employed in civil engineering projects, their shear and squeezing qualities must be understood. When tire crumbs were employed, the S-TC combinations had less shear intensity than when tire chips or shreds were used. The maximum attainable deviator tension was the result of a considerable increase in axial strain. There is some evidence that the brittleness of mixes may be connected to their ductility. In the first unloading stage, plastic strain is decreased and consolidation is reduced, both of which may be done by preloading [43].

Weaver and Reddy [44] examined a total of 5 densities of 60,102,305 mm-long shear boxes, each with a different density. None of the five sands had a friction angle that matched the sample size. Different densities of shear boxes determined to get the same friction angle in the Ottawa sand. According to the authors, Ottawa sand has the greatest box length to particle diameter ratio. L/D 50 may be used in direct shear testing, as per Jewell and Wroth (2013). Shear box boundaries had little effect on strength-deformation components during testing with L/D 50 to 50 because it had enough particles to allow local disruption and discontinuous to emerge [45].

Chyan, Senoro [46] conducted direct shear testing on Toyoura sand using square shear boxes of four different sizes. With equivalent densities, friction angles are similar in both large and medium direct shear boxes. In the smaller shear boxes, friction angles 28-38 times bigger led to a rise in mechanical boundary retention. As the size of the shear box grows, it is probable that a considerable number of shear bands might be shear zones, as stated by Shu and Huang [47].

Research on the effects of shredding on soil properties might lead to new or further uses. Using a sand-tire shredded embankment, researchers found that it performed effectively even under heavy loads. A 1 m soil layer on top of sand–shred mixtures, say the researchers, could prevent long-term settling. This cover's purpose is to keep tire shreds against burning and to limit the amount of settling.

1.3 Significance of the Research

It's a one-of-a-kind substance that can be compressed and molded. There are several times when the mechanical properties of tire chip sand mixtures are more reliant on their content than their form. Using shear strength, engineers may design metrics and materials that can be utilized to manufacture or produce pieces [21]. Materials are judged by how much they bend, break, or deform under the weight of their own weight. To put it another way, the shear strength of a material tells us how long it can endure a shearing force before collapsing. Cuts or sliding failures are shown by the cuts in relation to the force exerted on the aircraft. Manufacturing, vehicles, aeroplanes, and other technological fields may all benefit from materials having high shear strength [18].

3. Methodology

3.1 Materials

Sand: Standard ASTM C136/136M sieve analytical procedure was employed. Data from this study is used to verify that accumulated products and accumulated mixtures meet the relevant specifications for particle size distribution compliance. Use this information to determine the porosity and packaging connections of a material [48, 49]. The sieve analysis was done to determine the sand's characteristics, and a calibration container was utilized to measure its volume. Unit weight was calculated by conducting three trials of sand [50, 51]. It was critical to figure out the qualities of sand and classify it. Mechanical vibrators were employed instead of a sieve analysis shaker for sieve analysis. Following the ASTM standard, the sand particles utilized in the investigation were determined.

Using the ASTM D 854-00 standard technique for soil solids, water pycnometer testing, this inquiry. [52]. The sand utilized in this study has a specific gravity of, which is within the specified range.

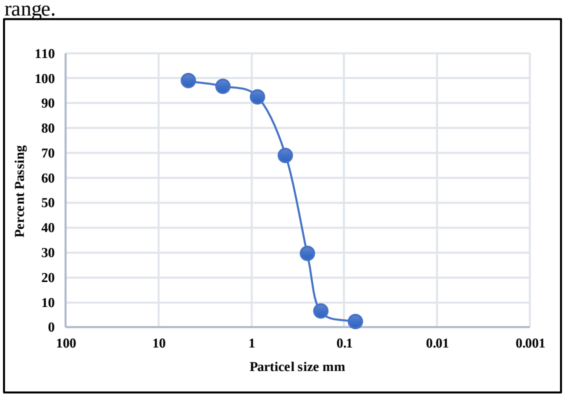


Figure:

Tire chips Classification: Tire chips were from local rubber where it is used for synthetic purposes.The aspect ratio of tire chips were the same.Tire chips dimension were not greater than .05 millimeters.In addition,the shape of tire chips were triangular and trapezoidal.However,dimension was measured by regular measuring tape.Pictorial representation is given below

Characteristics of materials:

Cc (curvature coefficient)	.045
Cu (Uniformity coefficient)	1.388
D60, D30, D10	0.25 mm, 0.24 mm, 0.18 mm
Unified Soil Classification System (USCS)	Poorly Graded (SP)
Specific Gravity of sand	2.65
Specific Gravity of tire chips	1.02

The optimal moisture content and maximum density of the dry soil were then determined using a modified proctor test ASTM D1577. Measuring the dry density was essential for both direct shear and triaxial procedures since it aided in sample processing. [52].

3.3 Programming and sample preparation for monotonic triaxial test

3.7.1 Triaxial Apparatus

The triaxial instrument was manufactured by the MATEST Triaxial private corporation. During testing, the frame's vertical load capacity ranges from 5 to 103 kilograms, however it never deforms. An axial compression or extension of 0.1 to 2.2 mm/min may be transmitted by the main hydraulic vertical press. A top plate with a metal frame split by a cylinder must be employed as a triaxial compaction chamber. When the piston fails while loading, it should not exceed 5% of the load owing to friction and side bending at the upper end of the piston and its screen. Except for the draining material, a robust, non-corrosive substance is employed. Top pore disc: If it collapses, its mass might contribute for as much as 10% of axial stress. The specimen may be drained by inserting a stiff, porous disc into either end of it. Leak protection should be provided by the rubber membrane used in the specimen container. Membranes must be properly inspected before use, and any membranes found to have faults or pinholes must be disposed of. A leak-proof seal is required for every valve. Consolidation and shearing can only be done in conditions where the temperature does not rise or fall over 64 degrees Celsius, and there is no exposure to direct sunlight. Tools including wire saws, steel linings, mitre boxes, and vertical trim lathes should be accessible upon request.

3.7.4 Sample Preparation

Before being put in the triaxial cell, the test specimen was first made from a soil sample. Trimming sand samples that had been extruded from Shelby tubes or block samples was part of this process. When the rubber membrane needed to be placed on a pedestal, a membrane suction stretcher was brought into play. Keep in mind that the specimen should be disrupted as little as possible throughout the preparation process. Twelve specimens were also prepared for triaxial test. Pure sand, 20 %, 30 % and 40 % by tire chips by weight of sand. The specimen size was in 38 mm in diameter and 76 mm in height. Tamping rod was for compacting specimen in spilt mold.

Assembly began once the specimen had been inserted into the triaxial cell. At this point, the cell had been filled with fluid, pressure/volume controls installed, and transducer readings set as appropriate.

We wanted to make sure that water had been injected into each and every pore of the test specimen as part of the saturation process in order to confirm that there were no remaining air pockets in the sample. When the transducer main drainage lines were partially vacuumed, a linear increase in cell and back pressure was applied. The specimens were saturated to the proper degree. Skempton's B-value was determined in a brief test before the consolidation process began. The saturation level is estimated using the pore pressure coefficient B using this method [53, 54].

When a material is pressured, as it would be if it were in-situ, it tends to consolidate. When it does, consolidation is almost always isotropic. Effective stress conditions may be determined in samples after consolidation, since the pore pressure is at or near the back pressure. Assuming that the minimum dissipation is 95%, there is a limit to how much extra pore pressure may be dissipated even before consolidation process ends [55, 56].

During the shear section of the test, the volume change of both specimens is documented [41, 57]. The deformation and shear load values were calculated, which is computed using Mohr's circle and stress path plots, may be obtained as a consequence of this stage of the test [57-60].

4. Results

Modified Proctor Test

The dry density and compaction parameters of the soil were assessed using a modified proctor test in accordance with ASTM D1577. Prior to being pounded into five layers, sand was passed through a sieve number #4. A total of 0.5 percent water of the soil mass was applied in increments, after each increment sample was oven-dried for 24 hours and analyzed. The greatest dry density was 1.75 gm/cm^3 with a moisture content of 13%. Using dry density as a basis, mass was estimated in devices using direct shear and triaxial test. As seen in Figure 4.2, the image is further explained.

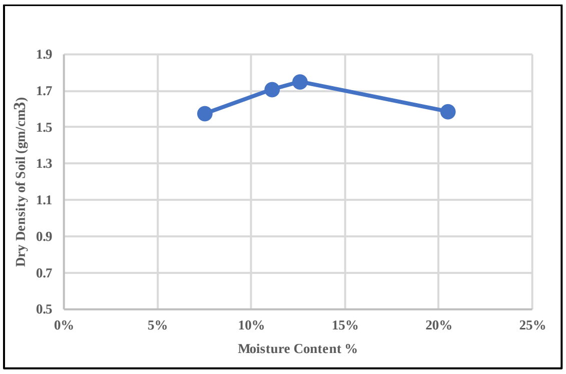
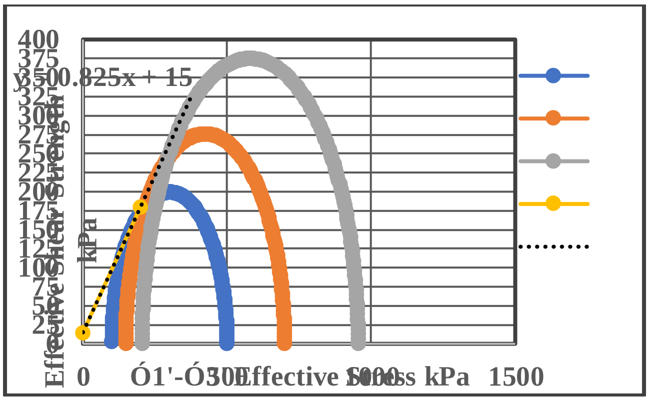


Figure 4.2 OMC

Triaxial Apparatus

In addition to the four samples of sand with no tire chips, the experiment includes samples containing 20%, 30%, and 40% tire chips by weight of sand. The control sample is plain sand. Stretching occurs at three distinct pressures for each sample (50 kPa, 100 kPa, and 150 kPa). The minor and major primary stresses, σ_3' and σ_1', respectively, are used to analyses the Mohr's circle, a depiction of the transformation equations for planar stress.

Mohr's circle for plain sand is calculated using three trials ranging from a minor primary stress to a considerable primary stress. The Mohr's circle for plain sand has cohesiveness15 kPa and angle of 39.51° when tangent line cross locations on drawn circles.



In the second sample, which included 20 percent of tire chips from Mohr's circles, the cohesiveness was 18 kPa and the angle was 38.88° degrees, as previously reported in Fig.

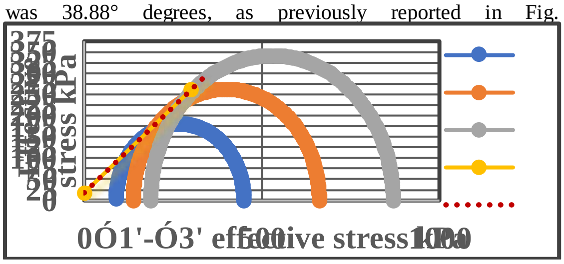


Figure 4.4 Mohr's Circle 20% Tire Chips Sand

An angle of 37.84° degrees and cohesiveness of 19 kPa were found in the third sample, which included 30 percent of tire chips.

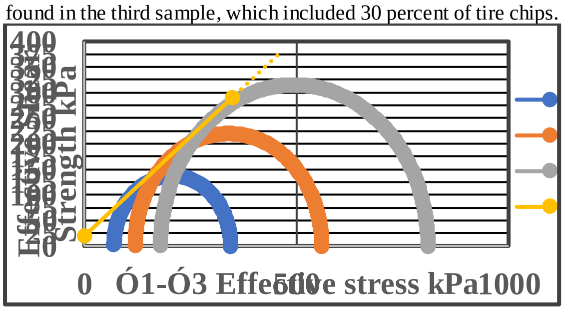


Figure 4.5 Mohr's Circle 30% Tire Chips Sand

Ultimately, the Mohr's circle assessment for the 40% tire chips sample reveals the same cohesiveness as for 30% tire chips, although the degree of angle differs by 36.98°. Fig. 4.6 shows the graphical depiction of the findings.

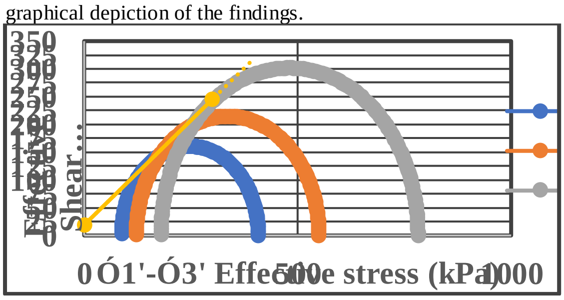


Figure: 4.6 Mohr's Circle 40% Tire Chips Sand

Comparison of stress-strain between the samples at 50kPa

To assess the stress versus strain peaks at 50 kPa confining pressure, four samples are examined. Pure sand samples exhibit a greater but diminishing peak, whereas 20% tire chips samples show a constant linear line indicating more potential for being strained. A straight line may also be drawn using samples containing 30 and 40 percent tire chips, respectively. The early start for all specimens is almost same, but when the deviator stress increases, as seen in Fig. 4.7, the results differ.

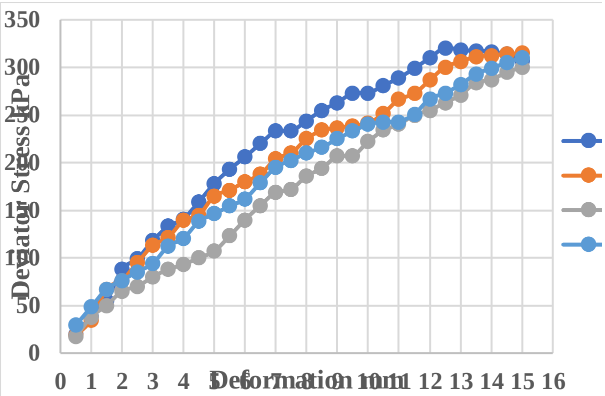


Figure 4.7 Comparison of stress-strain between the samples at 50kPa

Comparison of stress-strain between the samples at 100 kPa
Second, the relative shear strength of four samples is measured and compared using a 100kpa confining pressure, as shown in Fig. 4.6 below. The plain sand sample displays an obvious decline peak before the deformation reaches 15mm, however the sample with 20% tire chips exhibits a straight linear line even after the deformation reaches its peak at 100kpa loadings. 30 percent and 40 percent of the tire chips samples were linear, but not more than 20 percent of the tire chips samples were linear.

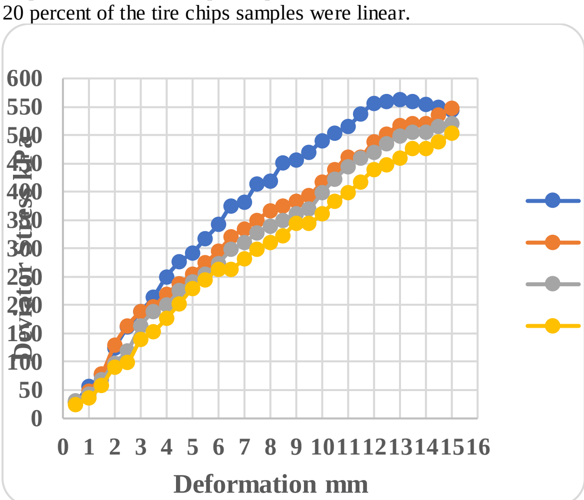


Figure 4.8 Comparison of stress-strain between the samples at 100 kPa

Comparison of stress-strain between the samples at 150 kPa
A comparison of the shear strength of the four samples (sand, 20%, 30% and 40% tire chips) with 150 kPa of confining pressure is shown in Figure 4.7. The yellow line on the pure sand sample is weakening as the deformation approaches 15 millimeters, whereas the linear line on the 20 percent tire chips sample shows that the distortion has achieved its pinnacle in this graph. yellow.

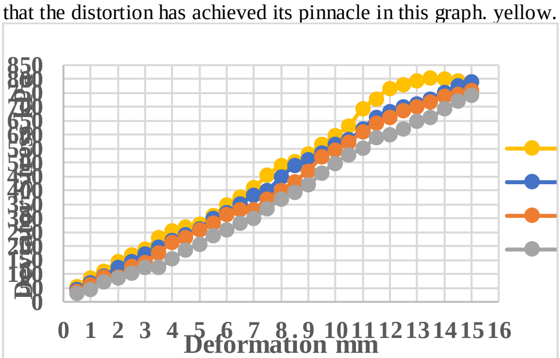


Figure 4.9 Comparison of stress-strain between the samples at 150kpa

4.5.3.1 Cohesion*:*

The values of cohesiveness produced using Mohr's Circle are shown graphically in the image below. An increase in cohesiveness may be seen with the addition of tire chips up to a certain percentage amount.

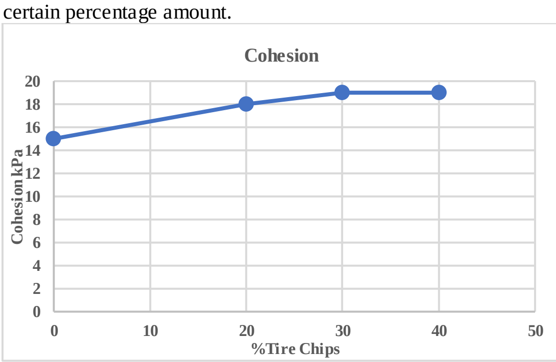


Figure 4.10 Comparative Analysis of Cohesion

4.5.3.2 Angle of Internal Friction:

Mohr's tangent-drawn circle shows that the angle of internal friction decreases from 39.5° to 36° when tire chips are added, as seen in Fig. 4.11.

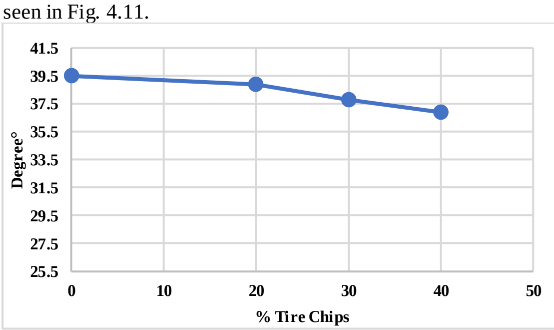


Figure 4.11 Comparative Analysis Angle of Internal Friction

4.6 Results from Direct Shear Apparatus

Four samples of sand, 20%, 30%, and 40% tire chips by weight have been used in the direct shear apparatus to evaluate the direct shear strength of the sand and sand-tire chips. In this experiment, the impact of tire chips sand was clearly seen. Comparing findings from both equipment was the goal of the research, so that the shear strength of the study sample could be clearly shown. All the shear stresses for each sample are shown in Table 4.2, which is made up of three separate normal stresses, which are the same for all of the samples. The highest shear stress values for each specimen's normal stresses are indicated in the table.

Table 4.2 Comparative Analysis of Normal Stress and shear stress investigated using direct shear

	Normal Stress (KPa)	Shear Stress (KPa)
0% TC	50	38
	100	70
	150	100
20% TC	50	45
	100	78
	150	110
30% TC	50	51
	100	84
	150	118
40% TC	50	47.5
	100	80
	150	112

Comparison of shear strength:

The direct stress values listed in the preceding table are used to determine shear strength, as shown in Figure 4.12. Compared to the 40 percent and 20 percent tire chips samples, the 30 percent tire chips sample had a higher shear strength. With the normal stress versus the maximum shear stress graph, we can easily see how much pressure is being exerted and how many tire chips are being generated. After 30 percent of the tire chips, the stress level drops.

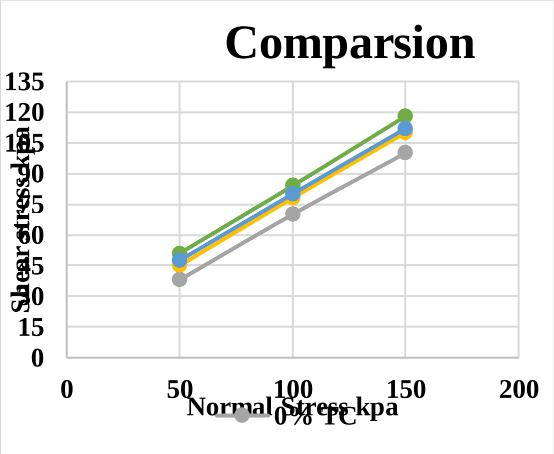


Figure 4.12 Comparative Analysis of Shear Strength

Samples' shear strengths are illustrated visually as stress versus strain graphs for three distinct loadings (normal stresses). According to this experiment, a sample with 30% tire chips has the maximum shear stress at 50 kPa loading, whereas samples with 40% and 20% tire chips have virtually identical strength, while the sample with 30% tire chips has the lowest strength. Difference in stress-strain between samples at 50 kPa loading is seen in Figure 4.13.

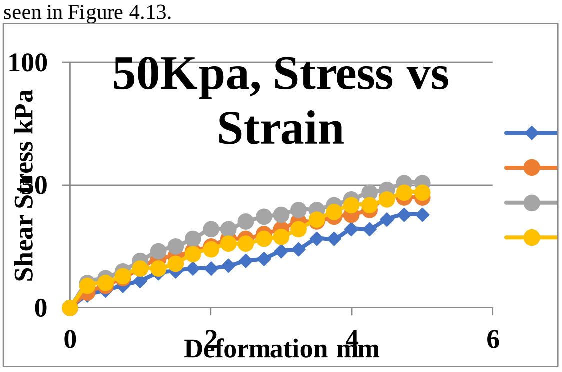


Figure 4.13 Comparison of stress-strain at 50 kPa

Figure 4.14 and 4.15 illustrate that the 30 percent tire chips have an improved shear stress compared to the others, but plain sand has very low shear stress, as can be observed for loading 100 kPa and 150 kPa respectively.

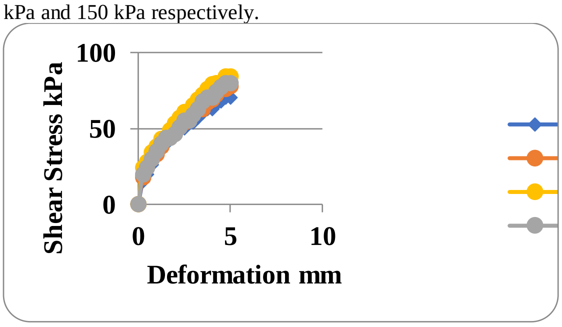


Figure 4.14 Comparison of stress-strain at 100 kPa

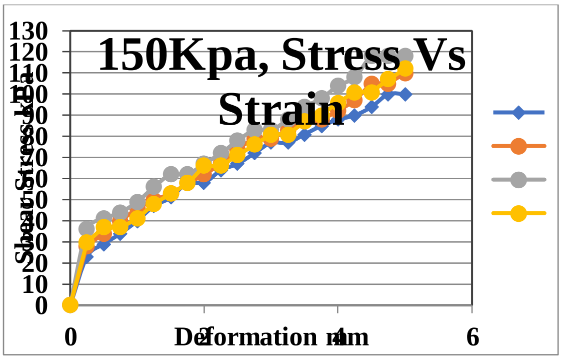


Figure 4.15 Comparison of stress-strain at 150 kPa

Internal friction and cohesion observed from direct shear apparatus are shown below Table 4.2. The cohesion and angle of friction for tire chips rises as the percentage of tire chips increases, however plain sand exhibits very little cohesion of 8 kPa and the angle of friction as well. A graph depicting the angle of friction and cohesiveness for each sample is shown in Figures 4.12 and 4.13.

Table 4.3 Cohesion and Angle of internal friction

% Tire Chips	Degree°	Cohesion kPa
0	31.79	8
20	33.02	13
30	33.81	19
40	32.61	17

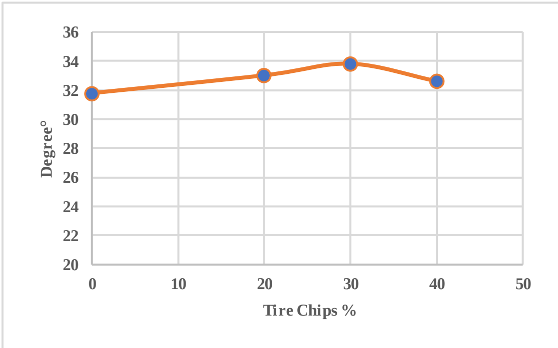


Figure 4.16 Comparative Analysis of Angle of Internal Friction

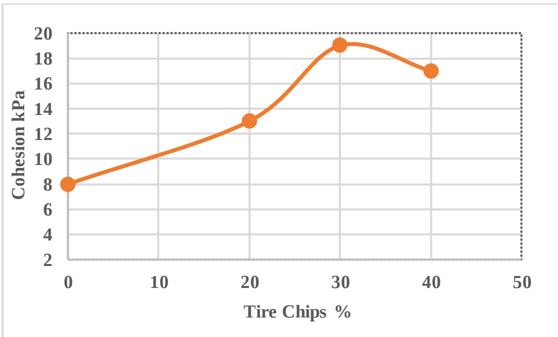


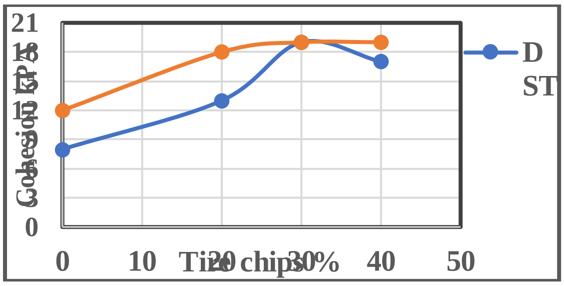
Figure 4.17 Comparative Analysis of Cohesion

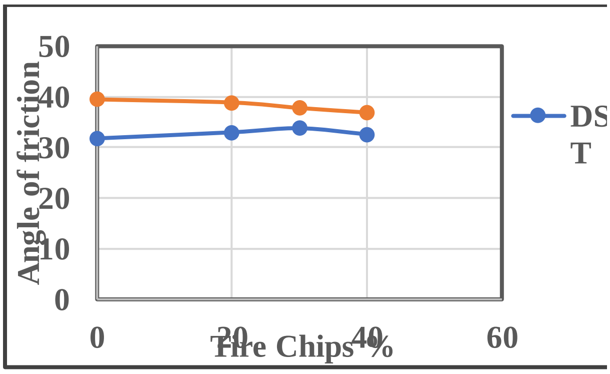
Comparison of direct shear, and triaxial apparatus

Triaxial shear testing, rather than direct shear, is more reliable and efficient in providing shear strength values for samples because it considers many dimensions, such as saturation, pore water pressure strain, and volumetric stain, which give a much better analysis as Table 4.4 shows shear strength parameters for plain sand with a 20%, 30%, and 50% saturation, and for sand with a 50% saturation, and for sand with a 50% saturation.

Table 4.4 Comparison of direct shear, and triaxial apparatus

% Tire chips	Direct Shear Test		Triaxial Shear Test	
	C	**Φ**	**c'**	**Φ'**
0	8	31.79°	15	39.5°
20	13	33°	18	38.88°
30	19	33.8°	19	37.8°
40	17	32.6°	19	36.9°





Conclusions and Discussions

Triaxial Shear Apparatus

Compared to sand, tire chips were shown to be more effective in reducing unit weight in this experiment [21]. For pure sand samples, the deviator stress axial strain graph shows the greatest peak shear stress values for all contained pressures. There was no peak deviator stress for the tire chips and the sand when they were mixed with 20 percent, 30 percent, and 40 percent by weight of sand. With more pneumatic chips in the sand mix, the maximum deviator stress is reduced. When the percentage of tire chips in the mixture increases, so does the strain that relates to the peak deviator stress. Increased chip content results in a reduction in shear stress, which in turn reduces the pressure exerted. With the addition of tire chips, the deformation increases with increase of deviatoric stress. While in pure sand we observe peak stress then decreases with increase of strain. In other words, the sand chips, unlike tire chips and shreds, divide the sand particles, reducing the friction and strengthening the particles (Zormberg et al. 2004). Because chip concentrations around 20 and 30 percent have a larger mixing strength, the shear strength loss is less noticeable at these concentrations. As the number of chips grows, the cohesion value improves [61]. The mix of tire chips and sand is expected to gain in popularity. The sample's ductility plays an important role in many civil engineering projects, which explains why axial stress rises. There is a significant reduction in volume when tire chips are included. There was no tendency for dilatation, although the tension was more than 15%, resulting in more compressible tire chips. There has been no dilatation seen at a distortive strain of roughly 20% for tire-chips in prior investigations, which also found them to be particularly compressible relative to sand [4]. As a result, the biggest percentage of sand was comprised of tires, which were separated from the other sand chips. The effect of tire chips on the stress-streaming behaviour of sand tire blends has been studied in relation to tire percent on the shear strength properties of sand tire blends. Axial stress rises when residual strength decreases and maximum stress (maximum differentiator stress) decreases. Sand-to-sand interaction is larger than sand-to-tire interaction or tire-to-tire contact because of this. The results of Zormberg as well as other researchers, who studied aspect ratios 1, 2, 4, and 8, show that increasing tire chips causes peak stresses to decrease [2, 62]. Tire chips and pneumatic chips behave as though they are becoming stronger when the amount of aspect ratios that are more than one and the larger size of the pneumatic chips increase. This research, on the other hand, used tire chips that were less than 5 mm in diameter and had an essentially same aspect ratio. In this case, the tire chips would not be able to act as a reinforced component in the sand combination. Increasing the amount of chips in the sand reduced its stiffness, making the specimen more ductile [3]

Direct Shear Apparatus

When tire chips are included into a mixture, the weight of the mixture drops, which decreases lateral pressure on the retaining structures. An important factor in the calculation of the experimental results is separation. Rubber or tire chips have been used to separate the sand. This segregation and effort by sand to fill up the base box was noticed when the sand to tire chip ratio was low in the mixture (for example, less than 50% based on volume). Sand tire chips and their shredders were studied by Edal and Bosscher (1994), and Bosscher (1992). Segregation is impossible when the amount of sand is significant. When Edil and Bosscher (1994) used volume and vibratory compaction to calculate the 50 percent mixing ratio, the sand and tire chip combination revealed segregation. Continuous mixing and monitoring of the mixture from the start of preparation until it is placed into the shear box is important to prevent segregation during sample preparation. As the chips are taken out, the mix sample's internal friction angle increases, and as more tire chips are added, it decreases. The insertion of chips with angularity causes the initial increase in the angle of internal friction. A shaving zone failure increases the inner friction angle by interlocking the soil sand phenomenon, which in turn affects tire chip cornering behaviour. In the shearing zone, the tire chips are placed and distributed in a random fashion. Shredded rubber tires or pneumatic cups coupled with sand either glide or resist being shaken off as the shears begin to cut [8].
As the soil shear strength decreased, the soil's thickness decreased as well. To further improve shear strength, more tire chips or fibers were added to the mix. They have greater contact areas with the grains of sand. The tire chips in the shear region may be considered as anchors to resist the shear force.
Pull buffers or chips and sand may be used as soil reinforcement in the constructing of embankments, allowing the embankment to withstand larger static loads without collapse.

Failure Pattern

Tests on triaxial apparatus found that samples with high deforestation failed along a shear plane at an angle greater than θ=45+/2, but this was reduced when tire chips were added. Using sand and a tire as a composite shows that it is. As a result, failure takes on a life of its own. Tire chips-sand was more noticeable in images as compared to the sand itself because of the cohesiveness of sand augmented by chips. The ductility of sand tire chips has been observed and found to be greater than that of sand. Sand tire chips are also less brittle than sand in terms of indices.
Unlike the direct shear test, where the failure plane is known and the kind of sample, we utilized is always horizontal, the failure plane in direct shear testing on sand and sand pneumatic chip combination by weight was the same, even for severe deformation materials. Direct shear devices are unable to collect a large number of critical parameters, preventing us from learning about a number of important characteristics.

Conclusions

- The present study was aimed to investigate the difference in the efficiency of the direct shear, and triaxial apparatus in finding the shear strength of tire chips mixed with the sand.
- The results of the study concluded that plain sand itself shows a less strength as compared to the mixed samples (20% tire chips).
- The study also concluded that the triaxial apparatus is more reliable to use, as compared to the direct shear apparatus which only represents the few parameters, while triaxial apparatus gives more details about the samples as demonstrated by the study in the above sections.
- The results from the experiment on plan sand shows a c´ value of 8 kPa, and 15 kPa with direct shear strength and triaxial shear strength correspondingly, suggesting better results through triaxial apparatus.
- The angle of (Φ´) for the plan sand was 31.79° with direct shear strength while 39.5° with triaxial apparatus concluding that triaxial test gives better in explaining angle of internal friction Φ´.
- Likewise, the experiment on the 20%, 30% and 40% tire chips, also shows the better results for c´ and Φ´ with triaxial apparatus as compared to the direct shear methodology.

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