Stabilization of River Sand with Waste Tire Crumb
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PROJECT REPORT APPROVAL

Nafis Zubair, Hasan Muhommed Ashiq, Sadman Sazid Khan, and Student IDs 180051105, 180051130, and 180051236 submitted a thesis with the title "Stabilization of River Sand with Waste Tire Crumb" that was deemed to be satisfactory and accepted as partial fulfillment of the requirement for the degree of Bachelor of Science in Civil Engineer.

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DECLARATION OF CANDIDATE

By signing this statement, we affirm that the undergraduate research work described in this thesis was carried out by us under the guidance of Professor Dr. Hossain Md. Shahin and has not been provided to any other party for any reason (apart from publishing).

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DEDICATION

Our joint thesis is a tribute to our individual parents. Additionally, we would like to extend our sincere appreciation to our parents for their support as well as to our esteemed supervisor Professor Dr. Hossain Md. Shahin for leading us along the route with the utmost sincerity.

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" In the name of Almighty Allah."

We are grateful to Allah (SWT) for giving us the chance to finish this book. We really appreciate Professor Dr. Hossain M. Shahin, our supervisor, for providing us with the necessary guidance and for listening to us whenever we needed it during the study process. We owe him a lot of gratitude for his insights and advice in helping us finish the thesis. We are very grateful to Md. Nizam Uddin and Md. Shahinur Hossen for their assistance and leadership throughout the Journey with the laboratory testing. We would like to thank the whole departmental faculty for their assistance and support, specially, Mozaher Ul Kabir Mahadi sir.

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ABSTRACT

The global population continues to experience an increase in the amount of tire waste, which is an undesirable surplus from the urban-industrial sector. One potential method of disposing of the waste can be the usage of the refuse as a stabilizing agent in sands, which can improve their strength properties and bearing capacity. However, there is a growing need to find alternatives to this waste, as improper disposal can lead to the breeding of mosquitos which can cause serious health and environmental issues, as well as creating a fire hazard. One potential use of these discarded tires is to mix crumb rubber which has been prepared by the shredding of waste tires with soils with weak fine grains in order to enhance its geotechnical properties. For the purpose of investigation of the effects of rubber on bearing capacity, shear stress of sand, some laboratory tests were conducted on sand containing a variety of sand and tire mixtures with 0%, 2.5%, 5%, 7.5%, and 10% waste tire particle weights. Direct shear test devices have been used for the purpose of examining effects of rubber in terms of shear stress. CBR test equipment are utilized for seeing the impact of rubber waste in bearing capacity of sand and rubber mixtures. The addition of 2.5% of rubber to the sand significantly reduced shear stress. After 2.5%, shear stress gradually increased. As the rubber content increases, so does the drop in unit weight, dry unit weight and water content. The specific gravity parameter also decreases with the increase in rubber content. The decrease in CBR value is also seen with the increase in the amount of rubber in the sand. Addition up to 2.5% of the tire crumb in the sand significantly reduces shear stress. However, more percentage of the crumb leads to an increase in this parameter. Different results are obtained with shear stress as the shear displacement increases. Adding tire crumb to the sand does not increase the CBR value. Sand and rubber mixtures are very lightweight materials. Tire crumb application for retaining structures is still promising.

Keywords: Direct shear test, California Bearing Ratio (CBR), sand and tire mixture, sand and rubber mixture, stabilizing agent, shear stress, rubber content.

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CHAPTER-1: INTRODUCTION

Soil is an authentic mortar which is very old. People have been using it in the structure sector for many years. Soil is the smallest natural element that can be found in the crust of the earth (Das, 2009). This element and its characteristics are responsible for the world's architecture as well as its ruins. Even though we now have so many new materials, the construction industry still uses a lot of soil, either directly or indirectly. Soil is the final product of weathering, according to the creationist view. It is the result of the physical and chemical destruction of stones, as well as the accumulation of leftover creatures that naturally disintegrate (Das, 2009).

Humanity has endeavored throughout history to improve the use of soil in a variety of contexts. This concept can be traced back to natural examples and models. Numerous species, particularly birds, use tiny branches and soil to construct their nests or to stabilize hillsides thanks to plant growth and their roots. Examples of this concept include the reinforcement of materials and earth constructions using crushed tires and polymer strands, as well as the idea of combining straw and clay to construct thatch mortar (Das, 2009).

One of the geotechnical specialties, soil support, has been enhancing and advancing the mechanical characteristics of dirt, such as pliancy, strength and versatile modules, via the use of cutting-edge technologies and appropriate substances. (Craig, 2004) The stabilization and strength of the soil, which have always been human concerns, can be enhanced through soil reinforcement, which is a dependable and efficient strategy.

Compaction, union, and seepage are illustrations of mechanical forms; chemical forms incorporate including characteristic or mechanical cementite materials; and at last, physical forms incorporate applying fortifying components such as strands, warming, or solidifying (Al-khanbashi & Abdalla, 2006). Billong demonstrated that "chemical stabilization" is finished by "including to the soil, other materials or chemicals that alter its properties either by a physicochemical response, or by making a lattice that ties or coats soil particles together." (Billong et. al., 2009) "Physical stabilization" alludes to the soil's texture, whereas "mechanically stabilization" is finished by subjecting the soil to mechanical powers such as surface compaction.

Due to population expansion, the marketplace, expanding advancements, shifting ways of living, security of the environment, and material and energy restrictions, on the one hand, and substance and power limitations, on the other, the effective use of renewable assets and the conservation of them by companies have become a priority. (Neville, 2012) Due to the growing issue of used automobiles, waste management of this sort has grown increasingly crucial and the increasing number of worn tires that need to be disposed of, as well as the global annual tire production. Clearly, recycling the old tires is the best option in this situation.

CHAPTER-2: LITERATURE REVIEW

Granular soil with WPFA: It was established that WPFA may replace traditional cementitious binders (cement) while still meeting mechanical requirements and addressing durability issues caused by potential expansion. (Baloochi et al., 2020).

Clay soil with Calcium Chloride: In order to determine the efficacy and ideal mixture of calcium chloride and Class F fly ash for soil stabilization, this study work concentrated on the strength increase caused by more than 1.7% pure calcium chloride utilized in soil. (Biscontin et al., 2005)

Fine-grained soils with crumb rubber tires: Maximum dry unit weight, unconfined compressive strength, coefficient of permeability, and compression index all rise with the addition of crumb rubber. (Ajmera et al., 2017)

Sand with waste tire crumb: Both the permeability and the compressional properties of the sand were improved by the addition of tire crumb grains. (Wiszniewski and Firat Cabalar, 2016)

Comparison between fiberglass and recycled tire strips: Tensile tests between fiberglass and recycled tire strips were conducted, and the results demonstrated that fiberglass is more effective than tire in resolving issues with soft soil. (Ahmad et al., 2016).

Silty clay with crumb tire rubber: Crumb tire rubber could be beneficial in enhancing the soil's properties against possible swelling, but it could not increase unconfined compressive strength. Low displacement values were also produced by boosting the soil's crumbling tire rubber content. (Hasan et al., 2020).

Black cotton soil with natural sand: After being combined with natural sand, soil has better permeability and unconfined compression strength. (Dayasagar Dama, 2018).

Geogrid reinforced-rubber waste in pavements: In both reinforced and unreinforced cases, the load bearing capacities of the soil + rw + soil and soil + rw inter mix are superior to those of the other combinations. They will lessen the plastic deformation of subgrade clay and increase the elastic strain that can be recovered. (Thenmozhi, 2010)

River sand with waste tire fiber: The inclusion of discarded tire fibers improves the soil's bearing capacity ratio and settling ratio at all fiber contents and reinforcing depths. (Kaushik et al., 2017)

River sand with tire chips: Normal stress, mixture unit weight, and rubber content a.re the influencing factors on the shear strength characteristics of sand-rubber mixes. It has also been demonstrated that adding tire chips up to 10% can enhance these properties. (Tonnizam & Marto, 2013).

Dune sand with crumb rubber: Cohesion (C) and angle of internal friction (Φ) were significantly improved when up to 20% of crumb rubber was added to dune sand. (Deepti et al., 2020).

Laterite soil with waste tire rubber: When waste tire rubber with a size smaller than 2.36 mm and one between 2.36 and 4.75 mm is combined, excellent strength is produced at 15% and 5%, respectively. (Helonde et al., 2018).

CHAPTER-3: MATERIALS AND METHODS

3.1: Sand

River fine sand was collected from Tangail. Then grain size analysis test of sand was conducted. The value of some parameters of the sand is given below:

Table 1: Results of grain size analysis of sand

FM	D10	D30	D60	Cu	Cc
1.017	0.12	0.17	0.22	1.83	1.09

Here we can see the value of fineness modulus, D_{10}, D_{30}, D_{60}, uniformity coefficient, coefficient of curvature is 1.017, 0.12, 0.17, 0.22, 1.83, 1.09 respectively. So, it was fine sand. Sand was sieved through 50 no. sieve before each test. The other parameters are specific gravity, unit weight, dry unit weight and water content. Unit weight, dry unit weight and water content was determined in California Bearing Ratio (CBR) test. Specific gravity was determined in specific gravity test. The values are given below:

Table 2: Parameters of sand

Specific gravity	Unit weight	Dry unit weight	Water content
2.69	20 kN/m^3	17.5 kN/m^3	14.3%

Figure 1: Sieved sand

3.2: Rubber

Waste tire was collected. Then grinding machine was used and tire was broken into small crumb. Then grain size analysis of rubber was conducted and values of some parameter were determined. The values are given below:

Table 3: Results of grain size analysis of rubber

FM	D10	D30	D60	Cu	Cc
3.41	0.4	1.1	1.6	4	1.89

Here we can see the value of fineness modulus, D10, D30, D60, uniformity coefficient, coefficient of curvature is 3.41, 0.4, 1.1, 1.6, 4, 1.89 respectively.

Figure 2: Waste tire crumb

3.3: Sand-rubber mixture

Sand-rubber blends, i.e., granular blends composed of destroyed tires and soil grains, have been broadly utilized for development purposes in different geotechnical applications, counting incline building, holding dividers, interstate banks, seepage layers, security for buried channels etc. In this thesis sand was mixed with 2.5, 5, 7.5 and 10% rubber by weight before each test. Then different parameters of these sand-rubber mixture such as shear stress, CBR value for two penetrations, specific gravity, unit weight and dry unit weight were determined.

Figure 3: Sand-rubber mixture before shear test

3.4: Grain size analysis

Grain size analysis is an expository method regularly conducted inside the soil sciences and executed as a routine research facility ponder. Other disciplines, such as archaic exploration and geoarchaeology, too utilize it routinely. It is a sedimentological examination carried out in arrange to decide the measure of the distinctive particles that constitute a particular unconsolidated sedimentary store, sedimentary shake, archeological locus, or soil unit. The most objective of this method is to decide the sort of environment and vitality related with the transport instrument at the time of statement; typically done by deduction from the sizes of the silt particles analyzed and their conveyances.

This test was performed according to ASTM D6913 standard. In this test weights of soil retained were measured. Then % retained, cumulative % retained and % passing was calculated and a semi-log graph of % passing vs sieve opening (mm) was generated. Then fineness modulus, D10, D30, D60, uniformity coefficient, coefficient of curvature was calculated. Grain size analysis of both sand and rubber was performed.

Figure 4: Grain size analysis test apparatus

(Source: https://theconstructor.org/practical-guide/grain-size-analysis/2261/)

3.5: Specific gravity test

A material's specific gravity (Gs) is defined as the difference between the mass of a unit volume of soil particles at a given temperature and the mass of a unit volume of pure gas purified water at the same temperature. The solid specific gravity of the soil is used to calculate the phase relationships of soils, including the void ratio and the saturation level. The typical reference point for soil specific gravity is 20 °C. Due to the fact that solids and liquids are measured in relation to water, a substance will float if its specific gravity is less than one and sink if it is more than one. Explicit gravity is an essential feature of soils and other building materials. Calculations of soil density, void ratio, saturation, and other properties may be done using this dimensionless unit, which measures the ratio of material density to water density.

Understanding the specific gravity of the fluids that will be combined is crucial when setting up a mixer since it will influence the amount of torque and horsepower needed to correctly mix your fluids.

In circumstances with higher explicit gravities, it would be expected that more force would be required to achieve the desired outcome. Results would be unexpected and motor failure or damage was a mixer was not adjusted properly and specific gravity was not taken into account.

This test was performed according to ASTM D792 standard. In this test, weight of dry soil, weight of pycnometer + water (filled to the mark), temperature of the water, weight of pycnometer + water (filled to the mark) + soil was measured. Then weight of equal volume of water as the soil solids, specific gravity of sand as well as specific gravity of different sand-rubber mixtures was calculated. The temperature of water was 24 degrees Celsius for the mixtures and 28 degrees Celsius for sand. Specific gravity of water at these temperatures was taken for calculating specific gravity of sand and sand-rubber mixtures. Then rubber content vs specific gravity graph was generated with these data.

Figure 5: Performing specific gravity test

3.6: Direct shear test

Direct shear test or Box shear test is utilized to decide the shear strength of the soil. It is more appropriate for cohesion less soils. The determination of a soil's shear strength is the goal of a direct shear test; This is accomplished by forcing the soil to shear at a constant rate along an induced horizontal plane of weakness.

The specimen fails in the shear box test along a planned or induced failure plane, such as the horizontal plane between the two parts of the box, rather than along its weakest plane. The main issue with this test is this. Additionally, when the load is being applied, it is impossible to gauge the stress level. Only until there are failure circumstances can Mohr's circle be drawn, and only then can it be assessed. Furthermore, failure advances.

A simple and expedient test is the direct shear test. Thinner specimens in a shear box speed up the process of quickly draining pore water from a saturated sample. This test may also be used to analyze friction between two materials that are in the bottom and top halves of the box. The degree to which sands resist being sheared at an angle depends on the degree of compaction, the coarseness of the grains, the form of the particles, the roughness of the grain surface, and the grading. It varies from sands with spherical grains that are consistently graded and in a very loose condition (28 degrees) to sands with angular grains that are well-graded and in a dense state (46 degrees).

The gradation, particle shape, state and type of packing, orientation of principal planes, principal stress ratio, stress history, magnitude of minor principal stress, type of apparatus, test procedure, method of preparing specimen, and other factors all influence the complex volume change in sandy soil. Overall free sands extend and thick sands contract in volume on shearing. There is a void proportion at which either development constriction in volume happens. This void proportion is called basic void proportion. The movement of the vertical dial gauge during shearing can indicate expansion or contraction.

The rubbing between sand molecule is because of sliding and moving grinding and interlocking activity. If the angle of friction value is calculated at the final stage, a slight density change during test specimen sampling and preparation will have little effect because the final values of the shear parameter for loose sand and dense sand are roughly the same.

Figure 6: Direct shear test apparatus

This test was performed according to ASTM D3080-04 standard. In this test sand was mixed with 2.5%, 5%, 7.5% and 10% rubber by weight. Then direct shear test was conducted on sand and sand-rubber mixtures. From the apparatus, data of shear displacement, normal displacement and load dial reading was taken. Shear displacement and normal displacement was in millimeter unit. Load dial reading was in Newton unit.

1 kg, 2 kg and 3 kg normal load were used. Sample size was 63 millimeters. From these data shear force and shear stress was calculated. Then shear displacement vs shear stress graph and rubber content vs shear stress graph was generated for all normal loads.

3.7: California Bearing Ratio (CBR) test

A CBR test is used to evaluate a material's California Bearing Ratio (CBR), which must be utilized for the subgrade of flexible pavements. Resilient Modulus, on the other hand, is the real factor influencing how strong a subgrade material is. Significantly stronger correlation exists between CBR and differences. Similarly, at each subgrade thickness, bends are displayed for the CBR versus the average traffic (million axles annually). In order to avoid becoming bogged down in the complexity of flexible modulus computation, CBR, which can be easily tested nearby, is used in its place.

CBR is, by definition, the ratio of the real crushing force of the stone in rate to the restricted bearing pressure encountered by a normal penetrator when inserted into it at a distance of 2.5 cm.

A plunger is used in a CBR test to measure the pressure needed to pierce a standard area soil sample. This value is equivalent to the pressure needed to accomplish an equal penetration through a typical, high-quality crushed rock material. The CBR is valued more highly the tougher the surface.

Flexible pavements utilize a variety of layers to resist traffic. The thickness of those layers, notably for foundation and subgrade materials, is anticipated to be determined by CBR esteem. The thickness of layers will be larger for lower CBR, and vice versa. If a material's CBR value is too low, layer thickness will be much higher. To use that stuff would not be wise.

The strength of the subgrade soil, subbase, and base course materials for roads and pavements must be determined using the CBR test. The thickness of roadway asphalt and the number of component layers are typically planned using the CBR value and precise bends.

The California Bearing Proportion (CBR) measures the ratio between the materials used in the construction of a street or other cleared area and the strength of the subgrade underneath it. The ratio is calculated using a standard penetration test first established by the California Division of Highways for highway engineering.

Figure 7: Performing CBR test

This test was conducted according to ASTM D1883 standard. In this test, specimen was prepared for unsoaked condition. Test was performed on sand and sand-rubber mixtures (2.5%, 5%, 7.5% and 10% rubber by weight). From the apparatus load dial reading was taken at different penetrations. Then CBR value was calculated for 0.1 inch and 0.2-inch penetration for sand and sand-rubber mixtures. After that rubber content vs CBR value graph was generated for both penetrations.

From this test, weight of mold, weight of sand, weight of rubber, weight of mold + compacted sample was measured and with the help of these data unit weight of sand and different sand-rubber mixtures was calculated. Then rubber content vs unit weight graph was generated. For only sand rubber content was 0%.

For the determination of moisture content different small cans are used. Weight of these cans, weight of can + wet sample, weight of can + dry sample was measured. With the help of these data moisture content was calculated for sand and different sand-rubber mixtures. Then rubber content vs moisture content graph was generated. With the help of unit weight and moisture content, dry unit weight of sand and different sand-rubber mixtures was calculated. Then with these data rubber content vs dry unit weight graph was generated.

CHAPTER-4: RESULTS AND DISCUSSION

4.1: Introduction

The test outcomes that were described in the preceding section's explanation will be covered in this section. These tests seek to ascertain how crumb tires affect several characteristics of nearby river sand.

When conducting these tests, a certain pattern was followed. Testing was done with 0% rubber crumb mixture for each test. Thus, only sand was tested during the procedure. In order to see the changes, 2.5 percent of rubber content was then mixed. The rubber content was then increased by 5%, 7.5%, and 10% for each test. The amount of rubber was thus increased by 2.5 percent each time. We will get our results following these patterns.

4.2: Specific gravity

Table 4: Rubber content & specific gravity

Rubber content (%)	Specific gravity
0	2.69
2.5	2.53
5	2.51
7.5	2.45
10	2.36
12.5	2.19

We can see from the table that the specific gravity (Gs) of the river sand without any rubber content was 2.69 at start. When 2.5 percent crumb was added the specific gravity becomes 2.53. We can see a drastic fall in the value. When we add 5 percent rubber content the value becomes 2.51 which differs highly from the value of river sand. On the other hand, if we compare it with 2.5 percent value it is not that high. When the rubber content is 7.5 percent, the specific value becomes 2.45 indicating reduction. Again, when we mix 10 percent tire crumb the value becomes 2.19 which means reduction.

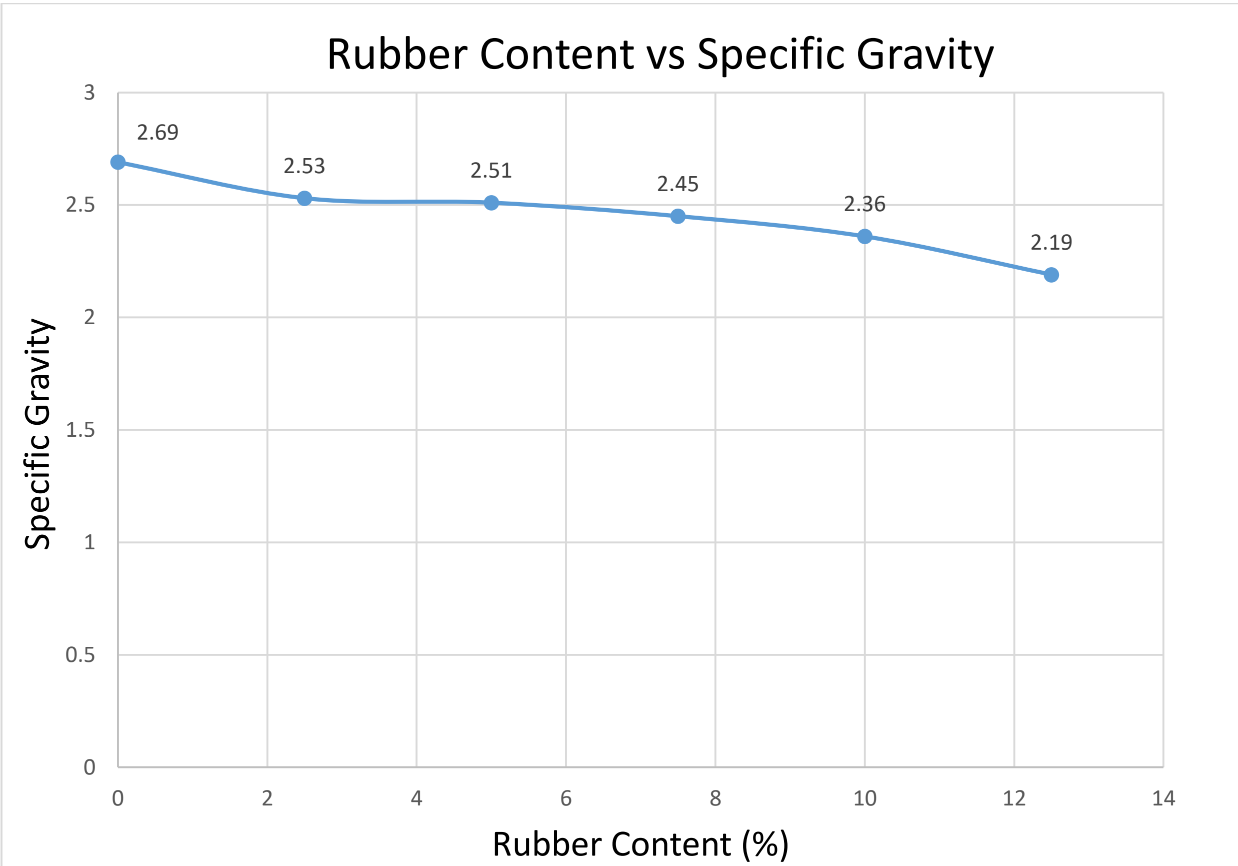

Figure 8: Rubber content vs specific gravity

The graph shows that the specific gravity value drops as the amount of rubber content rises. The specific gravity drops as the amount of rubber in the mixture increases. An increase of up to 2% causes a noticeable change. The change from 2% to 6% is not very significant. On the other hand, we can once more notice a significant change from 6% to 10%.

4.3: Moisture content

Table 5: Rubber content & moisture content

Rubber Content (%)	Moisture Content (%)
0	14.3
2.5	14
5	13.56
7.5	12.73
10	10.87

We can see from the table that the moisture content of the river sand was 14.3% at start. When 2.5 percent crumb was added the moisture content becomes 14%. We can see a fall in the value. When we add 5 percent rubber content the value becomes 13.56% which differs from the value of river sand. On the other hand, if we compare it with 2.5 percent value it is not that high. When the rubber content is 7.5 percent, moisture content value becomes 12.73 indicating reduction. Again, when we mix 10 percent tire crumb the value becomes 10.87%.

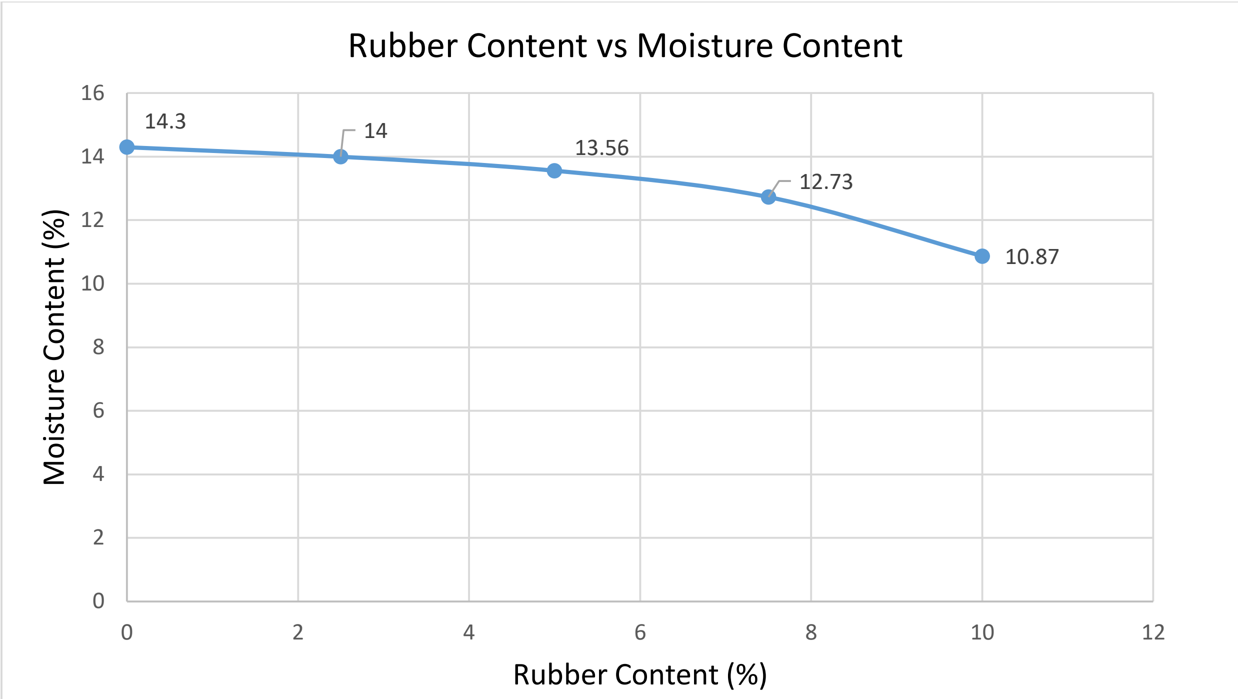

Figure 9: Rubber content vs moisture content

The graph shows that the moisture content value drops as the amount of rubber content rises. The moisture content drops as the amount of rubber in the mixture increases. An increase of up to 2% does not cause a noticeable change. The change from 2% to 6% is significant. On the other hand, we can once more notice a significant change when 10% crumb content is added. We can say that up to 4% there is slight change but after that we can see that the percentage of change is increasing.

4.4: Unit weight

Table 6: Rubber content & unit weight

Rubber Content (%)	Unit Weight (kN/m^3)
0	20
2.5	17.5
5	17
7.5	16.5
10	16

We can observe that the unit weight reduces when crumb rubber is added. For river sand, the unit weight was 20 (kN/m^3). A 2.5% rubber addition brought the value down to 17.5 (kN/m^3). After the addition of 5% rubber content, it once more dropped to 17 (kN/m^3). It again fell to 16.5 (kN/m^3) after 7.5% rubber content was introduced. Adding 10% rubber content caused a further reduction to 16 (kN/m^3). It has a reductive progression, as we might say.

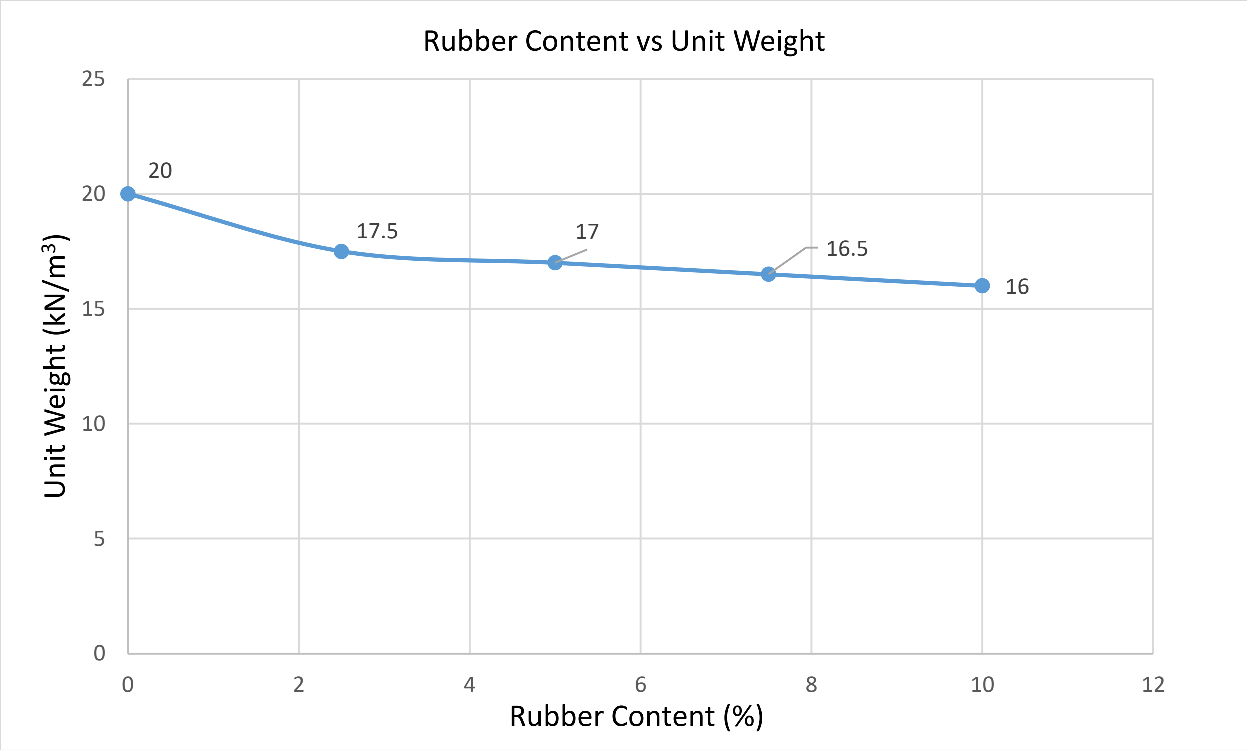

Figure 10: Rubber content vs unit weight

The graph shows that when 2.5% rubber crumb was added, the value for a unit weight significantly decreased. But after that we can see a gradual decrease up to 10%.

4.5: Dry unit weight

Table 7: Rubber content & dry unit weight

Rubber Content (%)	Dry Unit Weight (kN/m^3)
0	17.5
2.5	15.35
5	14.97
7.5	14.64
10	14.43

We can observe that the dry unit weight reduces when crumb rubber is added. For river sand, the unit weight was 17.5 (kN/m^3). A 2.5% rubber addition brought the value down to 15.35(kN/m^3). After the addition of 5% rubber content, it once more dropped to 14.97 (kN/m^3). It again fell to 14.64 (kN/m^3) after 7.5% rubber content was introduced. Adding 10% rubber content caused a further reduction to 14.43 (kN/m^3). It has a reductive progression, as we might say.

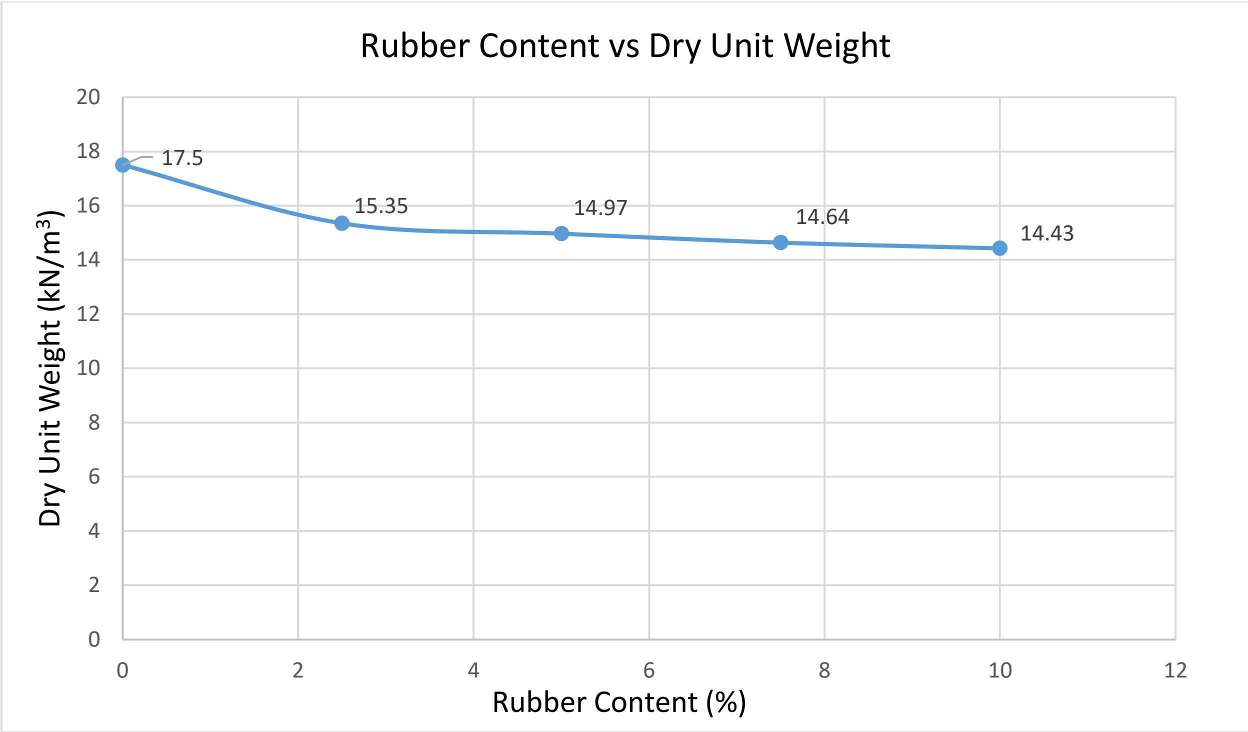

Figure 11: Rubber content vs dry unit weight

The graph shows that when 2.5% rubber crumb was added, the value for a unit weight significantly decreased. But after that we can see a gradual decrease up to 10%.

4.6: California Bearing Ratio test

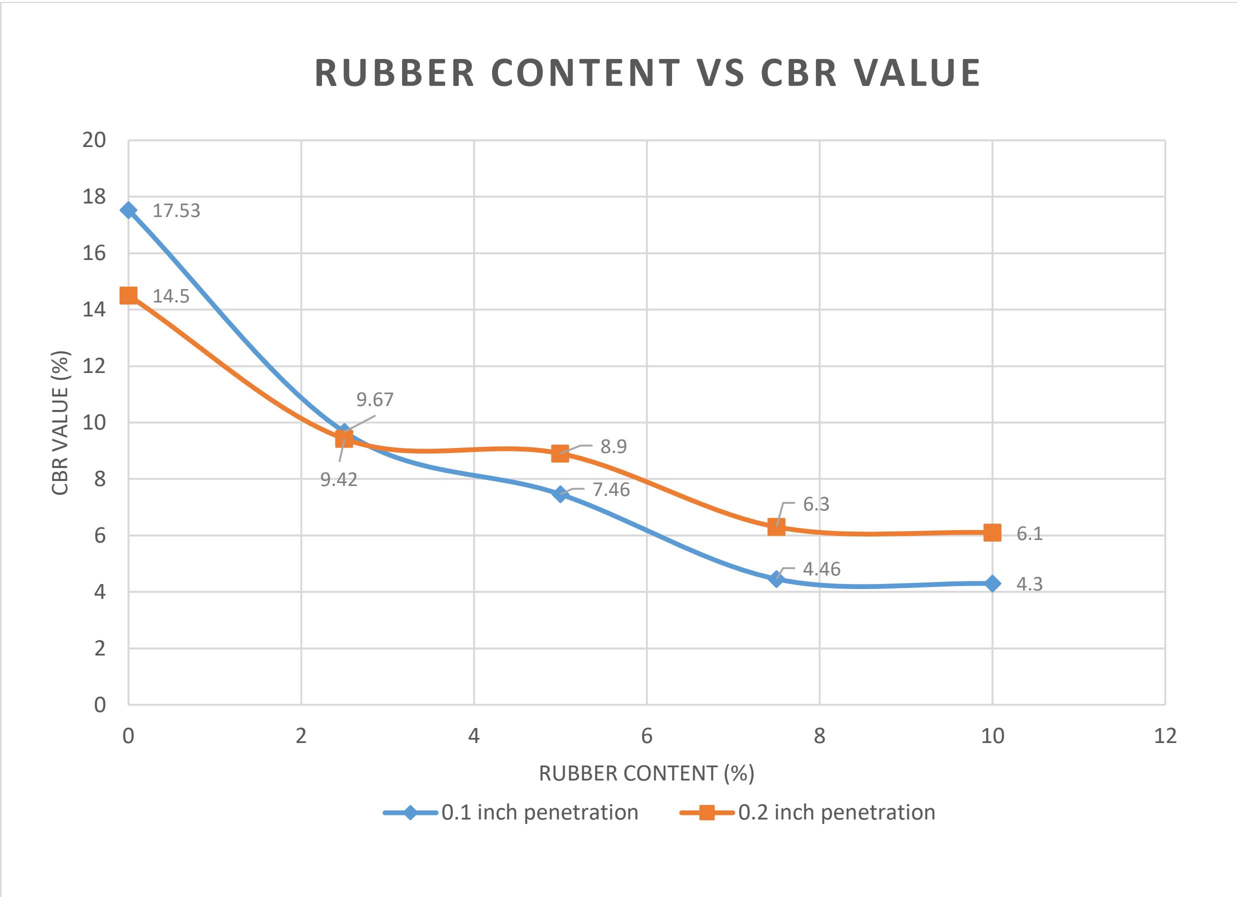

Figure 12: Rubber content vs CBR value

The CBR test was carried out for 0.1inch and 0.2inch penetration. The blue line tells the change for 0.1inch penetration and the black line tells the change for 0.2inch penetration. For 0.1inch penetration we can see that the value decreases from almost 18 to 11 when almost 2% rubber content is added. We can see another drastic change when the more amount of content is added and the CBR value drops to almost 4 when 8% rubber content is mixed. After that we can see a stable value up to 10%.

For 0.2inch penetration we can see the same pattern. The value decreases from 14 to 9 when almost 2.5% rubber content is added. We can see a stable value when the rubber content mix is between 2.5% to 6%. Then the value starts to gradually decrease and drops to 6. After that we can see another stable value.

4.7: Direct shear test

The 31.46 kPa, 62.92 kPa, and 94.38 kPa normal stress values were used in the direct shear test. These normal stresses were determined for 1 kg, 2 kg and 3 kg normal loads respectively. Here 1 kg, 2 kg and 3 kg normal loads are equivalent of 10 kg, 20 kg and 30 kg respectfully. In this section, the shear displacement vs shear stress graphs will be presented, examined, and compared to other charts in related categories. For rubber content, we adhered to the same guidelines as previously specified. We first tested the soil at 0% before gradually increasing it to 2.5%, 5%, 7.5%, and 10%.

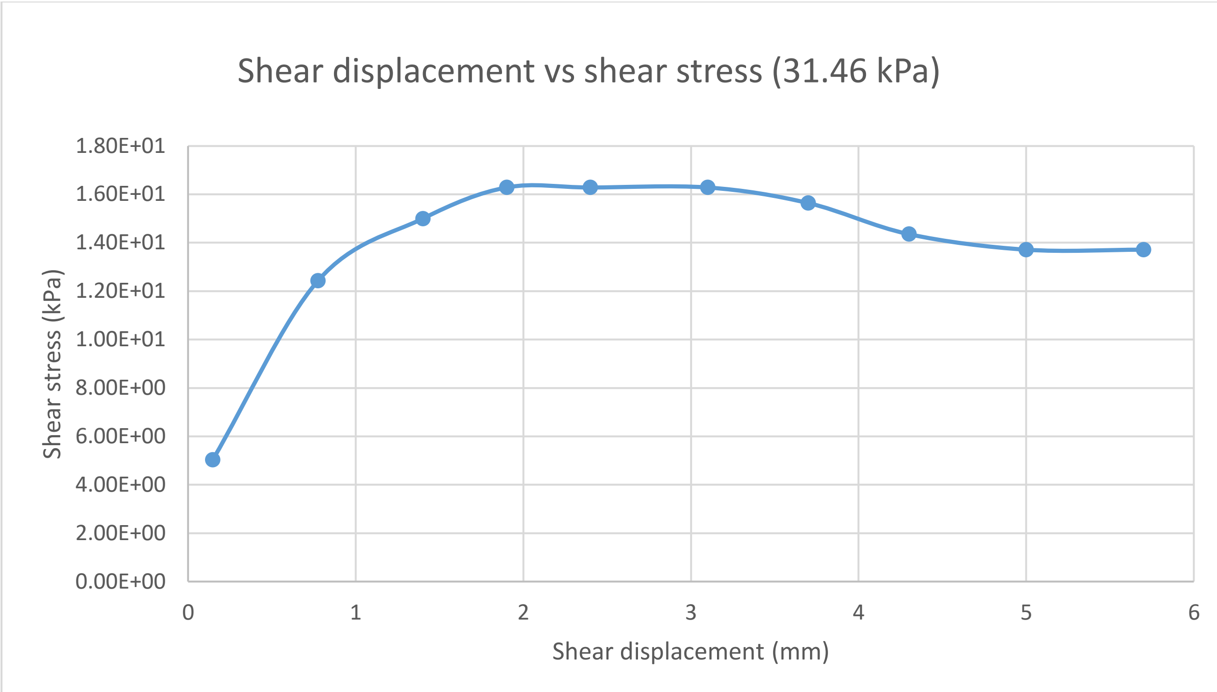

Figure 13: Shear displacement vs shear stress 31.46 kPa 2.5%

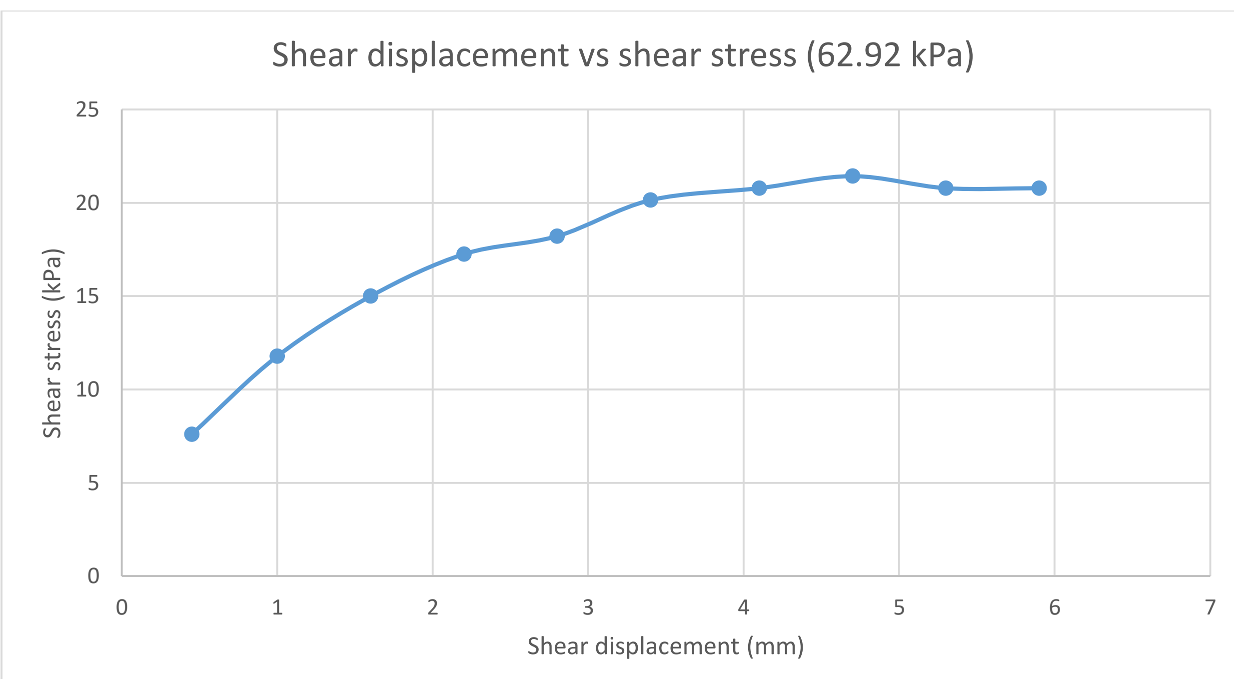

Figure 14: Shear displacement vs shear stress 62.92 kPa 2.5%

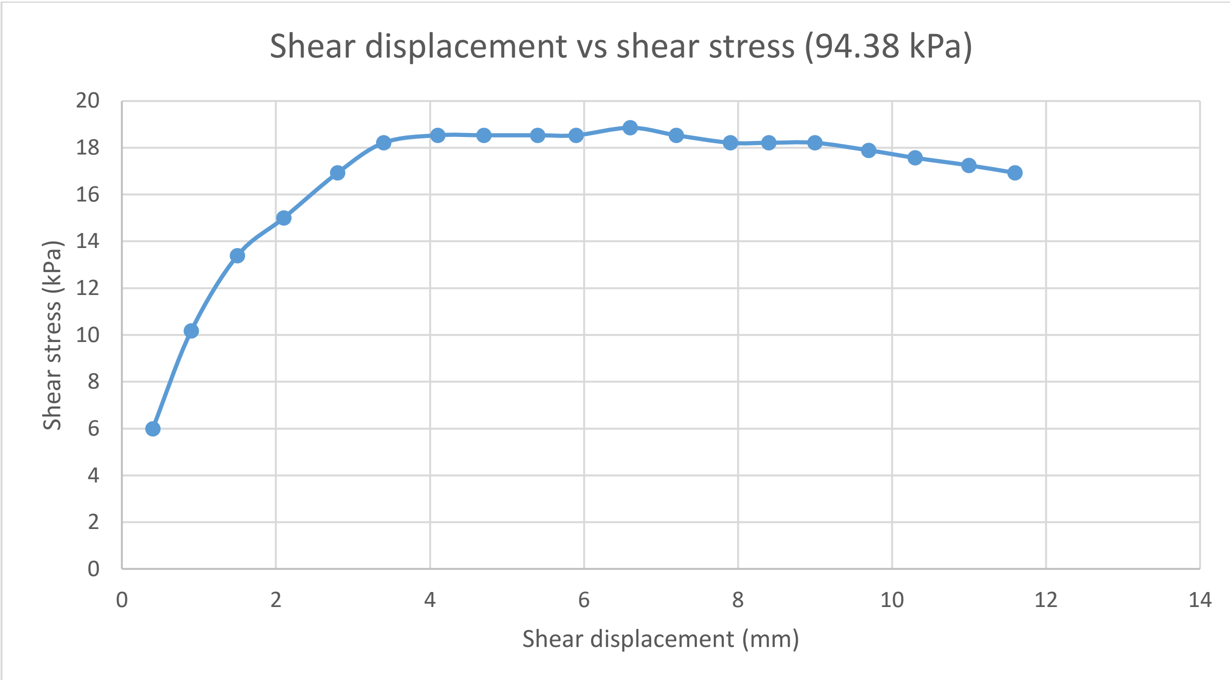

Figure 15: Shear displacement vs shear stress 94.38 kPa 2.5%

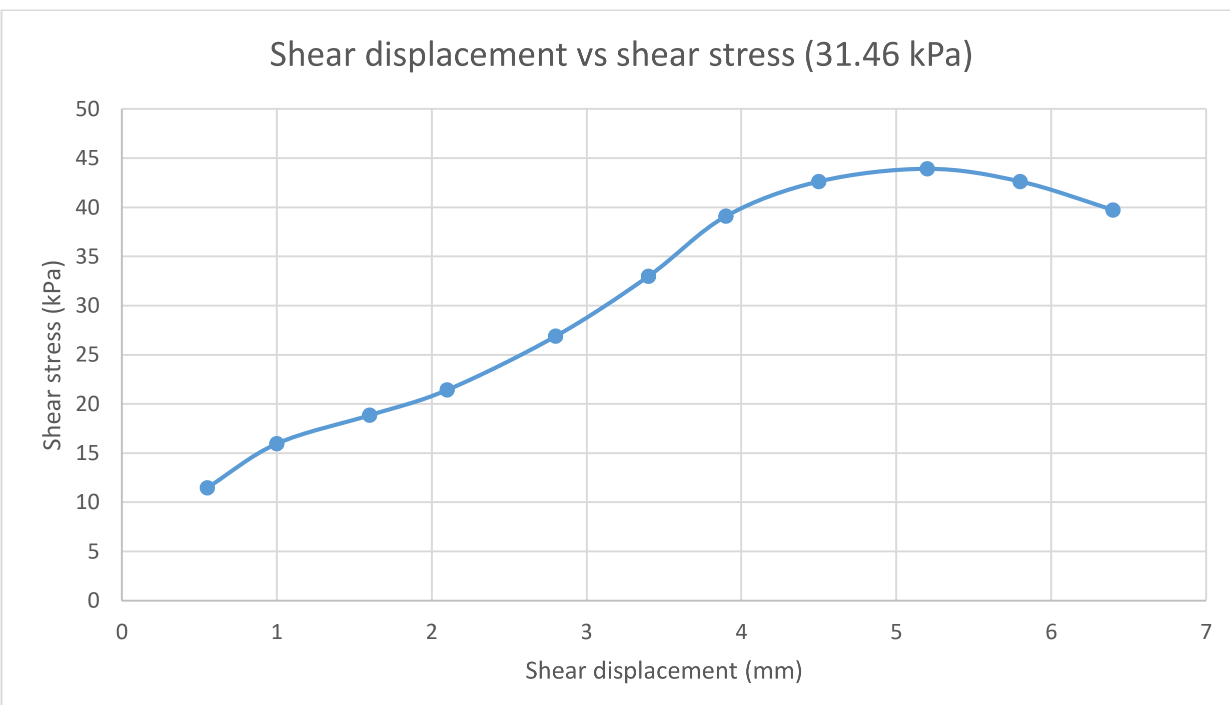

Figure 16: Shear displacement vs shear stress 31.46 kPa 5%

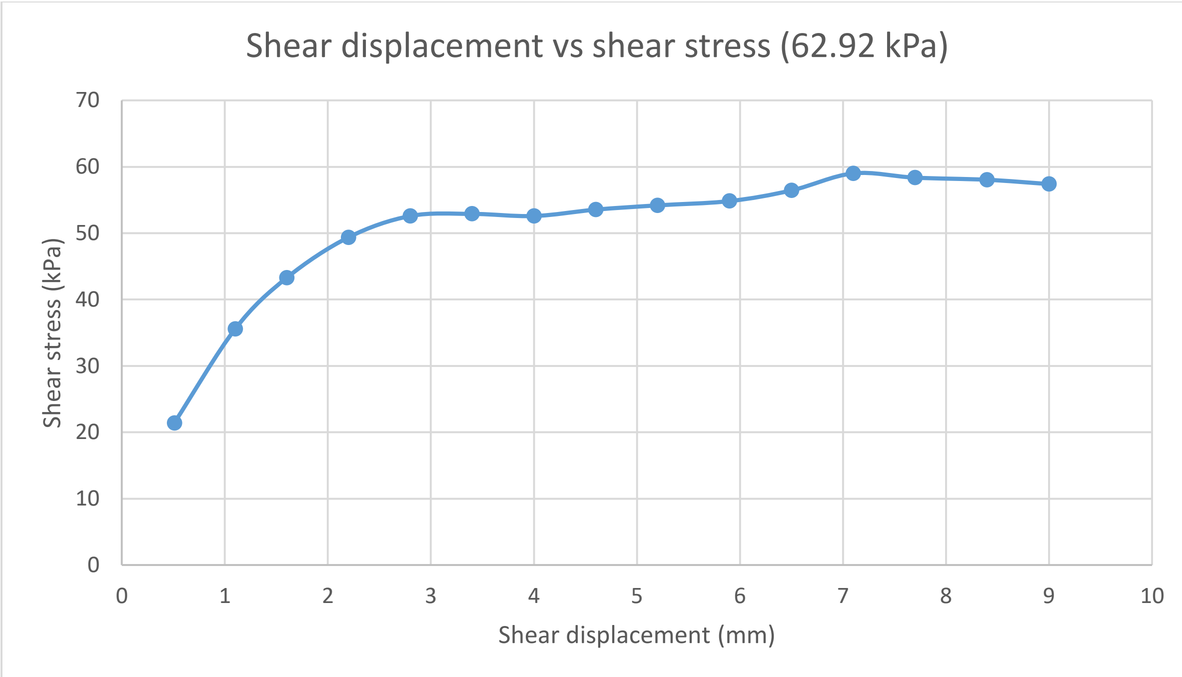

Figure 17: Shear displacement vs shear stress 62.92 kPa 5%

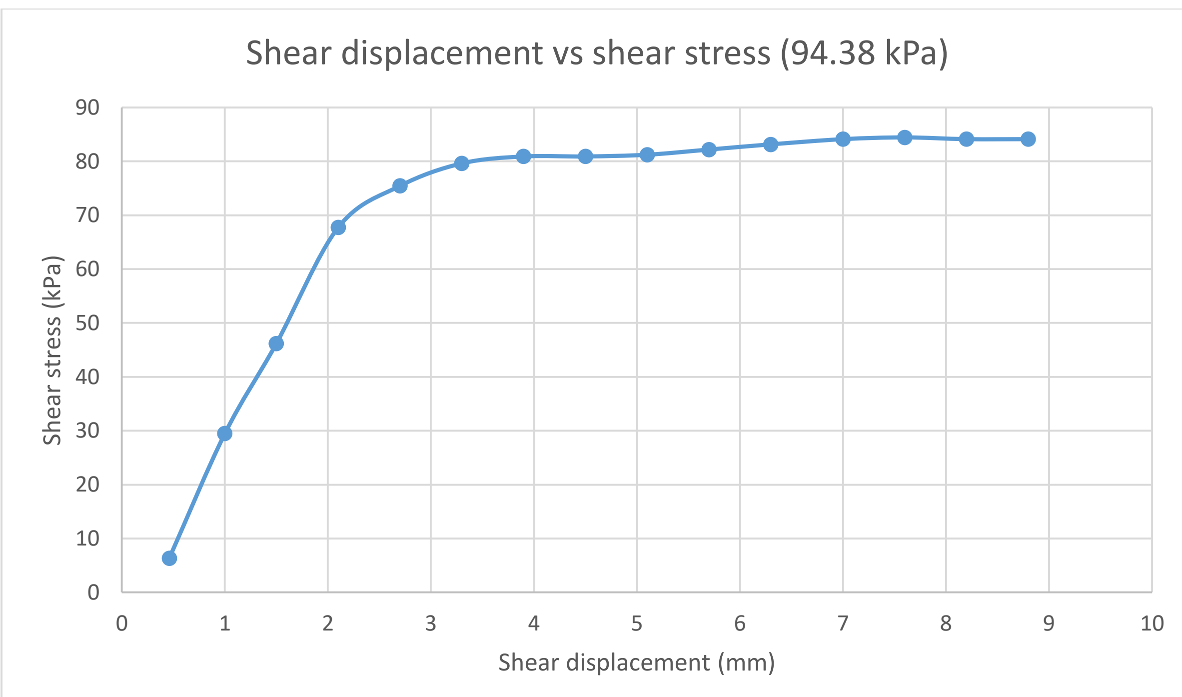

Figure 18: Shear displacement vs shear stress 94.38 kPa 5%

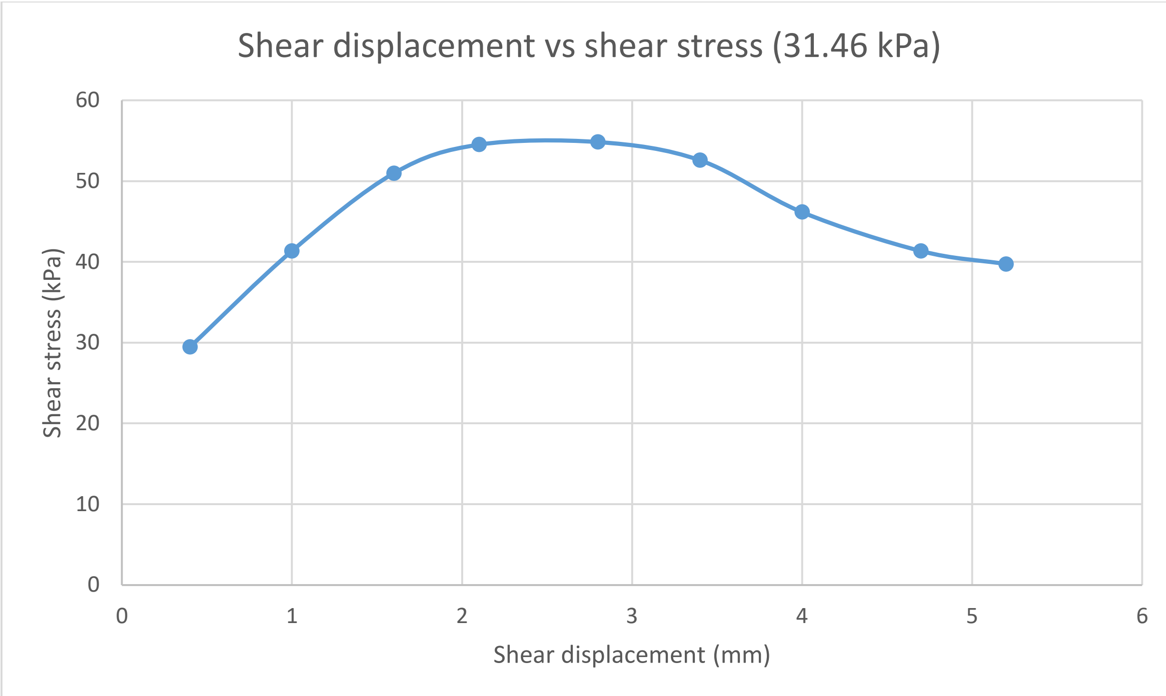

Figure 19: Shear displacement vs shear stress 31.46 kPa 7.5%

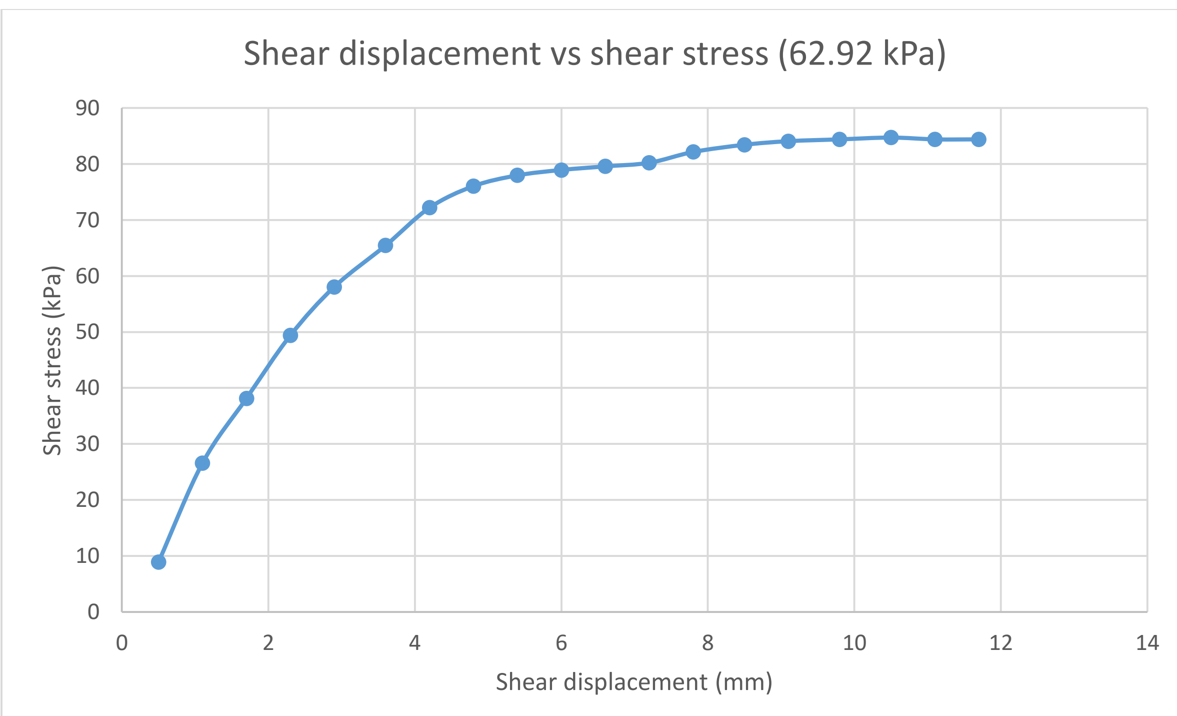

Figure 20: Shear displacement vs shear stress 62.92 kPa 7.5%

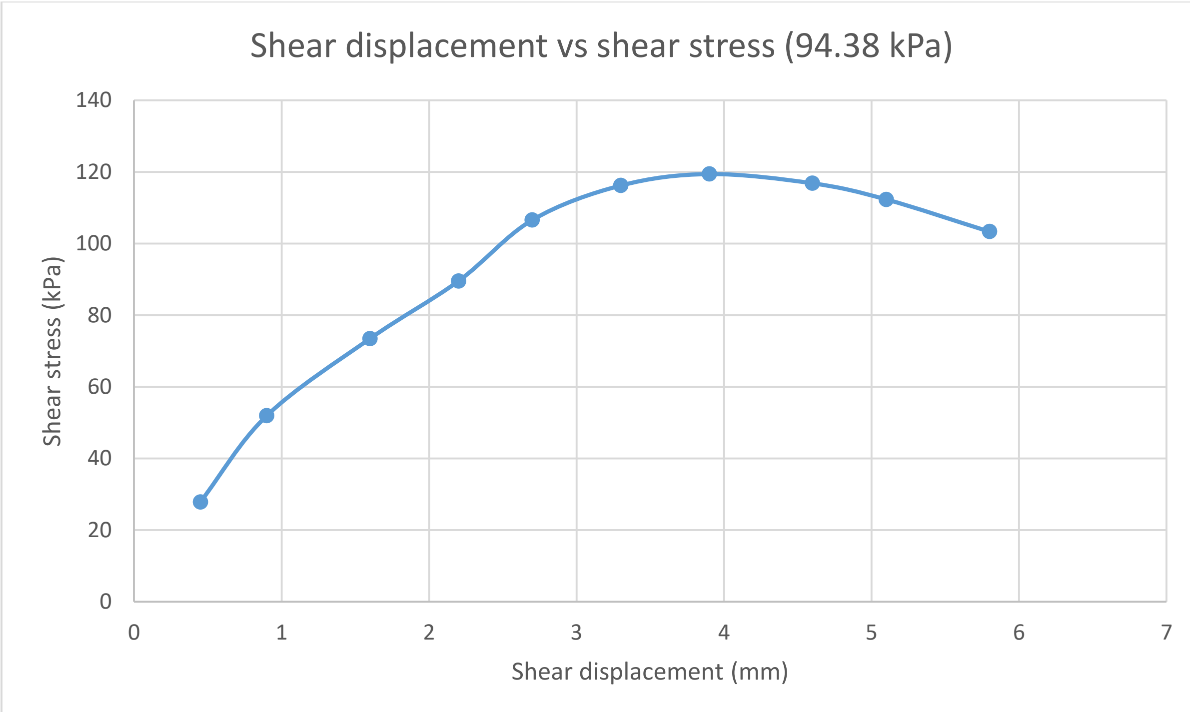

Figure 21: Shear displacement vs shear stress 94.38 kPa 7.5%

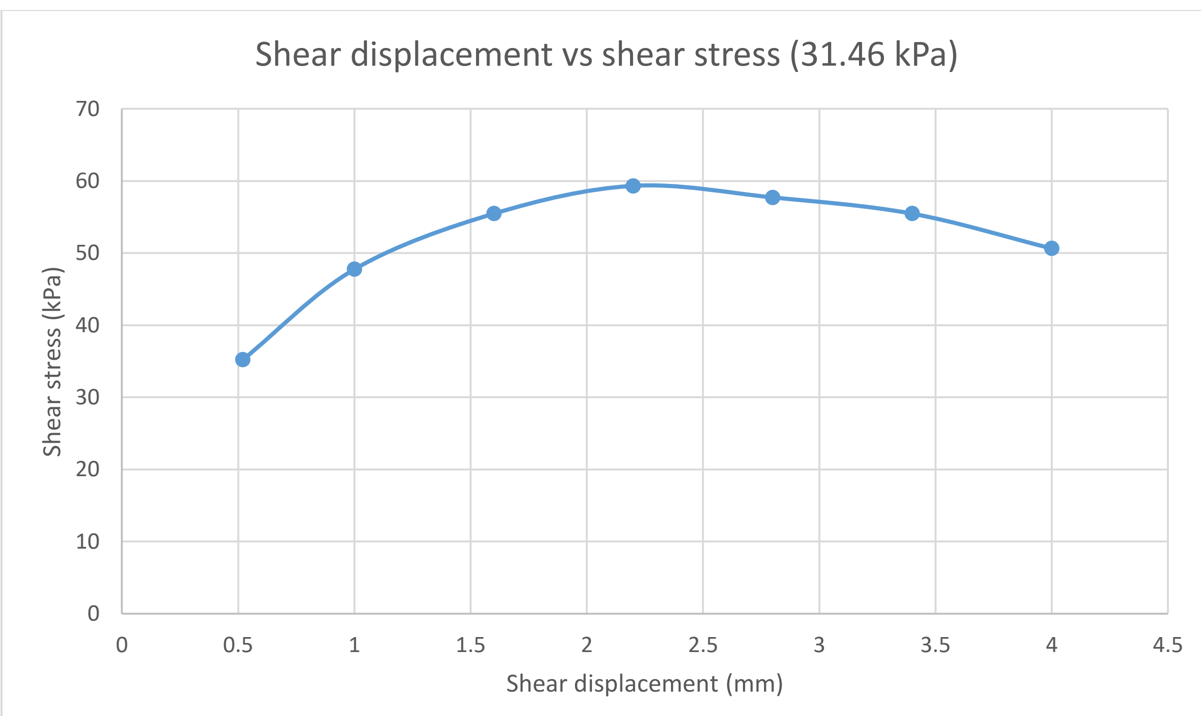

Figure 22: Shear displacement vs shear stress 31.46 kPa 10%

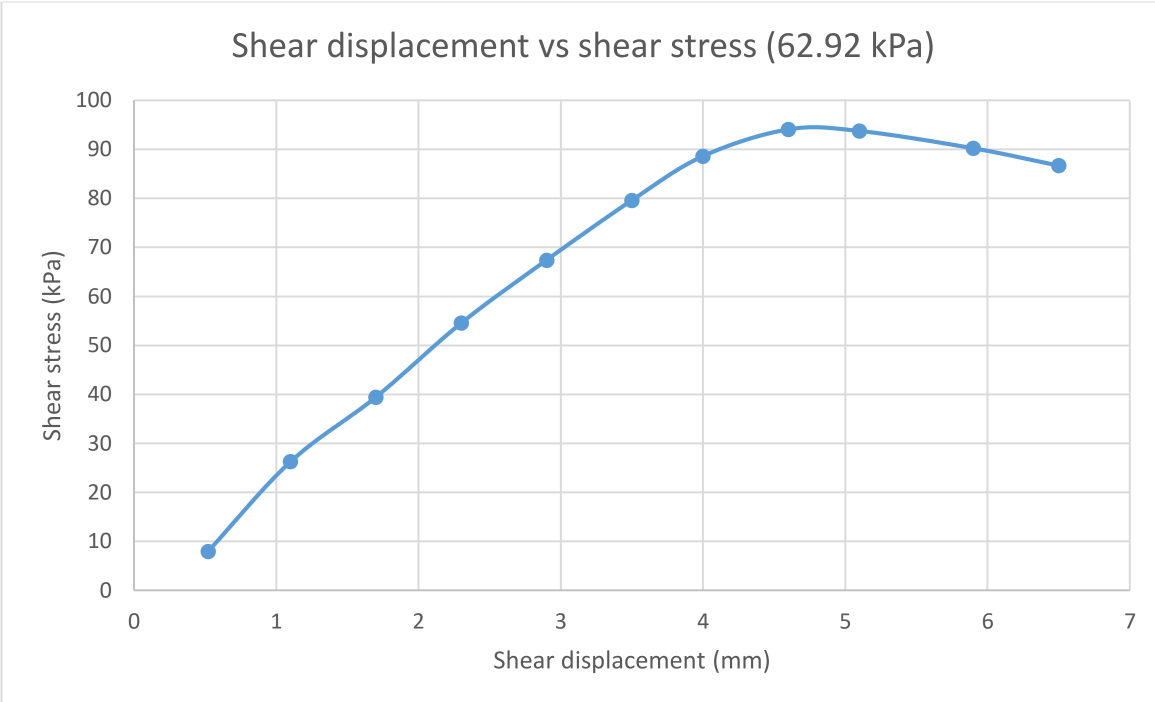

Figure 23: Shear displacement vs shear stress 62.92 kPa 10%

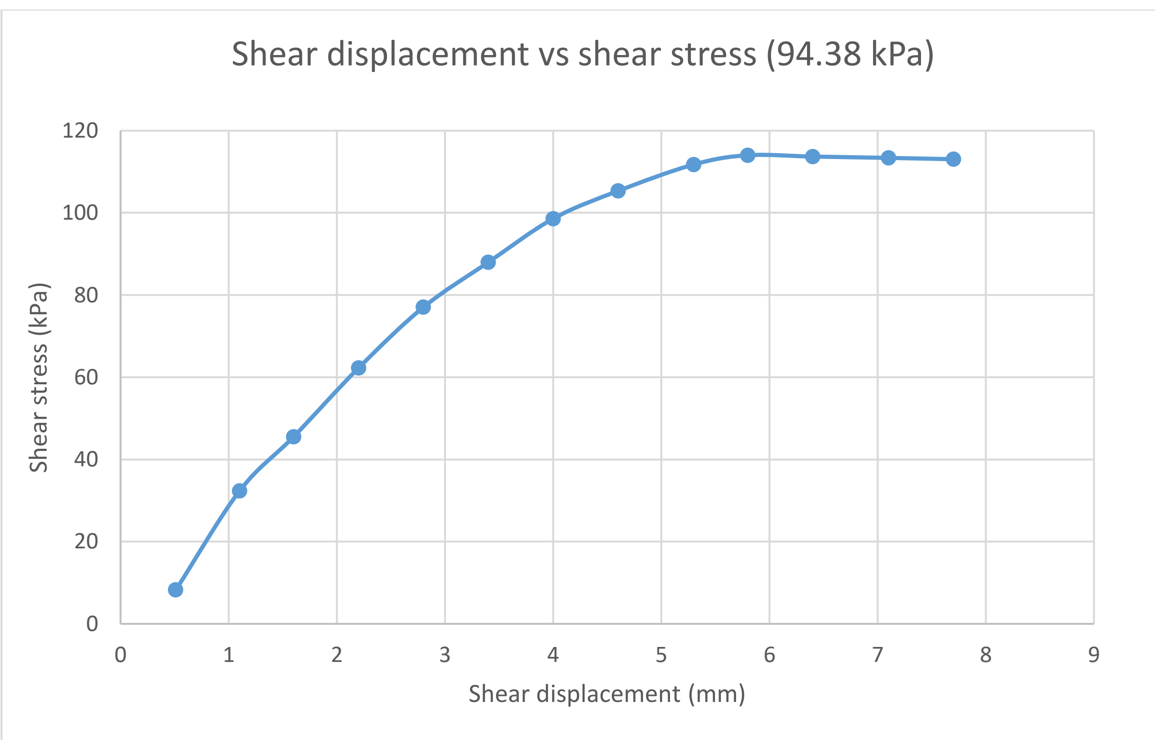

Figure 24: Shear displacement vs shear stress 94.38 kPa 10%

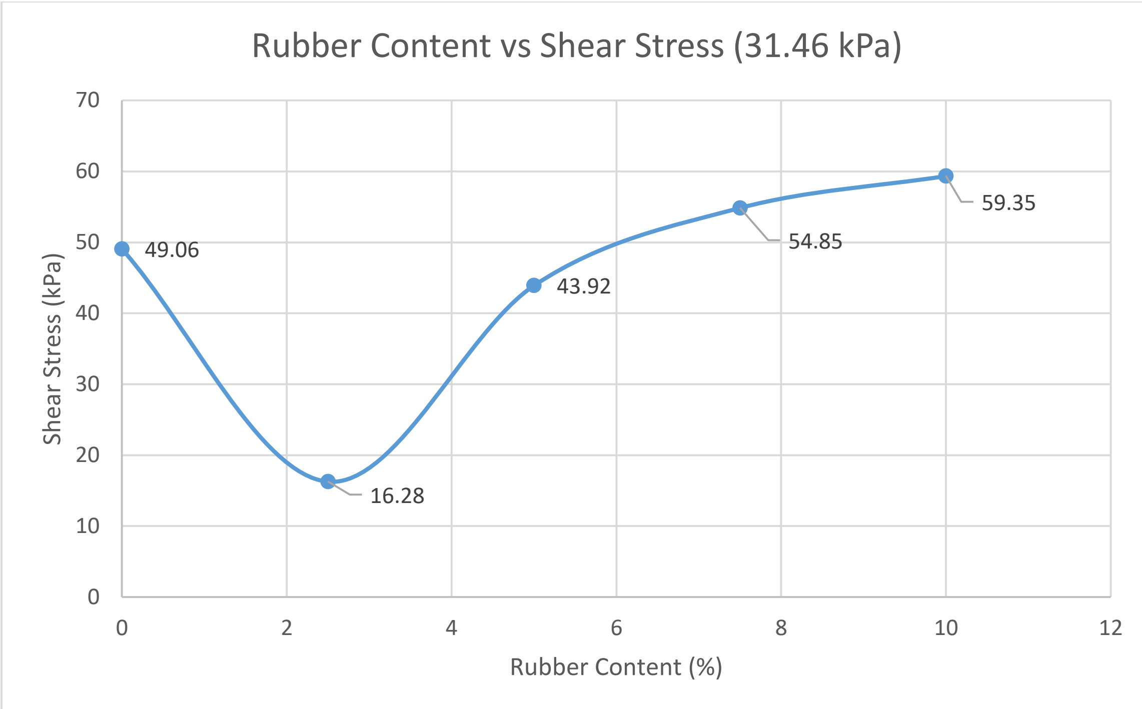

Figure 25: Rubber content vs shear stress (31.46 kPa)

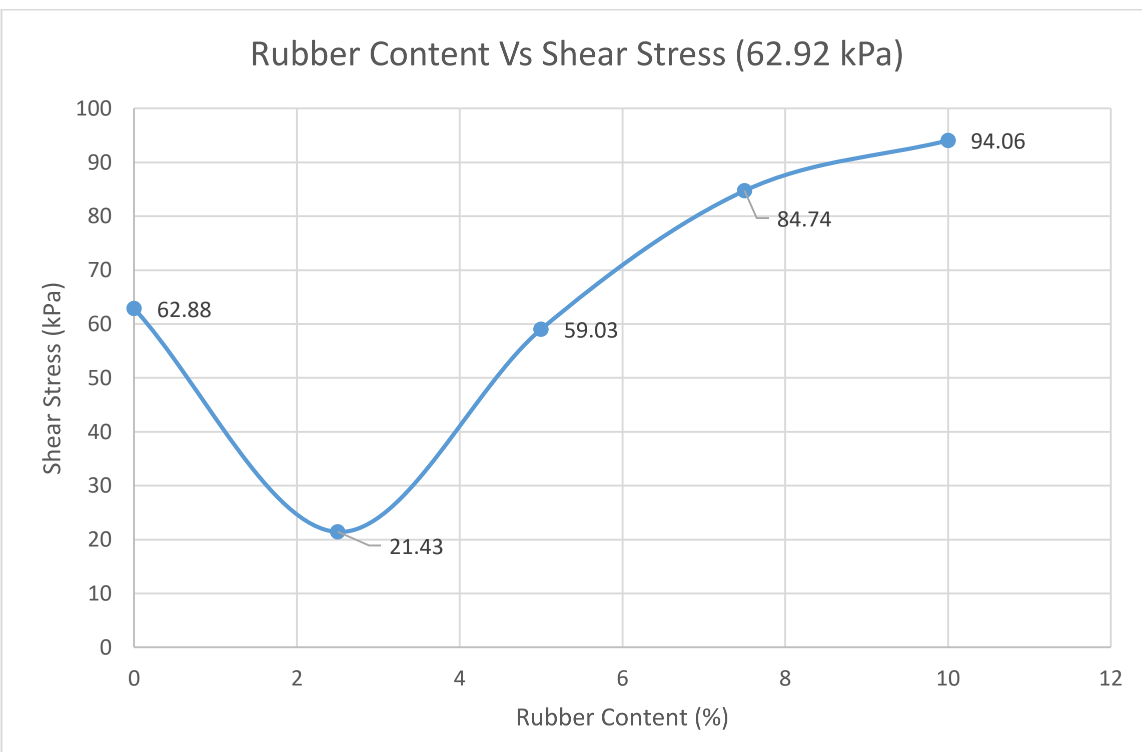

Figure 26: Rubber content vs shear stress (62.92 kPa)

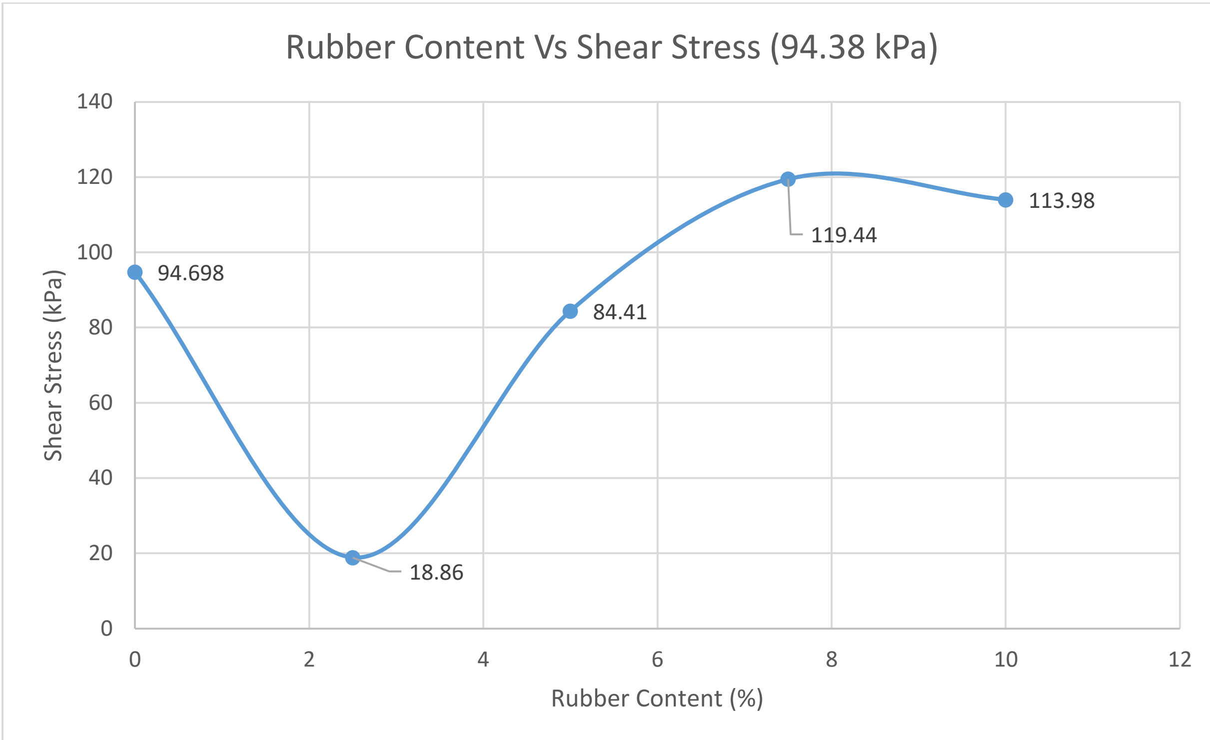

Figure 27: Rubber content vs shear stress (94.38 kPa)

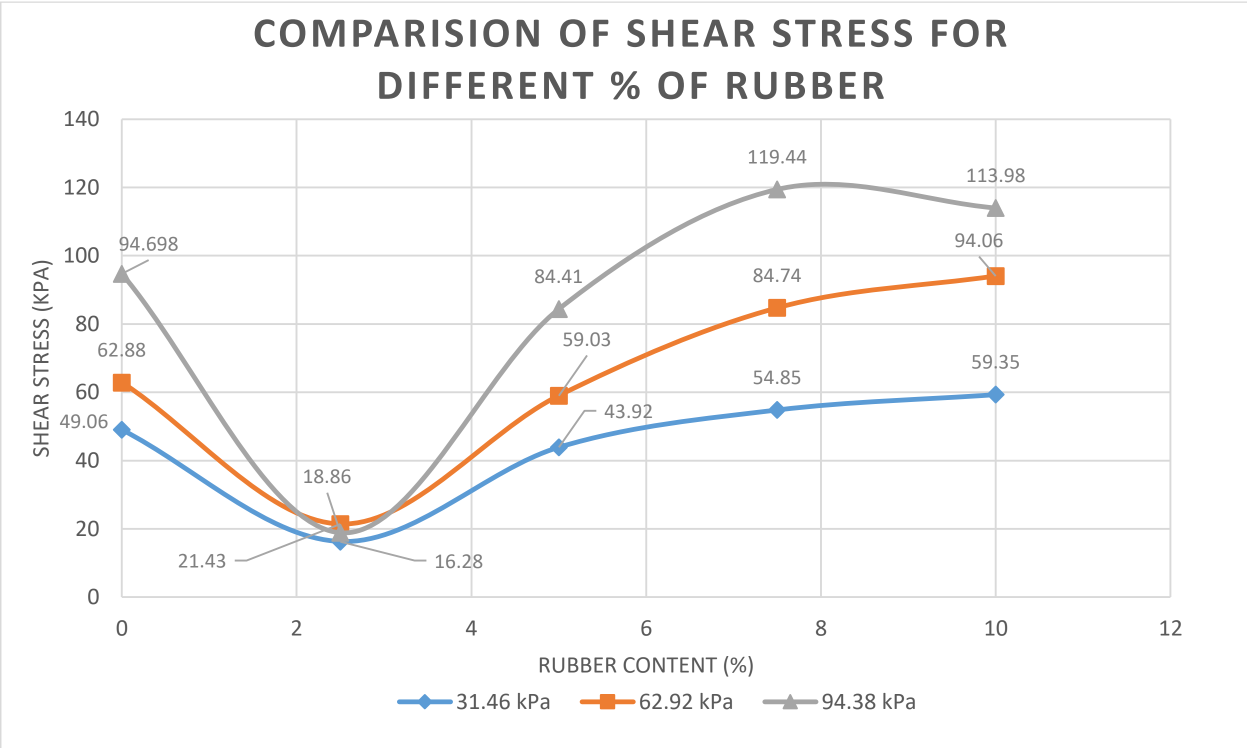

Figure 28: Comparison of shear stress for different % of rubber

The results are as follows after combining all of the graphs using the highest shear stress value. We can see for each percentage that the shear stress falls as the rubber content approaches 2.5%. Following that, the shear stress starts to rise as the rubber content rises. 10% is where the peak value is located for 31.46 kPa and 62.92 kPa normal stress. For 94.38 kPa normal stress peak shear stress is at 7.5% rubber content.

CHAPTER-5: CONCLUSIONS

5.1: Introduction

The fine sand's engineering properties benefit from the application of waste tire crumb. The shear stress may be enhanced by tire crumb. Shear pressure will essentially diminish up to 2.5% elastic substance. After that, it will begin to rise in tandem with the increase in rubber content, and at some point, shear stress will exceed the sand's initial shear stress.

5.2: Conclusions

In light of the experimental outcomes, the accompanying ends can be drawn:

1. Specific gravity of sand with 0% rubber content is 2.69. With the increase of rubber content in sand specific gravity decreases.

2. CBR value of sand with 0% rubber content for 0.1-inch penetration and 0.2-inch penetration was 17.53% and 14.5% respectively. With the increase of rubber content in sand CBR value decreases gradually for both penetrations.

3. Moisture content of sand with 0% rubber content is 14.3%. With the increase of rubber content in sand moisture content decreases.

4. Unit weight of sand with 0% rubber content is 20 kN/m^3. With the increase of rubber content in sand unit weight decreases.

5. Dry unit weight of sand with 0% rubber content is 17.5 kN/m^3. With the increase of rubber content in sand dry unit weight decreases.

6. Different peak shear stress was found for different shear displacements in case of different rubber content and different normal loads.

7. Shear stress significantly decreased up to 2.5% rubber content and after that with the increase of rubber content shear stress increased. This happened for all the normal loads (1kg, 2 kg and 3 kg). So, at 2.5% rubber content the shear stress was minimum for all the normal loads.

8. Peak shear stress increased gradually with the increase in normal load in rubber content vs shear stress graph.

5.3: Further studies

In this thesis, rubber crumb was mixed with sand and comparison of engineering properties of sand and sand-rubber mixtures was done. Sand was mixed with 2.5%, 5%, 7.5% and 10% rubber (by weight). Improvement in shear stress was seen in this research. No material was mixed with sand other than rubber. Further studies of this research can be like this:

1. Mixing sand with more than 10% rubber content by weight and analyzing the engineering properties (specific gravity, unit weight, dry unit weight, water content, CBR value, shear stress etc.) of sand and different sand-rubber combinations.

2. Other materials such as cement can be mixed with sand and rubber and changes in engineering properties can be analyzed.

3. Plaxis software can be used in analyzing different sand and rubber combinations.

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