
Influence of Shear Stress Mode on Deformation of Asphalt Stabilized Soil

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ABSTRACT

The pavement structure is subjected to repeated wheel loading throughout its service life, such loading exhibit shear stresses, tensile stresses, and tensile strain into the various pavement layers. The layers usually distribute the loading to the subgrade. In the present investigation, an attempt has been made to assess the influence of repeated shear stresses applied on the subgrade in two different modes, single punching, and double punching shear stresses on the deformation of untreated and asphalt stabilized subgrade soil. Specimens of 100 mm diameter and 63 mm height have been prepared at optimum fluid content of 16 % and at 0.5 % cutback asphalt higher and lower than the optimum, cured for one week, then subjected to repeated double punching shear stresses for 1800 repetitions using the Pneumatic Repeated Load System (PRLS) at 20 °C environment. Another set of specimens with 152 mm diameter and 127 mm height have been prepared like the previous set and subjected to repeated single punching shear stresses in the PRLS. The total, resilient, and permanent deformation of the specimens were monitored using Linear Variable Differential Transformer (LVDT). It can be observed that double punching shear exhibit higher total, resilient, and permanent strain than that of single punching shear in a range of (35.7, 28, and 111)% for mixtures with 16.5 % cutback content respectively. The total deformation, resilient Deformation, and Permanent deformation of asphalt stabilized soil at failure for specimens practicing double punching shear stresses declines by (28, 50, and 43.7) %, (28.5, 48, and 16.6) % and (50, 77, and 10) % than that of specimens practicing single punching shear stresses for cutback content of (16.5, 16, and 15.5) % respectively. Double punching shear exhibit higher deformation than single punching shear for untreated soil. However, the asphalt stabilized soil exhibit higher deformation under single punching shear stresses than that under double punching shear stresses.

Keywords: *Stabilization, Cutback Asphalt, Punching Shear, Deformation, Permanent, Resilient, Total.*

INTRODUCTION

Ogundipe, [1] investigated the stabilization of granular soil with cutback bitumen. The strength and compaction characteristics of the natural and stabilized granular soil were determined. In the study, 2%, 4% and 6% of cutback bitumen content were considered. The results showed that the optimum binder content required in achieving the highest maximum dry density and California bearing ratio is 4%. It was observed that when 6% cutback was used, the density and bearing capability decreased. Such reduction is probably due to the excess bitumen in the mix which filled the voids, thus resulting in slip and weakening the bond between the aggregates. It was found that the properties of the granular soil improved when stabilized with cutback bitumen. The impact of asphalt stabilization on the deformation

under repeated loading of subgrade soil was investigated by Sarsam and Barakhas,[2]. The subgrade soil usually used for roadway embankment construction was stabilized with optimum cutback asphalt and with additional 1% of asphalt above and below the optimum. Cylindrical Specimens have been constructed and subjected to repeated punching shear stresses to detect the resistance to permanent strain accumulation and resilient modulus under the test condition. It was concluded that addition of the Asphalt binder to the soil exhibit high resistance to repeated punching shear and exhibit low deformation, the rate of reduction in deformation is (-54% at 5% Asphalt content, - 62% at 6% and -65 % at 7%) indicating that the resistance to the repeated Punching Shear Stress increased by increasing the Asphalt content.Huan et al., [3] carried out tests to evaluate the impacts of the stabilization on the strength and compaction characteristics of granular soil using foamed bitumen and lime. The indirect tensile strength test and unconfined compressive strength test showed that the mixture attained the highest values when treated with 3% foamed bitumen. The results of resilient modulus test and permanent deformation test indicated that with an increased content of foamed bitumen, stiffness decreased, and failure became serious, indicating that the optimum value of the foamed bitumen must be known to achieve suitable results.The resilient behavior of asphalt stabilized subgrade soil in terms of changes in the deformation under repeated loading was investigated by Sarsam and Kais, [4]. Asphalt stabilized soil specimens have been prepared and tested for deformation under repeated shear stresses. It was concluded that asphalt stabilization exhibits positive impact on resilient modulus. It increases by a range of seven folds under double punch shear stress after one load repetition by the addition of asphalt. Significant reduction in total and resilient strain could be detected after liquid asphalt was implemented in the subgrade soil.The mechanism of treatment with liquid asphalt binder includes reduction of water absorption and penetration by waterproofing, addition of cohesive strength to the soil by the asphalt, and cementation action as revealed by Jones et al., [5].Al-Daffae, [6] presented that the cohesion of gypseous subgrade soil had improved with increasing asphalt content although the angle of internal friction reduced. It was concluded that using asphalt as a material for stabilization must be limited to reasonable concern with Gypseous soils.Ahmed, [7] stated that the cohesion of gypseous soil was 41 kPa and increased to 140 kPa after stabilization with emulsion. However, when gypseous soil was tested at absorption condition, the cohesion was found to be 29 kPa, but when the soil was stabilized with emulsified asphalt the cohesion increased to 53 kPa.Neto et al., [8] evaluated the shear strength parameters of mixtures of sandy soil with high asphalt emulsion contents for their use in geotechnical structures.Results showed that the use of a high asphalt emulsion content contributed to greater homogeneity of the mixtures. It was also found that the presence of residual asphalt gave a bilinear behavior to the sandy soil for the failure envelopes obtained from direct shear tests.

The aim of the present assessment is evaluating the influence of repeated shear stresses applied in the form of single and double punching on the deformation variables (total, resilient, and permanent) on asphalt stabilized subgrade soil.

MATERIALS AND METHODS

Subgrade Soil

The subgrade soil was obtained from Al-Taji district, north of Baghdad. The topsoil was removed to a depth of 30 cm, then the soil was excavated from a depth of one meter. Table 1 exhibits the properties of the subgrade soil. It can be noted that the soil is classified as poorly graded sand. Table 2 presents the chemical composition of the soil.

Table 1. Physical Properties of Subgrade Soil

Property as per ASTM, [9]	Test results
Specific gravity	2.620
Liquid limit	23
Plasticity index	Non plastic
Maximum dry density (modified compaction) (gm/cm ³)	1.760
Optimum moisture content (%)	16
Unified soil classification	SP
AASHTO Classification	A3
Coefficient of uniformity	0.260
Coefficient of curvature	60

Table 2. Chemical Composition of the Soil

Chemical composition	Test results
Total soluble sult (%)	1.31
Calcium carbonate (%)	1.11
Calcium sulphate (%)	1.06
Potential of hydrogen (PH)	10

Liquid Asphalt Binder

Cutback asphalt (MC-30) was implemented as liquid asphalt binder for stabilization. It was produced at Dourah refinery in accordance with ASTM D-2027, [9]. The properties of cutback as supplied by the refinery are listed in Table 3.

Table 3. Properties of Cutback Asphalt

Property	Test results
Grade	MC-30
Viscosity (Cst.) at 60°C	30-60
Flash point °C, (minimum)	38
Water (% V) (maximum)	0.2
Distillation test	(% V) of total distilled (maximum)
To 225 °C	25
To 260 °C	40-70
To 315 °C	75-93
Test on residue from distillation	
Penetration (25°C, 100 gm, 5 seconds, 0.1 mm)	120-250
Ductility (25°C, cm) minimum	100
Solubility in Trichloro ethylene (% wt.) minimum	99.0

Preparation of Asphalt Stabilized Soil Mixture

Soil passing sieve No.4 has been implemented. The soil was dried at a temperature (100C) for constant weight; the soil was then mixed with different percentages of water and liquid asphalt. Cut-back asphalt was mixed with the required water content by hand for 2 minutes till the mix become homogenous. After that, the essential several percentages of cut-back

asphalt were added and mixed for 2 minutes until the mixture combination become homogenous and exhibit proper coating of soil particles with asphalt. The optimum fluid content used was (6% cutback asphalt +10% water). Details of obtaining the optimum moisture and cutback content could be found at Sarsam and Kais, [4]. The asphalt stabilized soil mixture was left for aeration at laboratory temperature of 22 ± 2 for two hours as recommended by Sarsam et al., [10].

Preparation of Asphalt Stabilized Soil Specimens

Two sets of specimens have been prepared, the first set consists of asphalt stabilized soil compacted in the mold of 100 mm diameter and 63 mm height while the second set consists of asphalt stabilized soil compacted in the mold of 152 mm diameter and 127 mm height. The compaction of both sets of specimens was conducted to a target maximum dry density of 17.6 kN/m^3 and at the optimum fluid content of 16%.

Specimens with (15.5 and 16.5) % cutback were also prepared to assess the impact of binder content on deformation. Specimens were subjected to curing for seven days at room temperature as recommended by Sarsam and Prakash, [11] before testing.

Repeated Double Punching Shear Test

The first set of specimens were conditioned in the PRLS chamber at laboratory temperature of $20\pm 1^\circ\text{C}$ for 30 minutes, then the specimen in the mold was centered on the horizontal diametrical plane between two identical steel punches which have diameter of 25.4mm and height equal to 50 mm. Repeated Uniaxial compressive loading was applied. The constant stress was applied throughout the time of the test in terms of double punching shear stress. The load excitation function is a rectangular wave with steady frequency equal to one cycle of 10 Hz per second.

A maximum load pulse time is (0.1) second and (0.9) second is the rest period used throughout the interval of test. Before starting test, the pressure actuator was regulated to the specific pressure level of (55.16 kPa). LVDT was used to measure the deformation every second (every cycle) till the test is completed. The specimen was subjected to repeated double punching shear stresses from top and bottom surfaces, the repeated loading continued up to 1800 repetitions. Two specimens for each fluid content have been tested and the average deformation was considered. Figure 1. Shows the test setup for double punching shear strength.

Repeated Single Punching Shear Test

The second set of specimens were conditioned in the PRLS chamber at laboratory temperature of $20\pm 1^\circ\text{C}$ for 60 minutes, then the specimen in the mold was centered on the horizontal diametrical plane and the steel plunger was fixed on the top surface of the specimen. Repeated Uniaxial compressive loading was applied. The load excitation function is a rectangular wave with steady frequency equal to one cycle of 10 Hz per second. A maximum load pulse time is 0.1 second and 0.9 second is the rest period used throughout the test. Before starting test, the pressure actuator was regulated to the specific pressure level of (55.16 kPa). LVDT was used to measure the deformation every second (every cycle) till the test is completed. The specimens were subjected to repeat single punching shear stress applied on the top surface. Two specimens for each fluid content have been tested and the average deformation was considered. Figure 1. Shows the test setup for single punching shear strength.

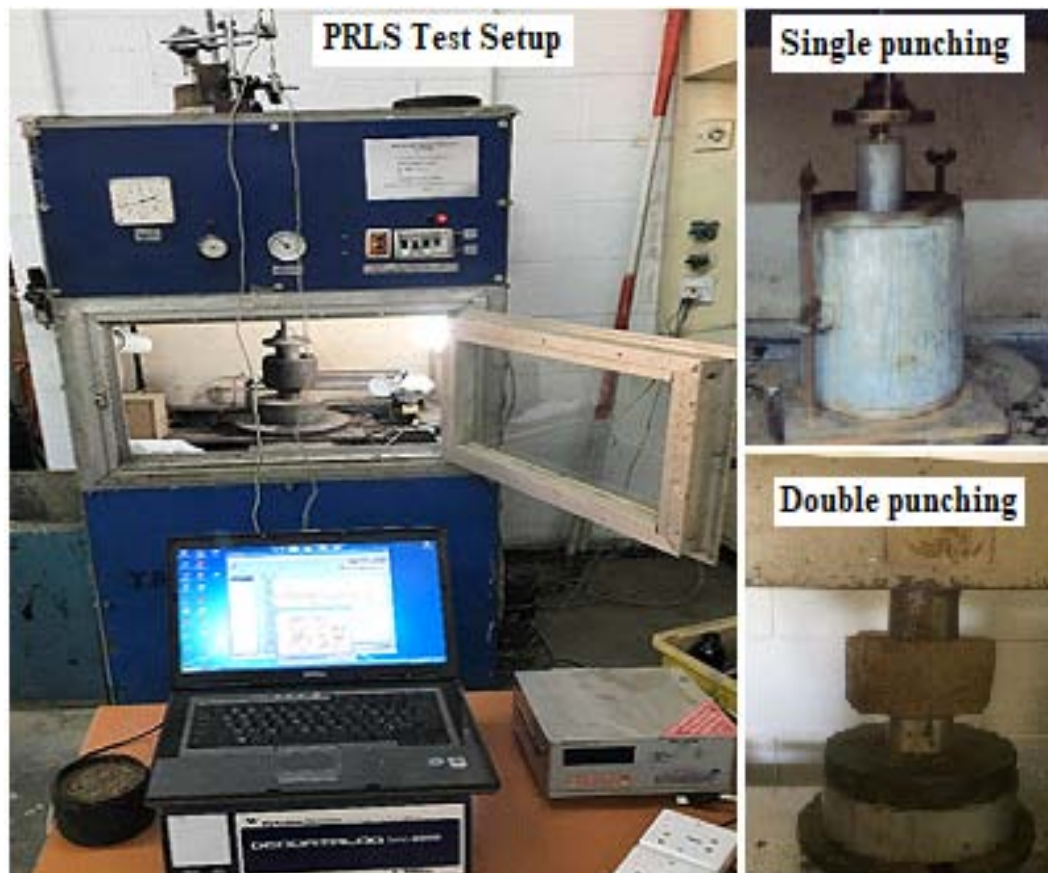


Fig. 1. Testing Apparatus and Test Setup

RESULTS AND DISCUSSIONS

Influence of Testing Technique on Percent Strain

Figure 2 demonstrates the influence of testing technique on percent strain of the mixtures; it can be observed that cutback asphalt stabilization declines the strain variables as compared with untreated soil. However, the strain increases as the binder content increase. In general, the strain under single punching shear stress is lower than that under double punching shear stresses. This may be attributed to the fact that the double punching action on the restricted specimen size in the mold applied from and bottom portions of the specimen's causes over compaction through the height of the specimen.

While, in case of single punching shear stress, the loading is applied on the top portion of the specimen. The diameter of the specimen is 52 % wider than that of the specimens practicing double punching shear stresses and the deformation can traverse in both vertical and lateral directions. It can be noticed that significant reduction in total, permanent, and resilient strain could be detected after cutback asphalt was implemented in the soil. In addition, asphalt stabilization exhibits an improvement in the resistance to strain variables. It can be observed that double punching shear exhibit higher total, resilient, and permanent strain than that of single punching shear in a range of (35.7, 28, and 111)% for mixtures with 16.5 % cutback content respectively. Such behavior may be attributed to the fact that loading from top and bottom on the specimens will increase the confinement state and increase the resilient strain when the load was removed. Such behavior agrees with Sarsam and Kais, [4] findings.

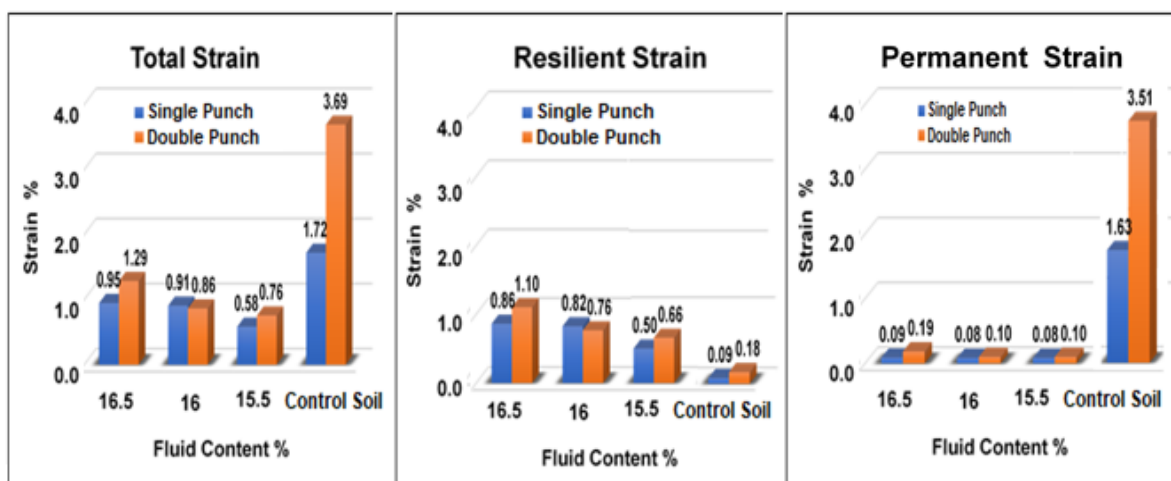


Fig. 2. Influence of Testing Technique on Percent Strain

Influence of Testing Technique on Total Deformation

Figure 3 exhibits the total deformation of untreated and stabilized soil under single punching shear stresses, it can be observed that the untreated soil exhibit the highest total deformation as compared with the asphalt stabilized soil. However, 15.5 % cutback content shows the lowest total deformation as compared with other mixtures. At failure, the reductions in total deformation of the mixtures after stabilization are (64.4, 44.4, and 46.6) % for (15.5, 16, and 16.5) % cutback content respectively. This may be attributed to cohesion created between soil particle and asphalt binder which provide strength and good resistance to deformation under the repeated shear stresses. However, after the first load repetition, the reductions in total deformation due to stabilization are (63.3, 50, and 36.6) % for (15.5, 16, and 16.5) % cutback content respectively.

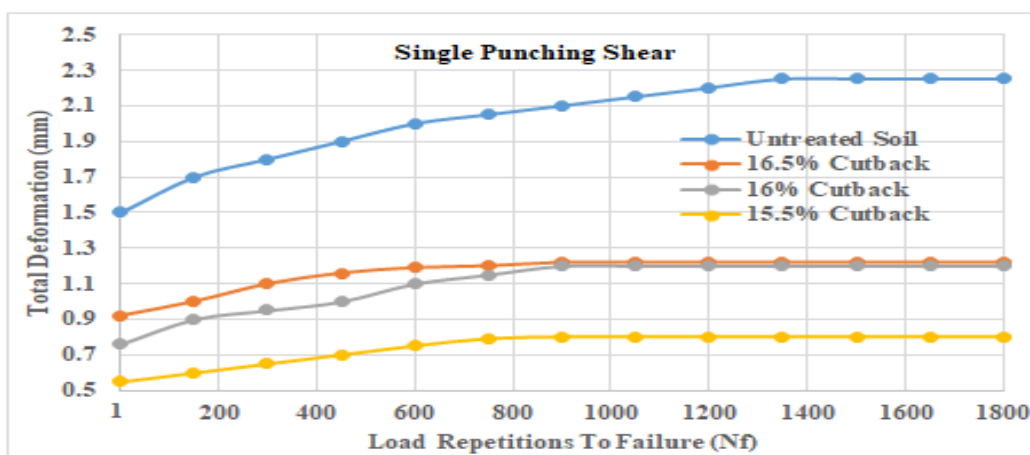


Fig. 3. Total Deformation Under Single Punching Shear Stresses

Figure 4 shows the total deformation of untreated and stabilized soil under double punching shear stresses, similar behavior of asphalt stabilization could be noted. It can be noticed that the deformation under double punching shear stresses is higher than that measured under single punching shear stresses by 13.4 % for untreated soil. The total deformation of asphalt stabilized soil at failure for specimens practicing double punching shear stresses is lower by (28, 50, and 43.7) % than that of specimens practicing single punching shear stresses for cutback content of (16.5, 16, and 15.5) % respectively. This may be attributed to the fact that

implementation of asphalt binder was able to provide cohesion that can sustain the height of the specimen when loading was splitted and acting from top and bottom of the specimen. Similar behavior was reported by Taha, [12].

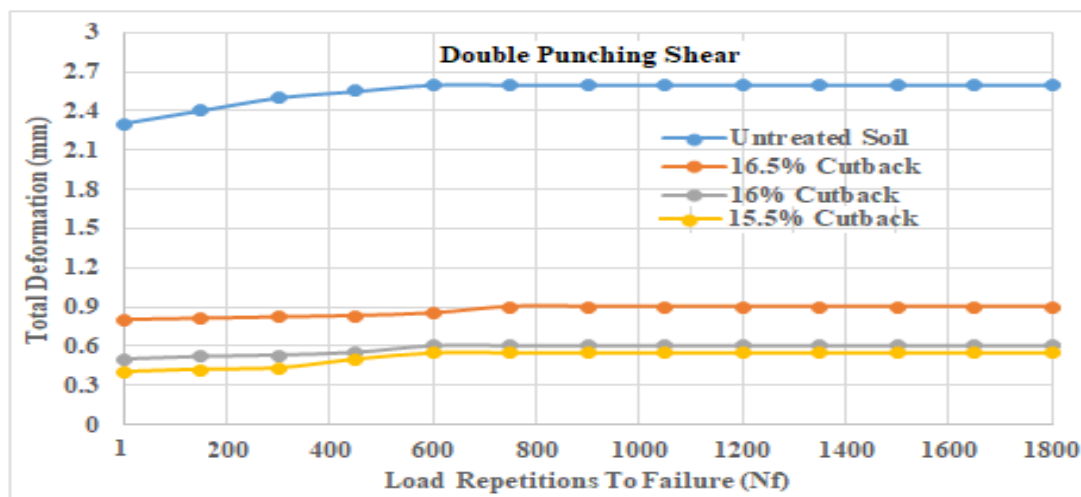


Fig. 4. Total Deformation Under Double Punching Shear Stresses

However, similar behavior can be noticed at the initial stages of load repetitions. On the other hand, the total deformation of untreated soil increases by (53.3 and 15.5) % after one loading cycle and at failure respectively when the specimen is tested under double punching shear stresses.

Influence of Testing Technique on Resilient Deformation

Figure 5 demonstrates the resilient deformation under repeated single punching shear stresses for untreated and stabilized soil. It can be observed that as the binder content increases, the resilient deformation increases. This may be attributed to the added flexibility to the soil by implementation of cutback asphalt.

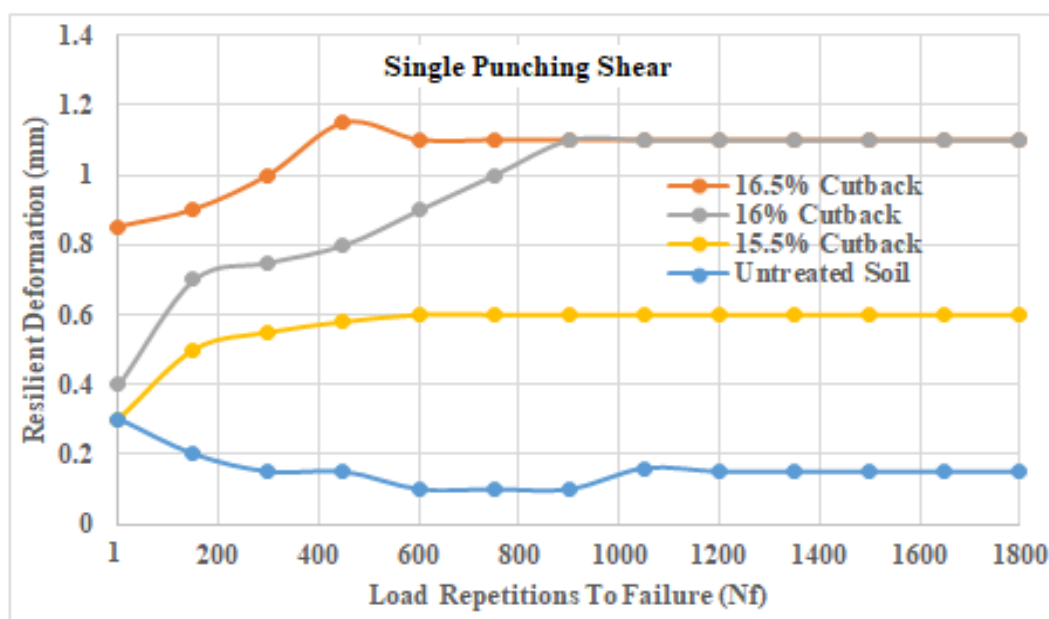


Fig. 5. Resilient Deformation Under Single Punching Shear Stresses

The resilient deformation at failure increased by (215, 470, and 478) % after implementing (15.5, 16, and 16.5) % cutback asphalt as compared with untreated soil. However, after the first load repetition, the resilient deformation increased by (1, 33.3, and 183) % after implementing (15.5, 16, and 16.5) % cutback asphalt as compared with untreated soil. Figure 6 exhibit the impact of applying double punching shear stresses on resilient deformation of untreated and the asphalt stabilized mixtures. It can be noticed the resilient deformation is restricted under double punching shear stress application as compared to the case under single punching shear test. The resilient deformation after the first load repetition declines by (14.2, 2.5, 17.6) % for mixtures with (15.5, 16, and 16.5) % cutback asphalt respectively when tested under double punching shear as compared to the case of testing under single punching shear test. However, at failure, the resilient deformation declined by (28.5, 48, and 16.6) % after implementing (15.5, 16, and 16.5) % cutback asphalt as compared with single punching shear test. Such behavior was in agreement with Sulaiman and Sarsam, [13].

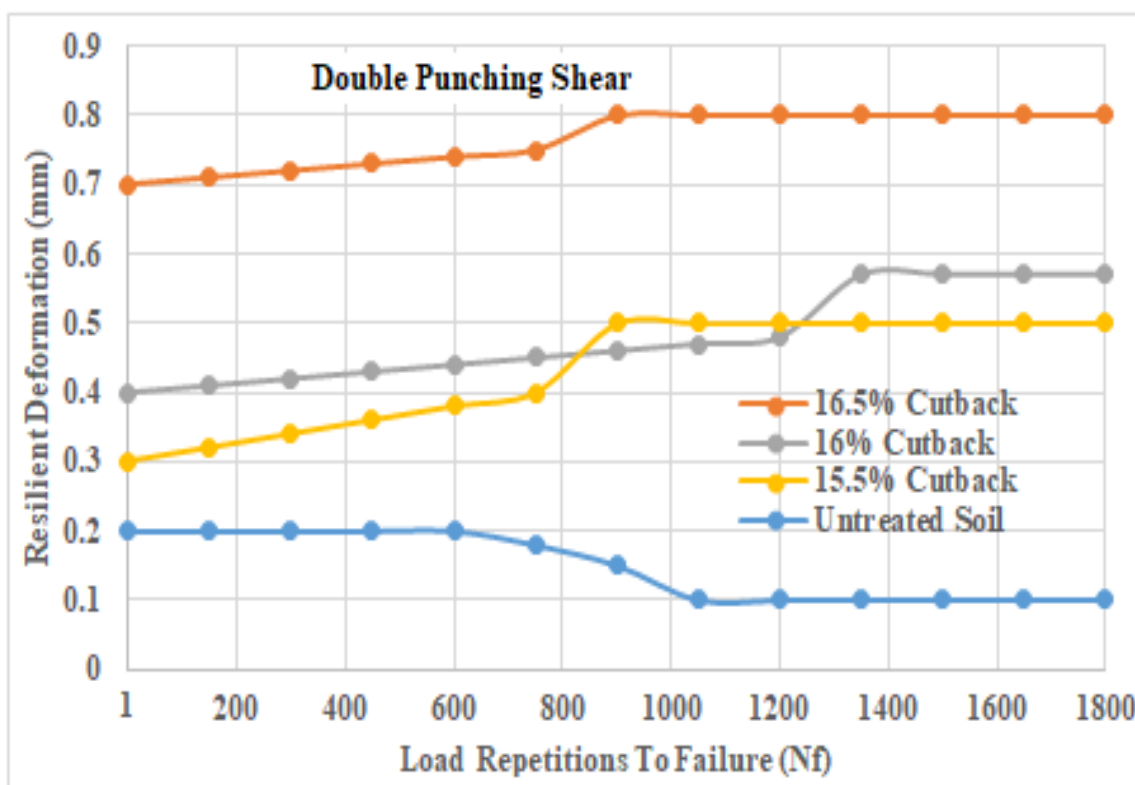


Fig. 6. Resilient Deformation Under Double Punching Shear Stresses

Influence of Testing Technique on Permanent Deformation

Figure 7 demonstrates the permanent deformation of the mixtures after practicing single punching shear stresses, it can be noticed that significant reduction in permanent deformation exists after asphalt stabilization as compared with untreated soil.

At failure, the reductions in permanent deformation of the mixtures after stabilization are (90.4, 95.2, and 94.4) % for (15.5, 16, and 16.5) % cutback content respectively.

However, after the first load repetition, the reductions in permanent deformation due to stabilization are (76.6, 70.8, and 41.6) % for (15.5, 16, and 16.5) % cutback content respectively. such finding agrees with Kadhim, [14].

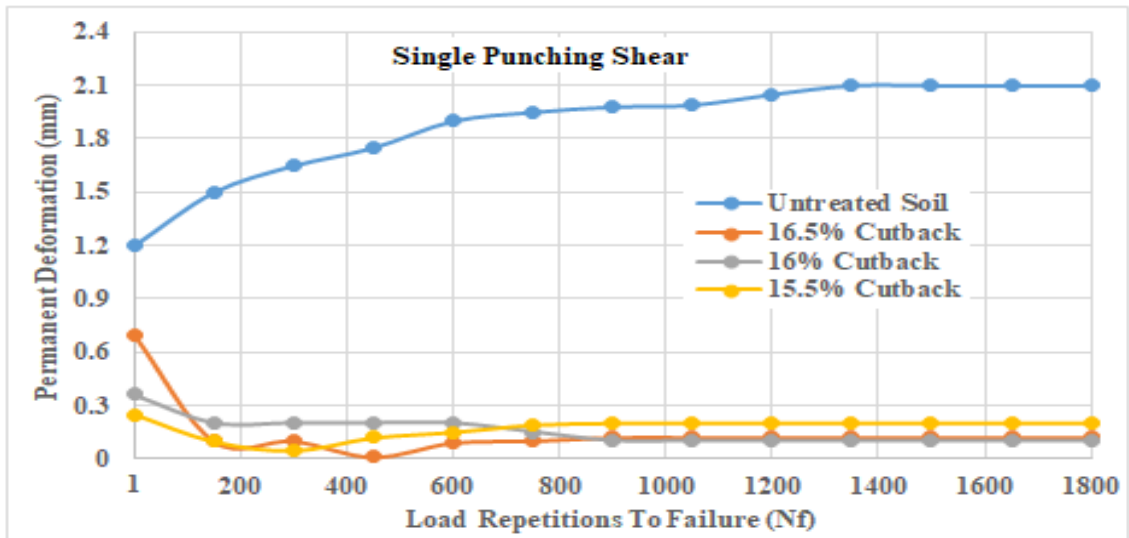


Fig. 7. Permanent Deformation Under Single Punching Shear Stresses

Figure 8 exhibit the permanent deformation of the mixtures under double punching shear stresses. For untreated soil, the permanent deformation increased after the first loading cycle and at failure by (75 and 19) % respectively when the specimen is tested under double punching shear stress as compared with the testing under single punching shear stresses.

However, for cutback asphalt stabilized soil mixtures, the permanent deformation declines after the first load repetition by (64.2, 71.4, and 85.7) % for mixtures with (15.5, 16, and 16.5) % cutback content respectively after practicing double punching shear stress as compared with mixtures practicing single punching shear stresses. The variation in permanent deformation at failure of asphalt stabilized soil is not significant among cutback content or testing technique. The permanent deformation declines at failure by (50, 77, and 10) % for mixtures with (15.5, 16, and 16.5) % cutback content respectively after practicing double punching shear stress as compared with mixtures practicing single punching shear stresses.

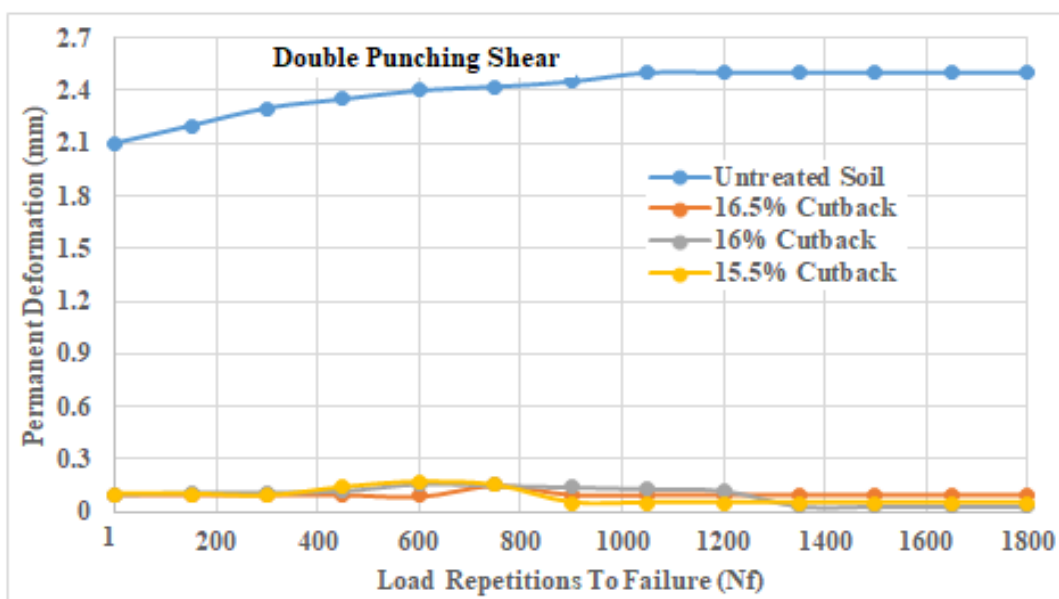


Fig. 8. Permanent Deformation Under Double Punching Shear Stresses

Figure 9 exhibit the summary of the variations in deformation under both testing techniques for untreated soil and for cutback asphalt stabilized soil. It can be noted double punching shear exhibit higher deformation than single punching shear for untreated soil. The intercept and the slope of the relationship are higher than those of asphalt stabilized soil relationship. However, the asphalt stabilized soil mixtures exhibit higher deformation under single punching shear stresses than that under double punching shear stresses. The slope and the intercept are lower than those of untreated soil by (38.4 and 97.6) % respectively.

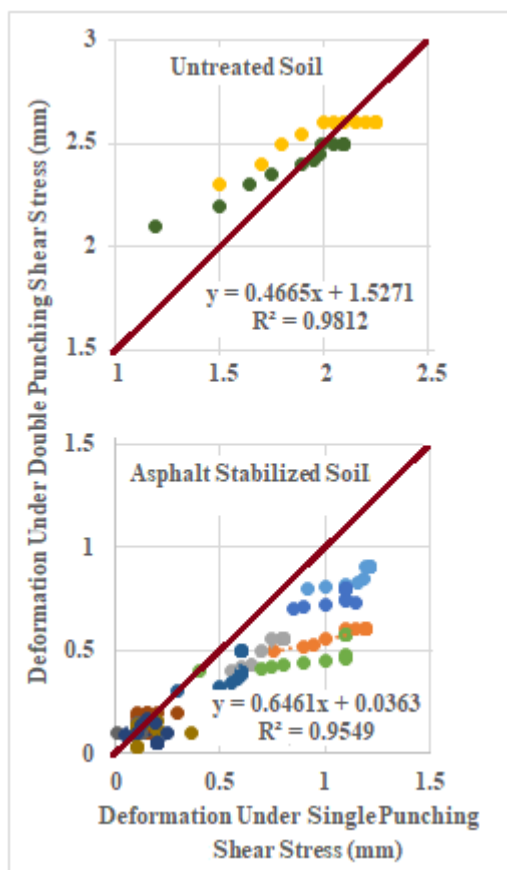


Fig. 9. Variations in Deformation under Both Testing Techniques

CONCLUSIONS

Based on the testing program and limitations of materials, the following conclusions may be drawn.

- 1) Double punching shear exhibit higher total, resilient, and permanent strain than that of single punching shear in a range of (35.7, 28, and 111)% for mixtures with 16.5 % cutback content respectively.
- 2) The total deformation of asphalt stabilized soil at failure for specimens practicing double punching shear stresses is lower by (28, 50, and 43.7) % than that of specimens practicing single punching shear stresses for cutback content of (16.5, 16, and 15.5) % respectively.
- 3) The resilient deformation at failure declines by (28.5, 48, and 16.6) % for mixtures with (15.5, 16, and 16.5) % cutback asphalt respectively when tested under double punching shear as compared to the case of testing under single punching shear test.
- 4) The permanent deformation declines at failure by (50, 77, and 10) % for mixtures with (15.5, 16, and 16.5) % cutback content respectively after practicing double punching shear stress as compared with mixtures practicing single punching shear stresses.

- 5) Double punching shear exhibit higher deformation than single punching shear for untreated soil. However, the asphalt stabilized soil mixtures exhibit higher deformation under single punching shear stresses than that under double punching shear stresses.

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