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EVALUATION OF PULL OUT CAPACITY FOR DEFORMED STEEL BARS EMBEDDED IN TIRE SHRED-SAND MIXTURE USING DIRECT SHEAR APPARATUS

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Abstract: *In the past many decades, the production of scrap tires increased in world. These tire are non-biodegradable in nature. In Pakistan a huge amount of tires are used for burning which caused environmental pollution and many health related issues. To overcome this issue, the scrap tire are used in many civil engineering projects as additives or replacements of geo-synthetic materials to reduce the hazardous effects. The scrap tires are used in many construction projects, i-e, in mechanically stabilized earth retaining wall, bridge embankments and as a fill material in other retaining structures. To calculate the pull-out resistance and friction angles for mechanically stabilized earth retaining wall, a numbers of laboratory pull-out and large scale direct shear tests were performed. In this research pull-out tests are conducting using different dia of deformed steel bars that are embedded in tire-shred sand mixture of different tire sizes and ratio respectively. The effect of confining pressure and tire- shred size on the pull-out capacity of the reinforcement in tire shred–sand mixtures are evaluated. Mixtures of sand with tire-shred of sizes 50, 75 and100 mm are prepared. Modified proctor tests are performed on different tire shred-sand mixing ratios (0, 20, 30 & 40% by weight of sand). From these results, it is encountered that MDD, for different tire-shred size (50, 75 &100mm), was achieved at 20% tire sherds-sand mixture. Pull-out tests and LSDS tests are conducted under three different normal stresses 20kPa, 40kPa and 60kPa for different tire-shred sizes at MDD. From the test results, it is determined that the deformed steel bar reinforcement offered higher pull-out resistance in tire sherds-sand mixtures than the pull-out resistance in sand alone. Subsequently internal shear resistance increased with the increase in the tire-shreds ratio. Moreover results also indicate that the pullout resistance and shear strength increased with increase in tire shreds size and size of deformed steel due to increase of contact area.*

Keywords*-shear strength; tire sherds; deformed bars; large scale direct shear test; pull out test*

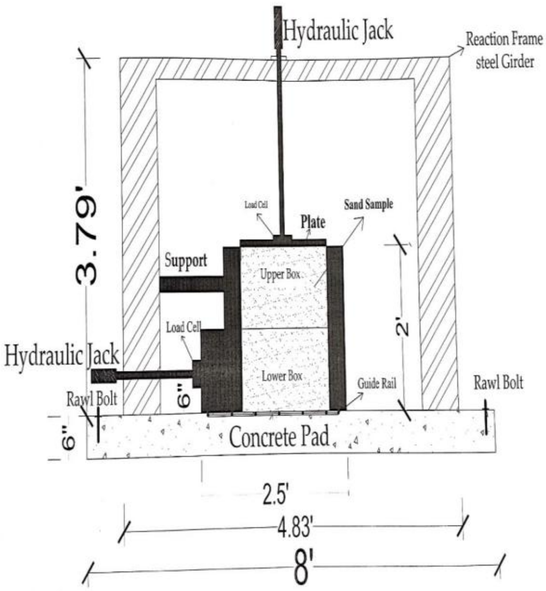
1. INTRODUCTION

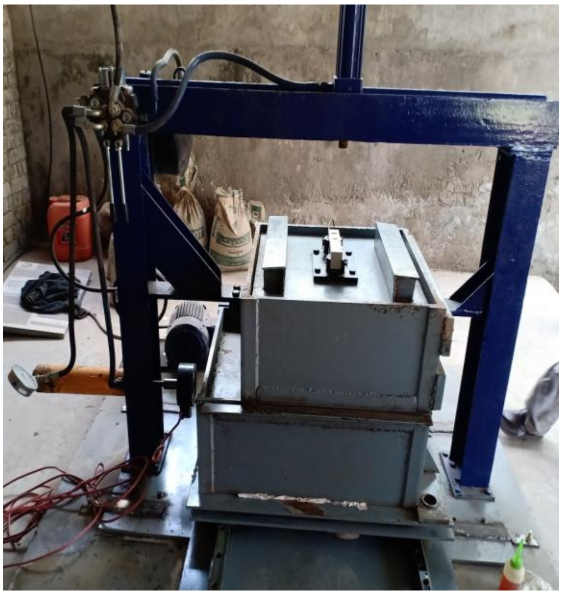
Soil is a natural material and its properties depends upon types of soil, which mainly consist of cohesion c and angle of internal friction. During the free flow of dry soil, it makes a natural slope and this slope is not in a vertical face. To retain the soil in a straight or in some required angle of inclination, it is required to build vertical supports like earth retaining structures [1]. Generally there are two basic retaining structures i-e externally stabilized and internally stabilized structure. Externally stabilized walls which are constructed by large materials size on the outside of the soil mass to restrain soil failure by their weight and internally stabilized earth walls, in which reinforcements are used in the soils to stabilize the soil mass to countering lateral thrust. These internally stabilized walls are generally known as mechanically stabilized earth [2]. MSE wall has number of advantages. They are easy to construct and take less time as compared to concrete retaining walls. MSE walls have the advantage to construct up to 60ft [3] and its construction does not require special skills labors or heavy machinery. .The construction of a MSE wall is cost effective, requires less site preparation, and is technically more feasible compared with a conventional concrete retaining wall. MSE walls can be constructed in a high seismic zones, at sites which have poor soil conditions, dam constructions and many more [4]. MSE walls now are the most commonly used earth retaining structures in the U.S transportation system which support bridge approach/ departure slabs and bridge decks, and retain embankment fill materials [5]. The backfill is generally clean granular cohesionless backfill materials with the innovation of new lightweight fills materials like shredded tires, geofoam, fly ash, plastic bottles etc are being explored as an additive with natural soil. These lightweight materials are beneficial in reducing earth pressures and lateral displacements of the retaining walls. One possible way for this problem is to finding new and beneficial methods to recycle and reuse the large volumes of scrap tires being an urban garbage [6]. The performance of the MSE wall strongly depends on the interaction and behavior of the backfill soil and rock materials with the components of MSE wall for successful wall design and performance [7]. Umashankar et al 2014, evaluate the effect of tire shred size, tire shred-sand mixing ratio and confining pressure on the interaction between the ribbed-metal strip and tire shred-sand mixtures using Large-scale laboratory pullout tests. Three sizes of tire shreds are considered: tire chips (with 9.5mm nominal size), tire shreds 50-to-100 mm and 100-to-200 mm in length, with mixing ratios of 0, 12, 25 and 100% of tire shreds in the mixtures (by weight) [8] . Cherdsak Suk siripattanapong 2013 used well-graded gravel, well-graded sand, poorly graded sand and crushed rock mixed with the tire shred of varying sizes from 50 to 100mm in length with irregular shapes. The backfill was prepared with different mixing ratios. The normal pressures were applied with the help of airbags. The ribbed reinforcements used in this study were 16mm in diameter and 2.6 meters in length. The result obtained from this study showed that the frictional pullout resistance was higher in the well-graded gravel than well-graded sand, poorly graded sand and crushed stone respectively. The pull-out friction resistance also increased with increase in the normal load [9]. A. Bernal et al evaluates the interaction properties of tire shred sand rubber-sand with geosynthetics through pullout testing and direct shear testing using a direct shear and pullout testing program. Woven geotextile and three different flexible geogrids (with different aperture sizes) within two different types of fill material are used as fill material. The first fill material was composed solely of tire shreds having a nominal area of 50mm×50mm, and the second fill material was a rubber-sand consisting of a mixture of the same tire shreds and a masonry sand. [10]

This research will focus on the evaluation of one of the important failure factor, failure due pullout resistance using deformed steel bars with tire sherds-sand mixture. The core aim of this work is to use local available materials for laboratory evaluation of pull-out resistance of MSE wall. Evaluation of Tire shred-sand mixture used as backfill for MSE walls against Shear load, lateral displacement and vertical deformation using LSDST apparatus. Subsequently evaluation of the pull-out performance of Deformed steel bar in Tire shred – sand mixture under different load conditions. The sample are prepared for different percentages of the tire shred with sand, for instance, 20/80 sample means that 20% is the tire shred and 80% is the sand by weight.

2. Test Apparatus

Tests are conducted in large scale direct shear test apparatus and is fabricated for this thesis. Shear box is designed as per ASTM D3080, which stated that box must be 6 times the size of largest particle. The machine consist of steel girder frame of size 3.8' x 4.8', placed on a concrete pad. Two boxes, the upper one is fixed and the lower box is movable, having dimensions of 2L x 2W x 1H and 2.6L x 2W x 1H in ft respectively. The lower box is used for both the tests pullout and DST. For normal and lateral pressures, jacks are installed as loading devices. For the application of vertical load, vertical jack having a capacity of the 150KN (15 tons) is used and for the application of the shearing force and pullout force, a horizontal jack of the capacity of 100KN (10 tons) is installed. Control levers are installed to control the flow of jack at a constant rate. A 5hp motor is also installed for power transmission to apply hydraulic pressure. Two load cells having the capacity of 150KN and 100KN are used to measure the normal forces and shearing forces respectively. Two LVDTs are installed to measure the shearing displacements and vertical dilation of the sample. Load cells and LVDTs are connected to the data acquisition system through data logger.





3. Data Acquisition system

The gathering of data is done through data loggers which feed figures in computer. This data logger records data of the time, shearing movement, vertical dilation, shearing force and normal force. A Matlab computer based software is used to collect data and this software draws graphs between the data, received from data logger connected to cords with desired channels.

4. Test Materials

Sand

The course sand which is used in this research project was obtained locally. Size distribution curve is shown as below

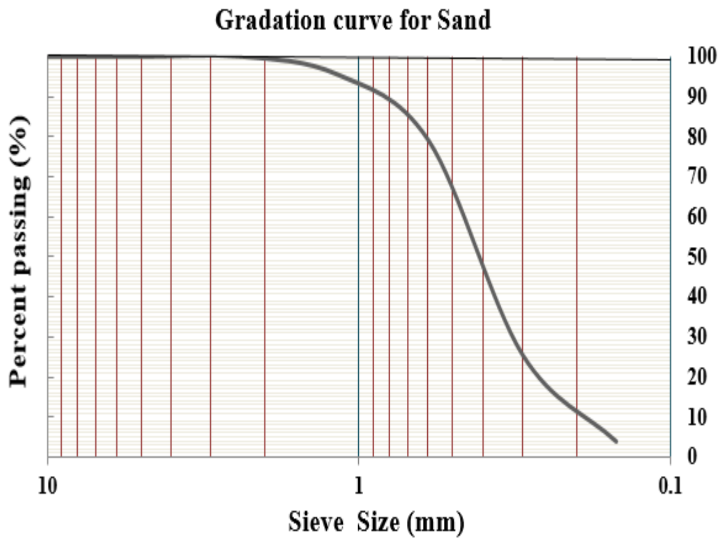


Fig 3.1 grans size distribution curve

Tire shred

Tires are cut into the required sizes as per ASTM 6270-08. In this study, different sizes of tire-shreds are used i-e 50, 75 and 100mm in length. According to the geometric consideration, the length of the tire shred was measured randomly using measuring tape.

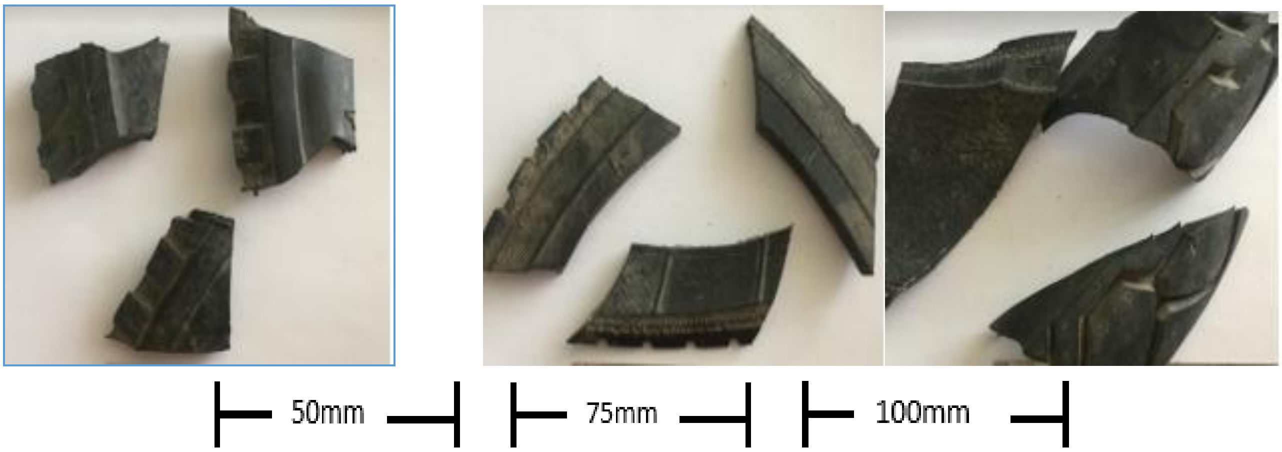


Figure: sizes of Tire-shreds

Deformed steel bar

Deformed steel round bars are selected as a reinforcement having tensile strength of 60Ksi as shown in figure. To achieve adequate contact friction, the dia is kept at least three times larger than the average (D 50) particle dia [22]. In this research, #4, #5 deformed bars are used. The length of the bar is kept 1.4ft (0.7H). Pull-out capacity depends upon two factors i-e frictional resistance between soil particles & reinforcement and the passive resistance due to contact area of bar.

Deformed steel bar

5. Modified proctor compaction test

Tests are performed to find optimum mixing ratio, MDD and OMC, modified proctor compaction tests are performed (ASTM 1557). The sample are prepared for different percentages of the tire shred with sand i-e 20/80 sample means that 20% is the tire shred and 80% is the sand by weight. The same procedure are adopted for all the tire-shred sizes.

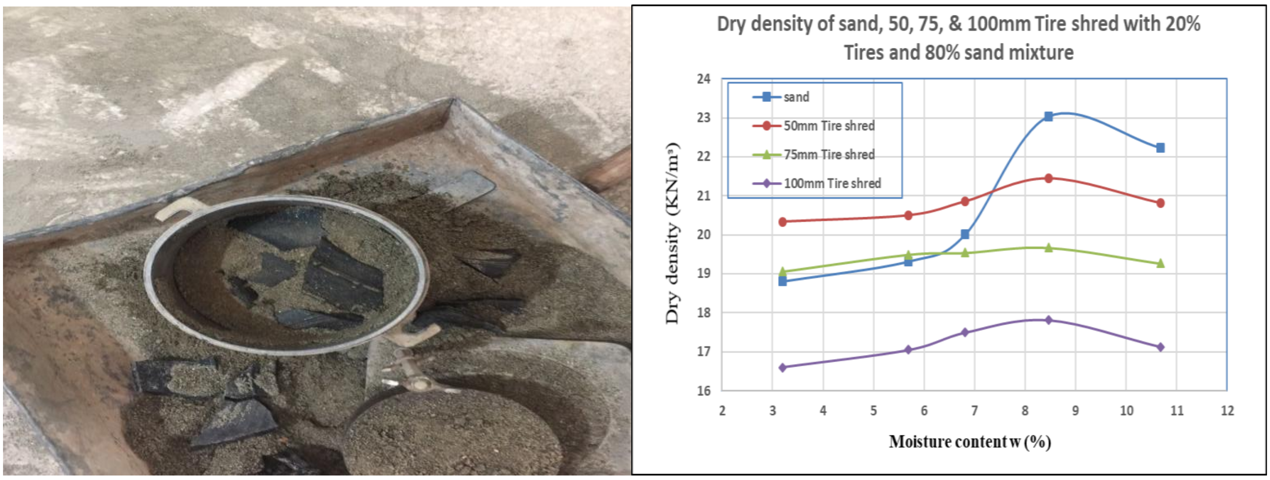
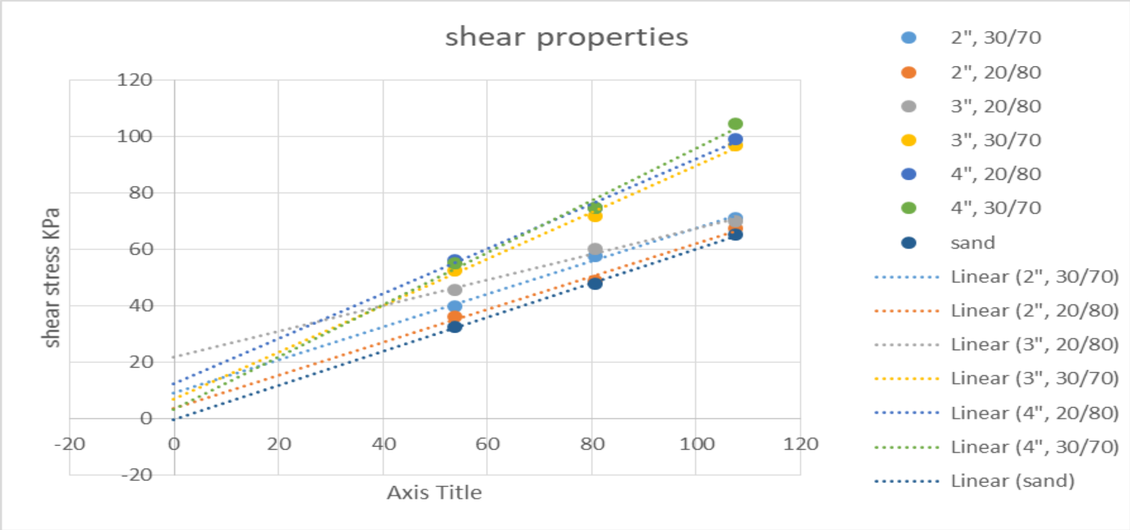


Fig 4.3 Compacted sample after tests and results

Size of shredded tires (mm)	Optimal mixing proportion of shredded-tires/sand (by weight)	$\gamma_{d,}$ (KN/m^3)	OMC
Sand only	0/100	23.0	8.46
50	20/80	21.5	8.46
	30/70	20.5	8.46
	40/60	20.0	8.46
75	20/80	19.7	8.46
	30/70	19.4	8.46
	40/60	18.4	8.46
100	20/80	17.9	8.46
	30/70	16.1	8.46
	40/60	16.5	8.46

6. Large scale direct shear test

07 x large scale direct shear tests are conducted to evaluate the shear strength of the tire sherds-sand mixtures. Shear stresses are applied through horizontal jack, capacity of 10tons. The data is recorded by load cell, which is linked to data logger for collecting data. In the apparatus, the lower box is moveable and the upper box is immovable. When the test is completed, the backfill material is removed and the apparatus is prepared again for the next test using the same procedures.

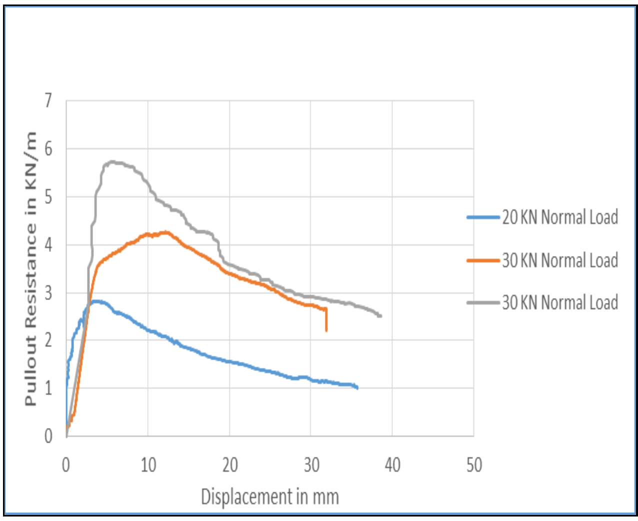


S.No	Mixing Ratio	Normal force	Fraction Angle	Cohesion; c	S= c+σ tan Φ
1	Only sand	20KN, 30KN, 40KN	31	0	32.0 KPa 48.5 KPa 64.7 KPa
2	20/80 , 50mm tire shred	20KN, 30KN, 40KN	30	3.95	35.0 KPa 50.5 KPa 66.0 KPa
3	30/70 50mm tire shred	20KN, 30KN, 40KN	30	9.40	40.2 KPa 56.0 KPa 71.5 Kpa
4	20/80 75mm tire shred	20KN, 30KN, 40KN	31	12.77	45.1 KPa 61.2 KPa 77.5 Kpa
5	30/70 75mm tire shred	20KN, 30KN, 40KN	39	7.25	50.8 KPa 72.6 KPa 94.4 Kpa
6	20/80 100mm tire shred	20KN, 30KN, 40KN	39	12.42	56.0 KPa 77.8 KPa 99.6 Kpa
7	30/70 100mm tire shred	20KN, 30KN, 40KN	42	3.70	52.1 KPa 76.3 KPa 100.6 Kpa

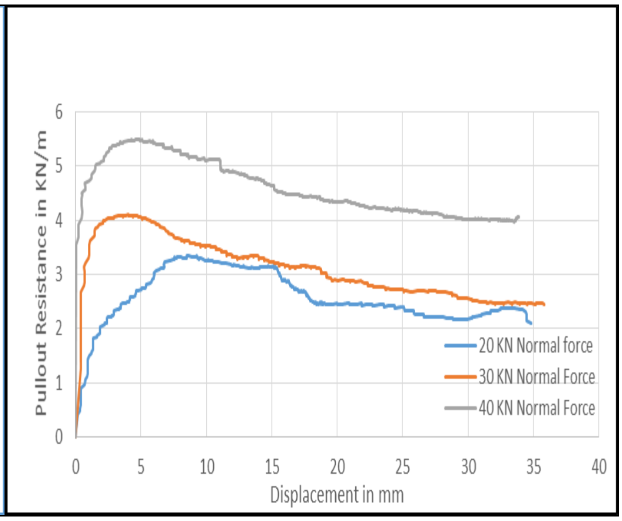
7. Pullout test

Two dia of deformed steel bars, i-e #4 and # 5, are used to assess the pull-out capacity of reinforcement in tire sherds-sand mixture. 42 tests are accomplished using different dia of deformed bars and different ratio of tire sherd-sand mixture. After application of normal pressures, pull-out value and displacement of deformed steel bar is calculated

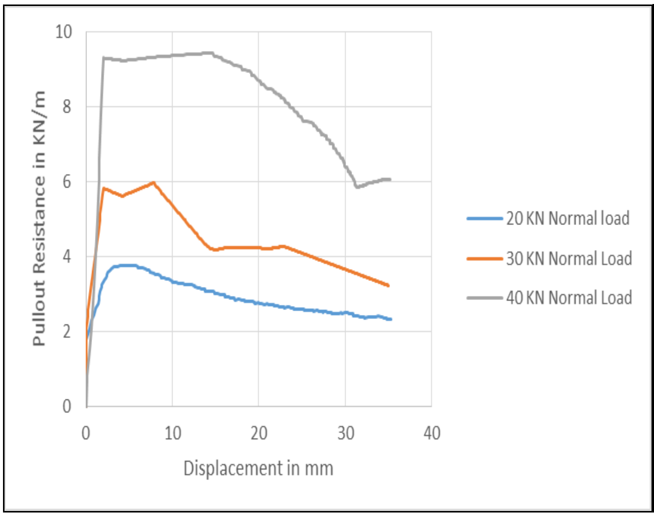
For sand



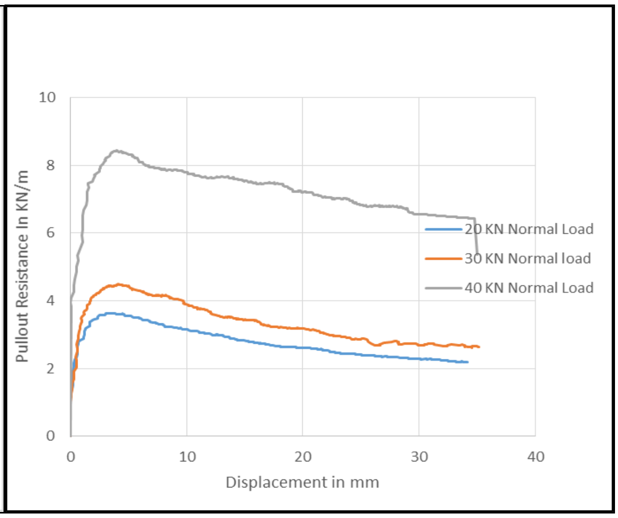
50mm tire-shred 20/80



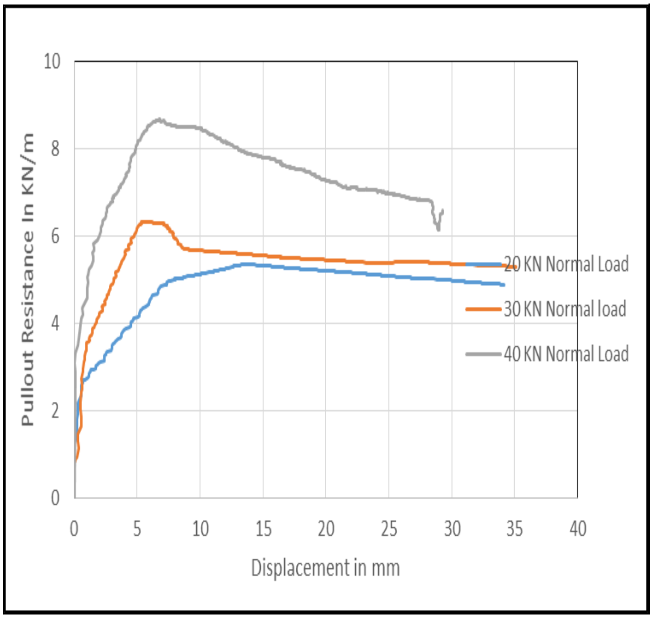
50mm tire-shred 30/70



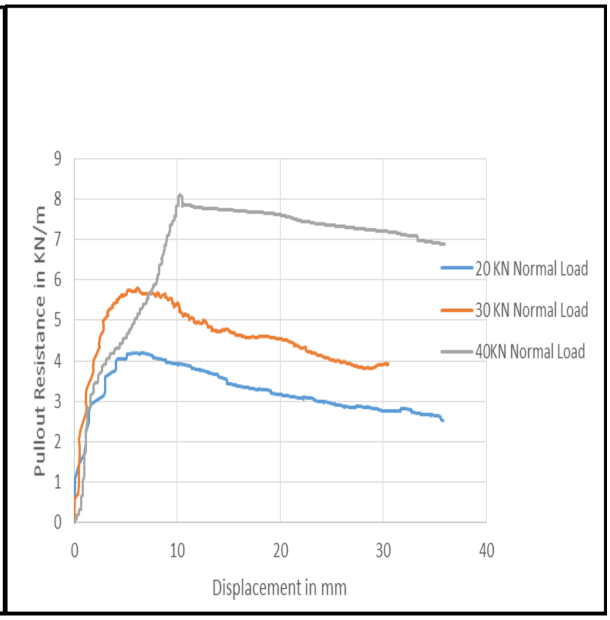
75mm tire-shred 20/80



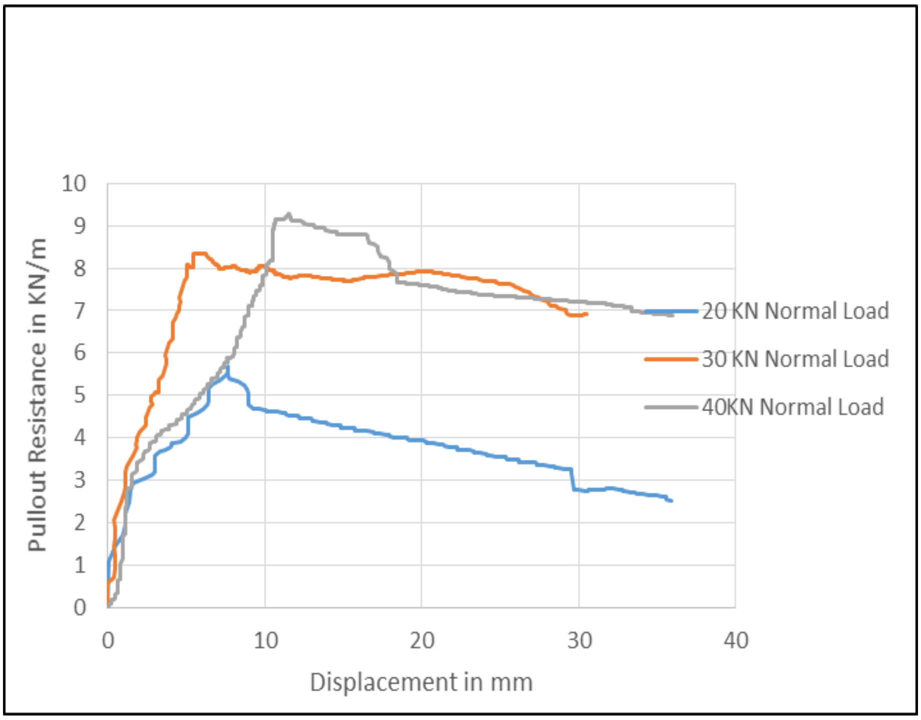
75mm tire-shred 30/70



100mm tire-shred 20/80



100mm tire-shred 30/70



No. 4 bar

S .NO	Size of the tire shred (mm)	Mixing ratio	Pullout resistance in KN/m	Normal load (KN)
1	Only sand	Only sand	2.8 4.3 5.3	20 30 40
2	50	20/80	3.4 4.1 5	20 30 40
3	50	30/70	3.9 5.8 9.5	20 30 40
4	75	20/80	3.4 4.5 8.5	20 30 40
5	75	30/70	5.1 6.2 8.6	20 30 40
6	100	20/80	4.2 5.8 8.1	20 30 40
7	100	30/70	5.6 8.1 9.2	20 30 40

8. Conclusion

Results show that Shear strength increases with increase in the normal stress. Similarly, shear strength increases with the increase in the percentage and size of the tire shred. The pullout resistance of the deformed steel bar embedded in the tire shred-sand mixture are larger than the sand alone. The pullout capacity of the deformed steel bar increases with increase in the normal load. The pullout capacity of the deformed bar also increase with the increase in the tire shred size and percentage. The pullout capacity of the deformed steel bar also increase with the increase in the diameter of the steel bar due to contact area.

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