EXPERIMENTAL STUDY ON BEARING CAPACITY IMPROVEMENT OF SANDY SOIL USING WASTE TYRE CHIP AND GEOGRID REINFORCEMENT

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Abstract: With rapid development of infrastructure and industrialization, ground improvement is needed to meet demand of heavy loads from industrial structures, high rise buildings, bridge pier etc. Huge growth of used tyres may cause environmental hazard and its disposal is one of the greatest challenges today. In the paper an innovative technique using waste tire-chip reinforcement is used to get very high increase in bearing capacity of sandy soil to meet demand of heavy loads from industrial structures, high rise buildings, bridge pier etc. Model footing tests were conducted in a test box of size 800 mm long, 77 mm wide and 400 mm deep on Solani river sand reinforced with tire-chip. A model footing of size 75 mm x 75 mm was used. Both tyre-chip content and depth of tyre-chip reinforced layer were varied. It was found that with increase in tyre-chip content bearing capacity increases and a maximum of 20% tyre-chip content can be used. By adding 20% tyre-chip content in the top 2B depth below footing BCR (bearing capacity of reinforced soil to bearing capacity of sand alone) increased to more than 6. To further increase bearing capacity another innovative technique is used by adding geogrid reinforcement also in addition to tyre-chip. Maximum increase in bearing capacity using only geogrid reinforcements was found by 3 layers of geogrid of sizes 75mm x 375 mm placed at spacing of 0.33B below footing. In this case BCR is 3.5. By further adding 5%, 10% and 20% tire-chip up to 2B depth below footing BCR increased to 5.0, 7.3 and 9.3 respectively. Such a high increase in bearing capacity of soil can permit use of isolated footings and prove to be an economical solution for foundations subjected to heavy loads. Also it will serve the purpose of disposal of waste tyre-chip in a beneficial way.

Keywords: bearing capacity, tire chip, geogrid, soil improvement

INTRODUCTION

Past research has demonstrated that random inclusion of discrete tire-chips significantly improves the engineering properties of soils. Waste tires are used for reinforcing soft soil in road construction, to control ground erosion, for stabilizing slopes, as lightweight material for backfilling in retaining structures. Bosscher et al. (1993) reported that an embankment constructed with sand–tire shreds satisfactorily operated even when subjected to heavy loads. Tire shreds have been successfully used in road embankment, and has been reported by Hoppe (1994) and summarized by Rao and Dutta (2001). Hataf and Rahimi (2006) carried out laboratory test on the model of shallow footing resting on sand reinforced with tire shreds. Five shred contents of 10%, 20%, 30%, 40% and 50% by volume were selected. Addition of tire shreds to sand increases BCR (bearing capacity ratio) from 1.17 to 3.9 with respect to shred content and shreds aspect ratio. The maximum BCR was attained at shred content of 40% by volume. It was shown that increasing of shred content increases the BCR. However, an optimum value for shred content was observed after that increasing shreds led to decrease in BCR.

Attempts were made to meet demand of heavy loads by increasing bearing capacity of soil by geogrid reinforcement. This technique is very well established based on last twenty years research (Binquet and Lee, 1975; Akinmusuru and Akinbolade, 1981; Fragszy and Lawton, 1984; Guido et al., 1986; Huang and Tatsuoka, 1990; Sridharan et al., 1988; Dixit and Mandal, 1993; Khing et al., 1993; Yetimoglu et al. 1994; Adams and Collin, 1997, Kumar and Saran, 2003, Dash et al., 2004) on it. Maximum increase in bearing capacity is found to be 3 to 4 times of virgin soil depending upon size, position and number of layer etc. of reinforcement.

For industrial structures, high rise buildings, bridge pier etc. normally deep foundations or rafts resting on piles are adopted due to low bearing capacity of soil in comparison to heavy loads imposed by these structures. Such alternatives are very costly in comparison to shallow foundations such as isolated and combined footings. Both randomly distributed tire-chip reinforcement and geogrid reinforcement can be used for increasing bearing capacity of soils. In present paper an innovative technique using combined tire-chip and geogrid reinforcement is explored to get significant increase in bearing capacity of sandy soil to meet demand of heavy loads.

EXPERIMENTAL PROGRAMME

Test Material

Sand was obtained from Solani river bed passing nearby Roorkee town. This sand is characterized as poorly graded sand (SP). Its various properties; specific gravity of solids (G_s), average grain size (D_{50}), coefficient of uniformity (C_u), maximum void ratio (e_{max}) and minimum void ratio (e_{min}) are given in Table 1.

Table 1. Properties of Soil Used in the Investigation

Soil Classification	G_s	D_{50} (mm)	C_u	e_{max}	e_{min}
SP	2.63	0.27	1.8	0.84	0.48

Tire-chips of size 10mm x 20mm are obtained by manually cutting tyres. Geogrid is Netlon CE 121, made of polypropylene and its important properties are given in Table 2.

Table 2. Geogrid Properties

Property	Material	Colour	Mass (gm/m^2)	Tensile strength (kN/m)	Thickness (mm)
Typical Values	Polypropylene	Black	730	7.68	3.3

Model Footing Test

Model footing tests were conducted to investigate the pressure settlement behaviour of unreinforced and reinforced sand with randomly distributed tire-chips and geogrids. All tests were conducted on the footing of size 75 mm x 75 mm in a tank of size 800 mm x 77 mm x 400 mm (deep). The base of the footing was made rough, to simulate the roughness of actual footings. Mercer et al. (1984) carried out small plane footing tests on dry sand with and without Mesh Elements at mesh content of 0.19%. The bearing capacity increased with increase in soil-mesh layer up to a thickness of 2B, beyond this point there was no significant increase in the bearing capacity of the footing. Thus, tire-chip reinforced sand was placed in the tank in layers in top 2B depth below footing and each layer was compacted using hand rammer to achieve the desired relative density. The footing was placed in the middle of the tank. The level of the footing was checked by sprit level. Load was applied through hand operated jack of 10kN capacity. Tests were conducted on sand reinforced with geogrids alone also to find its optimum condition. Tests were conducted on sand reinforced with tire chip and geogrid simultaneously. Model footing tests were performed under central-vertical load to study the pressure settlement curves of the Geogrid and tire-chip reinforced sand. In all tests a relative density of 30% was maintained.

TEST RESULTS AND DISCUSSION

In cases where a peak load cannot be established with certainty, the conventional ultimate bearing capacity is defined as the load causing a relative settlement 10% of the footing width (B) (Vesic, 1973). In present study for comparison ultimate bearing capacity is taken as pressure corresponding to 10% settlement ratio. Figure 1 shows the pressure settlement curves of the unreinforced sand and sand reinforced with tire chip. This figure 1 indicates that by inclusion of tire chips overall pressure-settlement curve improves significantly. By using 5%, 10% and 20% tire-chip content by weight in 2B depth below footing BCR increases to 2.92, 4.8 and 6.7 respectively. Bearing capacity increased at all settlement ratio and settlement reduced at any pressure intensity. Up to 5% settlement ratio a continuous improvement is noticed in comparison to unreinforced soil. However, beyond 5% settlement ratio pressure settlement curves are almost parallel. Beyond 20% tire chip content it becomes difficult to compact the soil and maintain the density of sample. Maximum benefits are available up to 20% tire chip content after that benefits obtained by interaction between tire chip and sand start reducing.

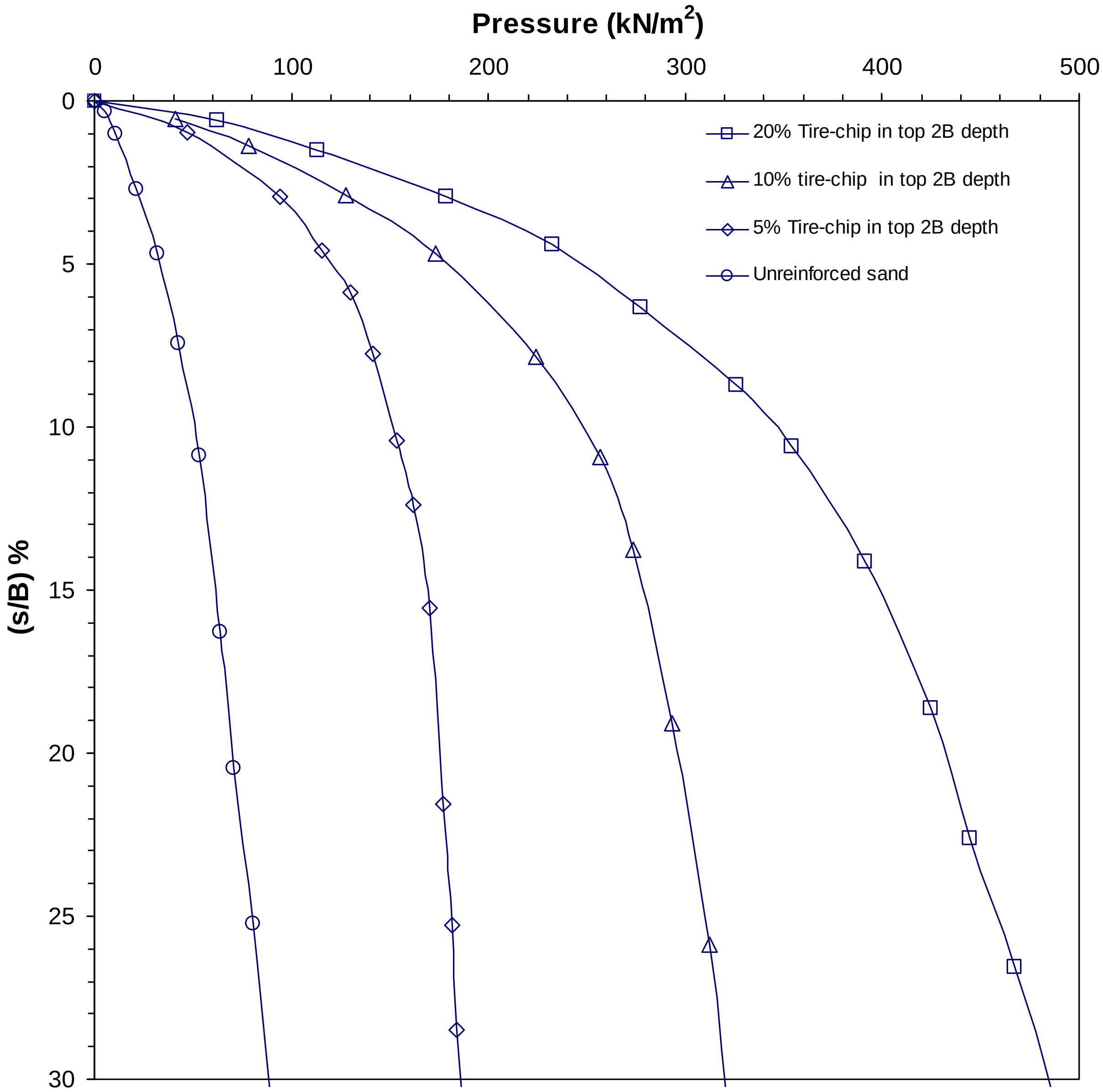

Figure 1. Pressure Settlement Curves of Sand Reinforced by randomly Distributed Tire-Chip

Figure 2 shows the pressure settlement curves of the un-reinforced sand and geogrid reinforced sand. Maximum improvements were noticed for three layers of geogrid and width of geogrid was kept three times width of footing. No further improvement was observed for four layers of geogrid. This figure indicates that by inclusion of three geogrids overall pressure-settlement curve improves significantly. In this case bearing capacity ratio (bearing capacity of reinforced soil to bearing capacity of sand alone at 10% settlement ratio.) increased to 3.5.

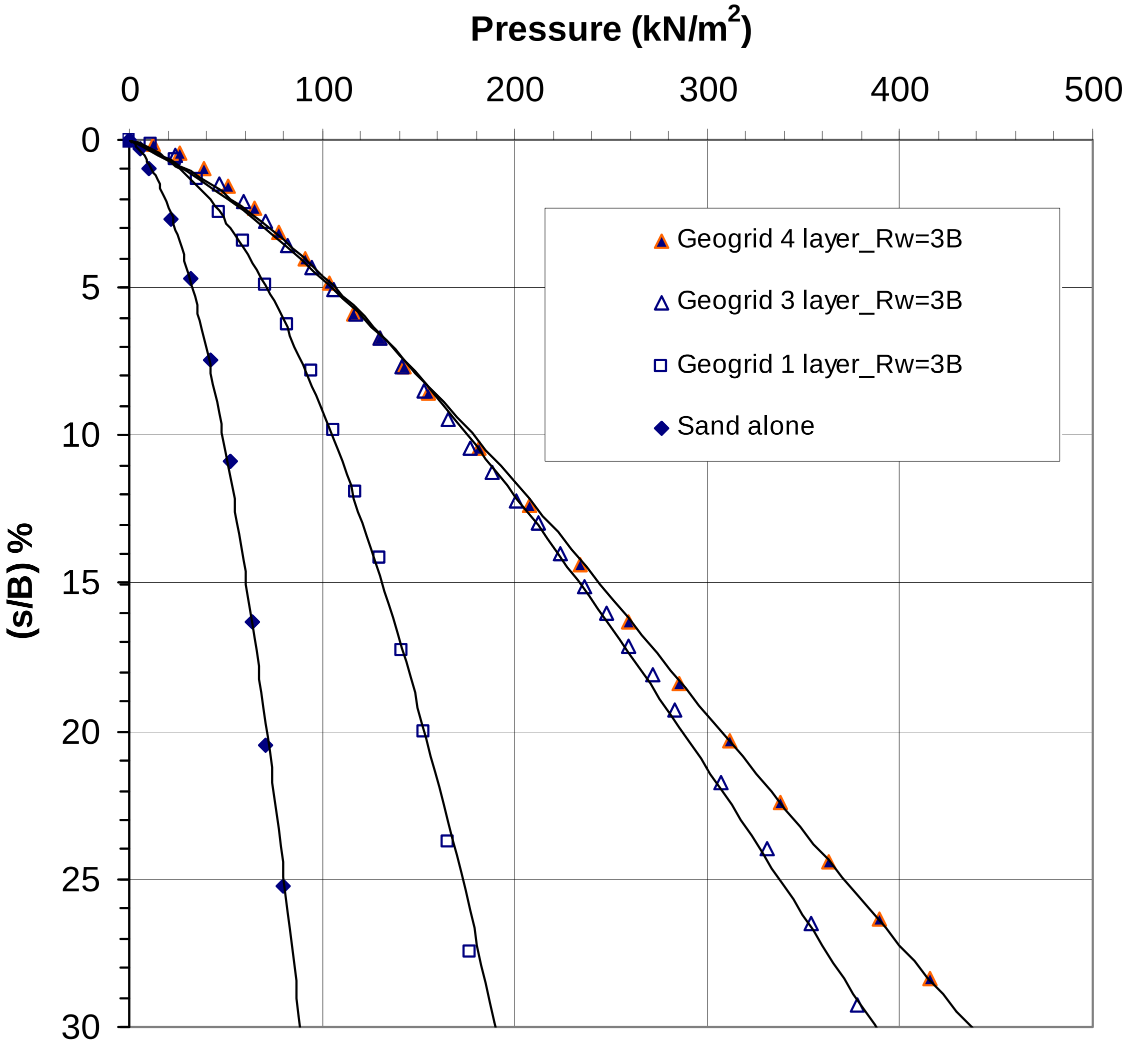

Figure 2. Pressure Settlement Curves of Sand Reinforced by Geogrid

Figure 3 shows the pressure settlement curves of the un-reinforced sand and sand reinforced with tire chip and geogrid simultaneously. By reinforcing sand with 5% tire-chip in 2B depth below footing and three geogrid layers of 3B width simultaneously substantially improvements were noticed and BCR increased to 5. By reinforcing sand with three geogrid layers and 20% tire-chip in 2B depth below footing simultaneously further increased BCR to a very high value of 9.3. Very high improvements are noticed even at very low settlement ratio. Strain hardening behaviour was observed at higher high settlement ratio opposed to poor performance of tire chip reinforcement at high settlement ratio. This behaviour is more clearly seen in Figure 4 showing comparison of pressure settlement curves of sand reinforced with randomly distributed tire chip and simultaneously by geogrid and randomly distributed tire-chip. The bearing capacity and BCR of the unreinforced sand, tire-chip reinforced sand and combined tire-chip & geogrid reinforced determined corresponding to 10% settlement of footing width is shown in the Table 3.

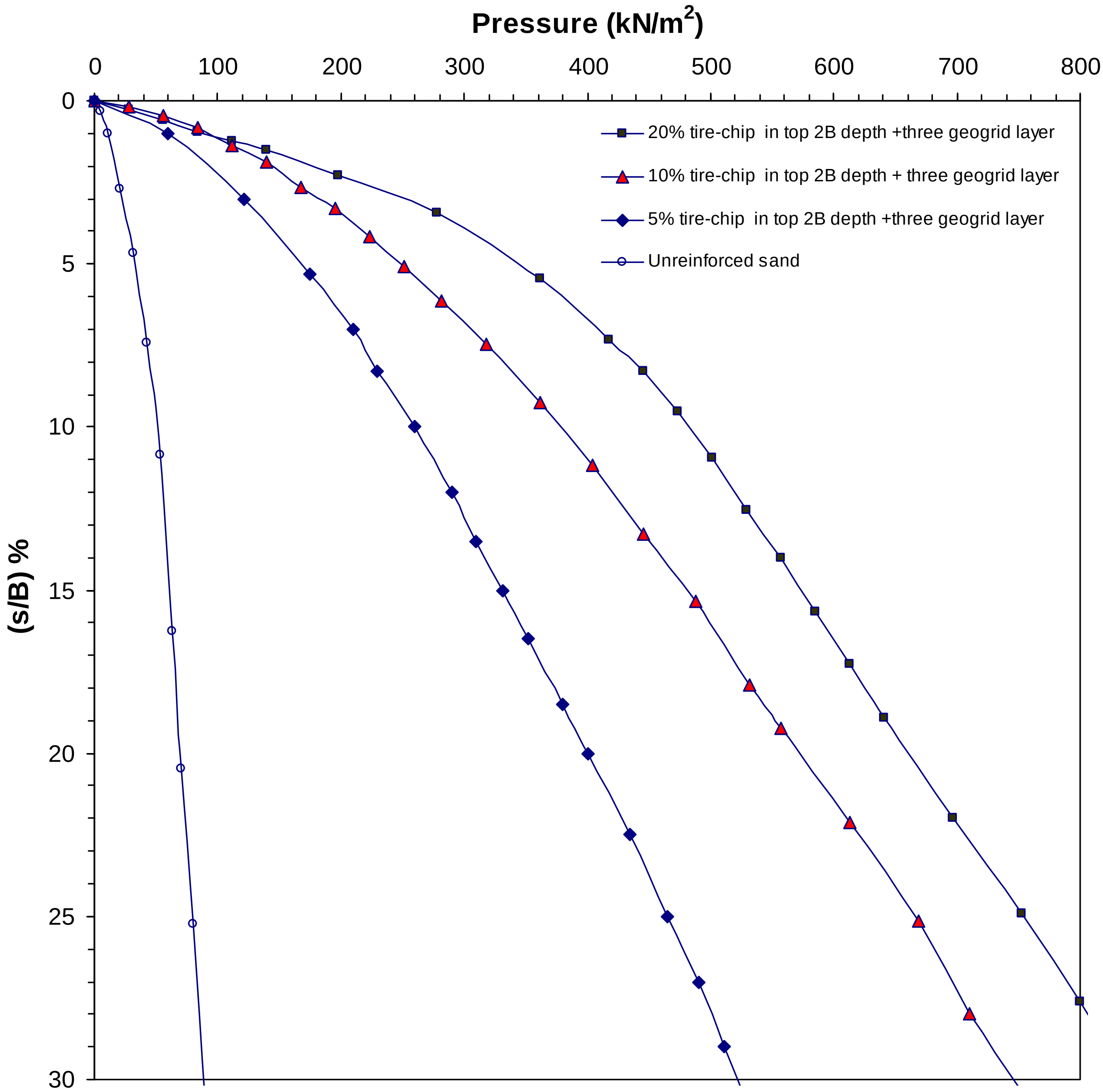

Figure 3. Pressure Settlement Curves of Sand Reinforced Simultaneously by Geogrid and Randomly Distributed Tire-Chip

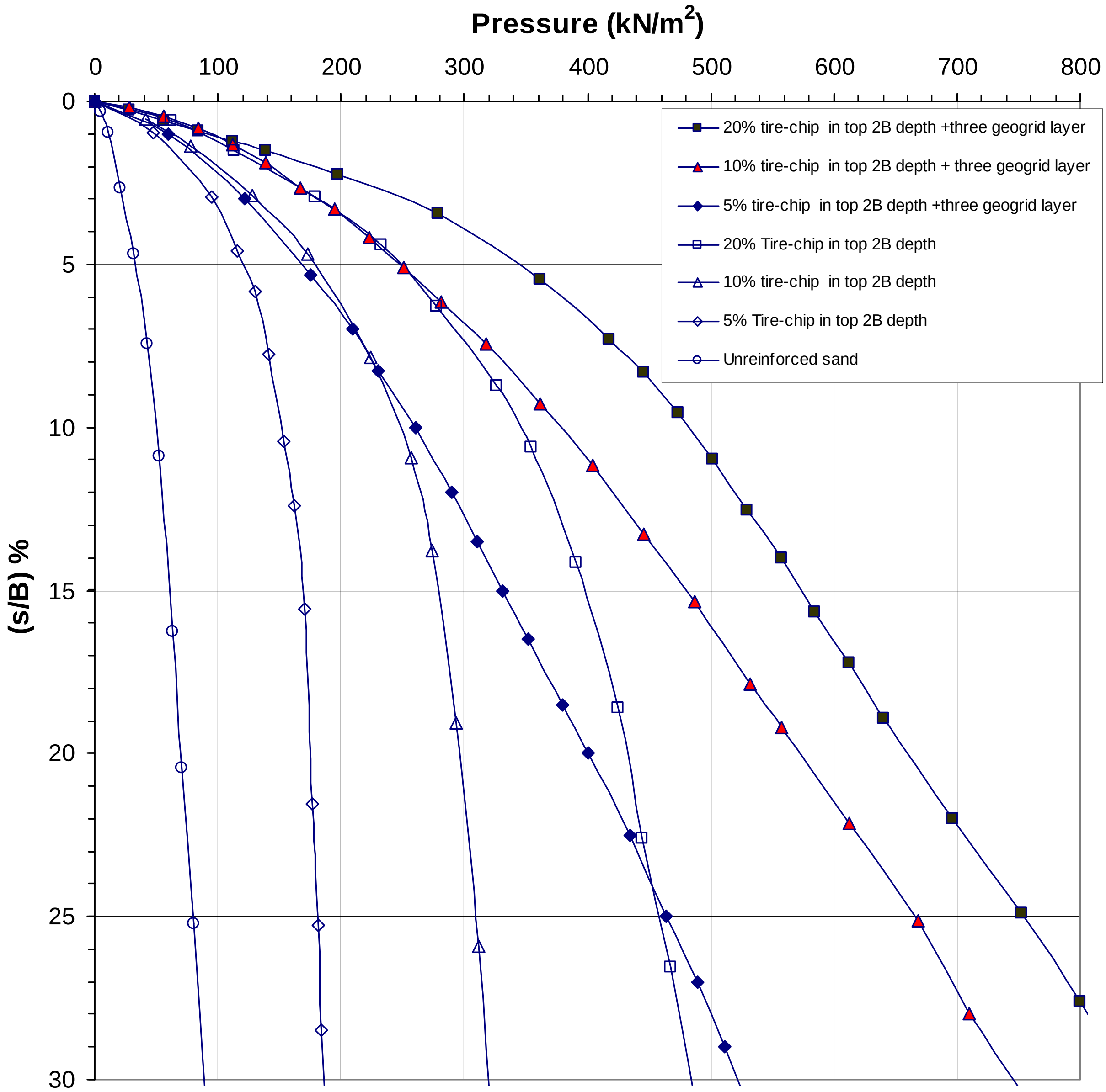

Figure 4. Comparison of pressure settlement curves of sand reinforced with randomly distributed tire chip and simultaneously by geogrid and randomly distributed tire-chip

Table 3. Bearing Capacity for Sand Reinforced by Randomly Distributed Tire-chip and Geogrid

Reinforcement details	Bearing Capacity (kPa)	BCR
Unreinforced sand	52	1
5% tire-chips in 2B depth below footing	152	2.9
1% tire-chips in 2B depth below footing	250	4.8
20% tire-chips in 2B depth below footing	350	6.7
3 Geogrid layer	184	3.5
3 Geogrid layer + 5% tire-chips in 2B depth below footing	260	5
3 Geogrid layer + 10% tire-chips in 2B depth below footing	378.2	7.3
3 Geogrid layer + 20% tire-chips in 2B depth below footing	482.6	9.3

CONCLUSIONS

An innovative approach using combined use of randomly oriented tire chip and geogrids may prove to be an economical solution for foundations of industrial structure, high rise buildings, bridge pier etc. Behaviour of sand reinforced with geogrid in addition to tire chip is superior in comparison to either one alone. By adding 5%, 10% and 20% tire-chip up to 2B depth below footing in addition to three geogrid layer BCR increased to 5, 7.3 and 9.3 respectively. Such a high increase in bearing capacity of soil can permit use of shallow foundations for heavy loads also. By combining tire chip and geogrid, both economy and superior performance is achieved. Further, it will serve the purpose of disposal of waste tyre-chip in a beneficial way.

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