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Characteristics of Densified Plastic Pellet Stabilized Lateritic Soil to Reduce the Impact of Accidental Explosions on Underground Structures

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Abstract: *This study examines the effect of compacted plastic pellets stabilized lateritic soil to reduce the impact of accidental explosions on underground structures. In this study, lateritic soil and plastic were taken from Ilaro, Ogun State, Nigeria. The plastic wastes were grounded into pellets and substituted with laterite. The tests were conducted in line with BS 1377 (1990) to determine the moisture content and compaction. The results were compared with the simulated results of Olarewaju (2013) in the study of the response of underground structures due to blast loads. In the said work, soil and pipes were modeled; loads from accidental explosions were estimated using Unified Facilities Criteria (2008). Various constituents of blast considered are ground media, pipes, intervening medium, blast, blast characteristics and method of analysis (finite element formulation and solution using ABAQUS/Explicit in ABAQUS). From the results, the lowest dry density value is 0.96kg/m^3 and 1.130 kg/m^3 respectively at 30% plastic pellets mixed with lateritic soil. In the work of Olarewaju (2013), dimensionless deflection at the crown, invert and spring-line of underground pipes in loose material is low compared to dense material. It is clear that at 30% and above plastic substitution, the density is relatively low and this could as soft backfill material reduce the impact of accidental explosions on underground structures. Consequently, loads arising from various accidental explosions on underground structures would be greatly reduce, if not completely eliminated*
Keywords: *Plastic Pellets, Explosion, Laterite, Underground, Structures.*

Background Study

Ground improvement techniques are forms of mitigation measure to reduce the impact of blast loads on underground structures which is carried out on the principles of consolidation, chemical stabilization/modification, densification and reinforcement as well as combination of the above. This is with a view to improving the stiffness of soil where structures are to be buried. Ground improvement refers to any technique or process that improves the engineering properties of the treated (stabilized) soil mass. These methods are consolidation using prefabricated vertical drains, placing soil surcharge and maintain it for the required time; vacuum consolidation, stone column; chemical modification with deep soil mixing, jet grouting, etc.; densification using vibro compaction, dynamic compaction, compaction grouting, etc.; reinforcement using stone columns, geo-synthetic reinforcement (Raju, 2010). Compaction grouting not only densifies the in-situ soils but also forms high strength, high stiffness grout bulbs that reinforce the ground. These methods have been used successfully in Jurong Island in Singapore, India, Penang in Malaysia (Raju, 2010). Tire-chip back filling is another mitigation measure to reduce the impact of blast loads on underground pipes. In terms of availability of used tires, more than 5.5 million metric tons of tires are stock-piled across United States and 3 million metric tons more are generated each year. About 30% of these tires are disposed of in landfills, and thousands of tires are left in empty yards and even dumped illegally. Used tires are causing environmental risk and now gaining prominence in the society, especially Nigeria. As a result of this, recycle of used tires is now an important issue in geo-environmental engineering. In the research carried by Towhata and Sim (2010), tire-chips were prepared by mixing coarse chips with fine crumbs. Underground pipe was embedded in tire-chip trench having particle size distribution similar to the materials used as trench fill. The whole pipes buried in tire-chips were covered by Toyoura sand. From the result of the shaking test on the tire-chip backfilling, according to Towhata and Sim (2010), it was observed that when the displacement is between 10 mm and 20 mm, tire-chip backfilling was able to reduce the bending stress and moment caused by displacement of underground pipes. If the thickness of the tire-chip backfilling is increased, it can resist and thereby reduce bending stress and moment caused by large displacement due to blast loads. From the results of Humphrey et al. (1993), the compacted density of tire-chips ranges from 0.618 Mg/m^3 to 0.642 Mg/m^3 while the Young's modulus of tire-chips ranges from 770 kPa to 1130 kPa. There is need to look for alternative source of soft material for backfilling which is the focus of this study. In the study of the response of underground pipes due to seismic activities such as accidental explosions, there is need to consider the ground medium. This is with a view to providing recommendations on the probable mitigation measures to be adopted to reduce the impact of blast loads on underground structures (pipes). One of such mitigation measures is soil stabilization which is a process by which the engineering properties of soil layers can be improved or treated by addition of other soil types, mineral materials or by chemical additives (Olarewaju *et al.*, 2011. Mechanical method of improvement of soil engineering properties is done by the addition of other soil particles which are missing from its natural grading. In ground improvement projects, this normally leads to soil compaction, both deep and superficial. The additive method of soil stabilization refers to a manufactured commercial product like Portland cement, lime, lime-cement-fly ash, bitumen, etc. that, when added to the soil in the proper dosage will improve the quality of the soil and soil layer. Another method is grouting which is a process of injecting under pressure a fluid sealing material (usually mixture of cement and water starting with a ratio of 5:1) into the underlying formations through specially drilled holes for the purpose of sealing off or filling joint seams, fissures or other openings.

Methodology

In this study, lateritic soil solid plastic wastes were taken at Ilaro, Ogun State, Nigeria The plastics wastes were grounded into pellets and substituted with laterite at 1% to 10% then 15%, 20%, 25% and 30% substitutions. The tests were conducted in line with BS 1377 (1990) to determine the moisture content and bulk as well as dry densities through compaction test. The results were compared with the simulated results of Olarewaju (2013) in the study of the response of simulated underground structures due to blast loads. In the said work, soil and pipes were modeled; loads from accidental explosions were estimated using Unified Facilities Criteria (2008). Various constituents of blast considered are ground media, pipes, intervening medium, blast, blast characteristics and method of analysis (finite element formulation and solution using ABAQUS/Explicit in ABAQUS). This numerical method employed incorporates the notion of infinity in the formation. The numerical tool, *ABAQUS* software package satisfies the geometric boundary conditions on irregular domains (Abaqus/Explicit, 2009; Abaqus Analysis User's Manuals 2009). Various parametric studies were equally carried out which comprises of the effect of Young's modulus of soil, Young's modulus of pipe, coefficient of friction, blast loads, pressure, deflection, depth, etc) at the crown, invert and spring-line of steel and concrete pipes buried in loose sand and dense sand. For Figures 3 to 8, *P* is the intensity of surface pressure, *H* is the cover depth while *D* is the diameter of pipe, *x* is the displacement at the crown, invert and spring-line of pipes, *M* is the modulus of soil, *P* is the surface pressure intensity and *r* is the radius of pipe.

Results and Discussion

The results of bulk density against moisture content at 30% substitution are presented in Figure 1 while the results of dry density against moisture content at the same substitution are presented in Figure 2. From the results of the work of Olarewaju (2013), the simulated results of pipe dimensionless deflection at the crown, invert and spring-line due to underground accidental explosions are presented in Figures 3 to 8. These pipes (i. e. concrete and steel pipes) are buried in loose sand and dense sand. In this study, the maximum bulk density is 1.131 kg/m^3 while the moisture content is 2%. From the results, the highest maximum dry density value is 2.045 kg/m^3 at 8% plastic pellets mixed lateritic soil while the highest maximum bulk density is 2.4 kg/m^3 at 1% plastic mixed with laterite. In addition to this, the lowest dry density value is 0.96kg/m^3 at 30% plastic pellets mixed with lateritic soil while the lowest bulk density value is 1.130 kg/m^3 at 30% plastic pellets mixed lateritic soil (Figures 1 and 2). It is obvious that at 30% plastic substitution, the density is relatively low (Olarewaju, 2016a, b, c, d, e, and f). Loose sand and dense sand were used as the ground media in the work of Olarewaju (2013) to study of the response of underground pipes due to blast loads. From the results of the dimensionless pipe deflection in loose sand for surface blast and dimensionless pipe deflection in loose sand for underground blast at the crown, invert and spring-line respectively (Figures 3 to 8), there is less deflection in pipes buried in loose sand compared to pipes buried in dense sand due to displacement for surface blast and underground blast respectively. It has been shown that the ratio of the dimensionless deflection of pipes (at the crown, invert and spring-line) buried in loose sand to that of dense sand at *H/D* ratios of 1 and 5 is 1 : 1.8 : 2.75 : 2.5 and 1 : 44 : 8 : 18 for surface blast and at *H/D* ratios of 1 and 5 is 1 : 2.74 for underground blast respectively (Olarewaju, 2012). The dimensionless pipe deflection at the crown, invert and spring-line due to underground accidental explosion is low in loose sand compared to dense sand in the work of Olarewaju (2013). This implies that an embedded pipe is subjected to greater hazard due to blast loads when backfill is more detailed and thoroughly compacted. This situation may be overcome by using softer material for backfilling. To realize a very soft backfilling material, a shredded-tire trench could be employed. However, if the tire trench backfill is sufficiently large to avoid the direct interaction and contact between sandy ground and the embedded pipe, it can resist large displacement that can cause induced moment in the buried pipe (Towhata and Sim 2010). Instead of the above method, mixing plastic pellets of about 30% substitution could also achieve soft material backfilling. In the work of Olarewaju (2013), dimensionless deflection at the crown, invert and spring-line of underground pipes in loose material is low compared to dense material (Figures 3 to 5). With the substitution of 30% plastic pellets or more in soil material, there would be less cohesion between the plastic pellets and the soil material. Consequently, the two would behave like loose material as investigated by Olarewaju (2013).

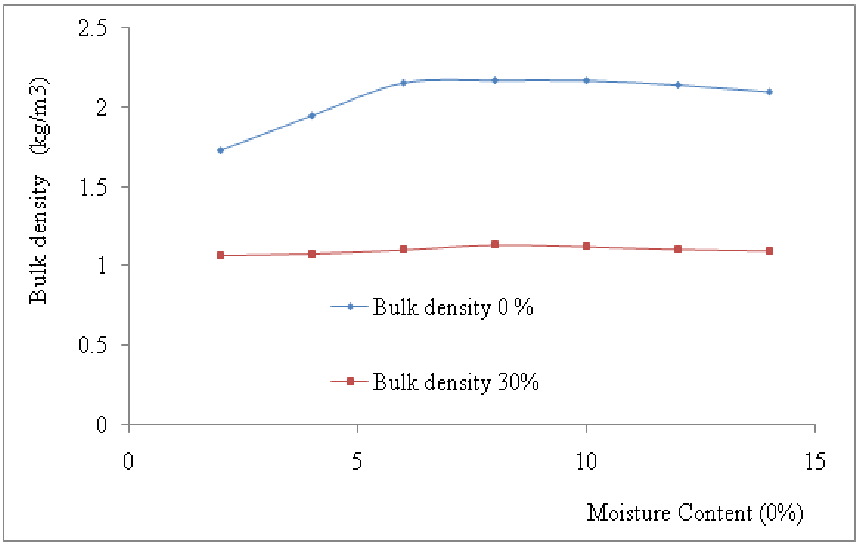

Figure 1: Results of bulk density against moisture content at 30% plastic pellets substitution

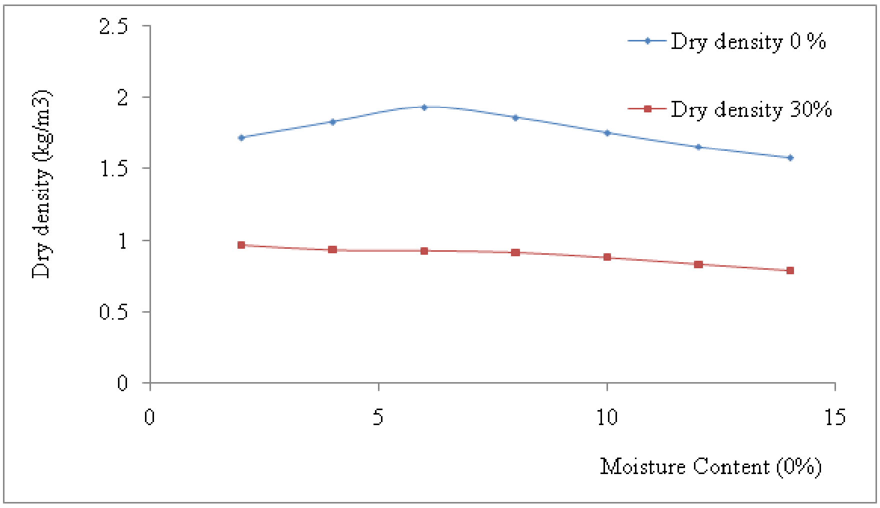

Figure 2: Results of dry density against moisture content at 30% plastic pellets substitution

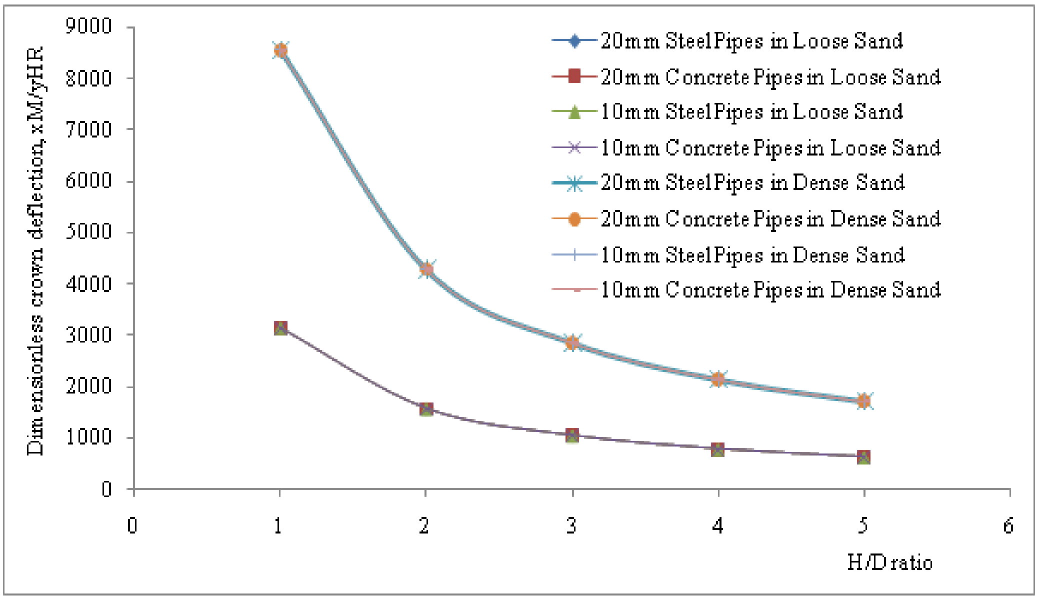

Figure 3: Dimensionless crown pipe deflection against H/D ratio in loose and dense sand for underground accidental explosion

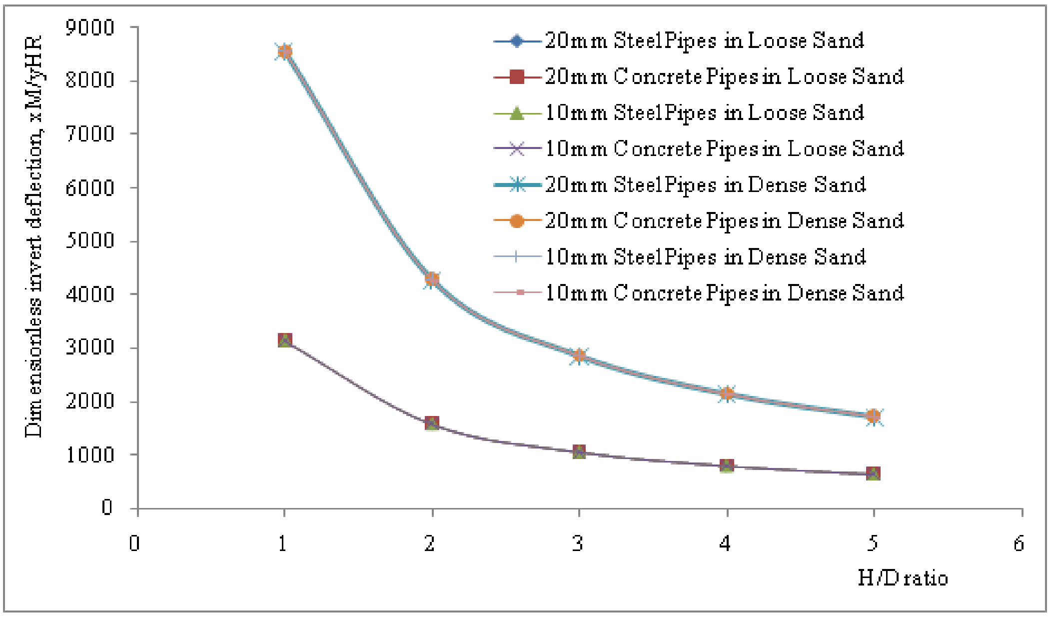

Figure 4: Dimensionless invert pipe deflection against H/D ratio in loose and dense sand for underground blast

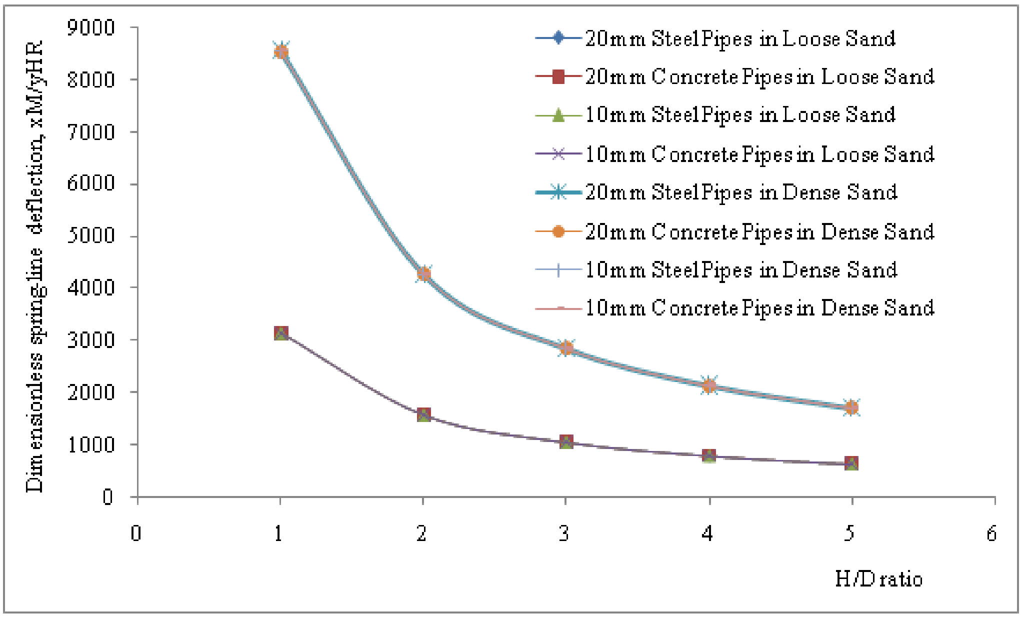

Figure 5: Dimensionless spring-line pipe deflection against H/D ratio in loose and dense sand for underground accidental explosion

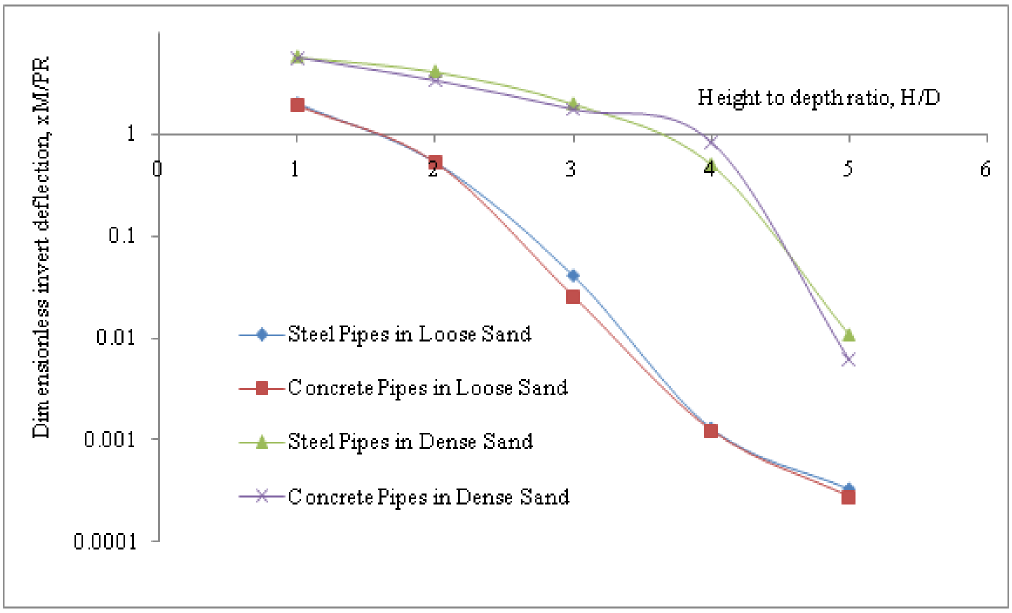

Figure 6: Dimensionless invert pipe deflection against H/D ratio in loose and dense sand for underground accidental explosion

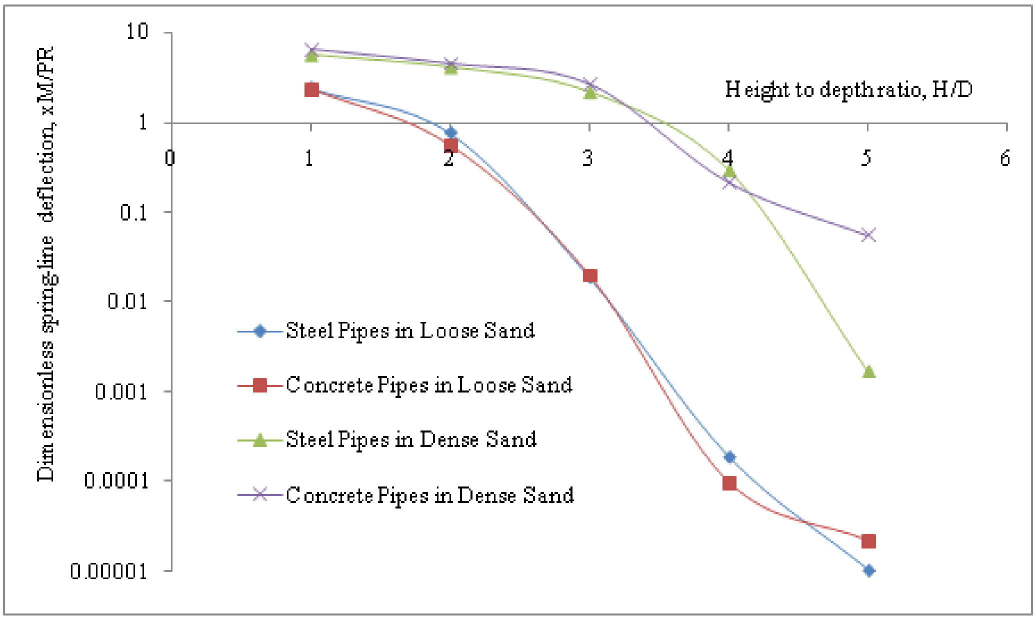

Figure 7: Dimensionless spring-line pipe deflection against H/D ratio in loose and dense sand for underground accidental explosion

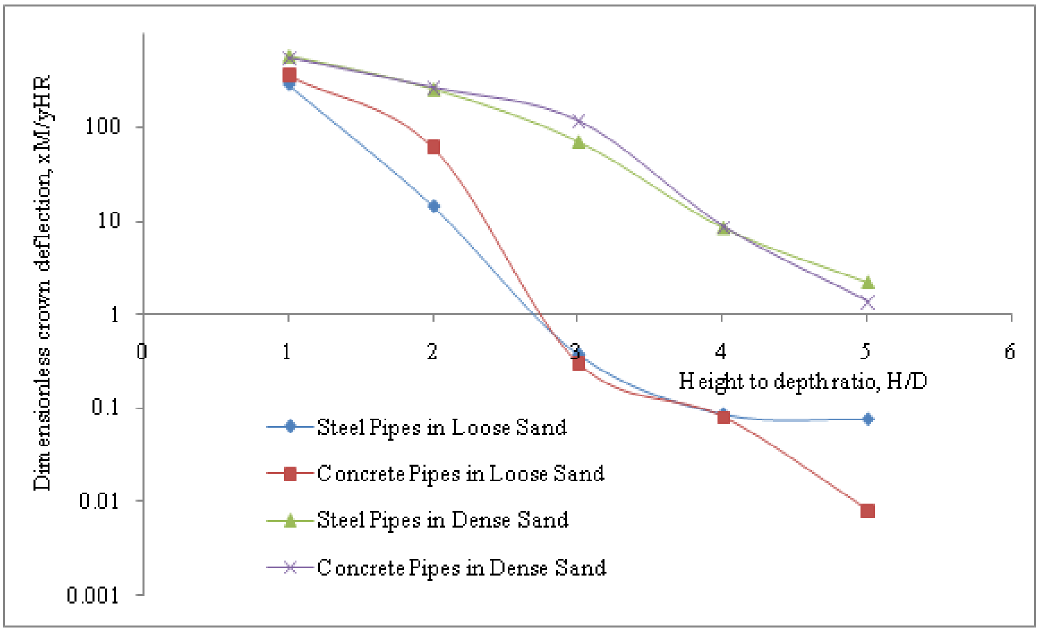

Figure 8: Dimensionless crown pipe deflection against H/D ratio in loose and dense sand for underground accidental explosion

Conclusion

This paper has shown that substituting plastic pellets in lateritic soil at 30% resulted in low density material; hence soft material backfilling could be achieved. Increasing the percentage substitution of plastic pellets above 30% in lateritic soil and other soil materials could also reduce the density further. Consequently, loads arising from accidental explosion on underground structures would be greatly reduced

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