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Ground improvement techniques to mitigate the impact of seismic action on underground structures

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Abstract
This study examines the various available ground improvement techniques to mitigate the effects of seismic actions like accidental explosions on underground structures (e.g. pipes). In this study, lateritic soil was taken at Abalabi, Ilaro, Ogun State, Nigeria and the solid plastic wastes were taken from different locations in Ilaro. The plastics wastes were grounded into pellets and substituted with laterite at 1% to 10%, 15%, 20%, 25% and 30% for compaction test with 0% serving as control experiment. Tests were conducted in line with BS 1377 (1990) to determine the moisture content, specific gravity and compaction. Another lateritic soil was taken from a borrow pit at Ona-Egbo, Ilaro, Ogun State, Nigeria and fly ash material was obtained from Ewekoro cement factory (*Lafarge Group Nigeria Ltd*) Papa-Itori road, Ewekoro, Ogun State. Cement used is elephant Portland cement. Fly ash at 2%, 4%, 6%, 8%, and 10% were used to replace lateritic soil at percentage water ratio ranging from 2% to 14%. Tests conducted in line with BS 1377 (1990) are the moisture content determination as well as 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. From the results, 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 with lateritic soil. It is evidently clear that at 30% plastic substitution and above, the density is relatively low and this would reduce the impact of accidental explosions on underground structures.

Keywords: Mitigation, explosion, fly ash, cement, plastic pellets, seismic, stabilization

1. Introduction
In the study of the response of underground structures due to seismic activities such as blast loads, there is need to consider the ground medium. Those that are applicable to blast are loose sand, dense sand and undrained clay where the structures would be buried. 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 such as pipes. One of such mitigation measures is soil stabilization. Soil Stabilization is the 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) [3]. Two general methods of stabilization are mechanical and additive. In mechanical method of soil stabilization, 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. In the additive method of soil stabilization, it refers to a manufactured commercial product that, when added to the soil in the proper dosage will improve the quality of the soil and soil layer. These products are Portland cement, lime, lime-cement-fly ash, bitumen, etc., alone or in combination. Grouting, another ground improvement technique, is a process of injecting under pressure a fluid sealing material (usually mixture of cement and water) into the underlying formations through specially drilled holes for the purpose of sealing off or filling joint seams, fissures or other openings. Grout as it is, is a liquid either a uniform chemical substance or an aqueous suspension of solids that is injected into the rocks or consolidated materials through special drilled boreholes to improve the bulk physical properties and/or to eliminate seepage of ground water.

There are three basic types; Portland cement-base slurries, chemical grouting solutions, and organic resins including epoxy resins.

1.1 Background Study

Ground improvement which is a form of mitigation measure to reduce the impact of blast loads on underground structures (pipes) 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 (pipes) are to be buried. According to Raju (2010) [5], 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). 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) [5]. Tire-chip back filling is another mitigation measure to reduce the impact of seismic action 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) [7], 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) [7], 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) [2], 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.

Trenchless technique is now gaining popularity in the rehabilitation of damaged underground pipes due to blast, aging, etc. in United Kingdom, United State of America and other parts of the world, especially in congested and built-up areas. This could be done through the usage of cement mortar lining, epoxy spray lining, polyethylene, polyester reinforced polyethylene, impregnation of fabric tube with an epoxy resin system- woven hose lining, resin felt composite, etc. Examples of these techniques are pipe jacking, auger boring, pipe ramming, cured-in-place pipe, spiral wound, slipping and micro tunneling methods. Large trenchless projects have been carried out successfully in Kuwait, Iraq, United Arab Emirates, Israel, Saudi Arabia and Qatar (Randall, 1999) [6].

Loose sand, dense sand and undrained clay were used as the ground media in the work of Olarewaju (2013) [4] to study of the response of underground pipes due to blast loads. From the results (Figures 1 to 6) 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, 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. 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, 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. Another method of achieving soft back-filling is the use of plastic pellets mixed with soil material (laterite) which is the focus of this study.

2. Methodology

The lateritic soil was taken at Abalabi, Ilaro, Ogun State and the solid plastic wastes were taken from different locations in Ilaro. The plastics wastes were grounded into pellets and substituted with laterite at 1% to 10%, 15%, 20%, 25% and 30% for compaction test with 0% serving as control experiment. The tests were conducted in line with BS 1377 (1990) [1] to determine the moisture content, specific gravity and compaction. Another lateritic soil was taken from a borrow pit at Ona-Egbo, Ilaro, Ogun State, Nigeria and fly ash material was obtained from Ewekoro cement factory (*Lafarge Group Nigeria Ltd*) along Papa-Itori road, Ewekoro, Ogun State. Cement used is elephant Portland cement. Fly ash at 2%, 4%, 6%, 8%, and 10% were used to replace lateritic soil at percentage water ratio ranging from 2% to 14% with 0% serving as control experiment. The tests conducted in line with BS 1377 (1990) [1] are the moisture content determination and compaction. The results were compared with the simulated results of Olarewaju (2013) [4] in the study of the response of underground structures due to blast loads.

3. Results and Discussions

From the work of Olarewaju (2013) [4] (Figures 1 to 6), through simulation, the results of dimensionless invert pipe deflection against H/D ratio in dense sand for surface blast are presented in Figure 1 while dimensionless spring-line pipe deflections against H/D ratio in dense sand for surface blast are presented in Figure 2. In addition, the results of dimensionless crown pipe deflection against H/D ratio in loose sand for underground blast are presented in Figure 3 while the results of dimensionless spring-line pipe deflection against H/D ratio in loose sand for underground blast are presented in Figure 4. Furthermore, the results of dimensionless crown pipe deflection against H/D ratio in dense sand for underground blast are presented in Figure 5 while the results of dimensionless invert pipe deflection against H/D ratio in dense sand for underground blast are presented in Figure 6. Finally the results of bulk density are presented in Figure 7. From the results, with plastic and fly ash substitution at less than 10% (Figure 7), there is close similarities in the compaction behaviours with 0% (i.e. control experiment – lateritic soil).

3.1 Plastic pellets

From the results, at 0% plastic pellets (control experiment), the maximum dry density is 1.94 kg/m^3 while the moisture content is 6.5%. In addition to this, the maximum bulk density is 2.17 kg/m^3 while the moisture content is 6.5%. At 1% plastic pellet mix, the maximum dry density is 1.98 kg/m^3 while the moisture content is 4%. In addition, the maximum bulk density is 2.4 kg /m^3 while the moisture content is 4%, Furthermore, at 2% plastic pellet mixed with laterite, the maximum dry density is 1.89 kg/m^3 while the moisture content is 6%. The maximum bulk density is 2.17 kg/m^3 and the moisture content is 6%. At 3% plastic pellet mixed with lateritic soil, the maximum dry density is 1.814 kg/m^3 while the moisture content is 6.2%. The maximum bulk density is 2.194 kg/m^3 while the moisture content is 6.2%. At 4% plastic pellet mixed with laterite, the maximum dry density is 1.952 kg/m^3 while the moisture content is 6%. The maximum bulk density is 2.13 kg/m^3 while the moisture content is 6%. At 5% plastic pellet mix, the maximum dry density is 1.913 kg/m^3 while the moisture content is 6%. The maximum bulk density is 2.112 kg/m^3 while the moisture content is 6%. At 6% plastic pellet mix, the maximum dry density is 1.945 kg/m^3 while the moisture content is 8%. The maximum bulk density is 2.058 kg/m^3 while the moisture content is 8%. At 7% plastic pellet mixed with lateritic soil, the maximum dry density is 1.87 kg/m^3 while the moisture content is 6%. The maximum bulk density is 2.013 kg/m^3 while the moisture content is 6%. At 8% plastic pellet mix, the maximum dry density is 2.045 kg/m^3 while the moisture content is 4%. The maximum bulk density is 2.125 kg/m^3 while the moisture content is 4%. At 9% plastic pellet mixed lateritic soil, the maximum dry density is 1.573 kg/m^3 while the moisture content is 4%.

The maximum bulk density is 1.756 kg/m^3 while the moisture content is 4%. At 10% plastic pellet mix, the maximum dry density is 1.72 kg/m^3 while the moisture content is 8%. The maximum bulk density is 1.854 kg/m^3 while the moisture content is 8%. At 15% plastic pellet mix, the maximum dry density is 1.2 kg/m^3 while the moisture content is 8%. The maximum bulk density is 1.418 kg/m^3 while the moisture content is 8%. At 20% plastic pellet mixed with laterite, the maximum dry density is 1.185 kg/m^3 while the moisture content is 8%. The maximum bulk density is 2.13 kg/m^3 while the moisture content is 8%. At 25% plastic pellet mixed with lateritic soil, the maximum dry density is 1.009 kg/m^3 while the moisture content is 8%. The maximum bulk density is 1.230 kg/m^3 while the moisture content is 8%. Finally at 30% plastic pellet mixed with lateritic soil, the maximum dry density is 0.960 kg/m^3 while the moisture content is 2%. 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. In the case of optimum moisture content, from the results, at 0% plastic mixed with lateritic soil, the optimum moisture content is 6.5% compared to 1% plastic mixed with laterite which has optimum moisture content of 4%. This is due to the absorption of water by the laterite compared to plastic pellets that cannot absorb water in its natural state. Laterite is a porous material, in the oven water turns to vapor and evaporate to the air leaving voids in the soil but plastic pellets are solid material that contains no void that can hold water except the surface.

3.2 Fly ash and cement

In the case of bulk density of fly ash substitution investigated, from the results, the maximum bulk density at 0% (i.e. control experiment) is 2.180 kg/m^3 at 8 percentage water ratio while the maximum bulk density at 2% of fly ash is 2.144 kg/m^3 at 12 percentage water ratio. In addition to this, the maximum bulk density at 4% of fly ash is 2.168 kg/m^3 at 12 percentage water ratio while the maximum bulk density at 6% of fly ash is 2.234 kg/m^3 at 12 percentage water ratio. Furthermore, the maximum bulk density at 8% of fly ash substitution is 2.181 kg/m^3 at 12 percentage water ratio while the maximum bulk density at 10% of fly ash is 2.354 kg/m^3 at 12 percentage water ratio. The maximum bulk density at 12% of fly ash is 2.234 kg/m3 at 10 percentage water ratio. Finally, the maximum bulk density at 14% of fly ash substitution is 2.190 kg/m^3 at 12 percentage water ratio while the maximum bulk density is 2.354kg/m^3 at 10% fly ash at 12 percentage water ratio. Similarly, in the case of bulk density of cement substitution investigated, the maximum bulk density at 2% of cement is 1.789 kg/m^3 at 8 percentage water ratio while the maximum bulk density at 4% of cement substitution is 1.710 kg/m^3 at 8 percentage water ratio. In addition to this, the maximum bulk density at 6% of cement is 1.776 kg/m^3 at 8 percentage water ratio while the maximum bulk density at 8% of cement substitution is 2.019 kg/m^3 at 8 percentage water ratio. In addition, the maximum bulk density at 10% of cement substitution is 1.998 kg/m^3 at 10 percentage water ratio while the maximum bulk density at 12% of cement is 1.945 kg/m^3 at 6 percentage water ratio. Furthermore, the maximum bulk density at 14% of cement is 2.099 kg/m^3 at 8 percentage water ratio while the maximum bulk density at 14% fly ash substitution is 2.099 kg/m^3 at 8 percentage water ratio.

In the case of dry density of fly ash substitution investigated, from the results, the maximum dry density at 0% fly ash is 1.667 kg/m^3 at 8 percentage water ratio while the maximum dry density at 2% fly ash is 1.545 kg/m^3 at 10 percentage water ratio. In addition to this, the maximum dry density at 4% of fly ash is 1.912 kg/m^3 at 10 percentage water ratio while the maximum dry density at 6% of fly ash is 1.945 kg/m^3 at 14 percentage water ratio. In addition, the maximum dry density at 8% of fly ash is 1.927 kg/m^3 at 10 percentage water ratio while the maximum dry density at 10% of fly ash is 2.075 kg/m^3 at 10 percentage water ratio. Furthermore, the maximum dry density at 12% of fly ash is 1.820 kg/m^3 at 10 percentage water ratio while the maximum dry density at 14% of fly ash is 1.805 kg/m^3 at 10 percentage water ratio. Finally, the maximum dry density is 2.075kg/m^3 at 10% fly ash substitution at 10 percentage water ratio. In the case of dry density of cement substitution investigated, from the results, the maximum dry density at 2% of cement is 1.578 kg/m^3 at 8 percentage water ratio while the maximum dry density at 4% of cement is 1.558 kg/m^3 at 8 percentage water ratio. In addition to this, the maximum dry density at 6% of cement is 1.587 kg/m^3 at 8 percentage water ratio while the maximum dry density at 8% of cement is 1.805 kg/m^3 at 8 percentage water ratio. Furthermore, the maximum dry density at 10% of cement is 1.845 kg/m^3 at 8 percentage water ratio while the maximum dry density at 12% of cement is 1.738 kg/m^3 at 6 percentage water ratio. Finally, the maximum dry density at 14% of cement substitution is 1.837 kg/m^3 at 8 percentage water ratio and the maximum dry density is 1.845kg/m^3 at 10% cement at 8 percentage water ratio. It is evident from the results of this study that at 30% plastic substitution, the density is relatively low to achieve the soft back-filling material to mitigate the impacts of various accidental explosions (Olarewaju, 2016) [8, 9].

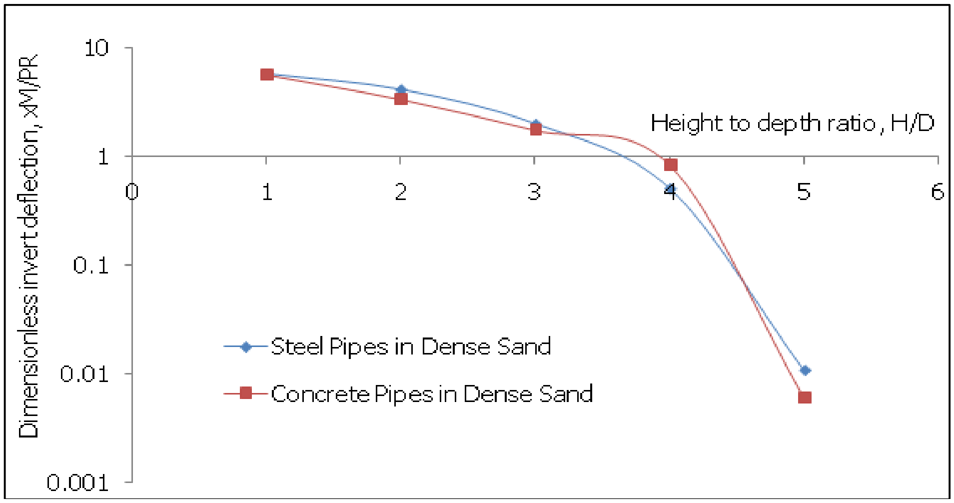

Fig 1: Dimensionless invert pipe deflection against H/D ratio in dense sand for surface blast (Olarewaju, 2013) [4]

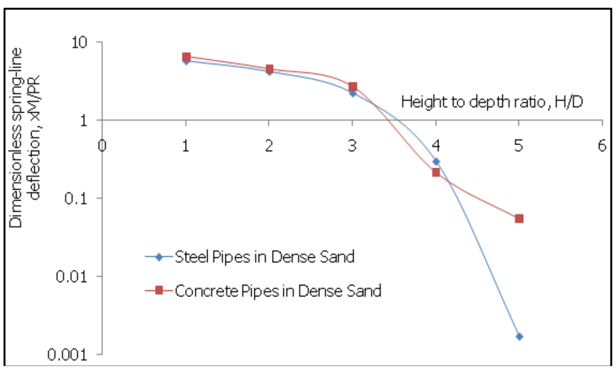

Fig 2: Dimensionless spring-line pipe deflection against H/D ratio in dense sand for surface blast (Olarewaju, 2013) [4]

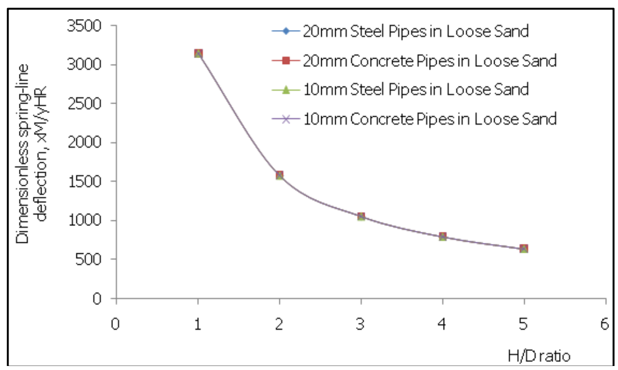

Fig 4: Dimensionless spring-line pipe deflection against H/D ratio in loose sand for underground blast (Olarewaju, 2013) [4]

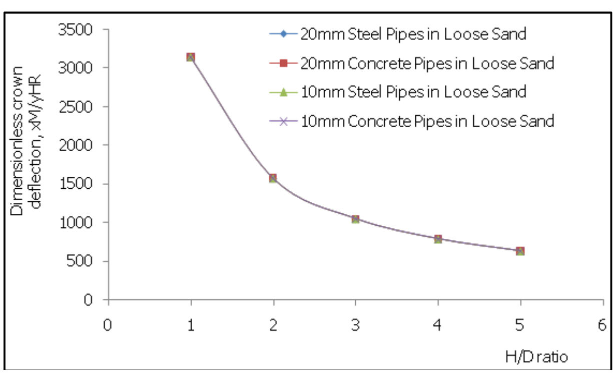

Fig 3: Dimensionless crown pipe deflection against H/D ratio in loose sand for underground blast (Olarewaju, 2013) [4]

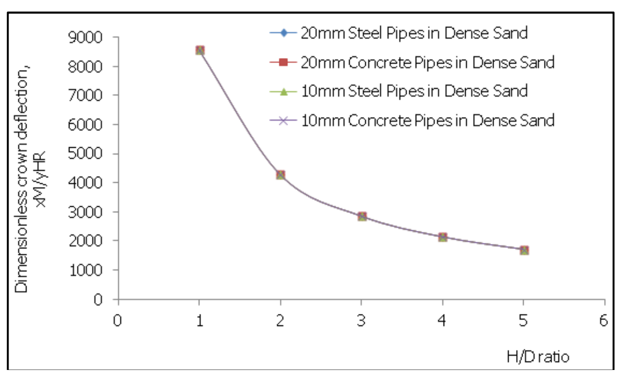

Fig 5: Dimensionless crown pipe deflection against H/D ratio in dense sand for underground blast (Olarewaju, 2013) [4]

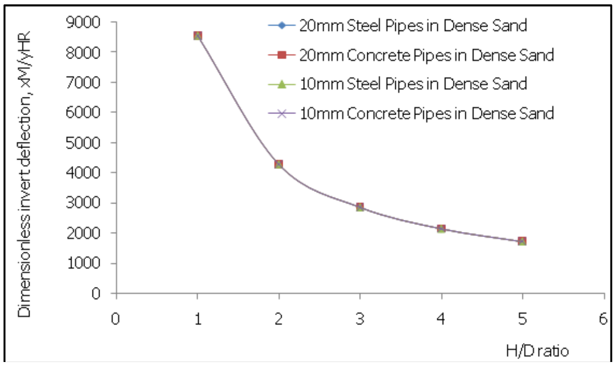

Fig 6: Dimensionless invert pipe deflection against H/D ratio in dense sand for underground blast (Olarewaju, 2013) [4]

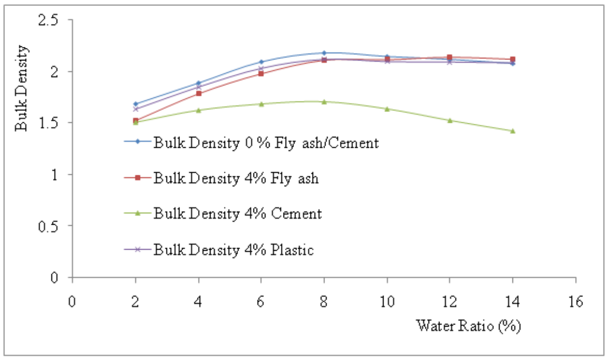

Fig 7: Results of bulk density

4. Conclusion

In this paper, different ground improvement techniques have been considered. Going by results of 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 with 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. Finally, the maximum dry density is 2.075kg/m^3 at 10% fly ash substitution, at 10 percentage water ratio and the maximum dry density is 1.845kg/m^3 at 10% cement at 8 percentage water ratio. It is evidently clear that at 30% plastic substitution, the density is relatively low.

5. Acknowledgement

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6. References

1. BS 1377, Methods of Test for Soils for Civil Engineering Purposes, British Standards Institution, 1990.
2. Humphrey DN, Sandford TC, Cribbs MM, Manion WP. Shear Strength and Compressibility of Tire Chips for Use as Retaining Wall Backfill. Department of Civil Engineering, University of Maine, Orono, Maine, 1993.
3. Olarewaju AJ, Balogun MO, Akinlolu SO. Suitability of Eggshell Stabilized Lateritic Soil as Subgrade Material for Road Construction. Journal of Geotechnical Engineering (EJGE). 2011; 16(H):899-908.
4. Olarewaju AJ. A Study on the Response of Underground Pipes Due to Blast Loads. Ph.D Thesis, School of Engineering and Information Technology, SKTM, Universiti Malaysia Sabah, Malaysia, 2013.
5. Raju VR. Ground Improvement – Application and Quality Control, Indian Geotechnical Conference, GE Otrendz, Macmillan Publisher India Ltd. 2010; III:121-131.
6. Randall C, Conner. Pipeline and Rehabilitation, Proceedings of the group of ASCE Technical Sessions at the American Public Works Association International Public Works Congress and exposition, September, 19-22, Denver Colorado, 1999,1-125.
7. Towhata I, Sim WW. Model Tests on Embedded Pipeline Crossing a Seismic Fault, Proceedings of the 3rd International Earthquake Symposium, Bangladesh University of Engineering and Technology, Dhaka, 2010,1-12.
8. Olarewaju, AJ. Densification characteristics of lateritic soil stabilized with plastic pellets, International Journal of Applied Research, ISSN (Print): 2394-7500 | ISSN (Online): 2394-5869, 2016; 2(9):300-305.
9. Olarewaju, AJ. Effects of Compaction on Lateritic Soil Stabilized With Low Dosage of Cement and Fly Ash, International Journal of Applied Research, ISSN (Print): 2394-7500 | ISSN (Online): 2394-5869, 2016; 2(9):290-295.