Improvement of Geotechnical Properties of Fine-Grained Soil using Locust Bean Powder

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Abstract:- This research work seeks to the improve the geotechnical properties of fine-grained soil using locust bean powder as a stabilizing agent. It was conducted to ascertain the suitability of stabilizing fine-grained soil with locust bean powder and to determine its influence on the geotechnical properties. It is aimed at establishing whether it is economical as a stabilizing agent in the improving the geotechnical properties of fine-grained soil. This could be obtained by Locust bean powder at 0%, 5%, 10%, and 15% percentage addition, where the 0% was used as a control sample. Tests such as specific gravity, particle size distribution, Atterberg limits test, compaction test and CBR test were performed. It was found that specific gravity, plasticity index, linear shrinkage and maximum dry density decrease with increase in percentage addition, while liquid limit, plastic limit, optimum moisture content, and CBR increase with increase in percentage addition of the locust bean powder. It is recommended for use as stabilizing agent to improve the CBR of the fine-grained soils.

Key works:- Fine-grained soil locust bean powder geotechnical properties CBR

1.0 INTRODUCTION

The depletion of naturally occurring soil as subgrade and subbase materials during road construction and the tremendous increment in the number of vehicles has promoted the exploitation of all viable available natural resources. The high plastic nature of fine-grained soil and its susceptibility to large volume changes are directly related to changes in moisture content. Fine-grained soils are frequently encountered during road construction projects across tropical regions. These soils cannot provide the needed engineering properties that could be suitable borrow to be a fill material for the construction of the sub-base and base courses for road pavement.

In most instances engineer has to borrow suitable laterite soils from a far distance that could be appropriate in the prevailing circumstances to improve the engineering properties of the soils. The Fine-grained soil deposits in these zones available are not for use as a road construction material as a result of their poor engineering properties which makes them unfit that poses a great challenge to engineers. Therefore, the improvement of such soil is the most viable means for it to be used for construction purposes (Attah, Etim, Yohanna, & Usanga, 2021). The soils are mostly dry because the water table is quite deep became wet only during the rainy season and expands during the dry season where the cycle of drying and wetting leads to severe movement of soil under any other structures built on it.

The subgrade is an important part of road pavement; its construction on a fine-grained subgrade is susceptible to damage (Irdhiani & Martini, 2020). The durability of road pavement is dependent on the wearing course, the underlying subgrade and subbase materials (Schaefer, Stevens, White, & Ceylan., 2008). Good subgrade provides pavement deflections to an acceptable limit and minimizes differential movement due to moisture changes as it provides the required uniformity of support to the pavement (Panchal & Avineshkumar, 2015; Candido, Braga, Gutierrez, Tambal, & Orale, 2016). These indicate that a weaker subgrade requires a thicker pavement to mitigate the effects of climate and the stress generated by the moving load of the traffic which greatly affects its performance resulting in a shorter life of pavement (Arun & Biradar, 2014).

Fine-grained soils are naturally occurring materials which are generally plastic in nature at appropriate water contents and will harden when (Obianigwe & Ngene, 2018). Fine-grained soil is not the best type of soil for subgrades and sub-bases materials. The Unified Soil Classification System (USCS) classified fine-grained soil as the percentage fines that is more than 50% passes sieve No. 200 (75μm) and A-4 to A-7 with the percentage of fines not less than 35% based on the AASHTO classification system. Any subgrade materials must have certain relevant engineering properties before they can be considered to be used for road pavement construction, (Andre-Obayanju, Edegbai, & Imarhiagbe, 2022).

Fine-grained soils exhibit poor engineering properties that are not desired for constructing road systems (Horpibulsuka, Suddeepong, Chamket, & Chinkulkijniwat, 2013; Huang, 1993); it also exhibits high-plasticity subgrade which is inappropriate for road construction (Çimen, Saltan, & Nilay, 2015). This engineering behaviour of - fine-grained soils is attributable mostly to the clay size fraction of the soil (Sridharan, 1990). The determination of a subgrade and subbase materials' strength and integrity is indispensable in optimizing pavement structural performance and safety (Bell, 1993; Powrie, 2014; Budhu, 2015; Nguyen & Mohajerani, 2015), soil index properties must be performed during the preliminary assessment of the suitability of a subgrade and sub base soil for a particular project (Pillai & Vinod, 2015; Ali, Rash, Hamakareem, & Muhedin, 2019).

African locust bean tree (Parkia Biglobosa), is the material resource required for the production of locust bean pod containing seeds which are embedded in the sweet, yellow, floury pulp that makes up the powder (Nwadiogbu & Salahdeen, 2014), it consists of 39% pod and 61%.yellowish pulp (Ige & Oyeniyan, 2018). The locust bean powder is effectively used as a construction material to increase the bearing capacity and engineering performance as well as reduce the settlement of foundations resting on weak/

poor soil like - fine-grained soils (Adama & Jimoh, 2012; Adama, Jimoh, & Kolo, 2013). Locust bean powder increases plasticity, improved workability and moisture-holding capacity when used as a stabilizing agent (Aliyu, Ma'aruf, Farouq, & Dawusu, 2019). Locust bean powder has pozzolanic properties (Ojewumi, Ayomide, Obanla, Awolu, & Ojewumi, 2014) classified as a Class C pozzolan as such it be used as a stabilizing agent in weak soils for road construction. A deficient soil suitable for use as subgrade or subbase material, its engineering properties should be improved, the improvement could either be by modification or stabilization or both (George & Oriola, 2010; Amu, Ogunniyi, & Oladej, 2011; Bello, Ige, & Ayodele, 2015; Ishola, et al., 2019). Therefore, this study aims to determine the effect of powdered locust beans in the improvement of geotechnical properties of - fine-grained soil such as California bearing ratio and other engineering properties. Most researchers in the field of geotechnical engineering are searching for cheaper and locally available materials for stabilizing. As such the studies will therefore meet engineers' need for better and cost-effective construction materials as opined by (Aliyu, Ma'aruf, Farouq, & Dawusu, 2019).

2. 0 MATERIALS AND METHODS

2.1 Materials

2.1.1 Fine-grained soil

Locally available - fine-grained soil was obtained as a disturbed sample from an existing borrow pit along Geidam - Maine Soroa international road to Niger republic from a distance of about 1km latitude (12°53`49" N) and longitude (11°55`49" E) away from Geidam town, Geidam local government area, Yobe State in the northern part of Nigeria. The - fine-grained soil sample collected would be subjected to tests per British Standards BS 1377 (1990) and BS 1924 (1990) for both treated soil samples at the predetermined appropriate agreed percentages.

2.1.2 Locust beans powder

The locust bean powder used for the research was obtained from a local Market day in Biu town Borno state, Nigeria. The locust bean powder would be mixed with the - fine-grained soil sample collected at predetermined percentage rate of 0%, 5%, 10%, and 15%. The 0% per cent replacement would act as a control specimen.

3.0 Methods

Laboratory tests were performed to determine the index properties of the natural soil samples per BS 1377 (1990) and locust bean powder stabilized - fine-grained soil samples by BS 1924 (1990). The compaction tests were carried out for the natural and modified fine-grained soil samples at a predetermined percentage rate of 0%, 5%, 10%, and 15% by dry weight of soil using the British Standard light (BSL) compaction. The strength characteristic test performed for the study is the California Bearing Ratio (CBR) carried out at OMC and MDD obtained.

3.1 Properties of test materials

3.1.1 Specific Gravity

The specific gravity of the fine-grained soil sample and Locust bean powder was determined. The specific gravity of the soil decreases with increase in the percentage addition of the locust bean powder (**Figure 1**). This might be due to the lower specific gravity of the locust bean powder compared to that of the fine-grained soil used. The specific gravity of the locust bean powder is 1.26 whlie that of the soil was found to be 2.48.

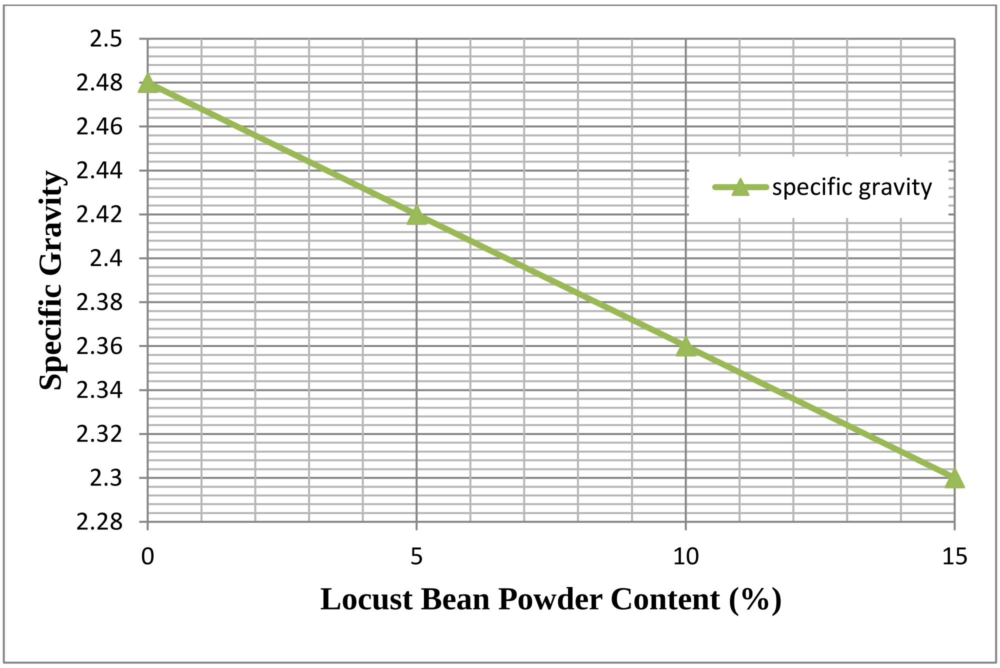

Figure 1: Specific gravity against Locust Bean Powder content

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3.1.2 Sieve analysis

The particle size distribution carried out on the soil was presented in **Figure 2**. The percentage of the soil sample passing sieve No. 200 (75 µm) is 53.5%, and this indicated that the soil sample obtained is a - fine-grained soil. According to the USCS classification fine-grained soil contains at least 50% passing sieve 200 while AASHTOA classified fine-grained soil as the soil with at least 35% passing the sieve.

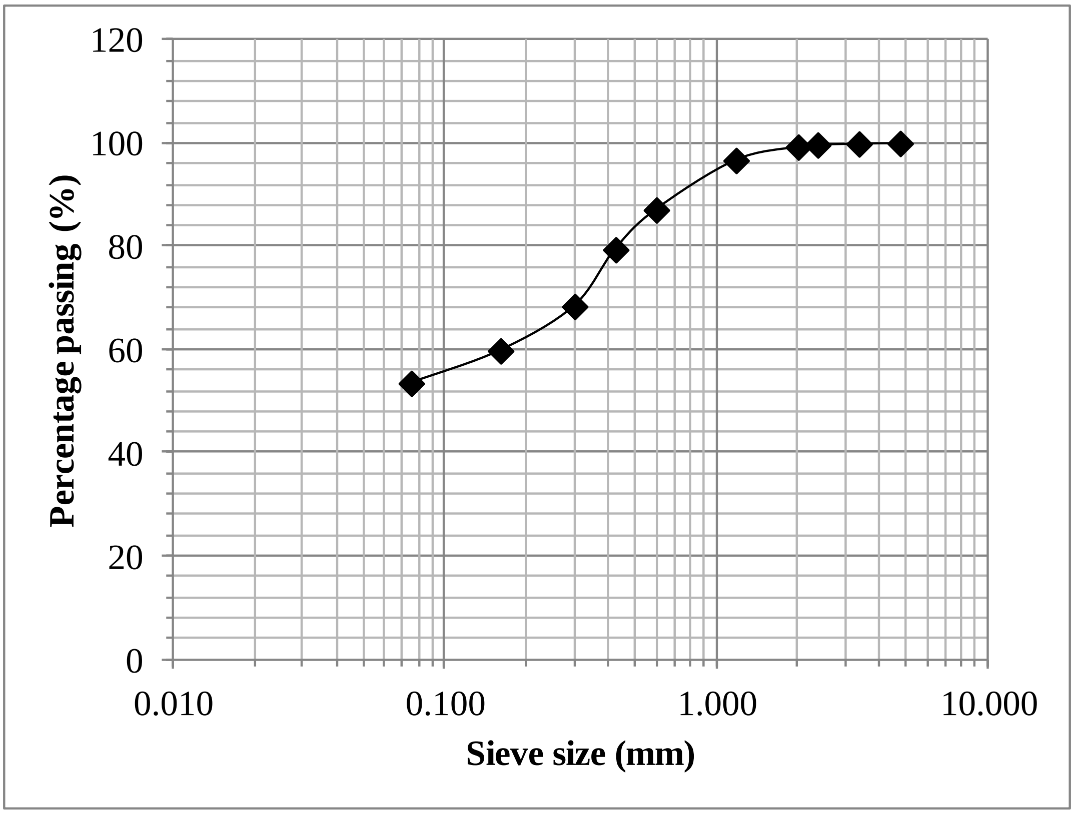

Figure 2:Sieve analysis of a fine-grained soil.

3.1.3 Consistency limits

The plastic and liquid limits of the soil increase with increase in the percentage of the locust bean powder (**Figure 3**). The finding is similar to that of Daha, Ma'aruf, Farouq, & Dawusu, (2018)This might be due to water absorption of the powder and sticky nature of the powder when in contact with water. However, the plasticity index of the samples reduce with the increase in percentage of Locust bean powder, this indicates that the decrease in plasticity index with a percentage increase of locust could lead to a significant reduction in the swelling potential of the - fine-grained soil. Hence this could conclude that locust bean powder will increase the engineering properties of - fine-grained soil. The reduction of plasticity index from 10% down to 6% at the 15% addition of the powder. The maximum plasticity index specified by the Nigerian Federal Ministry of Works and Transport (1997) is 12%. As the various percentage addition of locust bean powder reduced the plasticity index of the soil, it may be able to satisfy the condition even if the soil has plasticity index more than the required specification; as such it could be used for subgrade stabilized materials.

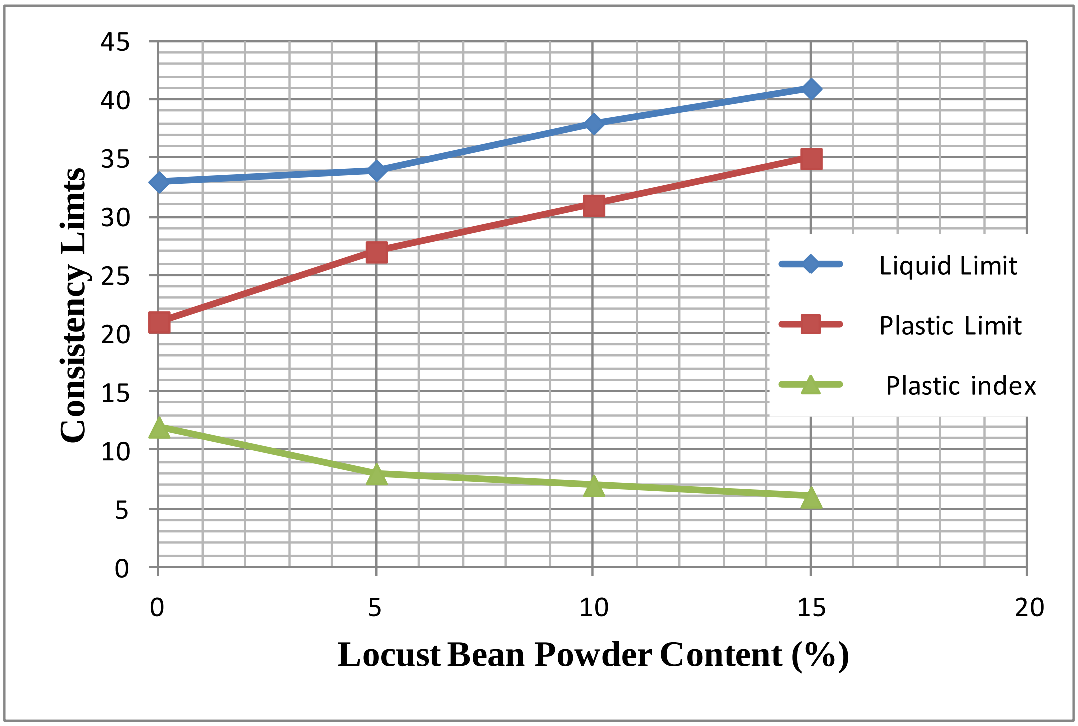

Figure 3: Consistency Limits versus Percentage addition of locust bean powder

The linear shrinkage of the soil sample in relation to the percentage addition of the locust bean powder is shown in the **Figure 4**. The linear shrinkage of the soil reduces with increase in the percentage addition of the locust bean powder (9.21, 7.88, 5.91, and 3.43% for 0, 5, 10, and 15% respectively). The maximum shrinkage limit specified by the Nigerian standard is 10%. Addition of the locust bean powder to the soil shows a significant impact on the consistency limits of the soil.

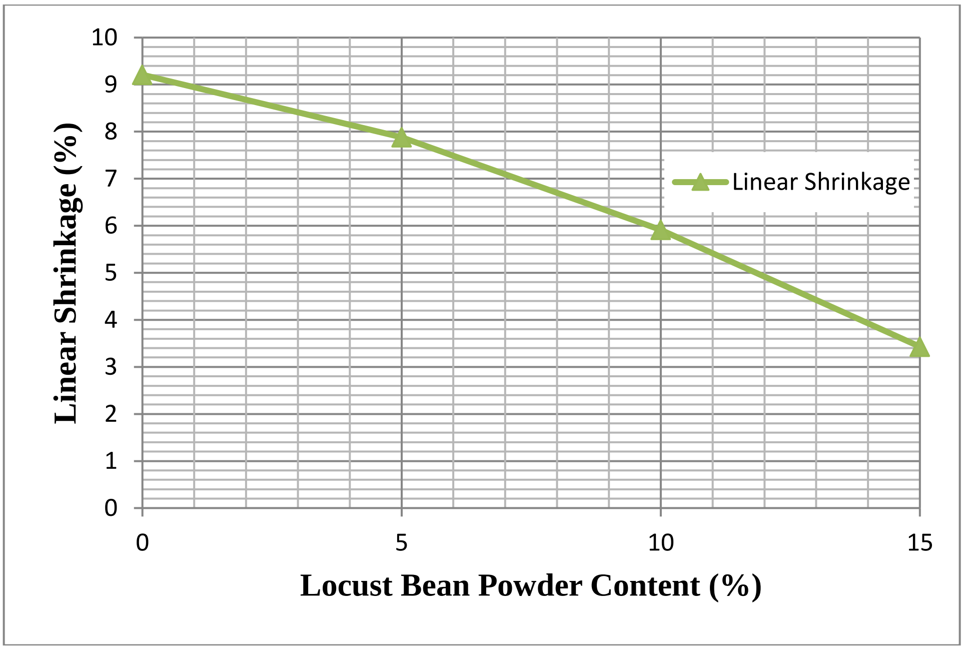

Figure 4: Linear Shrinkage versus Percentage addition of locust bean powder

3.1.3 Compaction characteristics

The relationship between maximum dry densities (MDD) and Percentage addition of the locust bean powder as well as that of the optimum moisture content are shown on the **Figure 5** and **Figure 6** respectively. The maximum dry density of the fined-grained soil decreased with an increase in locust bean powder while the optimum moisture (OMC) increases. This might be as a result of the relatively lower specific gravity of the locust bean powder compared to the fine-grained soil. Even though, the dry density decreases with increase in the percentage increment of the locust bean powder, it may not signify the low strength in the soil.

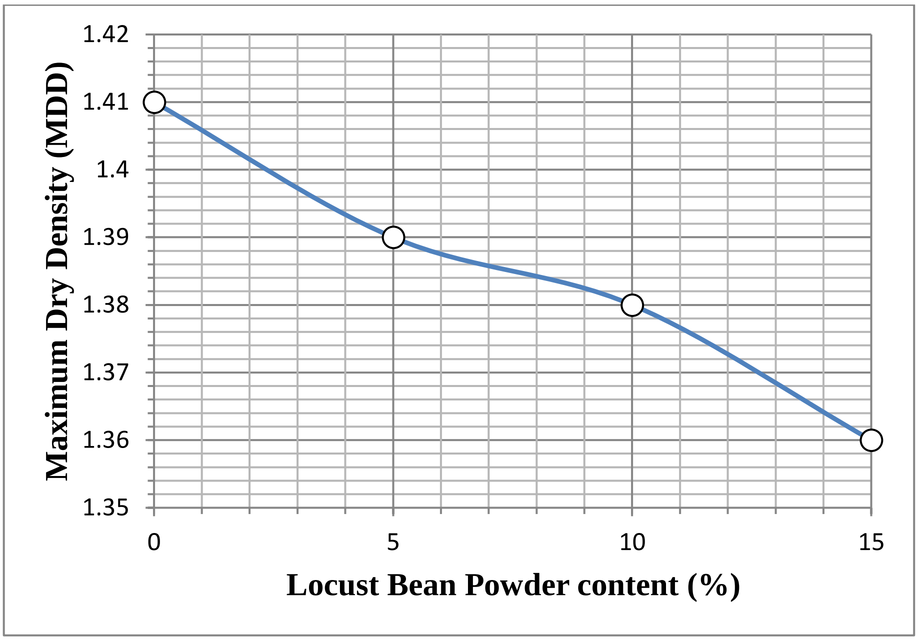

Figure 5:Relationship between Maximum Dry Density (MDD) and Locust bean powder(%)

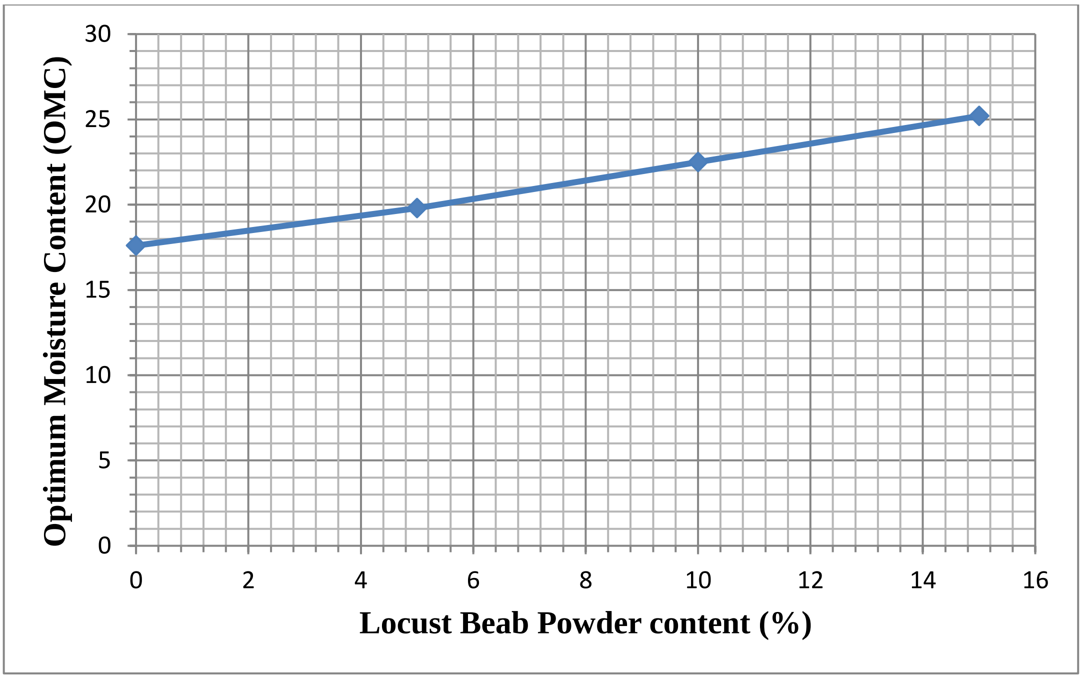

Figure 6:Relationship between Optimum Moisture Content (OMC) and Locust bean powder(%)

California Bearing Characteristics

Figure 8 and **Figure 8** show the relationship between the CBR and the percentage addition of the locust bean powder. The CBR values increase with percentage increase in locust bean powder. This might be as a result of high resistance of the locust bean powder to the penetration when loaded.

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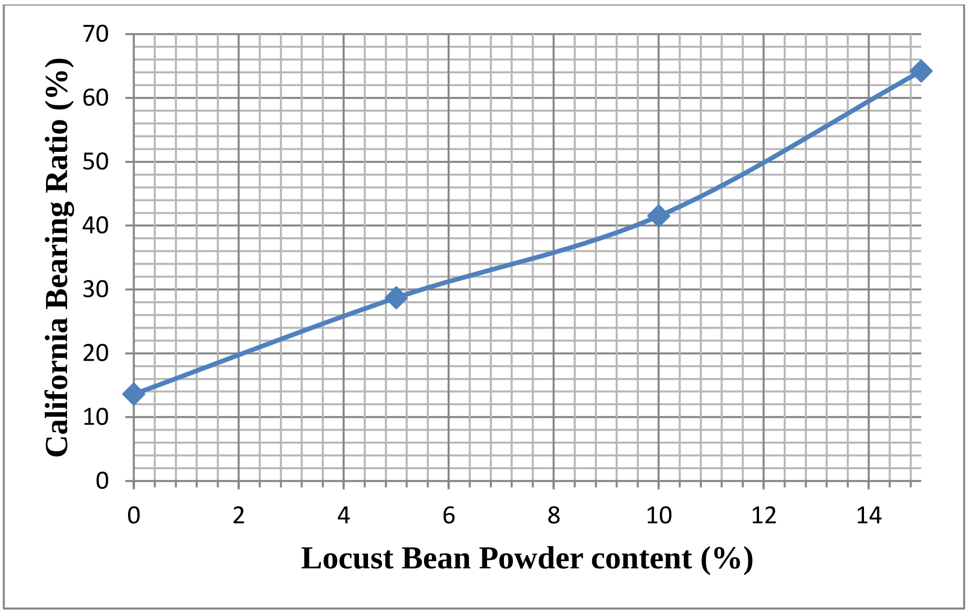

Figure 7: Relationship between California Bearing Ration (CBR) and Locust bean powder(%)

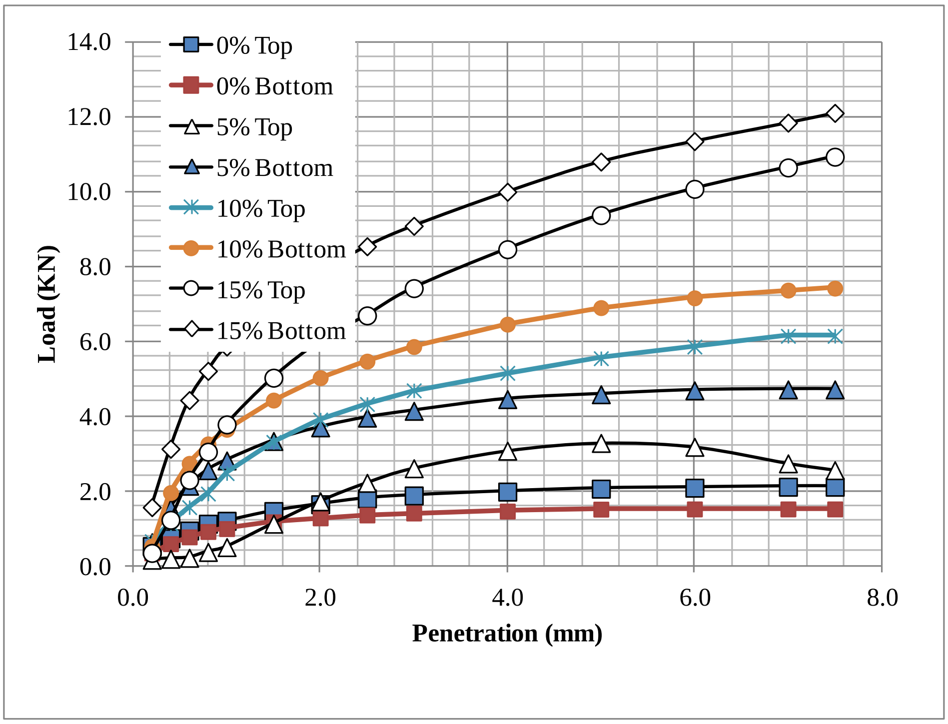

Figure 8: Relationship between California Bearing Ration (CBR) and Locust bean powder(%)

4.0 CONCLUSION

Based on the experimental work carried out on the fine-grained soil, it can be concluded that:

1. The addition of locust bean powder to the fine-grained soil increases the liquid limit and plastic limit of the soil. However, it reduces the plasticity index and linear shrinkage of the soil.
2. The specific gravity of the soil decreases with an increase in the locust bean powder
3. Maximum dry density decreases while optimum moisture content increases as the locust bean powder is increased in the soil
4. The CBR of the soil increases with increase in the amount of locust bean powder

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