Effects of Regrading on Properties of Coastal Plain Sands

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ABSTRACT

Silica sand, known to be physically, structurally and chemically stable is an important component of Coastal Plain Sands (CPS), a problem soil in Southern Nigeria. The CPS lateritic soil was stabilized with silica sand passing 0.425mm sieve, and the stabilized soil was subjected to Atterberg Limits, compaction and soaked/unsoaked California Bearing Ratio (CBR) tests. All tests were carried out according to BS 1377:1990.The results show that the plasticity characteristics (LL, PL, SL and PI) decreased, the maximum dry density increased, while the optimum moisture content reduced with sand content. The effects in these instances are most prominent at about 10% sand content. Peak soaked/unsoaked CBR of the sand stabilized soil were recorded at about 15% sand content. Sand was found to curtail the destabilizing action of water on CPS.The observed behaviour of the sand stabilized CPS soil has been explained through Engineering Geological principles and concepts. It is concluded that addition of 10% - 15% sand is optimum and cost effective in stabilizing CPS, and that the stabilized soil has a great potential in addressing the problem of road stability on CPS terrain.

KEYWORDS: *Coastal Plain Sands, silica sand, destabilizing action.*

1.0 INTRODUCTION

The past two to three decades has witnessed a lot of attention on soil stabilization, and of recent research effort is being intensified on the subject in developing countries, most probably because of their poor infrastructural development. Coastal Plain Sands (CPS) is one of the problem soil series that has been associated with foundation instability and certain undesirable behaviour as an engineering material [1,2]. The CPS is a sedimentary belt that extends from Benin Republic Border of Southwestern Nigeria, and continues in an almost unbroken stretch (except at the crossing of the Niger) to the Cameroon Republic (see Fig. 1). Jones and Hockey [3] who did some pioneering work on the soil series discovered that CPS consists of soft, very poorly sorted clayey sands, pebbly sands, sandy clays and rare thin lignites. Jackson's [2] work showed that the fractions in the soil are actually clay, silt and sand. According to the author, the upper reddish sample consists of 16.4%, 40.0% and 41.6% clay, silt and sand size fraction respectively. The corresponding proportions of these soil fractions in the lower profile of the same cross-section are 26.3%, 23% and 50.7%, respectively.

Laterite of sedimentary origin is lithologically, and by gradation CPS. In Nigeria for instance, the region designated as Coastal Plain Sands belt consists of large deposit of laterite and lateritic soils, as shown in Figure 1. Studies [2,4,5,6] have shown that because of its textural, mineralogical and chemical composition, behavior in the presence of moisture etc, the CPS or the CPS-derived lateritic soil possesses some properties which are not desirable when the soil is used for engineering purpose or when an engineering infrastructure is founded on it. Such properties include ferric iron impregnation, disintegration of apparent large grains into finer grains in the presence of moisture, swelling, shrinkages and loss of bearing capacity.

Samples of CPS obtained from Lagos area have been shown to contain Kaolinite and Montmorrilonite (howbeit in traces) as its clay minerals. The structure of the clay mineral unit is such that it makes the soil hygroscopic [7]. Thus water, a very strong destabilizing agent, is continuously attracted to the soil, resulting in detrimental effect to engineering infrastructures. CPS also contains iron in the ferric state. This ferric iron is an important cementing agent responsible for aggregation of finer particles to coarser particles [1,2,8]. The 'iron bond' is however not sustainable, as it breaks down rapidly in the presence of moisture. Jackson [2] reported that the clay, silt and sand size particles in a dry-sieved reddish brown CPS sample are 0.1%, 15% and 85%, respectively. The corresponding proportion of the soil fraction after wet sieving was found to be 16%, 47% and 43%, respectively. Thus the apparent granular particles are easily broken down to finer particles when the soil is agitated in the presence of moisture.

Variation of gradation characteristics of a soil makes it unpredictable as an engineering material. The implication of this becomes more manifest given that the shape, size and structure of the soil particles affect how they settle, their rearrangement, bulk density and free-air space [9]. The alteration of gradation characteristics of CPS may have detrimental effect on durability and integrity of highways and roads. This is so because while the maximum dry density decreases with fine content, the reverse is the case with the optimum moisture content [10].

Stabilization is the process by which a soil is improved and made good. A soil can be stabilized either chemically or mechanically (compaction or the use of additives). Laterite soils have been successfully stabilized with lime, cement, bituminous material and Sodium Hydroxide (NaOH) [11,12,13]. Attempt to substitute sand with laterite in laterized concrete engineering has shown that although it may be cheaper (especially for light weight concrete structures), laterized concrete in which laterite has been used to substitute sand) is always inferior to normal concrete [14]. This again shows that sand is a more stable component of the CPS than the whole or any of the other components.

It is recognized that considerable amount of work has been done in laterite soil engineering, especially in the area of textural characteristics, geochemistry and clay mineralogy as they affect engineering properties of soils, and stabilization of laterite. However, not much has been done on stabilizing CPS lateritic soil with a physically, structurally and chemically stable component of it (in this case the silica sand). Sand retrieved from wet sieving of laterite soil is devoid of fines or impurities, and is known as silica sand (locally referred to as clean sand, sharp sand or river sand). It is an important fraction of the CPS and it is stable physically, structurally and chemically [1]. It is on account of this that the possibility of stabilizing CPS with sand is being investigated in this study. The aim of this work is to investigate the potential of sand stabilized CPS, especially in the design and construction of highways and roads.

2.0 MATERIALS, AND EXPERIMENTAL PROCEDURE

Sedimentary (CPS) Lateritic soil used for this work was retrieved from Ososun borrow pit in Lagos, in the Coastal Plain Sands (CPS) belt of Southwestern Nigeria. Clean sand (silica sand) was obtained from the CPS terrain along Majidun riverbank in Ikorodu, Lagos, Southwestern Nigeria. The fraction of the sand used as stabilizer for the lateritic soil was that passing BS sieve No. 36 (with 0.425mm opening). Clean potable water from the Soil Laboratory of the Department of Civil and Environmental Engineering, University of Lagos was used for all laboratory tests.

Except otherwise stated, preparation of all materials was done according to BS 1377: (1990)[15] The Coastal Plain Sand (CPS) was stabilized with the following percentages of silica sand passing BS sieve No. 36: 0%, 5%, 105, 15%, 20% and 25%. Prepared samples of the stabilized soil with specific levels of stabilizer (sand) were subjected to relevant tests to determine the variation in their engineering properties related to design and construction of flexible pavements. These are Atterberg Limits, the compaction and the soaked and unsoaked CBR tests.

The apparatus and equipment specified in the BS 1377 Parts 2 and 4: 1990 [15] for Atterberg Limits, West African Compaction and the CBR tests were adopted for this work.The West African Compaction apparatus are the CBR 152mm diameter mould (fitted with detachable baseplate and movable extension), 4.5kg rammer, a weighing balance, scoop and other ancillary items. These equipment and apparatus were also used for the CBR test.

In order determine to the compaction characteristics (usually assessed quantitatively through maximum dry density and optimum moisture content), the stabilized soil samples were subjected to West African Compaction test The test procedures were in accordance with BS 1377 Part 4 (1990).The maximum dry density and the optimum moisture content for each level of sand content was determined.

Similarly the variation of soaked and unsoaked CBR of CPS with sand content was investigated by subjecting the stabilized soil samples to California Bearing Ratio (CBR) test.

3.0 RESULTS, ANALYSIS AND DISCUSSION

3.1 The Preliminary Soil Identification and Classification Tests

The result of the wet-sieving analysis showed that the natural (unstabilized) soil contains 44% sand size particles and 56% silt and clay size particles.The particle size distribution curves for both the dry-sieved and wet-sieved samples are given in Figure 2. Table 1 illustrates the index properties of the soil. The liquid limit and plastic limit of the soil are 49% and 37.8%, respectively, giving a plasticity index of 11.2%. The soil plots below the "A" line, and can be described as Organic Sandy Clays, with intermediate plasticity.

3.2 Variation of Atterberg Limit with Sand Content

Figure 3 illustrates the variation of liquid limit (LL), plastic limit (PL), shrinkage limit (SL) and the plasticity index (PI) of the soil with sand content. It shows that the limits generally decrease with sand content. While the LL drops drastically with sand content up to 10%, after which the drop becomes more gradual, the PL decreases at a uniform rate with sand content. Thus the LL decreases from 49% at 0% sand content to 39% at 10% sand content-a 10% drop. The reduction in the LL from 10% to

20% sand content is only about 4%. The PL at 0%, 10% and 20% are 37.85, 35.25 and 32.3% respectively. The variation of the shrinkage limit (SL) with sand content is such that the SL decreases rapidly from 0% to 15% sand content, after which the decrease becomes gradual. The variation of the PL with sand content follows that of the LL, but with the drop of the PI from 0% to 10% becoming even more drastic. The PI of the natural soil (0% sand content) is 11.2%. This drops to 3.8% at 10% sand content. The decrease of PI from 10% to 20% sand content is only marginal, the PI being 2.7% at 20% sand content. From the result of this investigation therefore it is clear that the effect of introducing silica sand into CPS is to decrease the plasticity of the soil. Clay is a chief component of the lateritic soil and that makes the soil to be very plastic. On the other hand, silica sand is non-plastic, and as it is being introduced into lateritic soil, the latter becomes increasingly non-plastic. The implication of this loss of plasticity and shrinkage on engineering properties of lateritic soil is very glaring. For instance, because of its clay content, lateritic soil has a tendency to become very soft when wet, with consequent loss of bearing capacity. On the other hand, the soil has a tendency to shrink and crack severely when it looses moisture. This behavior arising from the soil's contact with moisture or loss of moisture is very detrimental to engineering infrastructure. The action of silica sand, which manifests in the decrease in the soil's plasticity, is therefore beneficial.

3.3 Variation of Compaction Characteristics with Sand Content

The compaction characteristic of Coastal Plain Sands (CPS) improves continuously with sand content. Figure 4 shows that the maximum dry density (MDD) increased continuously from 1.85 Mg/m^3 at 0% sand content to 2.09 Mg/m^3 at 25% sand content. The optimum moisture content (OMC) on the other hand decreased from 17.5% at 0% sand content to 11.65% at 25% sand content. Figure 5 shows that the effect of sand on MDD and OMC is most prominent at 0% - 10% and 0% - 15% respectively, after which the effect becomes less noticeable and gradually reduces. The increase in MDD with silica sand content can be attributed to replacement of sand grains with more compact and granular soil particles. According to Osinubi et al [10] and Akanbi [4] bulk density and MDD increase with the granular content of a soil. The effect of introducing sand into the interstices of lateritic soil is to reduce considerable the effective surface area of the soil. O'Flaherty [12] , for instance established that the surface area of 1 gm of fine sand is 90.7cm^2, while that of clay is about 11,343.5 cm^2 about 125 times that of sand. Thus, as more and more sand particle is being introduced into the soil, the effective surface area reduces

Progressively, thus requiring less amount of water to attain OMC. This effective area concept is most probably the reason for the continuous decrease in OMC with sand content.

3.4 Effect of Sand Content on CBR

Figure 6 shows the variation of the soaked and unsoaked CBR of the soil with sand content. The CBR increases progressively from 0%-15%, after which it drops with higher sand content. The unsoaked CBR of the natural soil is 62.1% while the values at 15% and 25% sand content are 176% and 157.7%, respectively. The soaked CBR of the soil at 0%, 15% and 25% sand content are 4.8%, 122.2% and 112.0% respectively. The effect of further increase in sand content above the 15% optimum value is more detrimental to the soil at the unsoaked state than the soaked state. For instance the loss of CBR from 15% - 25% sand content is 18.3%, compared to 9.45 for the soaked. Thus sand inclusion may have reduced the destabilizing action of water on the soil (see the section on Effect of Sand on action of Water below). Stabilizing CPS with silica sand results in progressive filling of air voids with sand particles. Thus the soil becomes more compact and offers more resistance to penetration, resulting in higher CBR. Since the maximum CBR was obtained at 15% sand content (for both soaked and unsoaked) it could be inferred that 15% sand is required to completely fill the air voids in the soil. Sand grains in excess of this do not contribute to the filling of air voids and could be responsible for reducing the compactness of the soil. The drop in both the soaked and unsoaked CBR of the soil above the 15% sand content could be attributed to this.

3.5 Effect of Sand and Moisture Content

It has been established [1,2,5] that ferric oxide, a major cementing agent in lateritic soil, is responsible for aggregating finer particles of CPS to more granular particles . This gives the soil its apparent granular structure. Unfortunately, the ferric iron 'bond' is not sustainable, as it breaks down rapidly when the soil is agitated, especially in the presence of moisture. The ease with which the soil disintegrates in the presence of water is vividly depicted from the result of dry sieving and wet sieving of the soil as illustrated in Table 3 and Figure 2. The granular particles (sand and gravel sizes) of the soil in the dry state account for 98%, while the clay and silt size fractions account for only 2%. However, during the process of wet sieving a large proportion of the granular fraction of the soil got disintegrated to silt and clay size particles. Specifically agitation of the soil in the presence of water (wet sieving) results in disintegration of about 54% of the sand and gravel size particles into finer particles, resulting in the being introduced into the soil, the effective surface area reduces.increment of silt and clay fractions of the soil to 56% from 2% (see Table 2).

The destabilizing action of water on the CPS could be responsible for the loss of certain desirable engineering properties of the soil such as bearing capacity, non-plasticity and permeability. The disintegration of the ferric iron bond in the presence of moisture could also accounts for the general reduction of CBR of the soil from unsoaked to soaked. However, it was observed that the introduction of silica sand, a material that is physically, structurally and chemically stable, reduced the adverse effect of water on the soil. Figure 6 shows the loss of CBR (from unsoaked to soaked) for the natural soil (0% sand content), 5%, 10%, 15%, 20% and 25% sand stabilized soil. Due to the intervening role of the sand (the additive), the loss of strength (from unsoaked to soaked) of the natural soil is reduced from 92.3% to between 21.7%-30.4% for the stabilized soil.

4.0 CONCLUSION AND RECOMMEND-ATIONS

The results of this investigation revealed that the plasticity characteristics of CPS generally increased continuously with sand content. The drop in LL and PI with sand content is very drastic from 0-10% sand content, after which the reduction became more gradual. The progressive loss of plasticity has been attributed to replacement of plastic clay particles with non-plastic silica sand grains. The loss of plasticity has been found to enhance the bearing capacity of the soil, and results in its improved behavior when it looses or gains moisture.

While the MDD increased continuously with sand content sand content, the reverse is the case for the OMC. Again, the increase in MDD is most prominent from 0-10% sand content, while the decrease in OMC is most noticeable between 0-15% sand content. Unlike other properties, the soaked and unsoaked CBR of the stabilized soil increased steadily from 0\% to 15% sand content, after which they dropped with further increase in sand content. This means that 15% sand is just enough to fill the air voids in the soil. Sand in excess of this neither contribute to the compactness of the soil, nor increase its resistance against penetration, hence the drop in CBR.

It was observed that sand and gravel size particles of a sample reduced when wet-sieved, while the silt and clay fractions increased. This destruction of the apparent granular structure of the soil in the presence of moisture is also responsible for the drastic reduction of CBR from unsoaked to soaked. Silica sand has been found to reduce the deleterious effect of water on the soil. Thus while the loss of CBR of the natural soil from unsoaked to soaked stage was substantial, the loss was minimal for 10% sand stabilized CPS.

Stabilizing CPS with silica sand, itself a component of CPS could result in drastic reduction in the cost of road infrastructure on CPS terrain of Southern Nigeria. As a result of sand stabilization, the misbehavior of the soil when in contact with water is also greatly curtailed.

It is recommended that whenever CPS is used in road and highway construction, the soil should be stabilized with about 10-15% silica sand in order to improve the stability and durability of the infrastructure. As a first step toward this, existing deplorable roads and highways could be rehabilitated with stabilized CPS to assess its field performance.

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Table 1: Index Properties of the Coastal Plain Sands

PLASTICITY CHARACTERISTICS					COMPACTION CHARACTERISTICS	
LL(%)	PL(%)	SL(%)	PI(%)	NMC(%)*	MDD (kg/m^3)	OMC(%)
49.0	37.7	11.7	12.2	5.6	1850	11.8

*NMC=Natural Moisture Content

Table 2: Alteration of the Particle Size Distribution of Coastal Plain Sands in the Presence of Water

Condition	Sand and Gravel Sizes (%)	Silt and Clay Sizes (%)
Dry-sieved	98	2
Wet-sieved	44	56

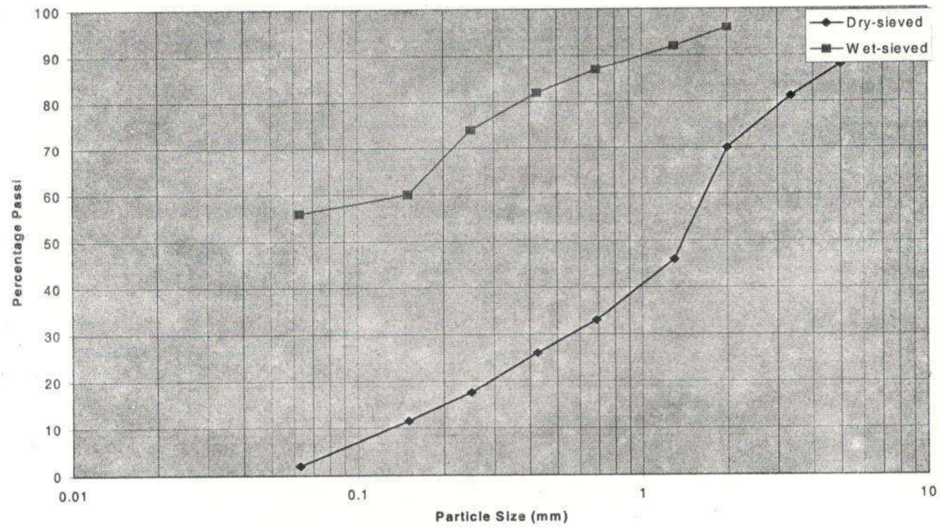

Figure 2: Particle Size Distribution Curves for both Dry-sieved and Wet-sieved Samples

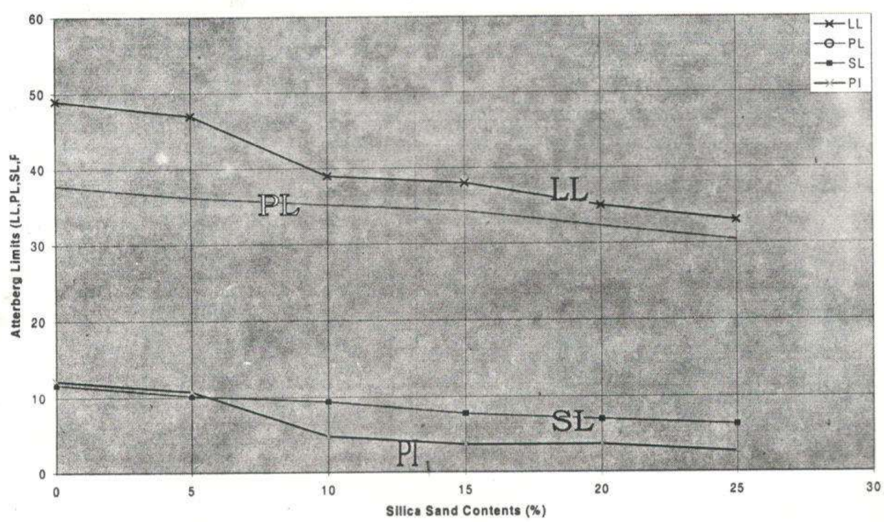

Fig. 3: Variation of Atterberg Limits with Sand Content

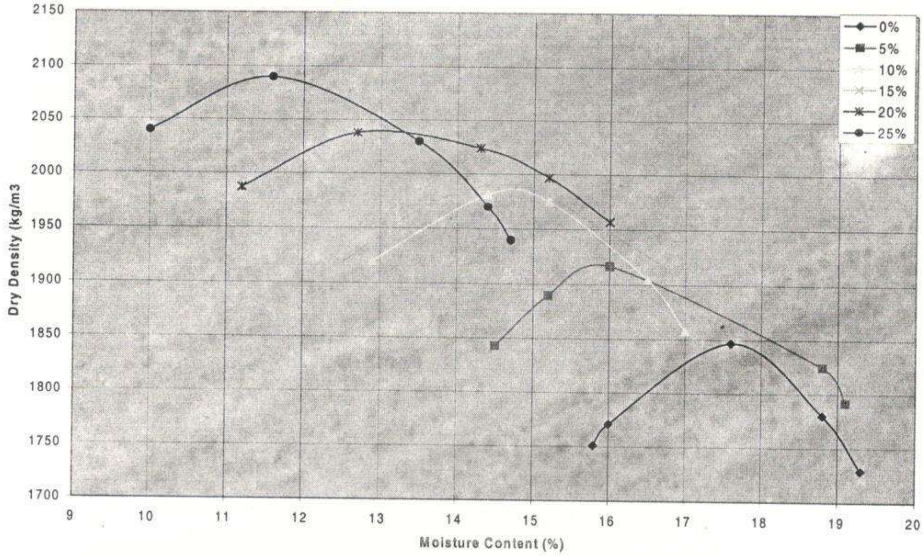

Fig. 4: Effects of Sand Content on Compaction Characteristics of CPS Lateritic Soil

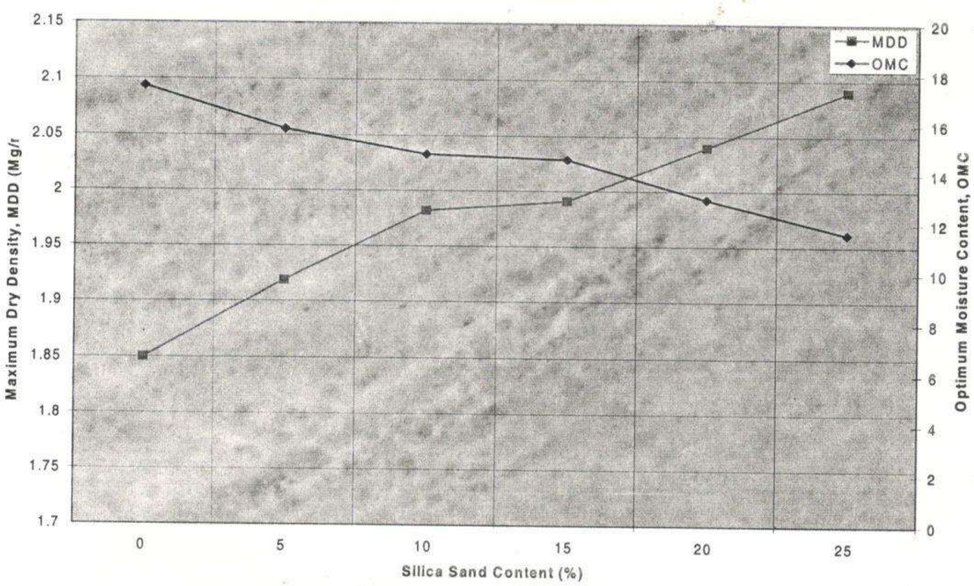

Fig. 5: Variation of Maximum Dry Density and Optimum Moisture Content with Sand Content

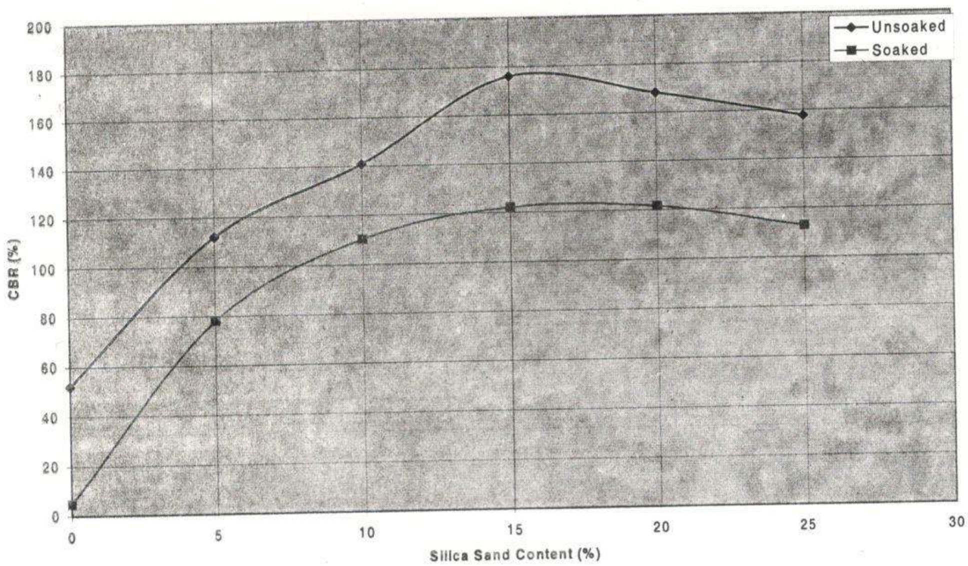

Figure 6: Effect of Sand Content on Soaked and Unsoaked CBR