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Influence of Silt Content and void ratio on the properties of sand silt mixture

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ABSTRACT

Consolidation coefficient (C_v), Hydraulic conductivity (K), and volume compressibility coefficient (m_v), especially have an enormous effect on the formation of the pressure in the pores whenever soils with granularity get loaded together with fines in an undrained or partially drained state. The objective of this study is to quantify what is the impact of the soil's void ratio and amount of fines on these soil parameters involved. The results of multiple tests on two poorly graded sands using flexible wall permeameters are displayed and discussed. These tests used nonplastic silt concentrations of 0%, 5%, 10%, 15%, 20%, and 25%. The experimental findings demonstrate that, in both cases, the consolidation and permeability coefficients are rising as the silt concentration falls. So, as the void ratio rises (because of a decrease in silt concentration), the K does as well. The void ratio affects the soil's ability to compress its volume, which has caused some variation. This study reveals that the finer native Khulna sand exhibits poor drainage conditions. In comparison to nearby sand, the somewhat coarser Kushtia Sand has excellent drainage characteristics. As a result, it seems to sense that coarser sand would be better for building any kind of structure. The soil beneath a foundation for a hefty structure or high-rise building should contain less silt.

Keywords: *Hydraulic conductivity, consolidation coefficient, Void ratio, Sand-silt mixture, volume compressibility.*

INTRODUCTION

When choosing soils for utilization in geotechnical engineering-related uses, the two primary considerations to take into account are longevity and material accessibility. It may be challenging to use silty soils in geoenvironmental projects because they are so prevalent in numerous countries. Their increased permeability, poor grading, and lack of cohesiveness between their grains are blamed for this behaviour [1]. In Bangladesh, the city of Khulna is located in the southern region, where alluvial deposits from many rivers (Rupsha, Vairab, etc.) have formed the soil [2]. If "Sundarban long ago," this area was also covered in a dense forest and these deep forests were submerged due to tectonic forces at various points in time in the past. They have incredibly porous soil, poor drainage that allows rainwater to seep through, compressible organic debris, and a low bearing capacity [2]. Geotechnical engineers must carry out in-depth analyses of the subsoil's consolidation properties prior to starting the building of any substantial and large-scale constructions. Only a small number of compositional factors, such as interactions among the components of soil, the type of soil substances that are minerals, the distribution of particle sizes, the shape and

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size of the soil particles, the composition of water in the pore, and retained cations, affect the manner in which engineering characteristics of soil mixes are determined [3, 4]. Critical boundaries of soil for both unsaturated as well as soaked soils incorporate pressure driven conductivity, compressibility, and the bend portraying the relationship between's characteristics of the dirt and water. The usage of materials of superior quality has an impact on these characteristics [5, 6].

The hydraulic conductivity characteristic of soil layers is an important measure in the context of several soil engineering investigations (water seepage, stability investigation, and drainage). It often correlates with several significant physical characteristics, such as fines percentage, permeability, gradation, particle dimensions, etc [7]. Finding an accurate K of soils is crucial since soil fluid movement has an enormous effect on the stability, building, and designing of many buildings and construction projects [8-11]. A lot of research has been done on K of combined soils in the last few decades, and there has been an increase in interest in planned combinations like sand-bentonite combinations for impermeable liners [12-17]. The results of the investigation show [18], Sand that has been blended with 50% low plastic particles could have up to four orders of scale fewer saturated hydraulic conductivity versus clean sand. In this research project, [5] the impact of the soil's void ratio and fines content on K, C_v, and m_v is attempted to be quantified. The results indicate that 25% fine substance-mixed sandy soil fails to solidify as swiftly as it has a lower K value than sand alone soil. This article [19] examined whether plasticity including particles percentage affected the CFM's index properties including K. Low plastic CFM showed a milder fall in K if fine percentage and plasticity index grew. [20] discovered that the values of K for Ottawa sand ranged from 0.6 X 10^{-3} to 1.3 X 10^{-3} cm/s for sand with 15% particles, and 0.6 X 10^{-5} to 1.2 X 10^{-5} cm/s for sand with 25% fines. Both [21] and [5] reported K_{sat} limits for two plastic-free sands with almost the same particles. This research [22] explored how different amounts of plastic-free components in sand-silt combinations affected their actions. It was determined that the quantity of fines in the mixture impacted the mechanical properties of sand since the texture among the sand, the void ratio, and the permeability did not significantly change with a rise in finer percentage throughout assessment. [23] examined K different combined soils containing silica grains of varying diameters. As the volume of the fraction of tiny fragments grew from 0% to 100%, K initially decreased, but it ceased at approximately fifty percent. From that point on, there was hardly an additional drop in K.

The soil subsiding triggered by the amount of weight of the load is predicted using the compression index (C_c). The proportion of volumetric variation in the aftermath of an increase or decrease in stress is measured as its compressibility, and it is influenced by the stiffness of the soil skeleton is [24]. The consequence of the fine portion on compressibility and packing has been studied historically [25-29]. Using mixtures of dredging clay and sand, a series of incremental loading oedometer tests were conducted. The findings revealed that, generally speaking, the Cc increased as the fines content climbed from 30% to 95%, whereas the C_c kept constant for fines content lower than 30% [30]. [32] stated the findings of an oedometer investigation using tailings gathered from the bottom portion of a top dam; Cc originally dropped as it accumulated nonplastic fragments, but the trend changed after an acceptable fines proportion ranging from fifty percent to seventy percent was reached.

The C_v is a unit used to assess the degree of the sample soil distortion under a force that is vertical. To specifically predict the engineering performance of remolded fly ash-soil combinations, consolidation and shear forecasting models founded on mixture theory have been developed. Confirmation studies show that it is feasible to employ mixture theory to forecast the consolidation and shear reactions of fly ash-soil combinations [33]. Critical boundaries of soil for both unsaturated as well as soaked soils incorporate pressure driven conductivity, compressibility, and the bend portraying the relationship between's characteristics of the dirt and water. [34]. C_v also drops with an increase in backfill fines contents (F_B) or backfill bentonite contents (B_B) due to the drop in K that occurs when F_B or B_B levels out. Last but not least, when the backfill only comprises low-plasticity fines, significant amounts of fines (40%) may be needed to reach k109m/s. The target of the exploration directed in [35] was to research what different compressibility qualities of soil-bentonite blends mean for different boundaries of bentonite, including fluid cutoff, dirt substance, enlarging limit, and replaceable sodium rate (ESP). The study found that regardless of the overburden pressure, increasing the concentration of bentonite and decreasing the coefficient of volume compressibility (Cv) led to an increase in the clay fraction, liquid limit, free swelling, and ESP of the soil-bentonite mixes. The purpose of this study [36] was to characterize how diatom concentration affects the consolidation of soil-diatom mixtures prior to frustule particle breakup. When the samples' diatom content rose, so did their C_c. Moreover, at greater diatom levels, the C_v rose, hastening the process of pore water dissipation. Moreover, the C_c from 0.27 when the diatom concentration is 0% to 0.08 when it is 60%.

It is impossible to practically pinpoint the precise effects of these factors using conventional field testing. In laboratory tests, the factors influencing the hydraulic conductivity (K) of soils can be more accurately regulated than in field tests. For laboratory investigations, it may be challenging to get sufficiently undisturbed samples or to reassemble soil specimens that accurately replicate the characteristics of wild soil. Many laboratory procedures can be used to determine the soil's K content. One strategy to gauge soil penetrability is the inflexible wall permeameter (RWP), while another technique is the adaptable wall permeameter (FWP) [37].Fixed-wall cells are considered most suitable for testing laboratory-compacted clays that are unlikely to experience significant effective overburden pressure when deployed in the field [38]. According to the research paper, flexible-wall cells are better suited for testing undisturbed soil samples as they can help reduce boundary leakages and are more suitable for testing soils that will experience significant effective stress in the field. In contrast, fixed-wall cells may be better suited for testing laboratory-compacted clays that will not experience significant effective overburden pressure in the field [38]. In the last 20 years, the use of FWP has become more prevalent among researchers due to its ability to simulate field conditions, especially with regards to controlling the hydraulic gradient and lateral earth pressure [39-44]. [45] The research paper reported findings from an experiment involving sands containing low amounts of silt. The results obtained from FWP testing indicated that the saturated hydraulic conductivity decreases gradually as the silt content increases from 0% to 30%, and then drops significantly when the silt content exceeds 30%.

The impact of confining stress, fines percentage, and void ratio on saturated hydraulic conductivity has only been inferred from limited experimental data. The primary objective of this study is to

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analyze how the saturated hydraulic conductivity of sand-silt mixtures is affected by the silt content and void ratio.

METHODOLOGY

Materials Description

This study looked at 2 hosting fragments of sand (poorly divided sand made from quartz grains). As the base sand for the very first tests, ASTM Graded Sand C-778-94A, frequently shortened by the designation Ottawa Sand or ASTM C 109, was utilized. It possesses uniformity coefficients (Cu) of 1.87 and curvature coefficients (Cc) of 1.04, correspondingly. In the next phase of assessment, 50:50 sand (i.e., 50% ASTM 20-30 sand) was prepared by combining exactly equal amounts of ASTM Graded sand as well as ASTM 20-30 sand C-778-93A by its dry weight. It possesses measurements for Cu as well as Cc of 2.46 and 1.09, accordingly. Due to their curving granular characteristics, all host sands have been designated as poorly divided sands (SP) under the Unified Soil Classification System (ASTM D2487-06). According to (ASTM D422-63), the grain-size ranges for ASTM Graded, 50:50 and ASTM 20-30 sands have been determined.

Work was carried out to find out the way the silt presence in sands with poor grading influenced its compressibility as well as hydraulic conductivity characteristics. The surrounding sands were mixed with Sil-Co-Sil #106 U.S. (Silica Company, Ottawa, Illinois) to generate samples that contained the desired silt percentages of 5, 10, 15, 20, and 25% by dry weight (together with a specific gravity value of 2.65) for the silt. That was carried out to find out how this study will be affected by the silt content. Sil-Co-Sil #106, a plastic-free silt, contains 99.7% powdered silica. This sand underwent hydrometer tests in accordance with ASTM D422-63. The specific gravity of both the sand and silt that were utilized in the present study is 2.65. As per ASTM D4254-00 (Method B) along with ASTM D4253-00, the sand-silt combinations' highest and lowest void ratios (e_{max} and e_{min}) were determined.

Preparation of Specimen

The scheme method of slurry deposition was utilized to prepare the specimens [46] and modified by [47] and [48]. Spotless, silty sand tests with textures looking like alluvial residue or water powered fills are created by this strategy. The technique enables the fabrication of specimens with a high B value prior to back pressure saturation and that are initially very loose or not at all. The slurry deposition method yields homogeneous specimens that are visible to the human eye, however, for the method to reliably produce exceptional specimens, the operator's expertise and competence are essential. Dry sand and silt were gently poured into a cylinder-shaped piece of fibreglass that was previously partly stuffed by deaired water that had been distilled. The piece of metal sized 525.0 mm in length, 64.15 mm in width, and 56.8 mm in diameter. The mixture required about 20% more substance than the typical sample weight. In order to secure the container's tube's bottom, a stopper made of rubber was relied on. The total number of bubbles of air which had been retained in the water's surface was lowered by adding more deaired water to the tube to maintain the level of water uniformly above the level of the soil. Finally, deaired water was poured into the mixing tube to the top, and the tube was shut off with a rubber stopper. The mixing tube was continuously turned upside down while simultaneously making half spins around its axis to mix the slurry. To release trapped air, vacuum was applied for at least 6 hours. The vacuum was let go after deairing the slurry, and the slurry was then mixed once more. According to the findings of the research paper, sands without any impurities were able to be mixed within a time frame of less than five minutes. However, when the sand contained a 25% concentration of silt, the minimum time required to mix the sand

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increased to 15 minutes. Following the complete mixing of the slurry, a porous stone that had been equipped with damp filter papers on both sides was used to replace the top rubber stopperThe porous stone was securely held in place with one hand while the mixing tube was carefully lifted and inverted into a split mold that featured a stretched latex membrane and collar. The second rubber stopper on the top end of the tube was then removed, and the slurry was poured progressively into the membrane that was located within the split mold.

Once the slurry was poured, a rubber hammer was used to strike the mold and collar to help densify the specimen. After the collar was removed from the specimen, the top cap made of porous stone and filter paper was placed onto it. However, before the specimen top could be attached to a vacuum source of around 25 kPa, the split mold had to be disconnected. In the research paper, it was recommended to gradually apply suction to prevent the specimen top from being excessively consolidated. The split mold was removed with caution before constructing the triaxial cell, and the dimensions of the specimen (height and diameter) were carefully noted. The specimens utilized in the study were approximately 160mm tall and 70mm in diameter. To prepare the specimen, back pressure saturation, and intended liquid, deaired distilled water was suggested for use.

Consolidation Tests

The research paper utilized an automatic triaxial testing device from the Soil Engineering Equipment Company in San Francisco, California for back pressure saturation, isotropic consolidation, and B-value checks. Once the test subject was placed inside the triaxial cell, the equipment was connected to the cell's pressure and drainage lines, allowing for the application of confining tension and back pressure like any other triaxial test. At first, a cell strain of 25-27 kPa was used before gradually releasing the vacuum, and the material was then compacted to 50 kPa, and the initial B-value was computed. Depending on the particle content and void ratio after tapping, the initial B values of specimens produced using the slurry deposition technique typically ranged from 0.45 to 0.85. Prior to testing pressure driven conductivity, the examples were soaked and isotopically combined under compelling restricting burdens of 50, 100, 200, and 300 kPa. Progressively applied back pressures somewhere in the range of 250 and 380 kPa were utilized to accomplish example immersion until B-upsides of no less than 0.97 were reached. B-values of 0.98 or higher were found in most of the samples that were tested.

Hydraulic Conductivity Tests

The study employed an automatic triaxial testing device for back pressure saturation, isotropic consolidation, and B-value checks. To test hydraulic conductivity, a Tri-Flex 2 Master Control Panel was used with three built-in burette channels, and the triaxial cell was also used as a permeameter cell. Two burette channels were connected to the specimen base influent line and the specimen top effluent line, and drainage lines were attached after each consolidation stage.

The pressure in both burettes was calculated from the back pressure in the specimen, and bottom-to-top flow was induced by slightly increasing the back pressure difference between the specimen's bottom and top. Differential pressures were adjusted based on the silt content to induce sufficient flow within a reasonable amount of time. Particle segregation was not observed, and hydraulic conductivity was measured using the constant head and falling head techniques.

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During the experiment, the temperature of the water was measured in a container located near the triaxial cell. After the pressure driven conductivity estimations were directed for a given compelling keeping pressure, the seepage lines of the example were separated from the control board and reconnected to the volume change gadget of the triaxial device to continue to the following combination stage. The B-values were calculated before and after each hydraulic conductivity test. To ensure accurate measurements, we used porous plates that had the same diameter as the specimen's cross-section. It is highly recommended to clean these porous stones using an ultrasonic cleaner before every test.

Upon completion of the testing, each specimen was dried in an oven. The fines were separated from the sand fraction using a No. 200 sieve. The actual fines content was then determined by wet sieving in accordance with ASTM D1140-00, method A, on the material that was retained in the sieve. The coarse fraction that was retained was then oven dried in order to measure the grain-size distribution of the specimen, following ASTM D422-63. This additional step was taken to ensure that the distribution of grains in the sand silt slurry combinations was consistent across all the samples that were produced and evaluated.

RESULT AND DISCUSSION

To lead the combination test, loads are applied in a mathematical movement with a heap proportion of 1 and a normal burden grouping of 8, 16, 32, 64, 128, and 256 kg. Different load increments can be used, but it seems that if the p/p increment ratio is not large enough, the soil tends to develop internal resistance to the loads and the total deformation of the sample will be lower than obtained if the p/p increment ratio is used (as indicated above).

The graph of √t (min) vs. dial reading for 5% Kushtia sand silt mixture for an 8 kg loading condition is presented in figure 1. The dial reading in this instance is set to reverse. √t graph is another name for the graph and it is necessary for the consolidation calculation. The calculations for t_{50}, D_0, D_{90}, D_{100} and D_{50} are as follows:

- ✓ A tangent was drawn from the beginning of the curve in this graph, as illustrated in figure 1, and intersected with the horizontal axis to obtain the horizontal distance.
- ✓ A horizontal distance was chosen that is 1.15 times the horizontal distance where the tangent intersects that distance.
- ✓ A line was drawn starting at the end of this 1.15 times horizontal distance and added to the vertical intersection point of that first tangent, and from there a second line was created that intersects the first line at a point on the curve.
- ✓ A line was drawn perpendicular to the horizontal axis from the intersection point of the curve of the second line and then calculated the t_{50} from that position.
- ✓ Once more, a perpendicular line was drawn between the intersection of the second line's curve and the vertical axis to obtain the D_{90}.
- ✓ The D_0 was calculated from the starting point of the first tangent of the curve at the vertical axis.
- ✓ Then we get D_{100}, D_{50} from these equation,

$$D_{100} = D_0 + \frac{10}{9}(D_{90} - D_0) \quad (01)$$

$$D_{50} = \frac{D_0 + D_{100}}{2} \quad (02)$$

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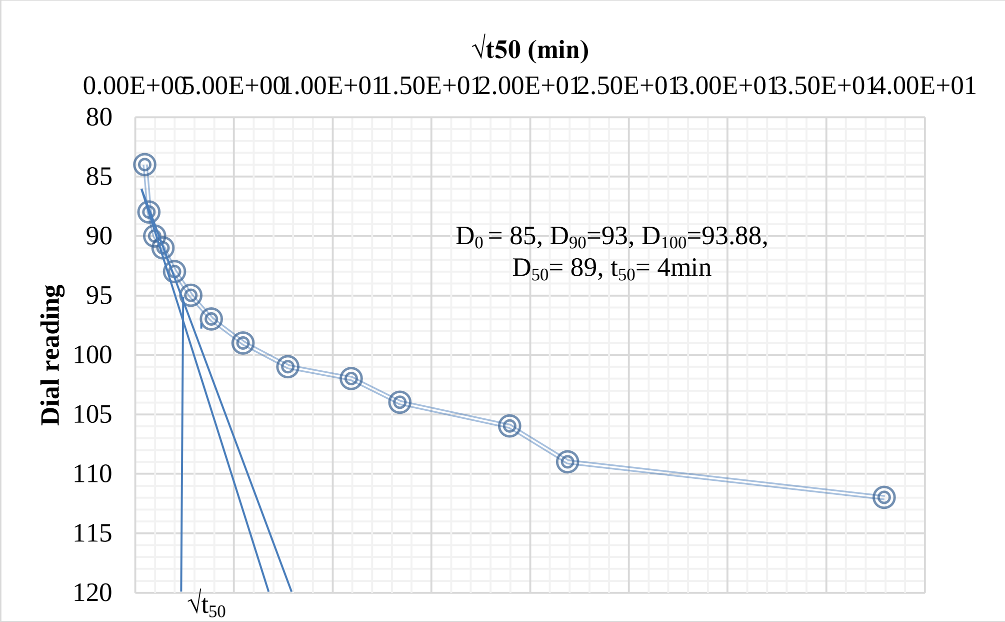

Fig.1:-*Graph √t vs. dial reading (5% Kushtia sand silt mixture with 8 kg loading condition*)

The process was the same for sand silt mixtures made with 5% for 16, 32, 64, 128, and 256 load conditions and also with 15% Kushtia, 25% Kushtia, 5% Khulna local, 15% Khulna local, and 25% Khulna local, respectively.

A graph of effective pressure vs consolidation co-efficient for a 5% Kushtia sand silt mixture can be seen in figure 2. From these, the Cv for an effective pressure of 100kpa was calculated. The effective pressure vs. void ratio is plotted in figure 3 on a logarithmic scale for a 5% Kushtia sand silt mixture. Then the compression index (Cc) and preconsoildation stress from these graphs were calculated.

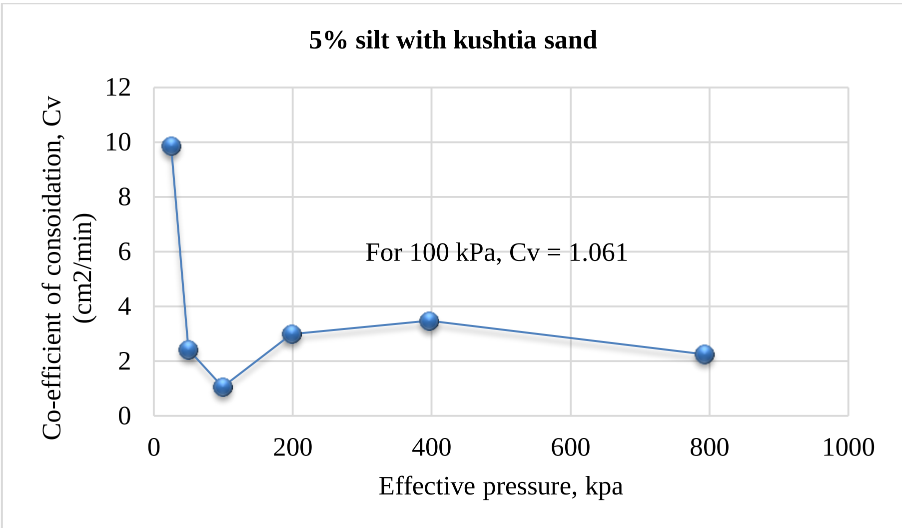

Fig.2:-*Variation of co-efficient consolidation with effective pressure (Kushtia sand with 5% silt)*

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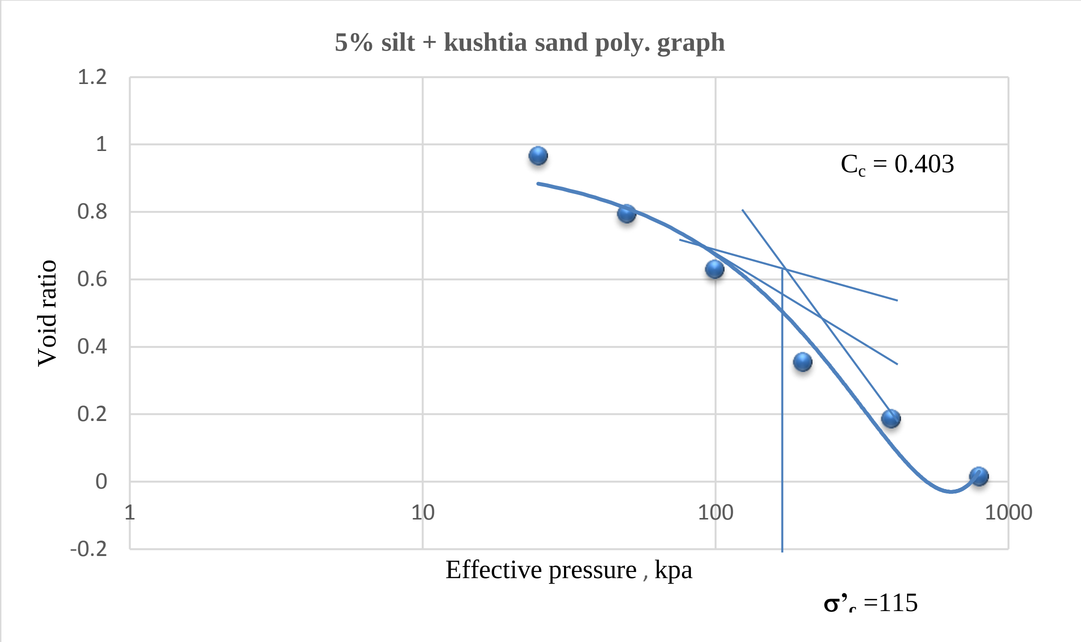

***Fig.3:**-Variation of void ratio with effective pressure (Kushtia sand with 5% silt)*

The calculation for C_c:

- ✓ A horizontal line was drawn at first from the place on the graph where the radius of curvature is the smallest.
- ✓ Next, a tangent was sketched away from that point has the smallest radius of curvature.
- ✓ Then, a bisector was created to split the angle.
- ✓
- ✓ Next, a second tangent was created from the graph's straight section that intersects the bisector at a single point. Finally, a line perpendicular to the horizontal axis was drawn from the bisector's intersection point; this is the preconsolidation stress σ'$_c$.
- ✓ Then C_c is computed by this equation,

$$C_c = \frac{\Delta e}{\log(^{p_2}/_{p_1})} \text{ (Neglect negative sign)}$$

(03)

The steps are for sand silt mixtures made of 15% Kushtia, 25% Kushtia, 5% Khulna local, 15% Khulna local, and 25% Khulna local, respectively.

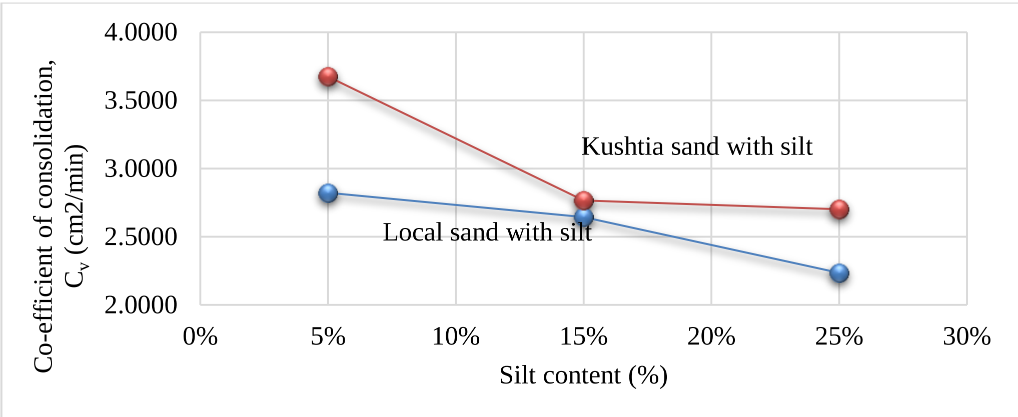

***Fig.4:**-Effect of silt content on co-efficient of consolidation*

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In Figure 4, a graph of the silt content (%) vs the co-efficient of consolidation (Cv) for the two types of local sand-silt mixtures—Kushtia and Khulna—is depicted. This graph shows the average value of C_v. The graph shows that when the silt content decreases, the value of the C_v rises. This is because the amount of void in the sand reduces and the rate at which water drains through the sand-silt mixture slows down as the silt concentration rises. According to the graph, the local sand silt mixture has a lower value than the Kushtia sand silt mixture. Increased consolidation coefficient enhances the quick settlement of this sand-silt mixture.

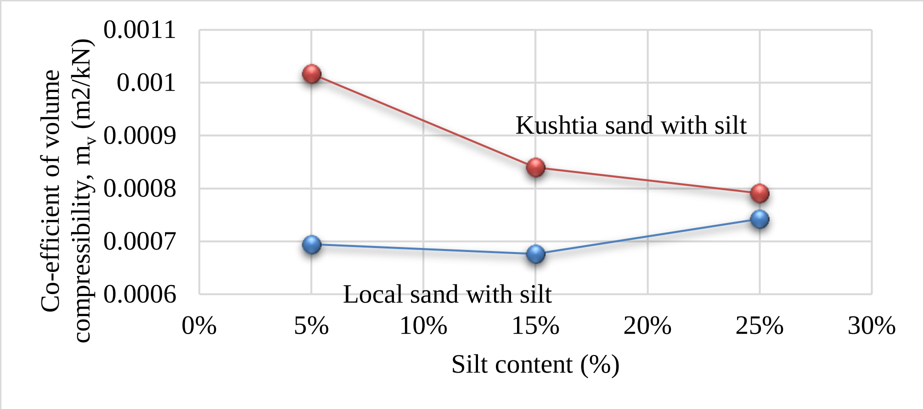

***Fig.5:**-Impact of the silt content on the volume compressibility co-efficient (m_v)*

A diagram of the residue content (%) versus co-effective of volume compressibility (mv) for the combination of nearby sand and Kushtia is introduced in figure 5. The graph demonstrates that the m_v of Kushita sand is higher than that of local sand. Due to the soil's greater pore water pressure and volume compressibility, which both lead to lower effective stresses, the Kushtia sands silt mixture's effective stress value is lower than that of the local sand silt mixture.

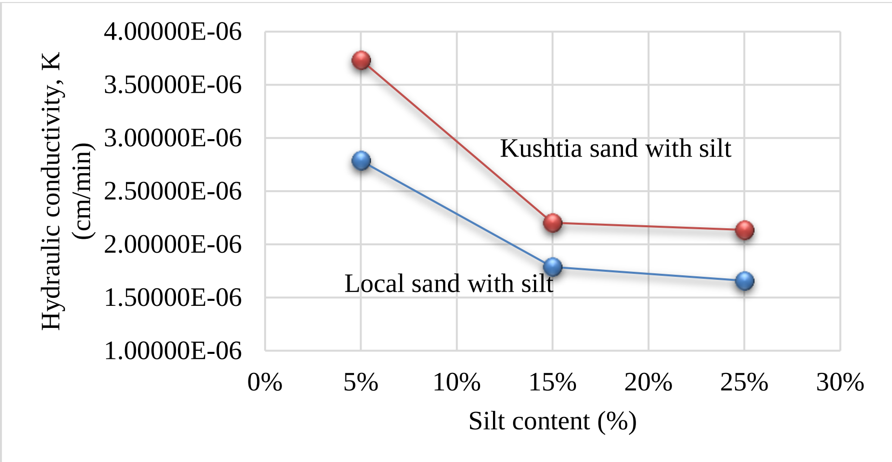

***Fig.6:**-Hydraulic conductivity (K) for various silt content*

A graph of silt concentration (%) vs. hydraulic conductivity can be seen in figure 6. From this graph, it is clear that the K value increases as the silt content falls because more silt fills the voids in the sand, which reduces water flow through the sand-silt mixture and lowers the hydraulic conductivity value or the co-efficient of permeability. The Kushtia sand silt mixture is more helpful in this situation than the

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native sand silt mixture. Sand with low silt content should be used there to stabilize the land since sand-silt combinations have a greater hydraulic conductivity rate, which allows water to swiftly drain out of the void space in any location where raw land is present.

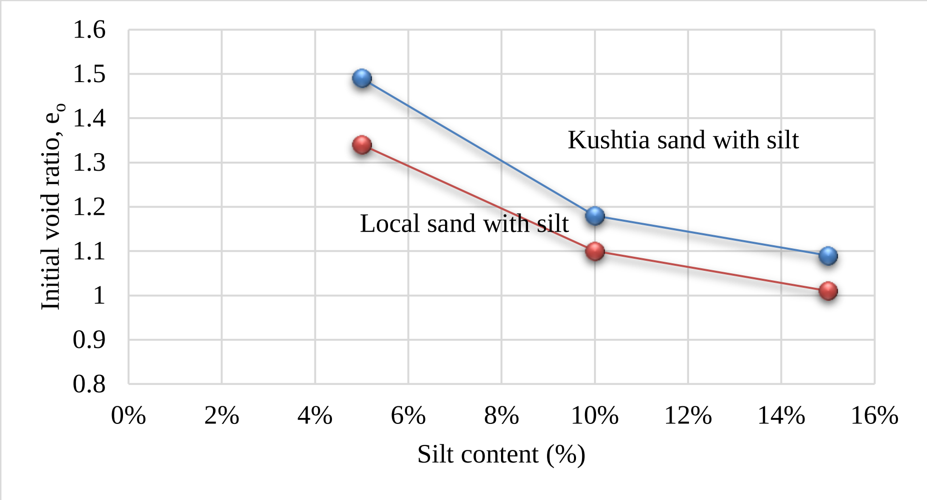

Fig.7:-*Initial void ratio (e_o) for various silt content*

The graph in Figure 7 illustrates the relationship between the silt content and the initial void ratio of the sand-silt mixtures. The graph demonstrates that an increase in silt content results in a decrease in void ratio and void space. Kushtia sand exhibits a higher initial void ratio than the local sand silt combination, possibly due to its coarser texture compared to the local sand from Khulna. The coefficient of combination is exceptionally affected by the void proportion of the dirt, which increments as the void proportion increments. More coarse sand is liked for development work. Nearby sand from Khulna is altogether better than sand from Kushtia. Nearby sand has preferred water grip properties over Kushtia sand. Local sand has the propensity to hold water in vacuum spaces and expand its volume because of this. This characteristic of soil is often referred to as sand bulking. Although local sand is finer than Kushtia sand for sand bulking, local sand exhibits higher emax and emin than Kushtia sand.

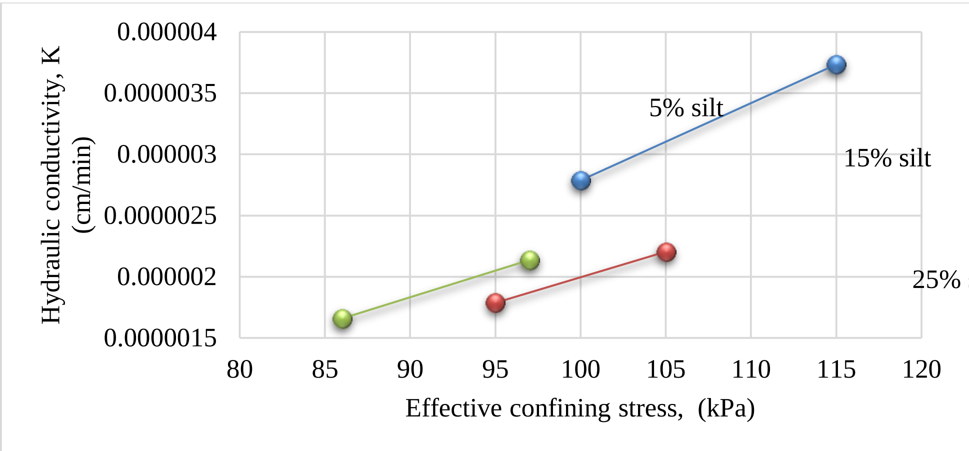

Fig.8:-*Consequences of effective confining stress upon hydraulic conductivity of sand*

Figure 8 shows how an increase in K causes the effective confining pressure or preconsolidation pressure of a sand silt mixture to rise. Likewise, the hydraulic conductivity and effective pressure values remain constant for the flow rates of 5%, 15%, and 25% for mixtures of sand and silt. The effective confining pressure of the Kushtia sand silt mixture is higher in this range compared to that of the local sand silt combination.

CONCLUSIONS

- The study presented the values of hydraulic conductivity (K) for Kushtia sand and local sand mixed with varying percentages of silt (5%, 15%, and 25%). The results indicated that as the percentage of silt increased, the hydraulic conductivity of both Kushtia sand and local sand decreased. The values for K were 3.73354 X 10-06 cm/min, 2.20278 X 10-06 cm/min, and 2.13456 X 10-06 cm/min for Kushtia sand mixed with 5%, 15%, and 25% silt, respectively. Meanwhile, the values for local sand mixed with the same silt percentages were 2.78636 X 10-06 cm/min, 1.78636 X 10-06 cm/min, and 1.6573 X 10-06 cm/min, respectively. It has been made abundantly evident that Kushtia sand has a better drainage system than local sand. K is increased by silt-free sand. C_v increases when the silt co-efficient of consolidation decreases. In construction sites, soil with a higher consolidation coefficient should be used. According to this stance, Kushtia sand is preferable to local sand.
- The pore pressure of granular soil is crucial for foundation design because it allows for the measurement of the effective soil pressure, which is crucial for determining the soil's bearing capacity. Finer sand indicates bad drainage conditions. Less consolidation co-efficient is also visible in finer sand. More coarse sand should be used on a construction site. Less silt should be present in the soil beneath the foundation for better construction.

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