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Review on soil stabilization using multiple additives

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ABSTRACT: The paper encompasses the study which has been done on the utilization of different waste when usedas soil stabilizers. Since, All the materials mentioned are used in enormous amount and act as a waste if not properlytreated or decomposed. Utilizing these wastes in soil stabilization and in construction industry is one of the ways to tackle this problem. Moreover, reuse of these materials in construction work to alter engineering properties willpromote the concept of sustainable development and make our environment and surroundings less polluted and eco-friendlier. In addition to this, these materials are easily available in the market or in the industries at very cheap rates and free of cost. Therefore, it is both beneficial and economical to use these materials for soil stabilization process. The paper contains the reviews of various literature available from the journals published by different researchersduring their course of study. After reviewing these journals, one can drive their own methodology regarding theeffective utilization of waste in different combination so that to get best possible result.

KEY WORDS: Stabilization, Waste material, Sustainable development, Engineering properties.

I. LITERATURE SURVEY

Babatunde, et. al. (2019) used powdered glass as partial replacement to stabilize the Black Cotton Soil. The glass was obtained from the coca cola bottles and it was crushed to a size <0.075 mm. The black cotton soil was collected from construction site located at Gombe after the removal of top soil and excavating up to a depth of 7m. After obtaining the black cotton soil, firstly preliminary tests were conducted on it, in order to obtain the gradation and index properties of soil. A number of tests were performed which included liquid limit, plastic limit, optimum moisture content, maximum dry density, unconfined compression test, California bearing ratio test. These tests wereperformed with varying percentage (0% 2%, 4%, 6%, 8%) of glass powder by weight. At 0% glass powder replacement, the highest Plastic Limit and Liquid Limit of 22% and 79% were recorded. It showed that increase in the glass powder percentage, there is reduction in the plastic limit of black cotton soil. At 2% glass powder treatment of black cotton soil, the highest optimum moisture content was observed. At 4% glass powder treatment of black cotton soil, the highest Maximum Dry Density and Unconfined Compressive Strength of 1.57 mg/m3 and 140 kN/m^{2}were recorded respectively. At 6% glass powder content, the lowest Liquid limit of 75.9 % was observed. Andfinally, at 8% glass powder replacement, the lowest Plastic Limit, Optimum Moisture Content and CBR value were noted. The recommendations were given by researchers that UCS test should be carried out for more days. In additionto this, other binding agents such as lime should be used with glass powder to stabilize the black cotton soil

Urmila S. Sarde (2019) [7] performed experimental study to increase the stabilization properties of black cotton soil using foundry sand and RBI Grade 81. Both foundry sand and RBI Grade 81 have been combinedly used in different proportions in black cotton soil. The varying percentage used were (0%,0%), (20%,03%), (20%,04%), (30%,03%), (30%,04%) for foundry sand and RBI Grade 81 respectively. After, mixing in different proportions CBR tests were performed on them one by one. The CBR value kept on increasing till the last percentage of mix. The maximum CBR Value of 10.01 % was obtained at the proportion 66:30:04 (Soil: Foundry Sand: RBI grade 81). As the percentage of foundry sand increased above 30%, the CBR Value started decreasing, in other words, it can be said that the strength of black cotton soil decreases with increase in the percentage of foundry sand. Thus, the optimum percentage of foundry sand was recommended as 30%. Due to increase in the percentage of RBI Grade 81, the CBR values increases. But, the higher use of RBI Grade would be uneconomical because of its cost. Hence, the optimum quantity

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recommended for RBI Grade 81 is 4%. In addition to the increment in the CBR value, the permeability was also reduced by using RBI Grade 81 and foundry sand in black cotton soil.

Naeethu S S and Shruthi Johnson (2019) studied the effect of foundry sand on the CBR value of kaolinite clay. The study was conducted on the processed kaolinite soil which was bought from English India Clay Limited Trivandrum. The soil was classified as low compressible clayey soil (CL). A series of tests were performed on the kaolinite soil which included liquid limit, plastic limit, plasticity index, optimum moisture content, dry density and unconfined compressive strength test. Foundry sand sample was obtained from a foundry of Trivandrum city. California bearing ratio (CBR) tests were conducted to determine the strength of the original soil as well as for the soil mixed with different percentage of fine foundry waste (0%, 10%and 20 %) by weight of the soil. Load- Penetration Curve was plotted which showed the variation of CBR with foundry sand addition in kaolinite clay soil.A significant increase in the CBR value of kaolinite soil was observed with the addition of foundry sand. The CBR value increased from 18.65% to 63.94%. It was concluded that the mixture of 80% soil and 20% foundry sand was found to be the best and appropriate combination resulting in maximum MDD Value.

Ajeet, et. al. (2018) conducted their studies on the stabilization of soil by combinedly using waste foundry and fly ash. Tests were performed which included sieve analysis, specific gravity, moisture content and Atterberg's limit test to determine the soil properties. Fly ash and foundry sand both were added in varying percentage (1% F.A and 0% F.S), (1% F.A and 0.25% F.S), (1% F.A and 0.5% F.S), (2% F.A and 0.5% F.S) and (3% F.A and 0.75% F.S). For each different percentage, standard proctor test was performed to obtain the value of optimum moisture content and maximum dry density simultaneously the graph was plotted between them to observe the effect of varying percentage of these additives in the soil. The conclusion was drawn, the addition of 1% fly ash and 0% of foundry sand waste gave 1.84g/cc of MDD, addition of 1% fly ash and 0.25% of foundry sand waste gave 1.88g/cc of MDD and addition of 1% fly ash and 0.5% of foundry sand waste gave 1.875g/cc of MDD. So, from the third attempt, it can be observed that there is reduction in the maximum dry density and it is the saturation point. Till this point of time, the percentage of fly ash was kept constant, but now it was also varied and attempt was made to verify the results. The result was obtained for this. Addition of 1% fly ash and 0.25% of foundry sand waste gave 1.88g/cc of MDD, addition of 2% fly ash and 0.5% of foundry sand waste gave 1.9g/cc of MDD and addition of 3% fly ash and 0.75%of foundry sandwaste gave 1.892g/cc of MDD. Here, also the saturation point was observed, which verified the earlier obtained results.

Roshni Ningthoujam and Kilabanur Pramod (2018) conducted investigations on black cotton soil by using multiple additives separately with it. They compared the result obtained from using a number of additives. The additives used were quarry dust, lime, stone dust and foundry sand. All of the above materials were mixed in differentpercentages with black cotton soil and experimental tests were performed. Quarry dust was mixed in percentage of 0%, 10% and 20% of soil by weight. Lime was mixed in percentage of 3%, 6% and 9% of soil by weight. Stone dustwas mixed in percentage of 5%, 10% and 15% of soil by weight. Foundry sand was mixed in percentage of 5%, 10%and 20%. Three experimental tests were performed which included optimum moisture content, maximum dry densityand CBR test. Except lime, for all other materials the CBR value kept rising on as the percentage of additives were increased. And in all the cases as the percentage of additives were increased the maximum dry density kept on increasing while the optimum moisture content kept on decreasing. In the case of CBR value, lime had provided with the best results as compared to the other admixtures. Comparing all other admixtures, foundry sand had provided uswith the least optimum moisture content. In conclusion, it can be said that all admixtures improve various characteristics of black cotton soil.

Mwajuma Ibrahim Lingwanda (2018) proposed improvement of soil subgrade by using crushed glass. This research was conducted in Tanzania, where the subgrades need to have a minimum CBR value of 15% and PlasticityIndex not more than 25%. First of all, the soil sample was collected and brought to the laboratory for the determination of its natural properties. The glass waste was collected from the nearby disposal area, it was crushed in Los Angeles Abrasion machine. After that gradation of crushed glass was determined and plotted. The prepared crushed glass wasmixed with the natural soil starting with 2% by weight of soil with increments of 2%crushed glass until the minimum requirements of an improved subgrade was achieved. At every percentage of crushed glass content, Atterberg limits,compaction characteristics and CBR value were determined. Different graphs for different tests were plotted with varying percentage of crushed glass content. The effect of varying percentage of crushed glass content was observed on different parameters and properties of soil and finally an improvement methodology was proposed. Thus, it was proposed to mix the soil with 10% crushed glass by weight which could potentially improve the subgrade by lowering

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its Plasticity Index from 26% to 14%, lowering its linear shrinkage from 8.6% to 4%, increasing the maximum dry density from 1425 kg/m3 to 1650 kg/m3, decreasing the optimum moisture content from 22% to 16% and most importantly increasing the soil strength from a CBR value of4% to 16%.

Shaik Sohail, et.al. (2018) performed soil stabilization using powdered glass and sodium hydro-oxide additives. The research was carried out in three phases where firstly the replacement was done with only glass powder in the percentage of 0%, 2.5%, 7.5%, 12.5%, 17.5% and 22.5%. The second phase involved replacement with NaOH only in the percentage of 5%, 10%, 15% and 20%. After that, in third phase the replacement was done with both glass powder and NaOH, but in this phase, the percentage of glass powder was kept fixed at 2.5% and NaOH was varied

with percentage of 5%, 10%, 15% and 20%. A series of tests were performed which included specific gravity test, moisture content test, Atterberg limits, standard proctor test, unconfined compressive strength test and California bearing ratio test. At different percentage of additives, different results were observed which were either increase or decrease in the different parameters of soil. After thorough observation, it was concluded that clay soil can be stabilize using glass powder and addition of NaOH content up to 5%. At this percentage it will also give the best result in development of strength in comparison to soil treated with glass powder alone. Some of the recommendations were also proposed by the researchers which said that UCS test should be carried out for some higher days of curing for knowing the strength behaviour of soil.

Jinu Rose, et. al. (2017) added the glass powder in clayey soil to enhance its engineering properties. The clayey soil was collected from the construction site located at Kuttanadu. Firstly, basic tests were performed to find out the gradation and index properties of soil. After that standard proctor test, direct shear test, unconfined compression test and California bearing ratio test were performed. These tests were performed with varying percentage of glass powder (2%, 4%, 6%, 8%,10%). With increase in the percentage of glass powder there was increment in the angle of internal friction, cohesion and shear strength of soil. At the addition of 10% of glass powder, all three of them were exhibiting peak value. But, in case of dry density a fall was observed at 8% and 10% of glass powder. The C.B.R value increased up to a max. value of 12.8 at 6% but at 8% it fell to 7.2. Thus, it can be said that cohesion, angle of friction, dry density, unconfined compressive strength and CBR values increases with increase in percentage of glass powder dueto increase in friction and reduction in settlement of the clayey soil. But after a certain limit the values decreases. Over all it was concluded that stabilization of soil using waste glass powder is good economical ground improvement technique especially in engineering projects on weak soil.

Kamyar, Norouzian and Nader Abbasi (2017) conducted research on improving the engineering properties of a clay soil sample using sewage sludge and hydrated lime. The results of the study showed that the maximum dry density of the treated soil samples increases from 1.67kg/cm^3 to 1.81kg/cm^3 and their optimum water content decreases from 19% to 17%, by using together 4% of sewage sludge and 3% of hydrated lime on the sample. It wasalso found that the compressive strength increases up to 3.8% times.

Mohammed A., et.al. (2016) performed the laboratory investigation to illustrate the effect of crushed waste glass on geotechnical properties of cohesive soil. Because of the wide availability of waste glass in Iraq and simplicity to recycle it in crushed form, it was chosen as the additive to improve the soil properties. Varying percentage (2, 4, 6 and 8%) of the crushed glass was used in the soil. The glass was crushed manually with the help of hammer and it was sieved to suit the particle size of cohesive soil. Physical properties, strength parameters and consolidation behaviour of cohesive soil were determined for the composite sample (soil + waste glass).A series of tests were performed in laboratory which included: sieving and hydrometer analysis, Atterberg's limits, compaction (optimum moisture content, maximum density) chemical tests, consolidation and shear strength tests. After reviewing the laboratory test results, it as concluded that addition of 4% crushed glass to the cohesive soil is suitable and effective in improvement of geotechnical soil properties. Addition of glass lead to increase in both soil shear strength and bearing capacity. The change in shear strength parameter occurred due to increase in the friction angle and decrease in the cohesion between soil particles. Since, the glass is a granular material, its behaviour showed reduction in specific gravity and liquidlimit while increment in the plastic limit with increase of additive. In addition to this, there was a noticeable decrement in the optimum moisture content and increment in the dry density, because the soil becamestiff with increase in the additive of soil. The composite soil exhibited reduction in compressibility and swelling.

H. Canakci, et.al. (2016) conducted research which indicated that use of soda-lime glass powder waste with clay has significant effect on the strength of the soil. The waste soda lime glasses were crushed and sieved through 75 μm sieve

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after that they were mixed with clay in varying percentage of 3%,6%, 9%, and 12% of dry weight of soil. The tests performed were standard proctor tests, atterberg limits test, california bearing ratio (CBR) test and unconfined compressive strength test. From the test results, it was concluded soda limeglass powder not only has the ability to improve the engineering properties of clay soil but also it has a positive effect onMDD (maximum dry density), OMC (optimum moisture content) and Atterberg limits. As the percentage of additive was increased, the maximum dry density of soil increased. The largest percentage increase in maximum dry density was 5.49 %when 12 % soda lime glass powder was mixed with clay soil. In addition to this, there was a significant drop in optimum moisture content was observed due to increase in the percentage of soda lime glass powder. The largest percentage decrease in optimum moisture content was 21.6 % when 12 % soda lime glass powder was mixed with clay soil. The reason behind this decrease could be that the absorption capability of glass is much less than that of clay. During Atterberg limits test, it was clearly seen that the values of plasticity index for the sample decreased due to increase in the percentage of soda

lime glass powder. The largest percentage decrease of plasticity index was to 44.05 %when 12 % from soda lime glass powder was mixed with clay soil. The CBR value of soil value also increased due to increment in the content of the additive. The largest percentage increases of CBR value was 140 % when clay soil was mixed with 12 % soda lime glass powder. It was also noticed that the swelling decreased due to increases in percentage of soda lime glass powder. There was a significant increase in the UCS values at 6% of soda lime glass powder, it was found that the UCS values increases 519 kPa at 3 days, 583 kPa at 7 days and 723 kPaat 28 days.

Adebisi, et. al. (2016) used rice husk ash, powdered glass and cement as stabilizers in lateritic soil.Lateritic soils are the most readily available and the most economical construction materials. However, the major problems associated with roads constructed with laterite include cracking of the surface pavement, stripping of the surface and waviness of the pavement surface just after a few years of construction. Thus, it becomes paramount to investigate the possible sub-grade improvement techniques. In this research comparison has been done between the stabilizing effects of three different materials, namely: rice huskash, powdered glass, and cement on the properties of lateritic soil. First of all, basic tests were performed to obtain the basic properties of lateritic soil. These tests included moisture content determination, specific gravity, particle size distribution and Atterberg limits tests. Chemical tests were also performed on all three stabilizing material to find out their respective compositions. The chemical properties of the materials were obtained by using Compact EnergyDispersive X-ray Spectrometer. From the chemical tests, it was observed that silica was the major component present in the powdered glass and rice husk ash. However, cement hadhigh concentration of CaO, which has high stabilizing property. After that each of the stabilizing material were mixed with soil in the varying percentages of 2.5%, 5%, 7.5%, 10%, 12.5% and 15% by weight ofthe soil. Thereafter, California bearing ratio test was performed to get the CBR value and compaction test was done to determine the optimum moisture content and maximum dry density. The aim of performing these tests were to determine the effect of these stabilizing materials on the lateritic soil. The compaction test showed that the highest maximum dry densities obtained for the mixed samples. These values were2.32 g/cm3 (at 2.5% cement addition), 2.28g/cm3 (at 5% powdered glass addition) and 2.18g/cm3 (at 5% rice husk ashaddition) with corresponding optimum moisture contents of 10.06%, 14.3% and 12.31% respectively. The CBR tests showed that the CBR values of the soil treated with cement and powdered may further increase if the percentage of the additives is increased beyond 15%. The CBR tests also indicate that the powdered glass treated soil will only produce results comparable to cement treated soils only under dry conditions. Therefore, powdered glass can be used as an alternative to cement under unsoaked conditions.

Prashant, et. al. (2016) investigated on stabilizing the subgrade by using foundry sand waste. The fines of foundry sand passing through 10 mm sieves were used as stabilizing material in this case. A number of tests were performed on the soil when foundry sand was mixed in different percentage. The foundry sand was mixed in soil with varying percentage (5%, 10%, 15% and 20%) by weight of the soil. A series of tests were performed which included liquid limit, plastic limit, optimum moisture content, maximum dry density, CBR test and direct shear test. Graph for each percentage variation was plotted to accurately determine the effect on the properties of soil due to addition of foundry sand. It was observed that the liquid limit went on decreasing with the addition of foundry sand and hence, it helped to reduce the drying shrinkage of the clayey soil which in turn will help to reduce the crack width of the soil. Foundry sand a non-cohesive material when added in soil, helped in reducing the cohesion of the soil, which can be correlated with the reduction in the value of optimum moisture content to 10%. The CBR value of soil kept on increasing, it increased from 8.9 to 18.21 with increase in the percentage of foundry sand. A significant improvement in angle of friction was also observed from 22 degrees to 28 degrees with the addition of foundry sand. Overall, it was all round improvement in the soil's properties with the addition of foundry sand.

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I.A.Ikara, et. al. (2015) investigated the suitability of using waste glass as an admixture in cement stabilized black cotton soil. Firstly, the soil was classified as A-7-5 and CH according to the American Association of State Highway and Transport Officials (AASHTO) and the Unified SoilClassification System (USCS). After that chemical analysis was done to find out the chemical constituents of waste glass. The chemical analysis revealed that the waste glass contains silica in high quantity (69.2 %). Thereafter, soil stabilization was carried out by varying percentage of cement (0%, 2%, 4%, 6% and 8%) and waste glass (0%, 5 %, 10%, 15% and 20%) by weight of the dry soil. A series of tests were carried out which included Standard Proctor test, California BearingRatio (CBR) test and Unconfined Compressive Strength (UCS) test. The results were obtained which showed that the addition of waste glass lead to reduction in the plasticity index, liquid limit and plastic limit. Furthermore, it also showed reduction in optimum moisture content and increment in the dry density of the cement stabilized black cotton soil. The peak value of UCS and CBR were obtained at 8% cement and 20% waste glass which are 1152kN/m²) and 53.8% respectively. Thus, this percentage of blend was considered as optimum blend. The results also showed that there is potential in utilization of waste glass as an admixture in case of black cotton soil.

Chandak N. R (2015) conduct a process of soil stabilization with lime sludge to help to improve the properties of the soil needed in a construction work. The optimum moisture content of the soil sample increases with an increase

in lime sludge. This may be as a result of the additional water needed for the necessary reactions for the stabilization process. The lime sludge also increased the MDD the angle of internal friction.

Shukla Devdatt1 , Rajan Shikha, Saxena A.K.and Jha A.K.4 (2015) investigate the experiment results from various tests carried out on a clay soil mix with Areca nut fibre. The changes in various engineering characteristics of the clay were analyzed. The standard proctor tesrt results shows a decrease in OMC from 14% to 12 % and an increase in MDD from 1.85 g/cc to 1.90 g/cc when the areca nut fibre content is increase from 0% to1%. The CBR test for the soak sample indicates an increase in it values from 3.9 % to 9.6 % as the content of the areca nut fibre increase from 0% to 1%.

B. M. Lecha (2015) carried out research on the behavior of soil and cement mixtures when reinforced with Areca nut fibre. The content of the Fiber was varying from 0.2% to 1% with a gradual increment of 0.2%. Laboratory tests such as durability and fatigue behavior, Unconfined Compressive Strength, California Bearing Ratio, were conducted as per IS code. The test results show that the improvements in properties of the soil, cement and fiber mixtures were as a result of the fibre dosage, the type of soil and curing duration. Durability test was optimum at 1%Areca fibre with 3% cement. The stress–strain values were also determined. From the results, it is observed that, the Areca nut fibre reinforced cementsoil mix can be used for low volume roads.

Ravi Kumar Sharma and Amrendra Kumar(2013) evaluated the impact on sub-grade characteristics of clayey soil blended with foundry sand and fly ash. The soil used in the research was locally available clayey soil and waste foundry sand was obtained from Nahan foundry. According to ASTM classification system, the soil was classified as clay with medium plasticity (CL). The fly ash was obtained as residue left after electronic precipitation of the burnt gases. The laboratory tests were conducted in accordance withASTM standards. The tests that were conducted include specific gravity tests, consistency limit tests, hydrometer analysis test, CBR test and standard proctor tests. The Compaction tests were also conducted on clay with varying percentages of foundry sand from 10% to 50% and optimum mixes were obtained. Variation of maximum dry density was observed for clay-foundry sand mixes. It was observed that maximum dry density of clay-foundry sand mixes increases with increase in sand content up to 40% after that it was reduced. The optimum moisture content kept on decreasing as the highest value of maximum dry density was reached. During CBR test, it was observed that soaked CBR value of clayey soil increased with addition of foundry sand and fly ash. The value of CBR increased from 2.44% for un-stabilized soil to 5.10%for stabilized soil. The California bearing ratio provides a basis of designing of sub-grades of flexible pavements. Generally, CBR value more than 5.0 is considered tobe satisfactory for the design of flexible pavements with traffic intensity of 1 to 10 million standard axles (msa). Thus, it can be said that the clayey soil blended withfoundry sand and fly ash can be effectively used in the construction of sub- grades of roads with low traffic volume. Also, it was concluded that the O.M.C. of clayey soil and foundry sand mix, decreased with the addition of foundry sand (up to 40% content) whereas it increased afterwards This occurred because lower quantity of water required to lubricate the foundry sand particles which are coarser as compared to clay particles.

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B M Patil and K A Patil (2013) conducted research on the effect of industrial waste and chemical additives on the CBR value of clayey soil. In this research, different industrial wastes such as fly ash, pond ash and stone dust were mixed with clayey soil along with RBI Grade 81, which is a chemical additive in different proportions and the CBR value was determined in the laboratory. CBR values were separately determined for different mixes. These mixes were RBI Grade81 and Pond Ash, RBI Grade 81 and Stone Dust, RBI Grade 81 and Foundry Sand. In case when RBI Grade 81 was onlymixed with soil, the CBR value of soil treated with 2% RBI Grade increased by 91.01%. It happened because RBI Grade 81 possesses binding property due to which the soil particles bind together and the CBR value of the mix increases. In case of Pond Ash, when the soil was treated with Pond Ash only, there was only slight increase in CBR value, on the other hand, when soil was combinedly treated with Pond Ash and RBI Grade 81, a significant increase in the CBR value was observed. The soaked CBR value of the soil treated with stone dust increased up to 20% after that it was reduced. Similar observation was recorded, when soil was combinedly treated with Stone Dust and RBI Grade 81, there was significant increase in the CBR value of soil. In case of foundry sand, the foundry sand helped to increase the compressive strength and RBI Grade helped in binding the soil particles, so that the CBR value of soil increases.

Venkara et. al (2012) research was carried out clay with high expansive properties. The soil was treated with lime sludge. The study indicates significant amount of reduction in the soil plasticity from 32% to 26 % takes place with deferent percentage of lime sludge from 1to 10%. The same percentage was found causes noticeable decrease in the soilplasticity from 45% to 24%. Differential free swell indicates decrease in swelling volume with an increase in lime sludge percentage. Thisresearch proves that lime sludge successfully improves the existing poor and expansive soil subgrade.

Akshaya Kumar Sabat (2005) conducts a study on expansive soil. The soil properties were improved by adding lime sludge. The tests performed are Standard proctor, Unconfined Compressive Stress and California Bearing Ratio. The deferent proportions of lime sludge used were 2%, 8%, 10%, 15%. The maximum strength increases at 8% lime sludge. That indicates Lime sludge can therefore be used to improve the quality of soil subgrade soil

Tarek et. al. (2002) [20] investigated the potential of foundry sand to be used as hydraulic barrier. The objective of the study was to assess the validity of the laboratory findings in a field setting and to find out whether special considerations were required for the construction of the hydraulic barriers with foundry green from single or multiple sources. Both laboratory and field study were performed for this purpose. In laboratory, flexible-wall permeameters were used for falling-head hydraulic conductivity testing. During the field study, tests were conducted on the test pads after exposure to winter weather causing freeze-thaw cycling and summer weather causing desiccation. Three test pads were constructedwith the use of compacted foundry green sand. The hydraulic conductivity was measured using sealed double ring infiltrometers (SDRIs), two-stage borehole (TSB) permeameters, and on large block specimens. Both field and laboratorytesting provided the same result. And, it was concluded that for the foundrysand to be used for the hydraulic barrier, need to have bentonite content greater than 6% (by weight), the plasticity index to be greater than3 or the liquid limit tobe greater than 20 and should have hydraulic conductivity less than10-7 cm/s.

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