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INVESTIGATION INTO THE UTILIZATION OF BLAST FURNACES SLAG AS FINE AGGREGATE IN CONCRETE DESIGNED FOR PAVEMENT

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Abstract:

Use of more and more environment-friendly materials in any industry in general and construction industry in particular, is of paramount importance. Environment of this 'only living' planet is wary of pollution due to emissions of a host of green house gases from industrial processes. Present day construction industry consumes huge amount of concrete and cement is the binding material used for making concrete. During production of cement huge amount of energy is needed and about 8 % of CO2 is released to atmosphere during cement production. This makes concrete a non eco-friendly material. In consideration of these points, construction industry has devised a substitute for concrete, popularly known as 'blast furnace slag. The striking feature of this form of concrete is that most of its important ingredients are 100 percent by-products of industries, yet having similar performance record as any other conventional concrete material. This project focused on the different ratios of both additions blast furnace slag to fly ash 20:80, 30:70, 40: 60, 50:50, 70:30, 60: 40 and 80:20. The final sample results are tabulated and analyzed for better outcomes.

INTRODUCTION

High strength concrete (HSC) is widely used in the construction of high-performance structures such as high rise buildings, long span bridges, etc. So, it should have higher workability, good mechanical properties than those of conventional concrete. In order to achieve HSC with good mechanical properties, fly ash or/and silica fume which are considered as waste materials are used as one of the main ingredients. Concrete prepared with such materials showed improvement in workability compared to normal concrete. Use of some waste materials has been well documented in design specifications. New by-products and waste materials are being generated by various industries, dumping or disposal of these materials causes environmental and health problems. Therefore, recycling of waste materials has a great potential in concrete industry. blast furnace slag slag is an industrial by-product material produced in the process of manufacturing blast furnace slag. It has been estimated that approximately 24.6 million tons of slag are generated from all blast furnace slag industries every year. blast furnace slag slag possesses mechanical and chemical characteristics that is eligible as the material to be used in concrete as a partial replacement as a substitute for aggregates. blast furnace slag slag has a favorable mechanical properties for aggregate use such as excellent soundness characteristics, good abrasion resistance and good stability .It also exhibits pozzolanic properties since it contains a low lime content and other oxides such as alumina, silica, and iron. Use of blast furnace slag slag in the concrete industry as a replacement for fine aggregates can has the benefits of reducing the costs of disposal and helps protecting the environment.

Cement is the world's most adaptable, strong and solid development material. By water, cement is the most utilized material, which required expansive amounts of Portland cement. Conventional Portland cement generation is the second just to the vehicles as the significant generator of carbon di oxide, which dirtied the air. Not with standing that huge sum vitality was likewise devoured for the bond creation. Subsequently, it is unavoidable to locate an option material to the current most costly, most asset expending Portland cement. Geo polymer cement is a creative development material which might be delivered by the compound activity of inorganic particles. Fly Ash, a by-result of coal got from the warm power plant is bounty accessible around the world. Fly ash is rich in silica and alumina responded with soluble arrangement delivered alumina silicate gel that gone about as the coupling material for the solid. It is a brilliant option development material to the current plain bond concrete. Geo polymer cement should be delivered without utilizing any measure of conventional Portland bond. Infrastructure sector in developing countries is growing very rapidly.

Geo polymer:

Geo polymer is a term used to characterize a classification of manufactured alumino-silicate materials with potential use, basically as substitution of standard Portland concrete in concrete, for cutting edge hello tech composites, earthenware application or as a type of cast stone. Geo polymer as a name was initially connected to these materials by Joseph Davidovits in the year 1970s, albeit comparable materials have been created in the previous Soviet Union since the year 1950s, yet was called soil This name however was utilized to portray soils which are solidified with a little measure of Portland concrete to improve its quality and dependability

Fly Ash:

Fly ash is also known as “pulverized fuel ash” is one of the coal combustion products and is composed of the fine particles that are driven out of the boiler with the flue gases. Fly ash is captured by electrostatic precipitators or particle separator equipment before the flue gases reach the chimneys of coal fired power plants. Depending upon the source and makeup of the coal being burned but all fly ash includes substantial amounts of silicon dioxide (SiO_2), aluminum oxide (Al_2O_3) and

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calcium oxide (CaO), the main mineral compounds in coal bearing rock strata Coal Fly Ash is classified as hazardous waste under Resource Conservation and Recovery Act (RCRA).Two classes of Fly Ash are defined by ASTM C618:

Figure: 1.1 Fly Ash

Class F Fly Ash:

The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzulonic in nature, contains less than 7% lime (CaO). Possessing pozzulonic properties, the glassy silica and alumina of Class F fly ash requires a cementing agent, such as lime or cement mixed with water to react and produce cementations compounds. Alternatively, adding a chemical activator such as sodium silicate can form a geo polymer

Class C Fly Ash:

Fly ash produced from the burning of younger lignite or sub bituminous coal, in addition to having pozzulonic properties, also has some self-cementing properties. In absence of water, Class C fly ash hardens and gets stronger over time. Class C fly ash generally contains more than 20% lime (Cao). Alkali and sulfate content are generally higher in class C fly ash.

LITERATURE REVIEW

blast furnace slag slag is a by-product obtained during matte smelting and refining of blast furnace slag. One of the greatest potential applications for reusing blast furnace slag slag is in concrete production Concrete, is the most versatile construction material. Engineers are continually working on it, to improve its performance with the help of innovative supplementary or replacement materials. Usage of new materials in concrete, which are by products from industries and other processes, not only helps in utilizing these waste materials but also enhances the properties of concrete in fresh and hydrated states. The usage of industrial slags, which are waste industrial by-products, in concrete is an important study today, of National and International interest. In the present status, research on blast furnace slag slag concrete is yet to get momentum in our country. reviewed and mentioned that large amounts of blast furnace slag slags are generated as waste worldwide during the blast furnace slag smelting process. blast furnace slag slag can be used in many applications such as concrete, landfills, Ballasts, bituminous pavements, tiles etc. The characteristics and utilization of blast furnace slag slag have been reviewed

R R Chavan & D B Kulkarni (2013) conducted experimental investigations to study the effect of using blast furnace slag slag as a replacement of fine aggregate on the strength properties and concluded that Maximum Compressive strength of concrete increased by 55% at

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40% replacement of fine aggregate by blast furnace slag slag and flexural strength increased by 14 % for 40 % replacement. Many researchers have investigated worldwide on the possible use of blast furnace slag slag as a concrete aggregate. Some of the important and published works are reviewed and presented briefly below. investigated the mechanical properties of high strength concrete replacing fine aggregate with blast furnace slag slag. Micro silica was used to supplement the cementitious content in the mix for high strength requirement. They observed that when blast furnace slag slag was used to replace fine aggregate, upto 40% blast furnace slag slag replacement, the strength of concrete was increases while the surface water absorption decreases. They also observed that when more than 40% of blast furnace slag slag is used, the microstructure of concrete contains more voids, micro cracks, and capillary channels which accelerate the damage of concrete during loading.

Al-Jabri et al (2009, 2011) investigated the performance of high strength concrete made with blast furnace slag slag as a replacement for fine aggregate at constant workability and studied the effect of super plasticizer addition on the properties of High Strength Concrete made with blast furnace slag slag. They observed that the water demand reduced by about 22% for 100% blast furnace slag slag replacement. The strength and durability of High Strength Concrete improved with the increase in the content of blast furnace slag slag of upto 50%. However, further additions of blast furnace slag slag caused reduction in the strength due to increase in the free water content in the mix. Also, the strength and durability characteristics of High Strength Concrete were adversely affected by the absence of the super plasticizer from the concrete paste despite the improvement in the concrete strength with the increase of blast furnace slag content. The test results also show that there is a slight increase in the density of nearly 5% with the increase of blast furnace slag slag content, whereas the workability increased rapidly with increase in blast furnace slag slag percentage.

Caijun Shi et al (2008) reviewed the effect of blast furnace slag slag on the Engineering properties of cement mortars and concrete. They reported that the utilization of blast furnace slag slag in cement mortar and concrete is very effective and beneficial for all related industries, particularly in areas where a considerable amount of blast furnace slag slag is produced. It proved both environmental as well as technical benefits. They observed that there was more than 70% improvement in the compressive strength of mortars with 50% blast furnace slag slag substitution.

Byung Sik Chun et al (2005) conducted several laboratory tests and evaluated the applicability of blast furnace slag slag as a partial replacement for sand. From the various tests performed, the strength of composite ground was compared studied and analyzed by monitoring the stress and ground settlement of clay, sand compaction pile and blast furnace slag slag compaction pile. studied the feasibility of using spent blast furnace slag slag as fill material in land reclamation. After conducting many laboratory tests, they finally concluded that the spent blast furnace slag slag was a good fill material and it can be used as a fill material for land reclamation. The physical and geotechnical properties of the blast furnace slag slag were assessed by laboratory tests and were compared with sand. The potential environmental impacts of using blast furnace slag slag for land reclamation were evaluated by pH and Eh measurements, batch-leaching tests, acid neutralization capacity determination and monitoring of long-term dissolution of the material. The blast furnace slag slag was found to be slightly alkaline, with pH 8.4 at a solid /water ratio of 1:1. The batch leaching test results showed that the concentrations of the regulated heavy metals leached from the material at pH 5.0. They were significantly lower than the maximum concentration for their toxicity limits referred by United States Toxicity Characteristic Leaching Procedure.

Mobasher et al (1996) investigated the effect of blast furnace slag slag on the hydration of cement when upto 15% of blast furnace slag slag replaced Portland cement. By X-Ray diffraction and the porosity hydration reactions were examined using mercury intrusion porosimetry and it si found that there is significant increase in the compressive strength for up to 90 days of hydration. A decrease in capillary porosity measured using MIP indicated densification of the microstructure. Addition of blast furnace slag slag decreased the Fracture properties such as critical stress intensity factor and fracture toughness.

Arino and Mobasher (1999) presented the effect of ground blast furnace slag slag on the strength and fracture of cement-based materials. Portland cement was replacement with ground blast furnace slag slag up to 15% by mass. By closed-loop controlled compression and three-point bending fracture tests, it is observed that, the compression test utilized a combination of the axial and transverse strains as a control parameter to develop a stable post-peak response. A cyclic loading-unloading test was conducted on three-point bending notched specimens under closed-loop crack mouth opening control. The test results indicated that GCS concrete was stronger but more brittle than ordinary Portland cement concrete. Fracture test results confirmed the increased brittleness of concrete due to the use of GCS. Long-term results showed equal or higher strengths for the GCS specimens without concern for degradation of other properties.

METHODOLOGY

Compaction is the most common and important method of soil improvement. Compaction is the process whereby air is crowded out & its volume decrease due to physical stress. Test is performed to determine the relationship between the optimum moisture content (OMC) and the maximum dry density (MDD) of a soil for a specified compactive effort. It is the process by which the soil grains get rearranged more closely, the volume of air voids get reduced, and the density of soil increased. it is almost an instantaneous phenomenon. Compaction generally leads to an increase in shear strength and helps to improve the stability and bearing capacity of soil. It also reduces the compressibility and permeability of soil. The densification of soil by the application of mechanical energy is known as compaction. Smooth wheel roller, pneumatic tyred rollers, sheep foot rollers and vibratory rollers are used in the field for compaction. Vibratory rollers are used mostly for densification of granular soils. The technique of vibration is extensively used for compacting in situ deposits of granular soil up to considerable depths. The degree of compaction of a soil is measured in terms of dry unit weight, i.e., the amount of soil solids that can be packed in unit volume of the soil.

Factors affecting compaction Water content:

At low water contents, the soil is stiff and the soil grains offer more resistance to compaction. As the water content increases, the particles develop larger and larger water films around them, which tend to lubricate the particles and make them easier to be worked around, to move closer into a denser configuration, resulting in a higher dry unit weight and lower air voids.

Compactive effort:

For a given type of compaction, the higher the compactive effort, the higher the maximum dry unit weight and lower the optimum moisture content. Type of soil Coarse grained soils, well graded, compact to high dry unit weights, especially if they contain. Some fines however if the quantity of fines is excessive max dry unit weight deceases. Poorly graded are uniform sands lead to the lowest dry unit weight values. In clay soils the maximum dry unit weight tends to decease as plasticity increases. Cohesive soils have generally high values of OMC. Heavy clays with high plasticity have very low maximum dry unit weight and very high OMC.

Method of compaction:

Ideally speaking the laboratory test must reproduce a given field compaction procedure because the mode of compaction does influence somewhat the shape and the position of the dry density verses water content plot. However it does not warrant the devicing of special laboratory tests that can simulate the different field compaction procedures.

Standard proctor:

test In the standard proctor test, a standard volume (944 cc mould) is filled up with soil in three layers. Each layer is compacted by 25 blows of a standard hammer of weight 2.495 kg. Falling through 304.8 mm. knowing the weight of the compacted soil and its water content, the dry unit weight of the soil can be calculated.

Fig compaction mould

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Figure: mixing of blast furnace slag

Weigh 2.5 kg of blast furnace slag slag and 2% of admixture to the weight of blast furnace slag slag in a clean tray. 69

2. Add 2% of water to the weight of blast furnace slag slag and mix it thoroughly and divide it into
3 equal parts.

3. Now place the first layer of sample into the mould. Make sure that the mould is placed properly on base plate.

4. Then compact the layer by giving 25 blows with the rammer weighing 2.495 falling through 304.8mm.

5. As soon as the first layer is compacted, repeat the same procedure for the other two layers. 6. Use collar to avoid falling of sample on to the ground.

7. Then remove the collar and trim out the excess sample. 8. Weigh the mould (along with base plate) and note the reading as weight of compacted sample.

9. Take 20-30 g of compacted sample in to a container along with lid. Note the reading as wet weight of compacted sample.

10. Note the container number and keep it in oven to know the dry weight of sample.

11. Repeat the same procedure for different percentage of admixture by increasing water percentage.

12. Perform analysis for optimum moisture content (OMC) and maximum dry density (MDD) with the noted values.

RESULTS AND DISCUSSIONS

Options for various river sand alternatives, such as offshore sand, quarry dust and filtered sand have also been made Physical as well as chemical properties of fine aggregate affect the durability, workability and also strength of concrete, so fine aggregate is a most important constituent of concrete and cement mortar. Generally river sand or pit sand is used as fine aggregate in mortar and concrete. Together fine and coarse aggregate make about 75- 80 % of total volume of concrete and hence it is very important to fine suitable type and good quality aggregate nearby site Recently natural sand is becoming a very costly material because of its demand in the construction industry due to this condition research began for cheap and easily available alternative material to natural sand. Some alternatives materials have already been used as a replacement of natural sand such as fly-ash, quarry dust or limestone and siliceous stone powder, filtered sand, blast furnace slag slag are used in concrete and mortar mixtures as a partial or full replacement of natural sand

CBR TEST:

California bearing ratio tests was conducted on blast furnace slag slag as per IS: 2720 (part XVI) 1979 on the optimum mix for the subbase course,

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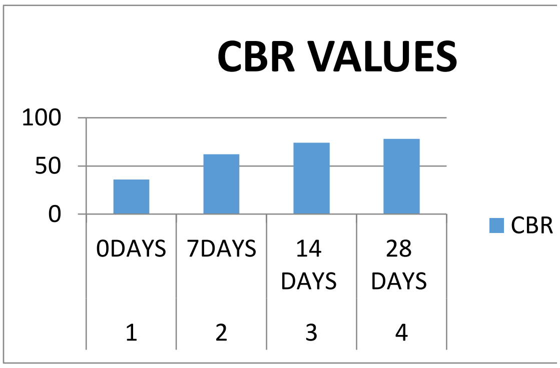
i.e., 30% fly ash + 70% blast furnace slag slag. After compaction the CBR samples were sealed in airtight polythene bag and cured in humidity chamber at constant temperature of 300 C and relative humidity of 85% for a period of 7, 14 and 28 days. The CBR samples were soaked in water for 4 days prior to testing. The CBR value of the mix increases with the curing period. However, the rate of increase is high in the beginning but slows down beyond 14 days of curing period. the increase in the curing period results in the binding of the slag and fly ash particles more efficiently which imparts strength to the mix. As per IRC: 37-2001, the minimum CBR value for the material should be 30 for use in the sub base course. The 30F+70C mix satisfies these criteria. Hence, this mix may be recommended for use in the sub ase course.

Table: California Bearing Ratio (CBR)

S.no	CURING PERIOD	CBR VALUES
1	0DAYS	36
2	7DAYS	62
3	14 DAYS	74
4	28 DAYS	78



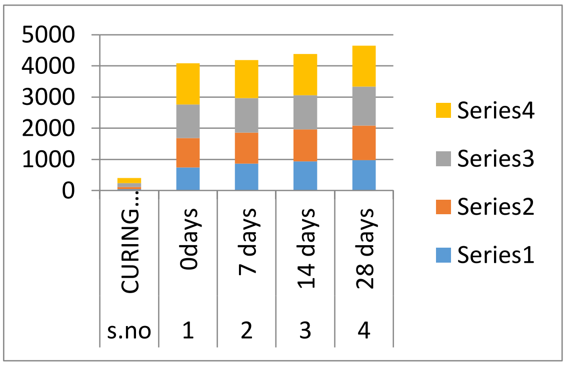
Graph: CBR test results

TRIAXIAL SHEAR STRENGTH:

Unconsolidated Undrained triaxial tests were conducted on the optimum mix, i.e., 30F+70C at Stress-strain curves were drawn and the modulus of elasticity (E) was determined from the initial tangent to the curve. shows the variation of deviator stress at failure with cell pressure and Fig. 5 shows the variation of modulus of elasticity with cell pressure. The deviator stress at failure and modulus of elasticity increases linearly with the cell pressure for all the curing periods. This is quite logical as the confinement of the sample increases its resistance to failure. The relationship between deviator stress at failure and modulus of elasticity with cell pressure is given in Table

Triaxial shear strength

s.no	CURING PERIOD	40	80	120	160
1	0days	740	940	1080	1320
2	7 days	862	1000	1100	1220
3	14 days	940	1020	1100	1320
4	28 days	980	1100	1250	1320



Graph: Triaxial shear strength

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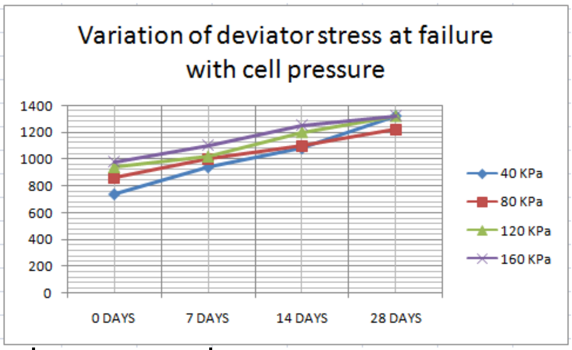
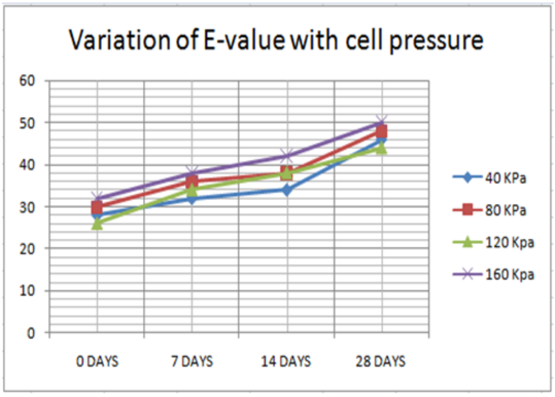
UNCONFINED COMPRESSIVE STRENTH

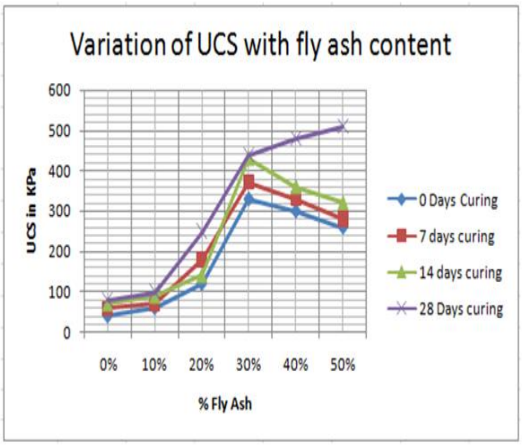
Table: Variation of BFS(UCS)with fly ash content

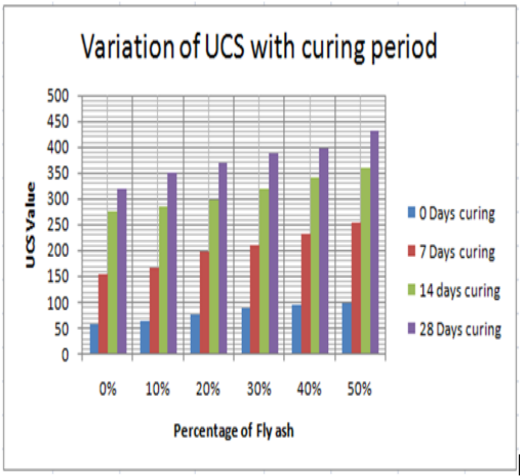
S.no	%Fly Ash	UCS (KPa)		
		0 days curing	7 days curing	14 days curing
1	0%	40	60	70
2	10%	60	70	90
3	20%	120	180	140
4	30%	330	370	430
5	40%	300	330	360
6	50%	260	280	320

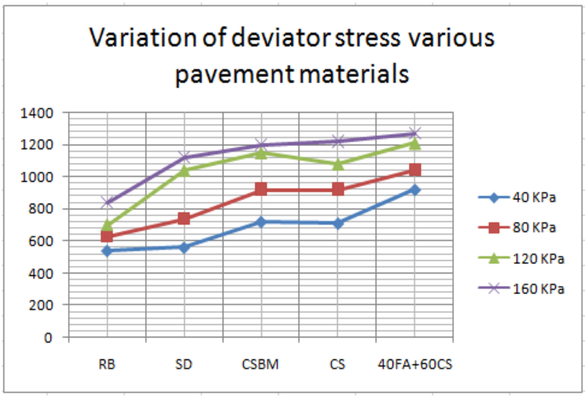
100

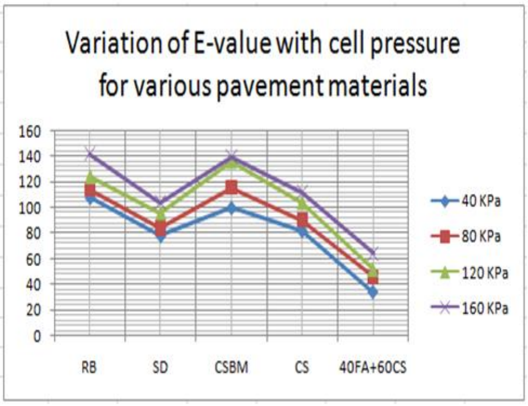












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CONCLUSION

To make the soil stable, stabilization of weak grounded soil is required. blast furnace slag Slag (CS) is one of the waste materials that are being used extensively in the civil engineering construction industry. blast furnace slag producing units in India leave thousands of tonnes of blast furnace slag slag as waste every day. Based on I.S. environmental protection agency regulations, governing solid waste characteristics, blast furnace slag slag can be classified as a non-hazardous material. blast furnace slag slag (BFS) is one of the waste materials that are being used extensively in the civil engineering construction industry. blast furnace slag producing units in India leave thousands of tonnes of blast furnace slag slag as waste every day. Large quantities of the accumulated slag is dumped and left on costly land, causing wastage of good cultivable land. It is a byproduct generated during pyro metallurgical process to produce blast furnace slag The influence of blast furnace slag Slag is studied by means laboratory experiments such as proctor and direct shear test. With the obtained results, analysis was carried and the following observations are made:

The Maximum Dry Density increases with increase in the percentage of BFS from 1.706g/cc to 1.833g/cc for 0% replacement to 30% replacement respectively.

The Angle of Internal Friction varied from 33.53˚ to 40.60˚ for 80% replacement to 20% replacement respectively. – Slope Stability Analysis shows, with 30% replacement of Sand by BFS has stabilized the ground.

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