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A STUDY ON ENHANCING CBR PROPERTIES OF GRADED GRAVEL SOILS WITH CRUSHER DUST AND BOTTOM ASH

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Abstract - Major streets and highways are perfect candidates for flexible pavement because, when laid in very thick layers, it can endure large and more frequent traffic flows. Repair work is quite straightforward since this pavement type requires frequent maintenance. Standard standards are not met by the majority of the soils.

However, disposing of the massive amounts of industrial waste that are produced by fast industrialization is no easy feat. Inhaling fly ash, a significant component of coal ash and a byproduct of thermal power plants, may cause asthma attacks, inflammation, and immune system responses if it becomes stuck in the lungs. According to research, these particles are associated with the top four killers. cardiovascular disease, cancer, lung disease, and stroke. Fly ash toxics may move about in the ecosystem not just by leaching, but also via erosion, runoff, and even fine particles in the air. The chemicals in fly ash are dangerous because they may escape and travel across the ecosystem. When stone crushing facilities produce aggregate of the desired size, they leave behind a byproduct known as crusher dust.

As a concentrated byproduct of crushing, quarry dust is ideal for use as aggregates in concrete, particularly fine aggregates. Quarries produce dust as a byproduct of crushing rock into different sizes; this waste product is known as quarry dust. Crusher dust is a viable substitute for coarse-grained, non-plastic soils due to its inherent properties, such as being non-plastic, incompressible, and having high dry densities. In this work, graded gravel-crusher dust mixtures are investigated for compaction and CBR characteristics using stone crusher dust instead of particles smaller than 4.75 mm. Through the preservation of non-plastic conditions, the aforementioned mixtures achieved high dry densities and CBR values. You may utilize GC1, GC2, GC3, and GC4 as base courses since they have achieved CBR values larger than 60.

On the other hand, GC5, GC6, and GC7 can be used as sub base courses because they have achieved CBR values greater than 30. Construction projects may make good use of bottom ash, a significant byproduct of thermal power plants. The CBR values of the graded gravel and Bottom Ash mixtures tested ranged from 60 to 65, which is considered high. The dry densities of the aforementioned mixtures were likewise somewhat high, ranging from 1.8 to 2.02 gm/cc. It is feasible to employ gravel and Bottom Ash mixtures with high CBR values and high dry densities as component layers in the building of flexible pavements.

***Key Words*:** *CBR, Bottam Ash, Gravel, Flexible Pavement.*

1. INTRODUCTION

The improvement of a country's infrastructure is the single most important factor in boosting its economy. One example of a piece of infrastructure that links land masses all over the world is road networks. The layers of pavement and the material requirements determine how long-lasting flexible pavement is, making it an attractive road networking option. Through grain-to-grain contact, the bottom layers of a flexible pavement are subjected to vertical compressive stresses. The qualities of the material, such as its plasticity, density, and grain size distribution, determine the quality of the pavement layers. Soils made of well-graded, compacted gravel with a variety of particles may distribute compressive loads uniformly and provide a strong, flexible pavement layer; broken stones and gravels are common sub-base and base course materials. Flexible pavement materials often include natural soils, crushed stones, gravel soils, or traditional bitumen. Pavement may get damaged when small plastic particles, such as clay, absorb water and bend or break when subjected to stresses. On top of that, certain materials could not have specs that are up to par with MORTH requirements. Researchers have recently turned their attention to finding better ways to use industrial waste in road building in order to slow the depletion of more costly traditional materials. Various research organizations and researchers worldwide have advised using industrial wastes like as fly ash, bottom ash, crusher dust, etc., at the sub-grade, sub-base, and base courses in the building of flexible pavements. This technique is based on the results of such research. This research investigates the feasibility of using non-plastic materials such as crusher dust and bottom ash, which are byproducts of stone crushing facilities and thermal power plants, respectively, in combination with crushed stone and graded gravel particles to create soft pavements.

1.1 Objectives of the study

- To study of using graded gravel soils as a basis and sub-base.
- To study of crushed gravel and bottom ash blends work as sub-base and base course materials.
- To study graded gravel and bottom ash as substitutes for crusher stone and sand in sub-base.

2. COLLECTION OF LITERATURE DATA

Hameed ,et. al (2009), reviewed the literature on the topic and discovered that using crusher stone dust as fine sand improves the flexural strength of concrete compared to using natural sand, however this benefit diminishes with increasing proportion of crusher dust.

Nayak ,et .al (2010), noticed that the MDD number went up when the sand % went up. The ideal moisture content dropped from 22.5% to 15.4%, a loss of 32%.

Ramadas, et.al (2010), observed that when fly ash and stone dust is added to the expansive soils the Atterberg's limits, OMC, FSI are decreased and MDD, UCS, CBR values are increased. Improving the qualities of expansive soils is best accomplished with 25% fly ash and 30% stone dust, according to the observations. Two of the expansive soils studied showed that adding a mixture of twenty percent stone dust and twenty-five percent fly ash at the optimal moisture content reduced swelling and increased strength (Source: https://link.springer.com/article/10.1007/s12665-013-2833-x).

Ali, et.al (2011), Experiment findings suggest that crusher dust might be used to improve the stability of expansive soils, such as black cotton soil, by altering their engineering properties. Soil performance in terms of expansiveness and improved strength characteristics were examined in relation to Stone Dust treatment.

Mahzuz ,et.al (2011), found lower compressive strengths. They reported that the compressive strength of concrete with stone powder is 14.8% higher than that of the concrete made of normal sand.

Mir Sohail Ali, et.al (2011), researched the effects of stone dust and fly ash on expansive soil, looking at index values, compaction characteristics, swelling, and unconfined compressive strength, states that limiting the swelling of expansive soil is best accomplished by adding a mixture of equal parts stone dust and fly ash, rather than either material alone.

Quadri Syed Ghausuddin, et.al (2011), tested polypropylene-reinforced soil-quarry dust mixes and found that 24-millimeter-long fibers performed best when added at a dose of one percent by weight of the soil-dust combination. The CBR value of the soil without the fibers was found to be four percent percent. Soil Quarry dust with 0.5% fibers of 12 mm, 24 mm, and 40 mm lengths increases CBR by 56.50%, 83.10%, and 49.50%, respectively. The CBR is increased by 154%, 251%, and 208%, respectively, when 1.0% fibers of 12mm, 24mm, and 40mm length are added to the soil quarry dust mix. According to a study on the effects of industrial wastes, adding 1.5 percent fibers with lengths of 12 millimeters, 24 millimeters, and 40 millimeters to soil quarry dustmix increases CBR by 160%, 270%, and 235%, respectively.

Pradeep Muley, et.al (2013), studied on the betterment and prediction of CBR values forStone dust mixed poor soils in order to strengthen the soil.

Bshara, et.al (2014), studied the improvements of strength characteristics of poor soil byadding the stone dust and observed better results in the strength aspects.

Bindhu Lal, et.al (2014), This study shows that stone dust can be satisfactorily used as a cheap stabilizing agent for sub-grade layers and sub-base layers of a Flexible Pavement. Observed that the Optimum Moisture Content, Maximum Dry Density and California Bearing Ratio properties are optimally improved by adding stone dust.

Purushotham, et.al (2014), There is an increase of 18% in maximum dry density (MDD) values for the addition of 50% quarry dust. Observed the improvements in the Geotechnical properties of Lithomargic Clay.

Shiva Prasad, et. al (2014), The results of the tests on the two soils showed that as the proportion of crumb rubber on the soils increased, the maximum dry density and optimal moisture content decreased. Maximum UCS values of 45% at 10% crumb rubber and 80% at 15% were noted for soil sample S1 and soil sample S2, respectively, as the proportion of crumb rubber rose.

Naman Agarwal ,et.al (2015), Come to the conclusion that the addition of stone dust to soil mixes has a discernible impact on the soil's maximum dry density. The maximum dry density may be increased by adding a tiny amount of stone dust. The research also shows that the optimal moisture content drops as the amount of stone dust in soil increases, which helps reduce the quantity of water needed for compaction.

Venkateswarlu, et.al (2015), noticed that both the liquid and plastic limits decreased regardless of the proportion of Quarry Dust added. Maximum Dry Density was determined to be 10% Quarry Dust, and OMC continues to decrease as the proportion of Quarry Dust increases. It was found that the Un-soaked CBR continues to rise when the proportion of Quarry Dust added increases.

Kurama et al. (2008), studied cement mortars with coal bottom ash as cement substitute evidenced the benefit of this residue on compressive strength, which is associated to a pozzolanic effect.

Esteban López et al. (2015), Researched the load-bearing capabilities of bottom ash and soil mixtures. Adding bottom ash concentrations ranging from fifteen to forty percent of the soil's weight may enhance soil quality. Blenders that incorporate ash into soil alter grain size, which in turn reduces plasticity and boosts bearing capacity. When fine-grained materials like bottom ash are mixed with plastic soils, the soil's fine-grained particles are replaced. This process creates a new kind of soil that is superior in bearing capacity, easier to compress, and more workable. A CBR of 24% or higher has been achieved using an additional 40% ash.

3. METHODOLOGY

In order to identify, plan, and execute effective waste management systems during stabilization, geotechnical characteristics information of different types of industrial waste is crucial. In order to determine if these industrial wastes are suitable for use in civil engineering construction operations, it is necessary to conduct experimental evaluations of their physical, index, engineering, and mechanical qualities. Utilizing industrial waste dumps requires careful geotechnical characterization. Using industrial waste in construction projects that use a lot of materials—like building highway pavement, filling basements, or backfilling behind retaining structures—is a great way to reduce landfill waste and save money. It's also a great way to solve the disposal problem.

The following In order to examine their use and compatibility across all layers of a specific flexible road pavement component, the following industrial waste materials, generated by companies in and around the north coastal districts of Andhra Pradesh, are chosen for the research.

Soils consisting of gravel are gathered from several sites in the Nellore areas. The stone crushing facility close to Nellore city in Andhra Pradesh, India, is the source of the aggregate.
The stone crushing facility next to Nellore City in Andhra Pradesh, India, is the source of the crusher dust. The Nellore Districts of Andhra Pradesh also collect crusher dust for validation purposes. As an added bonus, the findings are also checked against crusher dust mixtures from Zones I to IV.3. Coal from power plants is burned to produce pond ash, an industrial waste product.

The five aforementioned industrial waste materials undergo comprehensive laboratory testing to ascertain their physical, index, engineering, and mechanical properties. This is done to establish their potential as reinforcing materials and to ensure compatibility across all layers of the road's flexible pavement.

Fig -1: **CBR Apparatus**

Fig -2: **Crusher dust sample**

Fig -3: **Bottom Ash**

Fig -4: **Aggregate sample**

- Utilization of crusher dust as flexible pavement material at sub -grade.
- Utilization of crusher dust, crushed stone and ground granulated waste tyre as flexible pavement materials at sub-base course.
- Utilization of crusher dust, crushed stone and crumb rubber waste tyre as flexible pavement materials at base course.
- Utilization of polyethylene and styrene butadiene styrene as flexible pavement materials at bse course.

4. RESULTS AND DISCUSSIONS

Gravel soils are collected from local quarries of Nellore, Crushed stone is collected from stone crushing plants of Nellore. Bottom ash is collected from Nellore of Andhra Pradesh, India.

After collecting the gravel soils, this research uses wet and dry sieve analysis to separate them into their individual particles. Then, these particles are categorized into eight categories. Particle sizes in this Graded Gravel soil range from 75.0 mm down to less than 0.002 mm. Particle sizes of the gravel range from 75 to 4.75 millimeters.

A. Particles which are >4.75mm (75-4.75mm)

B. Particles which are<4.75mm (4.75-0.002mm).

A% : B% i.e. G1 : 85%-15%, G2: 75%-25%, G3: 60%-40%, G4:50%-50% G5:35%-65%, G6: 25%-75%, G7:15%-85%, G8:0%-100%.

Table -1: Grades of gravel soils

Grades	G1	G2	G3	G4	G5	G6	G7	G8
75-4.75 mm	85	75	60	50	35	25	15	0
<4.75mm	15	25	40	50	65	75	85	100

Table -2: Grain size distribution of graded gravel soils

Grain Size (mm)	Percentage finer of grades							
	85-15	75-25	60-40	50-50	35-65	25-75	15-85	0-100
	G1	G2	G3	G4	G5	G6	G7	G8
75	100	100	100	100	100	100	100	100
53	90	90	95	100	100	100	100	100
26.5	75	75	85	85	90	95	100	100
12.5	50	55	65	70	80	85	95	100
9.5	37	45	52	64	74	82	92	100
4.75	15	25	40	50	65	75	85	100
2.36	11	19	25	42	56	65	74	85
1.18	9	15	22	36	49	56	63	70
0.425	7	13	18	28	35	41	47	53
0.075	5	10	15	20	25	30	35	40
0.002	2	3	5	7	9	10	13	15

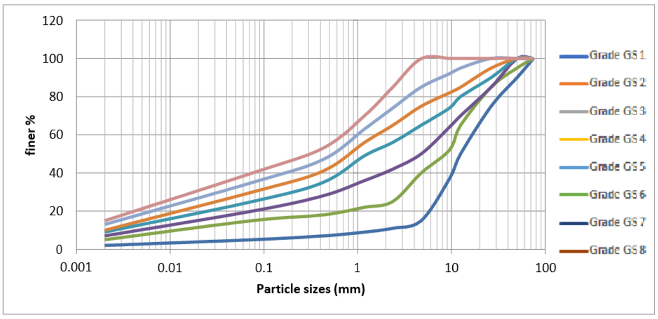


Fig -5: Grain size distribution curves of graded gravel soils

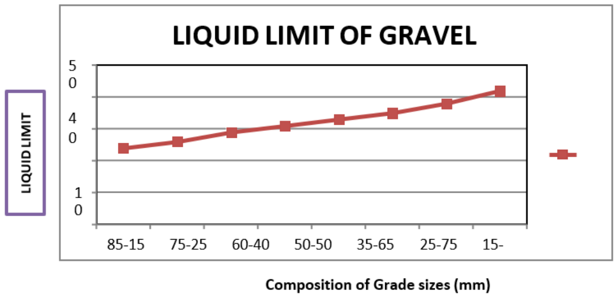


Fig -6: Liquid limit of gravel soils

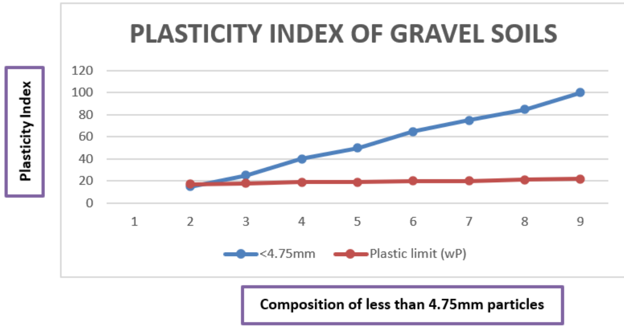


Fig -7: Plasticity Index values of gravel soils less than 4.75mm particles

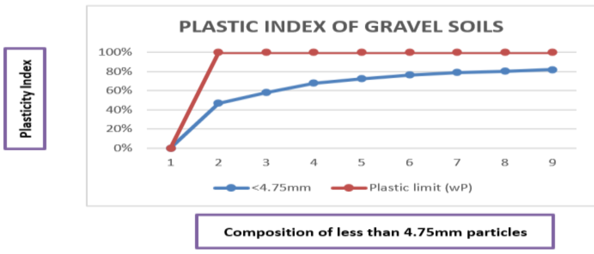


Fig -8: Plastic Index values of gravel soils less than 4.75mm particles

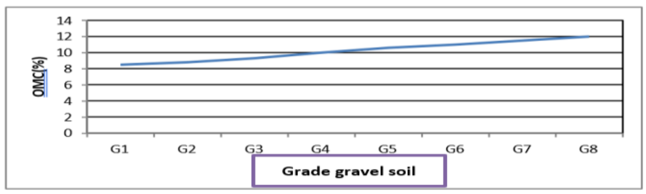


Fig -9: OMC(%) of graded gravel soil

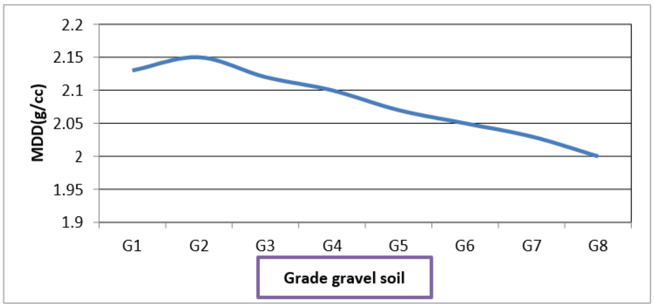


Fig -10: MDD(%) of graded gravel soil

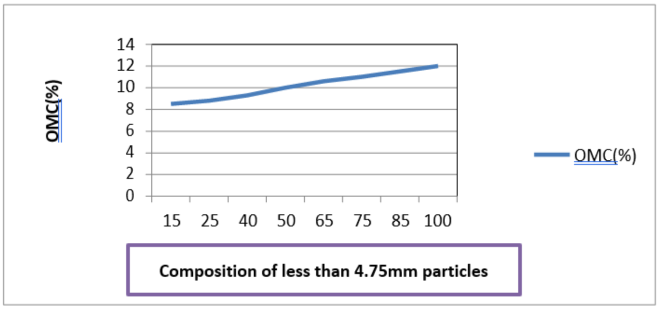


Fig -11: OMC OF GRAVEL SOILS FOR LESS THAN 4.75mm PARTICLES

The maximum dry density (MDD) values and optimum moisture content (OMC) values of graded gravel soils are both affected by the proportion of gravel particles (> 4.75mm), as shown in the tests. The inverse is also true for particles smaller than 4.75mm. In the same vein, OMC levels vary from 8.5% to 12.0% and MDD values from 2.00 g/cc to 2.15 g/cc. Plus, CBR values for graded gravel soils are between 18 and 48. There is a dominance of coarser particles in graded soils G1, G2, G3, G4, and G5, which have CBR values higher than 30. The fluctuations in CBR values are caused by the deformation of finer particles under saturated conditions under loading. With certain mechanical adjustments, gravel soils with CBR values above 30 may be used as a sub-base course.

Increase in the percentage of gravel particles increases MDD values and decreases OMC values. Increase in the percentage of fines increases the liquid limit and plastic limit values there by increases plasticity index values which increases OMC and decreases MDD values. Domination of single size particles either sand or fines increases OMC values and decreases MDD values.

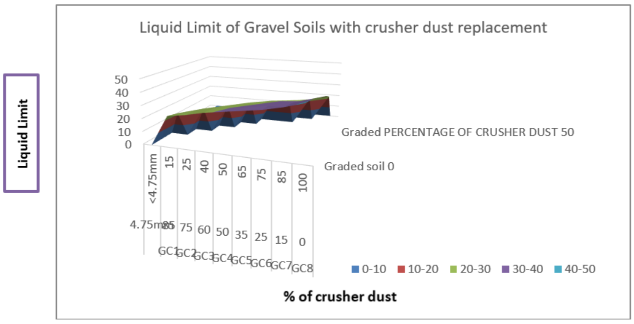
The maximum density and open-mix concrete (OMC) values were both high for mixtures of gravel and sand with a low fines percentage.When the majority of the particles in a gravel soil are of a single size, the soil matrix becomes poorly graded and honeycomb-shaped. In contrast, when the majority of the particles are of different sizes, such as gravel, sand, and fine particles, the soil matrix becomes cohesive and dense.

A higher specific surface area means more water is needed to lubricate the particles, which in turn means higher OMC values, when the proportion of fines (silt and clay particles) rises. Similarly, a broad range of particle sizes is represented by a large number of particles, which results in well-graded conditions that aid in filling up spaces, but also increases the necessity of water and the interlocking of particles.

Therefore, in order to achieve high densities compared to single-size particles, such as in poorly graded soils with their honeycomb structures, it is necessary to increase the variety of particles in a given volume. Thus, gravel soil gradation aids in enhancing plasticity, compaction, and CBR properties.

The CBR values of graded gravel soils (G1, G2, G3, G4, G5) vary from 48 to 33.The liquid limit is between 24 and 33 and the plasticity index is between 7 and 13.Soils G6, G7 that are graded gravel have CBR values between 18 and 28, a Liqiud limit between 35 and 38, and a plasticity index between 15 and 17. The following graded gravel soils are suitable for use as sub-base course material according to MORTH: WL<25, IP<6, and CBR>30. For use as base course material, CBR >60 is recommended. The graded gravel soils that were tested did not match the standards set by MORTH. To achieve the MORTH criteria, stabilization was necessary for these graded gravel soils.

To study the performance of graded gravel soils with crusher dust as geotechnicalmaterials like sub base ,base course and fill material in construction of roads Tests areconducting tests on these materials about their characterizations and suitability w.r.t standard specifications.



Liquid Limit of Gravel Soils with crusher dust replacement

Fig -12: Variation of liquid limit w.r.t crusher dust

As the proportion of crusher dust in graded gravel soils increases, the results of consistency tests reveal that the values of the plasticity index and liquid limit are reduced. Soils with a high liquid limit for gravel need a high dose of crusher dust to become non-plastic, while soils with a low liquid limit need a low dosage.The following percentages of crusher dust, relative to the dry weight of soil particles <4.75mm: GC1 and GC2 need 20%, GC3 and GC4 require 30% to 40%, GC5 and GC6 require 50%, GC7 require 60%, and GC8 require 70%.

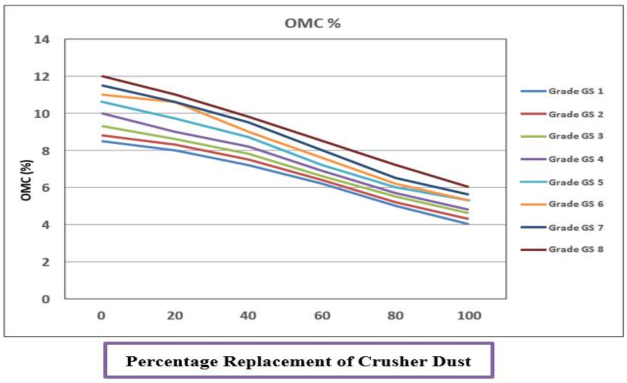


Fig -13: Variation of OMC w.r.t gradation mixes

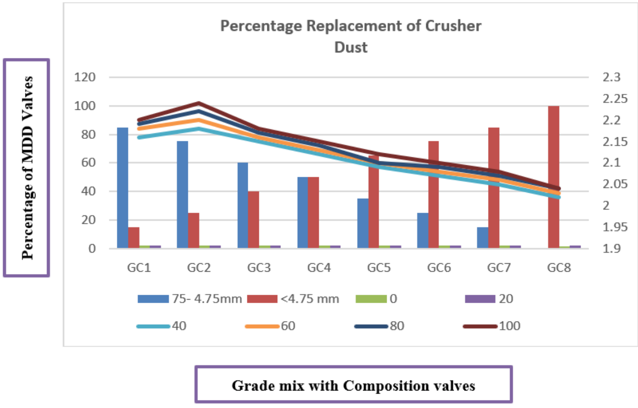


Fig -14: Variation of MDD w.r.t gradation mixes

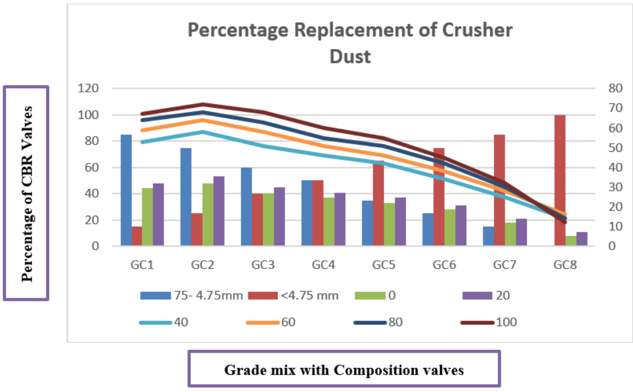


Fig -15: Variation of CBR w.r.t gradation mixes

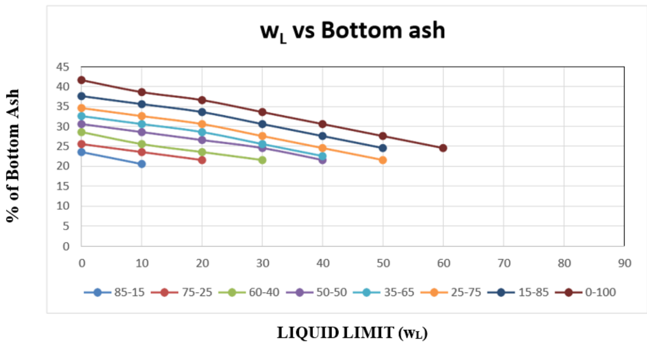


Fig -16: Variation of liquid limit of gravel soil- bottom ash mixes

A lower plasticity index and lower liquid limit are seen in graded gravel soils when the amount of bottom ash is increased, according to consistency test results. To make gravel soil non-plastic, a high dose of bottom ash is required for soils with a high liquid limit, but a low dosage is sufficient for soils with a low liquid limit.The dosage of bottom ash relative to the dry weight of soil particles no larger than 4.75mm is 70% for GB8, 60% for GB7, and 10% for GB2. For GB3 and GB4, the required amount is 30-40%. For GB5 and GB6, the required amount is 40-50%.

As the amount of bottom ash in graded gravel-bottom ash mixtures increases, the maximum dry density drops from 2.02 g/cc to 1.28 g/cc, according to the test findings. As additional bottom ash particles are incorporated into the gravel particles, resulting in a compacted and cohesive matrix, the maximum dry density value decreases. As the proportion of bottom ash increases, these values also rise in the event of optimal moisture content levels. Graded gravel soils have lower OMC values than blends of graded gravel and bottom ash. This is because, in contrast to gravel soils that have a high concentration of tiny particles, bottom ash particles occupy this space instead.

As the amount of bottom ash particles in graded gravel soil-bottom ash mixes increased, the maximum dry densities decreased from 2.04g/cc to 2.15g/cc to 1.28 g/cc to 2.02 g/cc, according to the test findings. The highest dry densities achieved with 25% dose for the densest gravel mix G2(75-25) are 2.15 g/cc, while for GB2 (75-25) it is 2.02 g/cc and for (GB1 TO GB4) it is 1.80 to 2.02 g/cc. In comparison to graded gravel soils (8.5 - 11.0%), all of the graded gravel - bottom ash mixtures had greater OMC levels, ranging from 9.2% to 13.0%, with the exception of GC8 (0 -100).

Soil mass density (MDD) decreases and organic matter content (OMC) increases when bottom ash particles, which are non-plastic, replace smaller particles (less than 4.75 mm and especially less than 0.075 mm), allowing for a higher concentration of solid particles per unit volume of soil mass while requiring less water.

Increasing the proportion of bottom ash in graded gravel-bottom ash mixes raises the CBR values for all of the mixes, according to the test findings. With a full replacement of graded mix GB2, the maximum value is 65. Combinations of GB1, GB2, and GB3 with bottom ash ranging from 60 to 80 percent have produced CBR values of 60 or higher. When it comes to replacing bottom ash in whole or in part, all mixtures except GB7 have attained results over 30. Base course materials made of GB1, GB2 with bottom ash replaced by 60-100% work well. You may utilize mixes (GB1, GB2,.....GB6) with a replacement of 20-100% as a sub-base for your course materials.

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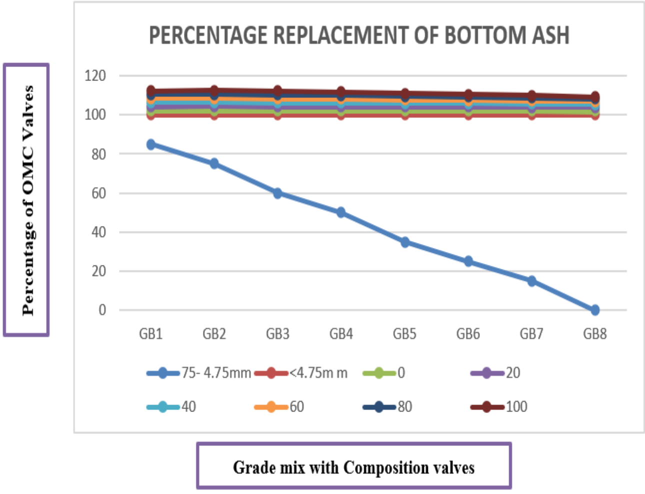

Fig -17: Variation of OMC w.r.t gradation mixes

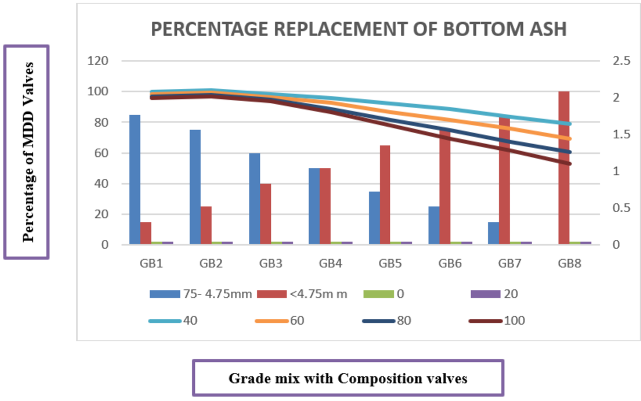

Fig -18: Variation of MDD w.r.t gradation mixes

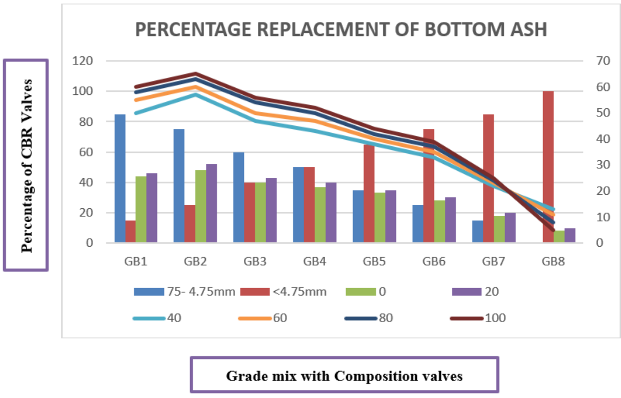

Fig -19: Variation of CBR w.r.t gradation mixes

5. CONCLUSION

- In graded gravel soils, the findings reveal that the maximum dry density (MDD) values and optimum moisture content (OMC) values are affected by the proportion of gravel particles (> 4.75mm). The inverse is also true for particles smaller than 4.75mm.
- In the same vein, OMC levels vary from 8.5% to 12.0% and MDD values from 2.00 g/cc to 2.15 g/cc.
- The CBR values are likewise rising as the proportion of gravel particles increases, which may be anywhere from 18% to 48%. There are graded soils with CBR values larger than 30, which are dominated by coarser particles, and graded soils with CBR values less than 30, which are G6, G7, G1, G2, and G3.
- The deformation of smaller particles under saturated circumstances under loading causes the CBR values to vary. With certain mechanical adjustments, gravel soils with CBR values above 30 may be used as a sub-base course.
- G1, G2, G3, G4, and G5 graded gravel soils have CBR values between 48 and 33. Properties: plasticity index 7–13, liquid limit 24-33. The CBR, liquid limit, and plasticity index of graded gravel soils G6, G7, and G8 are between 18 and 28, 35 and 38, and 15 and 17 respectively.
- The following graded gravel soils are approved for use as sub-base course material according to MORTH: WL<25, IP<6, and CBR>30. On the other hand, base course material may be produced with CBR >60.
- The tested graded gravel soils did not meet the requirements established by MORTH. Stabilization was required for these graded gravel soils to meet the MORTH requirements.
- Results from tests on blends of graded gravel and crusher dust show that their maximum dry densities initially reach 2.24 g/cc before falling to 2.04 g/cc.
- A more compacted and cohesive matrix, caused by the increased participation of crusher dust relative to gravel particles, results in an increase in the maximum dry density value.
- As the proportion of crusher dust increases, these values decrease in the event of optimal moisture content. When compared to graded gravel soils, the OMC values of mixtures including crusher dust are consistently lower.
- As opposed to gravel soils, which contain a high proportion of fine particles, this is because crusher dust particles occupy the space instead.
- With an increase in the proportion of crusher dust particles, the maximum dry densities of graded gravel soil - crusher dust mixtures go from 2.00g/cc - 2.13g/cc to 2.04 g/cc - 2.24 g/cc, according to test findings.
- Experiments on mixtures of graded gravel and bottom ash have shown that the maximum dry density drops from 2.02 g/cc to 1.28 g/cc as the amount of bottom ash increases. As additional bottom ash particles are incorporated into the gravel particles, resulting in a compacted and cohesive matrix, the maximum dry density value decreases. As the proportion of bottom ash increases, so do the ideal moisture content levels.
- The OMC values of the graded gravel-bottom ash mixes ranged from 9.2% to 13.0%, which is more than the values of graded gravel soils, which range from 8.5% to 11.5%. Based on the results of the tests conducted on graded gravel-sand mixes, it was found that increasing the percentage of sand increases the maximum dry density up to 2.20 g/cc, after which it decreases to 2.06 g/cc.

- The highest possible dry densities are rising to 2.24 g/cc (GC100)2 and falling to 2.08 g/cc (GC100)7. Compared to graded gravel soils, all of these values are greater.
  OMC levels have been rising and have reached 8.5% for GC100.7 . When compared to graded gravel soils, all of these OMC levels are much lower.
- Here are the findings of compaction tests on mixtures of graded gravel and bottom ash, where the latter is used to completely replace particles less than 4.75 mm in size.
- The highest and lowest possible dry densities are 2.02 and 1.28 g/cc (GB)2 and GB, respectively. In order for 100 graded gravel soils to meet the MDD values, the following combinations of (GB)1 and (GB)2—(85-15, 75-25, 60-40)—with CBR values of 100 and 100 greater than 60, respectively—are required.

5.1. SCOPE FOR FURTHER STUDY

Using flyash, GGBFS, or RHA instead of particles smaller than 4.75 mm is a potential extension of the current study. Additional applications include replacing crusher stone with coarse slag (e.g., copper, ferrochrome, oxygen, etc.) as the coarse aggregate, and enhancing the material's elastic characteristics with crumb rubber or tire waste.

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