International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-5, March 2020

Experimental Examination on Utilization of Processed Mine Overburden Sand by Substituted to River Sand in Construction

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Abstract: ***Overburden is the unutilized rock or soil bands that are generated during the mining process and are dumped near the marked placed inside the mine boundaries. It contains alluvial, sandstone, soil, gravel, clay, debris other than mining material. Dumping or management of this mine waste is a significant environmental problem, and additional cost spends to the mining industry. And also, most of this waste is disposed of at the surface, which inevitably requires extensive planning. Sand and gravel are low energy-intensive construction materials, but the growing demand for industrial uses has depleted this natural source. Limitations to natural sand extraction and legal regulations have been imposed in several countries due to environmental concerns. Due to the above, all the reasons river sand has become very costly in recent years. The research has been carried out to convert the overburden to processed overburden sand after that compared the geotechnical properties like specific gravity, permeability, moisture content, and grain size analysis, swell factor of both the overburden processed sand and natural river sand. Then we check the suitability of processed overburden material as a replacement to natural river sand in construction by comparing the strengths of the concrete samples prepared with both the river sand and processed overburden sand. We found the average compressive strength of overburden sand brick is 24.69 MPa, and river sand brick is 28.08 MPa of 14 days curing of bricks. The results obtained that the processed overburden sand can be used as the best alternative for the river sand because the geotechnical properties of both are almost the same. This processed overburden utilization in the coal mining area to reduced environmental impact, more availability of a land resource, minimizing the overburden disposable cost to the mining industry, and it's also helpful to the preservation of natural river sand.***

Keywords: Overburden waste, Processed Overburden Sand, River Sand, Concrete Brick, Compressive Strength.

I. INTRODUCTION

Coal is the primary energy source for power production in India, similar to other developed such as the USA, China, and Australia. The Indian energy-producing sectors are dependent on coal, which accounts for more than 70 percent of total electricity generation[1]. The opencast mining method is used to extract shallow coal seams. During opencast mining, the overlying soil is removed, and the fragmented rock is heaped in the form of overburden dumps. Most of this waste is disposed of at the surface, which inevitably requires extensive planning and control to minimize the environmental impact of the mining [2].

Revised Manuscript Received on March 30, 2020.
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There are 84 million m3(Mm3) annual overburden removal with an accumulation of 916 Mm3) since 1990, only in one coal company of India (South Eastern Coalfield Ltd., SECL) [3]. This volume of overburden is going to increase every year due to the dumping of overburden, increase of depth of coal seam, and coal production[4]. OB generated along with valuable mineral shows a specific ratio (mineral/OB) called stripping ratio. The average stripping ratio in Indian coal mines is found to be about 1.97 m3 /t in the last few decades[5].

The construction materials are classified as non-renewable, requiring a large volume of natural resources and energy consumption. Sand and gravel are low energy-intensive construction materials, but their use constitutes the most significant volume of natural resources in the world (25000 million tons/year) exceeding fossil fuels and biomass [6]. Mining of natural materials such as sand serves as the primary source of construction aggregate used throughout the world[7]. Sand mining has where this practice is becoming an environmental issue because of the demand for sand increases in industry and construction[8]. Usage of river sand for the Industries also faces severe problems such as the risk involved in transportation, availability of the sand during non-raining seasons, and water table depletion. Many countries have imposed strict laws against sand mining activities, including India. Due to the above, all reasons river sand has become a high cost over the years, so found alternative materials.

During mining/excavating the coal, a lot of overburden material is generated, which is having the content of silica sand but requires processing to achieve desired quality specifications[9]. Processed overburden utilization in the coal mining area reduces environmental impact, more availability of a land resource, and reduction in mining cost, which occurs on the maintenance of mine spoil as reclamation, plantation, slope stability, etc. By choosing overburden as a source of sand has now made it possible to convert these wastes into valuable products[10].

II. OBJECTIVES OF STUDY

1. To study the process of conversion of overburden to processed overburden (OB Sand).
2. To conduct laboratory tests on OB sand and results that are generated made to compare with the natural river sand.
3. To determine the suitability of processed overburden material as a replacement to natural river sand in construction by comparing the strengths of the concrete samples prepared with both the river sand and OB sand.

III. METHODOLOGY

A. Sample Collection

Samples of overburden material were collected from the locations of KTKOCP-I of the Bhupalapally area of Singareni.

From transportation, fragmentation, and handling point of view, Overburden received from KTKOCP-I was found to be more feasible. Kakatiyakhani opencast sector–I project (KTK OCP-I) is located in the area of Bhupalpally area, which comes under the district of Warangal situated in Telangana state.

B. Cyclic Operational Procedure for Preparation of Processed Sand

The Overburden is taken from KTK OCP-1 mines is loaded into the trucks from the dump yard by the shovels. The trucks unload the OB in the Hooper of grizzly type at the Plant. From here, the actual processing takes place. The material travels from Hooper to the belt conveyor-1 through the Vibro feeder. From the conveyor, the content is sent to the Blake type jaw crusher where the size of the material is reduced from 500 mm to 40 mm[6]. The crushed OB is forwarded to the scrubber through the belt conveyor-2.

Fig .1. Overburden in Kakatiyakhani Opencast Project-1, SCCL

Fig .2. Processing plant.

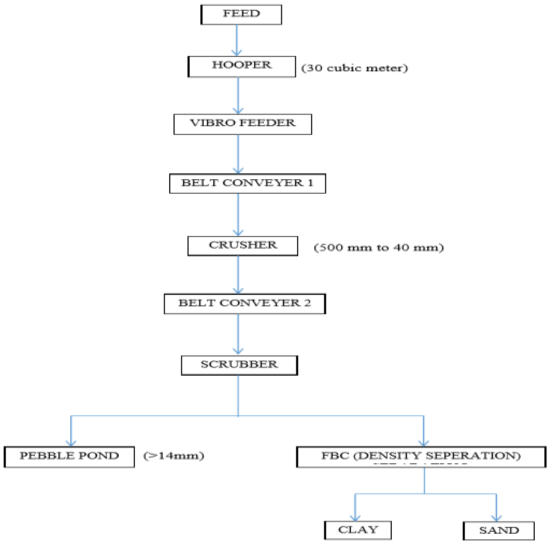

Fig .3. Cycle operation of mine overburden to processed overburden sand.

IV. EXPERIMENTAL INVESTIGATION

The following geotechnical properties of both river sand and processed overburden are investigated in the rock mechanics lab.

A. Specific Gravity

The specific gravity of solids (Gs) is a measure of solid particle density and is referenced to an equivalent volume of water.

B. Moisture Content

The moisture content gives an idea of the state of soil in the field.

C. Grain Size Distribution

The Grain Size Distribution consists of two tests, namely Sieve analysis and Hydrometer analysis based on this we can characterize the type of soil.

D. Sieve Analysis

It is the first test that has to be carried out to draw the grain size distribution curve.

Fig.4. Set of Sieve

Fig.5. Mechanical Sieve shaker

E. Hydrometer Analysis

Hydrometer analysis is used to determine the grain size distribution of soil sample containing a considerable amount of fines (clay)

Fig.6. 50g Fine passed through 0.075 mm sieve

F. Compaction Test (Light Weight)

In the test to determine the proper amount of mixing water to be used while compacting the soil in the field. In this test, we will find optimum moisture content (OMC) and maximum dry density (MDD).

Fig.7. Weighing

G. Permeability Test(Falling Head Method)

The coefficient of permeability is used to determine the rate of settlement of structures.

Fig.8. Compaction Mould with filter paper

H. Swell Factor

The swell factor gives us the idea of volume expansion of soil after the absorption of water. This parameter plays a vital role while using the soil in construction.

V. PREPARATION OF CONCRETE SAMPLES

The samples of size 150 cu.mm are prepared according to IS 456 (2000). The grade of the samples prepared is M 2O. Where M means to mix, 20 is the compressive strength of 150 cu.mm sample after 28 days of curing. For an example of grade M 20, the ratios of cement, sand, and aggregate are taken as 1:1.5:3, respectively[12]. The samples of river sand and processed overburden are prepared separately and tested at seven days and 14 days curing. The strength of the sample after a particular time of curing is taken as the average of three samples. So, the number of samples prepared for both river sand and POB is 12.

A. Materials Needed

Cement, Aggregate, Sand, and Water

The cement used in the preparation of samples is 33 grade conventional Portland cement.

B. Aggregates

Aggregates shall comply with the necessities of IS 383. As far as possible, preference shall be given to natural aggregates. The nominal extreme size of coarse aggregate should be as large as possible within limits specified but in no case higher than one-fourth of the minimum thickness of the size of the sample. For most work, 20 mm amassed is suitable. In concrete elements with thin sections, carefully set apart reinforcement cover, consideration should be given to the use of a 10mm nominal maximum size.

C. Water

Water is used for mixing and curing shall be clean and free from dangerous amounts of oils, acids, alkalis, salts, sugar, organic materials that may be damaging to steel[13]. Potable water is usually considered satisfactory for mixing concrete. In this preparation of samples, the ratio of water to cement is taken as 0.6 [14].

D. Curing

Curing is the process of checking the loss of moisture from the concrete while maintaining a satisfactory temperature regime. The anticipation of moisture loss from the concrete is particularly crucial if the water-cement ratio is small if the cement has a high rate of asset development. The curing should also prevent the development of high-temperature gradients within the concrete.

Fig.9. Concrete before Curing

Fig.10. Concrete after Curing

Fig.11. Compression Testing Machine.

E. Compressive Strength

The compressive strength of the samples is calculated according to the IS 516 part 5 (1959).

VI. RESULT AND DISCUSSION

In the paper, we show the different geotechnical properties of both the processed OB sand and river sand.

A. Specific Gravity

The specific gravity of overburden sand has near to the river sand specific gravity the details are mention following table 1

Table-I: Specific Gravity Values of two Samples

S. No	Sample Name	Weight of empty pycnometer with stopper (W1) in grams	Weight of pycnometer with the stopper having 25g of the sample (W2) in grams	Weight of pycnometer with the stopper having 25 g sample and sufficient water after treating with vacuum generator (W3) in grams	Weight of pycnometer filled with water (W4) in grams	Specific Gravity $= \frac{(w2-w1)}{(w4-w3)+(w2-W1)}$
1	OB sand	47	72	167	151	2.7
2	River sand	450	650	1370	1252	2.63

B. Moisture content

Table-II: Moisture content of two Samples

S. No	Sample Name	Weight of clean container (W1) in grams	Weight of box filled with soil (W2) in grams	Weight of oven-dried container filled with soil (W3) in grams	Moisture content $= \frac{(w2-w3)}{(w3-w1)}$
1	OB sand	84.4	134.7	127.2	17.52 %
2	River sand	152	183.8	180.7	10.8 %

C. Sieve Analysis (Grain size distribution)

Table-III: Determination of %finer in OB Sand

Sieve Size, mm	Retained weight, g	Retained weight, %	cumulative % Retained	% Finer
45	0	0	0	100
20	0	0	0	100
13.5	0	0	0	100
10	0	0	0	100
5.6	2	0.8	0.8	99.2
4	1	0.4	1.2	98.8
2	7	2.8	4	96
1	22	8.8	12.8	87.2

0.425	90	36	48.8	51.2
0.25	50	20	68.8	31.2
0.125	75	30	98.8	1.2
0.075	2	0.8	99.6	0.4
<0.075	1	0.4	100	0

In the table, the % finer greater than 0.075 mm in OB sand is calculated.

Table-IV: Determination of %finer in River sand

Sieve Size, mm	Retained weight, g	Retained weight, %	cumulative % Retained	% Finer
45	0	0	0	100
20	0	0	0	100
13.5	0	0	0	100
10	0	0	0	100
5.6	2	0.8	0.8	99.2
4	1	0.4	1.2	98.8
2	7	2.8	4	96
1	22	8.8	12.8	87.2
0.425	90	36	48.8	51.2
0.25	50	20	68.8	31.2
0.125	75	30	98.8	1.2
0.075	2	0.8	99.6	0.4
<0.075	1	0.4	100	0

In table 4, the diameter of the particles greater than 0.075 mm in River sand is calculated

From the above curve, it is clear that the river sand doesn't contain any clay and silt particles.

That's why the Grain size distribution curve is a little bit steeper. The amounts clay, silt,

sand and gravel ate given in table 4

Table-V: Result of the Grain size distribution of River Sand.

Soil type	Percentage, %
Gravel	1.2
Sand	98.8
Silt	0
Clay	0

D. Hydrometer Analysis

Table-VI: Hydrometer analysis of OB Sand

Time, min	Hydrometer Reading, cm	Meniscus Correction	Effective Height, Cm	Corrected Reading, cm	Diameter of Particles, mm	% of finer in 50g of soil
1	23.5	24	9.8	21	0.041	67.14
2	21	21.5	10.7	18.5	0.03	59.15
5	19	19.5	11.4	16.5	0.0197	52.7
10	17	17.5	12.1	14.5	0.014	46.3
20	15.5	16	12.6	13	0.01	41.5
40	14.5	15	12.95	12	0.0074	38.37
60	13.5	14	10.3	11	0.0061	35.17
120	12	12.5	13.8	9.5	0.0044	30.37
1440	7	7.5	15.6	4.5	0.0013	14.38

In table 5, the diameter of particles less than 0.075mm in OB sand is calculated. S

The diameter of particles = K $\sqrt{L/T}$ mm

Where K is constant = 0.0131, L is the sufficient height, T is the time in minutes.

Retrieval Number: E3206039520/2020©BEIESP
DOI: 10.35940/ijitee.E3206.039520
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
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Table-VII: Values for Grain Size Distribution Curve of River Sand.

Grain size, mm	% finer
5.6	99.2
4	98.8
2	96
1	87.2
0.425	51.2
0.25	31.2
0.125	1.2
0.075	0.4

Table-VIII: Values for Grain Size Distribution Curve of OB Sand.

Grain size	mm % finer	Grain size	mm % finer
5.6	99.6	0.041	8.5
4	99.6	0.03	7.51
2	98.8	0.0197	6.69
1	90.8	0.014	5.88
0.425	62	0.01	5.27
0.25	39.2	0.0074	4.87
0.125	18	0.006	4.46
0.075	13.2	0.0044	3.85

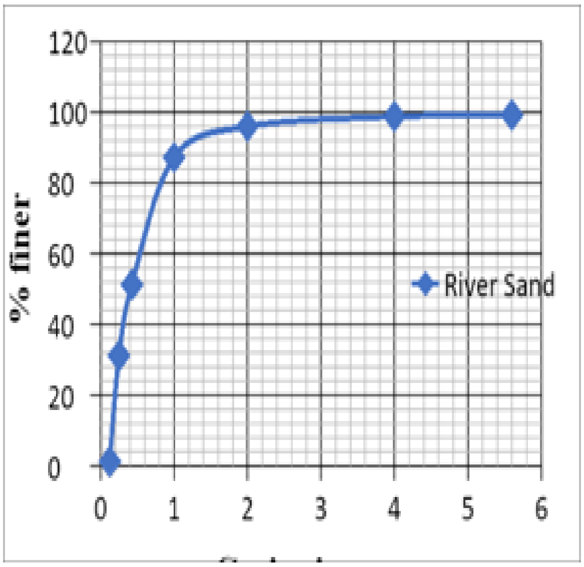

Fig.12. Grain Size Distribution Curve

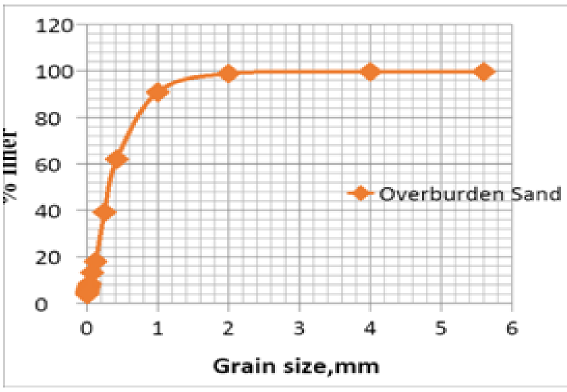

Fig.13. Grain size distribution Curve of over burden sand.

From the above curve, it is clear that the OB sand contains a small amount of silt and clay.

From the below curve shows, the river sand did not contain any clay and silt content,

but OB sand has both of them in it. That's why the grain size distribution curve of river sand

is a little bit steeper than OB sand.

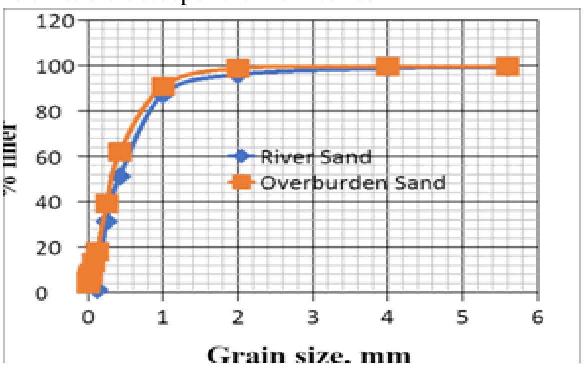

Fig.14. Comparison of results of both OB sand & River sand grain size distribution.

E. Permeability Test (Falling Head)

The soil sample for the test was prepared according to the procedure explained in the above chapter. 3 kg of soil was mixed with 324 ml (OMC) of water for optimum compaction.

Table-VII: Results of Permeability of two samples

S. No	Sample Name	Coefficient of Permeability, cm/sec
1	OB sand	3.14×10^{-5}
2	River sand	4.95×10^{-5}

F. Compaction Test

In this test, we will find optimum moisture content (OMC) and maximum dry density (MDD).

Overburden Sand:

Table-IX: Values for Omc-Mdd Curve

Water content, %	Dry density, g/cc
8.71	1.67
5.78	1.76
7.6	1.77

8.45	1.78
9.64	1.83
13.65	1.8
15.2	1.76

In the below figure, the values of dry density are gone on increasing with the increase of water content to some extent and then start decreasing. The coordinates of the deflection point give us OMC & MDD. From the curve, the OMC of OB sand is 9.5% and MDD is1.83 g/cc.

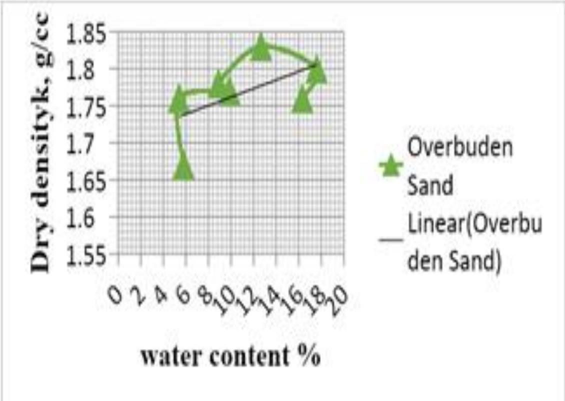

Fig.15. Dry density and water content values of overburden sand.

River Sand:

In this section, the determination of the OMC & MDD values of River sand is discussed. The initial water content added in the experiment is 6%.

Table-X: Values for Omc-Mdd Curve Of River Sand.

Water content, %	Maximum Dry Density, g/cc
5.8	1.566
5.39	1.605
9.86	1.573
8.89	1.632
12.66	1.593
17.59	1.565
16.33	1.612
13.45	1.646

In table x, the water contents and dry densities of OB sand are given for the designing of the OMC- MDD curve.

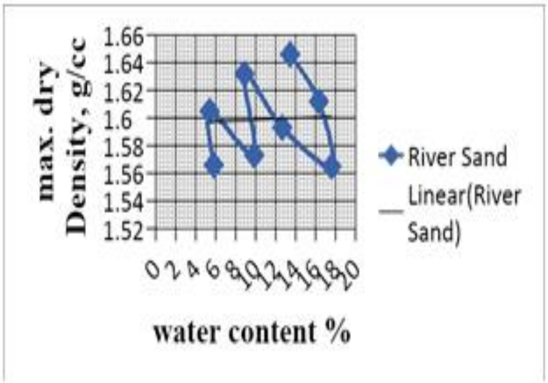

Fig.16. Dry density and water content values of river sand.

In the above figure, the values of dry density are gone on increasing with the increase of water content to some extent and then starts decreasing. After some extent, the dry masses again went expanding with water content and then drops. This phenomenon is called as bulking of River sand. The coordinates of the point with Dry high density give us OMC & MDD. From the curve, OMC is 13.4 %, and MDD is 1.64g/cc.

G. Swell factor

The swell factor gives us the idea of volume expansion of soil after the absorption of water. This parameter plays a vital role while using the soil in construction.

Table-XI: Results of Swell factor of two samples

S. No	Sample name	Swell factor, %
1	OB sand	7.69
2	River sand	10

H. Determination of Compressive Strength of Concrete Bricks

In this experiment, M 20 concrete samples are prepared by using OB sand and River sand separately. For determining the appropriate strength of the samples, I had taken the strength as the average of three samples. These samples are tested at the curing time of 7days and 14 days. As the curing time increases, the strength of the concrete also increases to some extent.

Table-XI: Compressive Strength at the Curing of 7 Days

Sample name	Curing for seven days	load, KN	load/area, MPa	Average, MPa
	sample 1	491	21.8	
River sand	sample 2	504	22.4	22.33
	sample 3	513	22.8	
	sample1	436.5	19.4	
OB sand	sample 2	450.1	20	19.41
	sample 3	424.2	18.85	

In table 11, the compressive strengths of concrete samples of OB sand and River sand are determined. The average of three samples is taken as the absolute strength of the sample.

From the below graph shows, the compressive strength of OB sand concrete at a curing time of 7 days is19.41 MPa, and that of River sand is 22.33 MPa. The compressive strength of OB sand concrete at a curing time of 14 days is 24.69 MPa, and that of River sand is 28.08 MPa. Both of the samples giving strength greater than 20 MPa at a curing time of 14 days.

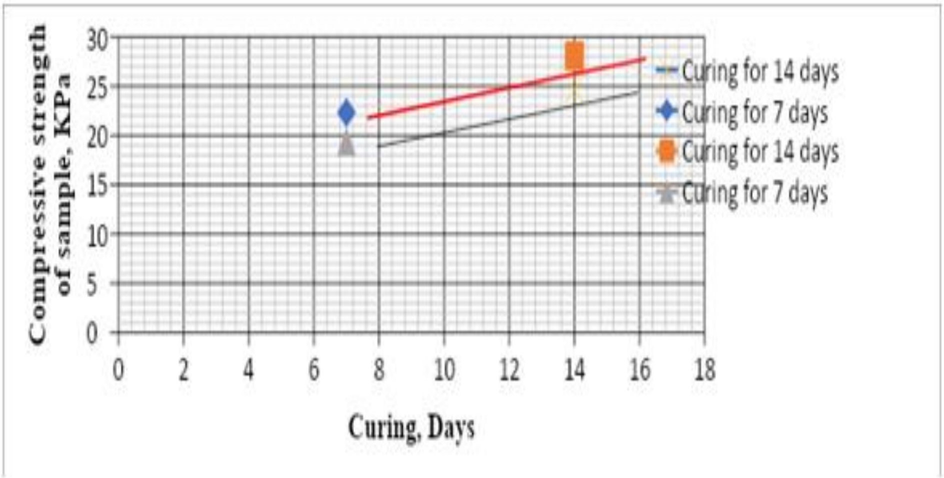

Fig.17.Compressive strength of both the prepared brick sample

VII. CONCLUSION

In this research work-based, we concluded the following:

1. From the above results, based both samples of OB sand and river sand are giving almost the same strength for curing of 14 days. In this experiment, M 20 concrete has prepared, that means its strength should be 20 MPa, both the concrete of OB sand and the river sand are satisfying this condition. These are giving the strength of 28 MPa for river sand and 25 MPa for OB sand, which is quite higher than 20 MPa.
2. The specific gravity of OB sand is 2.7 and 2.63 for river sand. These are having almost the same specific gravity. The moisture content of OB sand is a little bit greater than that of river sand because of the presence of clay content in it.
   The presence of clay will cause the absorption and accumulation of moisture in a place.
   The river sand doesn't have clay content in it. That's why the permeability of river sand is more significant than OB sand.
3. The Maximum Dry Density (MDD) of OB sand is more significant than river sand having MDD of OB sand 1.83 g/cc and that of river sand 1.64 g/cc.
   The Optimum Moisture content of OB sand is less than river sand due to the presence of silt and clay content in OB sand, which in result requires some less quantity of water in comparison to river sand while compacting the soil.
4. The swell factor of the OB sand is 7.69, and that of river sand is 10. It indicates that the volume expansion of OB sand after mixing with water will be lesser than that of river sand, and this property supports OB sand for using as a constructional material effectively.

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