CHAPTER 48

Evaluation of Silver Sand as Backfill Material for Reinforced Earth Walls in Highway Projects as per MORTH (5th Revision, 2013) and IRC: SP:102–2015

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ABSTRACT

RE walls have become an integral component of modern highway engineering due to their malleability, economy, and improved performance characteristics under differential settlement conditions compared to conventional rigid retaining structures. The performance characteristics of RE walls are significantly affected by the engineering properties of the backfill material used. The MoRTH Specifications for Road and Bridge Works, 5th Revision, 2013, and IRC: SP:102-2015 specify granular free-draining non-plastic soils with adequate shear strength as reinforced soil backfill material. In Guwahati, Assam, the cost of construction is appreciably higher since the crushed aggregate backfill material is transported from a long distance away with limited availability in the region. Silver sand, on the other hand, is abundantly available from the river deposits of the region and can thus be considered as a viable alternative material; however, most of the existing literature or codal specifications have not comprehensively ascertained the suitability of the same. The silver sand is experimentally assessed in the current study through laboratory and field tests, such as grain size analysis, Modified Proctor compaction test, liquid limit test, plastic limit test, California Bearing Ratio (CBR) test, and field dry density test. The obtained results have been compared systematically with the results of the other two types of backfill materials, i.e., clay soil, as per the requirements of MoRTH Clause 3105 and IRC: SP:102-2015 for the construction of Reinforced Earth Walls. The technical feasibility, along with the cost-effectiveness, of using silver sand as backfill material for the Reinforced Soil Structure, in the rainy climatic zone of Assam, has been established.

Keywords: Reinforced Earth walls, Silver sand backfill, MoRTH and IRC:SP:102–2015.

1.0 Introduction

Reinforced Earth (RE) walls are widely used in highway projects due to their efficiency in terms of structure, construction time, and economy in different soil conditions.

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However, when compared to conventional reinforced cement concrete (RCC) retaining walls, in the case of RE structures, the soil-reinforcement interaction plays an important part; therefore, the selection of an appropriate backfill material becomes an essential input in the design. Inappropriate properties of the backfill material can lead to increased lateral earth pressures.

The MoRTH Specifications (5th Revision, 2013) and IRC: SP:102-2015 provide particular recommendations for reinforced soil structures, specifying that a well-graded, non-plastic, free-draining, granular soil should be used. The specifications for soil were again largely for crushed aggregates or generic sand, without any specific emphasis on other regional types of sand, such as silver sand. The silver sand has generally been assumed to have uniform gradation, high permeability, be non-plastic, but doubts have been raised regarding compaction, density, or strength compared to normal sand.

The silver sand is available in a large quantity at a river site near Guwahati, whereas the aggregate materials that are crushed are often available from a substantial distance away. Thus, a scientific analysis is required to determine suitability with respect to other materials like clay soils that can act as a potential alternative for reinforced earth walls.

2.0 Backfill Requirements as per Codal Provisions

2.1 MORTH Specifications (5th Revision,2013)

As stated in MoRTH Clause 3105, the backfilling in the reinforced soil should be granular, non-plastic, free-draining material that can be compacted. The most important criteria are as follows:

- Maximum fines content does not exceed 15 percent
- Plasticity Index (PI) no more than
- Sufficient shear strength and bearing capacity
- Permeability is high to prevent the accumulation of pore water pressure

These criteria are aimed at ensuring a positive interaction between the soil and the reinforcement, as well as the stability and functionality of the reinforced earth structure.

2.2 IRC: SP:102–2015

IRC: SP:102–2015 provides guidelines for design and construction, stating that the internal stability (rupture and pullout of reinforcement, as well as external stability (sliding, overturning, and bearing capacity)) should be verified. The characteristics of the Backfill material influence:

- Active Earth pressure coefficient
- Reinforcement length and spacing

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- Factors of safety against pullout and sliding

There is an implicit assumption that well-graded granular soils are used. In this manner, the relevance of evaluating alternative available local material, such as silver sand, is determined.

Table 1: Codal Requirements

Property	**MoRTH**	**IRC: SP:102–2015**	**Importance**
Fines content	≤ 15%	Low fines preferred	Prevent pore pressure
Plasticity Index	≤ 6 (preferably non-plastic)	Non-plastic	Avoid shrinkage
Permeability	High	High	Drainage behind wall
Shear strength	Adequate	Mandatory	Internal stability
Gradation	Granular	Well-graded preferred	Reinforcement interaction

Source: Created by authors

3.0 Review of Previous Studies

3.1 Experimental study on waste foundry sand as partial replacement of retaining wall backfill

This study was designed to explore the possibility of using a waste foundry sand, which is an industrial by-product in the metal casting process as a partial replacement of natural sand in retaining walls. Considering the fact that the demand of natural sand is high because of the unavailability of natural sand resources, the authors had tried to explore a sustainable alternative of natural sand without compromising the performance of the retaining walls. To achieve the above objective, small-scaled models of retaining wall were collected and tested in a controlled laboratory environment. The waste foundry sand was increasingly substituting the natural sand in varying ratios. Lateral earth pressure, horizontal movement of the wall, and interaction between backfill and geogrid were some of the key elements that were measured continuously during the experiment.

The experimental results were very clear that, when it was confirmed that waste foundry sand was added, the effect was the decrease in the lateral earth pressure on the wall. Further, the lateral movement of the retaining wall proved to be less than that of walls with traditional soils, which is an indication of enhanced stability. It is worth noting that the backfill was highly drained and with enough shear strength just like clean sand. This study is quite applicable in terms of the application of silver sand. Since silver sand is also a clean uniformly graded and high silica content sand, the good performance of waste foundry sand further supports the argument that sand materials make a good retaining wall backfill. In that way, one can say that silver sand is technically qualified in the purpose.

3.2 Performance analysis of geosynthetic reinforced earth wall

The research will also examine the reinforcement behaviour of reinforced earth walls with sand backfill material when reinforced with geosynthetic material. The main aim was to determine the efficiency of sand to geosynthetic reinforcement load transfer and the influence on the stability of the wall. In this research, the earth wall was designed as reinforced to be used with sand as the backfill, and geogrids separated at a given vertical distance.

A combination of analytical calculations, laboratory tests, and finite element modeling was used in the analysis of the performance of the wall. This facilitated a close comparison of the theoretical and experimental outcomes. The findings revealed that the sand backfill substance can be used in enabling the transfer of loads between the soil and the geosynthetic reinforcement and this leads to the large ecrease in the deformation of the wall. Geogrid inclusion enhanced the overall stability of the wall through limiting the lateral movement.

Further, the well-graded sand was observed to interact with geogrids in a better manner due to the improved interlocking and resistance of friction. This can be directly applied to silver sand. Silver sand has good interactions with the soil and geosynthetic reinforcements and this is essential requirement of the reinforcement of the earth walls with soil because it is selected as clean and well graded sand.

3.3 Earth pressures on retaining walls backfilled with sand admixed with building-derived materials

The present study investigates the influences of lateral earth pressure distribution in case of retaining walls filled with sand, which do contain construction waste materials or the building wastes materials. The primary objective of the study was to establish whether there are other materials that can be as efficient as sand backfill. In order to attain this research, laboratory models of retaining walls were constructed and earth pressure sensors were installed on the depths of the retaining wall.

The research was done using various combinations of sand and compared with the findings of pure sand backfill. The findings demonstrated that sand in the purest form led to smaller and predictive lateral earth pressure. Nevertheless, the earth pressure was erratic when sand was mixed with construction wastes.

This study emphasized the reasons why clean sand is the conventional material to be used to backfill retaining walls due to the predictability of its behavior. This study agrees wholeheartedly with the use of silver sand since it demonstrates that high quality and clean

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sand is most predictive with regards to the earth pressure response, which is essential in the keeping wall design.

3.4 Retaining wall model test with waste foundry sand mixture backfill

The retaining wall model test involving waste foundry sand mixture backfill was done using backfill of size 10 cm. The paper is among the pioneer experimental efforts to determine the feasibility of industrial sand used as a retaining wall backfill material.

This research was aimed at studying the mechanical characteristics of waste foundry sand as a backfill material behind retaining structures. The laboratory constructed physical models of retaining walls and waste foundry sand mixtures were applied as the backfill material. The researchers monitored the lateral earth pressure development, as well as, the horizontal wall displacement as the loading conditions were varied when the experiments were being carried out.

The study results indicated that the waste foundry sand mixtures resulted in low lateral earth pressures as compared to the conventional soils that are cohesive. The backfill and free-draining material ensured that the pressure of the pore water was not accumulated. The sand mixture had also a greater frictional resistance, which resulted in more stable walls.

This study proposes that silver sand may be effective and thus as effective as the use of waste foundry sand as a retaining wall backfill material since it is cleaner and of better grade.

3.5 Seismic resilience of retaining walls backfilled with sand–tire chip mixtures

The paper explores the seismic behavior of retaining walls using sand based backfills. The lateral forces on retaining walls may increase significantly during seismic loading and as such, the backfill properties have to be observed during seismic loading.

The authors conducted retaining wall model shaking table tests. A flexible and energy-dissipative system was created using sand combined with tire chips to create the backfill. The wall displacement, acceleration, and earth pressure were measured during the process of simulation of seismic loading.

The results indicated that the use of sand heavy backfills has the potential to minimize the seismic earth pressure and the displacement of walls significantly. The loose characteristics of the backfill were beneficial in seismic energy dissipation and the sand provided major contribution in the strength and drainage qualities.

Silver sand is best suited to the use in dynamic and seismic conditions as it does not have any grain size variations and is highly permeable to create less excess pore pressure and to drain rapidly during shaking.

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3.6 Geosynthetic-reinforced soil walls with sustainable backfills

This paper will make a comparison between the conventional sand backfill and alternative sustainable and recycled materials in geosynthetic-reinforced soil walls. It was done to analyze the ability of other materials to substitute sand without affecting the performance of the wall. Numerical analysis was conducted as well as laboratory testing. The traditional backfill material that was used to make a comparison was sand and the performance of the walls that were constructed using recycled materials was compared with it. The findings revealed that sand backfill had the least wall deformation and the most reinforcement performance. Clean sand was easier to mobilize the pull forces in the geogrids and also possessed better drainage properties.

The other materials had to be of the same kind as sand as far as shear strength and permeability were concerned. As it has been confirmed in this paper, the best material used to backfill a RE wall is sand, and silver sand is the most obvious.

3.7 Effect of backfill sand density on dynamic response of MSE walls

The effect of the density of sand backfill on the behavior of mechanically stabilized earth (MSE) walls especially under dynamic load such as vibration of traffic and earthquake movement is the primary focus of the research. The model of MSE walls of different relative densities of sand backfill was undertaken through numerical analysis. The analysis was based on the factors such as displacement of walls and strain of reinforcements. It was observed in the research that the effect of a dense sand backfill is quite concrete as it minimizes the displacement and strain of reinforcement in walls. But the sand was compacted too little, which resulted in an over deformation. Compaction property of silver sand is better that enables it to achieve high relative density in the field. This sand can therefore be used in reinforced retaining structures where deformations are of paramount importance.

3.8 Evaluation of mechanically stabilized earth retaining walls – a review

The given paper provides the in-depth review of the research work performed over the years concerning the mechanically stabilized earth (MSE) and reinforced earth (RE) retaining walls. The review points out the significance of clean granular backfill having small proportions of fines. It also shows that poor-quality of backfill material is among the primary contributors to high earth pressure, drainage and premature wall breakage. This paper provides strong theoretical support of using clean sand as a backfill material, which also supports the use of silver sand as a backfill material of reinforced earth walls.

3.9 Suitability of silver sand as backfill material

The characteristics of silver sand are:

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- High silica content
- Uniform grain size distribution
- Low plasticity
- High permeability
- Good compaction properties

The above characteristics match well with the IRC: SP:102-2015 and MoRTH requirements for reinforced earth wall backfill material. When compacted, silver sand has the potential to attain high relative density, thus increasing its shear strength and reducing deformations.

From the literature reviewed, it can be concluded that silver sand has the potential to:

- Resist lateral earth pressure
- Improve soil-reinforcement interaction
- Drain effectively
- Ensure long-term durability of retaining and RE walls

4.0 Experimental Investigation on Silver Sand

Moreover, in this research, silver sand is subjected to various lab and field tests as per IS code guidelines to check its effectiveness as a backfill material for reinforced earth walls. The results are then compared with that of Conventional sandand other materials.

4.1 Grain size analysis

The grain size analysis is carried out as per IS 2720 (Part 4), which helps to check the particle size distribution. Silver sand is found to be poorly graded sand (SP) as per the Indian Standard Soil Classification System, while for clay soil, there is a high percentage of fines. The low percentage of fines in silver sand is desirable for drainage, with less possibility of pore water pressure development in rear walls with RP waterproof structures.

4.2 Atterberg limits (liquid limit and plastic limit)

Liquid limit and plastic limit tests are carried out as per IS 2720 (Part 5). Silver sand is non-plastic and has a plastic index of almost zero, while Conventional sandis highly plastic. The non-plastic nature of silver sand satisfies MoRTH standards and does not have volume change and shrinkage problems.

4.3 Modified proctor compaction test

Modified Proctor compaction curve tests as per IS 2720 (Part 8) are carried out to determine the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC). It is

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observed that the MDD of silver sand is less compared to the crushed aggregates, but it can achieve a good density with the help of optimized moisture content. The OMC and compaction efficiency of Conventional sandare high.

4.4 California Bearing Ratio (CBR) test

The CBR test is carried out as per IS 2720 (Part 16) to determine the strength and bearing capacity of silver sand. The CBR value of silver sand is much higher compared to the CBR value of clay soil, which shows that silver sand has better bearing capacity properties for the distribution of loads

4.5 Field dry density test

The field dry density is determined by the normal field method like the sand replacement method as per IS 2720 (Part 28). The result shows that it is possible for silver sand to achieve the required percentage of MDD in the field, whereas Conventional sandis sometimes faced with difficulties in achieving equal compaction due to its vulnerability to moisture.

Table 2: Comparison of Engineering Properties of Silver Sand and Clay Soil

Property	**Silver Sand**	**Clay Soil**
Grain size	Uniform sand (SP)	Fine-grained
Plasticity	Non-plastic	Highly plastic
Permeability	High	Very low
Compaction	Easy	Moisture-sensitive
CBR (%)	High	Low

Source: Created by authors

5.0 Comparative Performance with Conventional Sand and Other Materials

After a comparative study it has been noted that the performance of silver sand is far much superior to that of Conventional sand in terms of drainage and compaction properties, plasticity as well as strength. The permeability of a silver sand material is high in this case due to the lower fineness and non-plastic nature hence good drainage property and no pore water pressure at the back of the wall. Conventional sand, on the other hand, is not so permeable and is very plastic making it trap moisture and weaken.

Based on the compaction perspective, silver sand allows equal density, and less sensitivity to the change of moisture content, but in comparison to clay soil, there ought to be the right moisture content, and numerous issues could occur in terms of density. Silver sand

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shear strength and California bearing ratio were also discovered to be superior to clay soil, which implies superior interaction and load transfer. Though crushed aggregates are more dense and stronger, The silver sand has been determined to be a better replacement that is less expensive and acceptable, when the sources of the natural aggregates are justifiable and unlike the conventional aggregates, the source of the silver sand is available in the region.

Table 3: Comparative Performance of Backfill Materials

Parameter	Silver Sand	Clay Soil	Crushed Aggregate
Availability	Local	Local	Distant source
Cost	Low	Low	High
Drainage	Excellent	Poor	Excellent
Plasticity	Nil	High	Nil
Suitability for RE walls	High	Poor	Very high

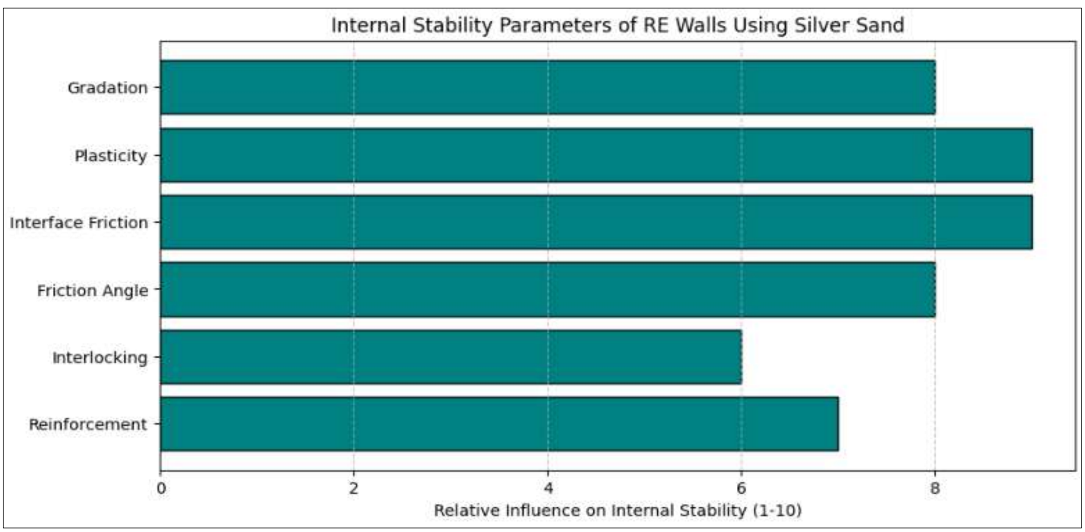
Source: Created by authors

6.0 Stability Considerations for Re Walls using Silver Sand

6.1 Internal stability

The reinforced earth wall stability relies on the soil-reinforcement interaction as the main factor of internal stability to determine the pull-out and direct pull resistance.

Figure 1: Internal Stability Parameters – Influence of Silver Sand Properties



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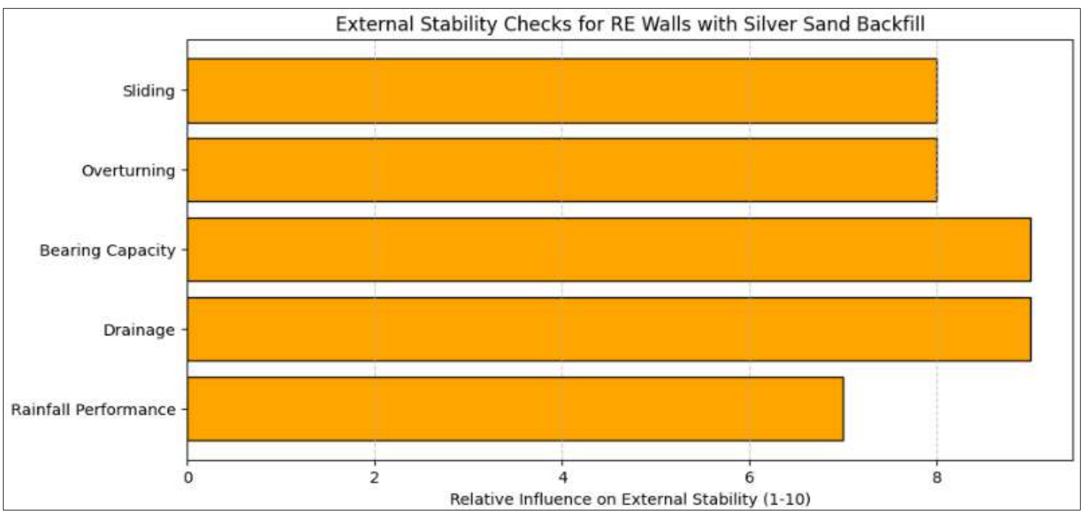
The low fines and the non-plasticity of silver sand applied in this research study enhance increased soil-reinforcement interface friction. Based on laboratory analysis, the outcome of grain size examination and shear strength parameter examination tests done on silver sand show that the stability of pull-out is satisfactory by means of friction. Friction angle values, which are applied in the calculation of pull-out, are obtained directly through the laboratory testing as required in IRC: SP:102-2015.

Nonetheless, the same graded quality of silver sand, as determined by the analysis of the grain size, requires the additional precaution to be taken during the design. The reason is that, the uniformly graded sands will, generally, be less interlocked than the well-graded sands, which will, perhaps, affect the interaction parameters of the reinforcement and the soil. In this case, the research methodology follows the analysis checks with the most limited design parameters, reinforcers spacing maximum, and length.

6.2 External stability

The overall behavior of the mass of reinforced soil against the slides, overturning, and bearing weight failure are basically connected with the verification of external stability of reinforced earth walls. The input parameters of the external stability analysis of this investigation are the calculated density and strength parameters through Modified Proctor compaction, CBR and field dry density tests. The fact that the unit weight of silver sand was rather lower than the crushed aggregate, led to lower unit pressure laterals in earth, which is beneficial to the overall stability.

Figure 1: External Stability Parameters – Influence of Silver Sand Properties



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An analytical evaluation provided in compliance with IRC: SP:102-2015 shows that the reinforced earth walls with silver sand backfill are related to the appropriate factors of safety against sliding, overturning, and bearing capacity failure provided that the appropriate design aspects are considered. The incredibly high permeability of silver sand as the evaluation of the gradation and plasticity values further enhance the exterior stability by eliminating the accumulation of pore water pressure in the background of the wall. The method therefore forms a direct relationship between the experimental research and analytical evaluation of external stability.

7.0 Research Gap and Need for Study

Though Indian conditions have ensured an ample supply of local silver sand, there is a lack of sufficient regime-specific experimental work available in literature to determine its effectiveness as a reinforced earthing wall backfill material. The existing codal provisions such as MoRTH (5th Revision, 2013) and IRC: SP:102-2015 are prepared taking into consideration the traditional granular materials and do not have a separate section describing the uniformly graded river sands. In fact, the overall lab and field test analysis of silver sand as a material for reinforced earthing is still inadequate. The comparison of its effectiveness as a different material type, such as clay and other commonly available backfilling materials, is even rarer, especially in a high rainfall region such as Assam. This is because the absence of established experimental results makes it difficult to make a safe choice of selection. This issue is addressed in this study and the effectiveness is determined through a lab analysis process of grain size, compaction, plasticity, strength, and field densities of silver sand and a comparison analysis of the results with Conventional sandand other materials.

8.0 Conclusion

The experimental and comparative study reveals that silver sand does not possess plasticity, compaction properties are satisfactory, CBR values are good to be used for the reinforcement earth wall backfill, and drainage properties are good.

Silver sand is much better than Conventional sandin reinforcement earth wall backfill and is nearer to the MoRTH and IRC: SP:102–2015 specifications for plasticity and permeability. Although the aggregates may cause strength to be crushed at high singular values, silver sand has proved to be an economical and readily available alternative. It can therefore be efficiently used as a reinforced earth wall backfill material.

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