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Special reinforcement solutions of railway permanent ways' soil substructures

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Abstract: This mini review aims to summarize relevant international publications. Thus, based on this, giving a comprehensive review about the reinforcement solutions of permanent ways' soil substructure. Generally, the core weakness of soil is its inadequacy to resist tensile stresses. The main target of strengthening the soil is to enhance the engineering characteristics of the soil to build up specific parameters such as shear strength, compressibility, density, and hydraulic conductivity. In addition, special reinforcement techniques of railway permanent ways' soil substructures will be considered in this paper due to the increasing demand of improving railways and rehabilitation process. The main findings of this study that there are a lot of special reinforcement techniques which can be considered as effective solution for soil stabilization such as geosynthetic reinforcement.

Keywords: permanent ways; soil reinforcement; substructures; subgrade

1. Introduction

It is known that soils possess a low tensile strength. So, civil engineers have attempted to address this challenge for quite a long time. To increase the tensile and shear strengths of soil, various methods of reinforcing have been utilized in different sorts of earth designs, for example, retaining walls, earth dams, slopes, etc. Various reinforced earth rehearses have been used throughout the world [1][2].

The substructure of railway track incorporates the ballast, subballast, and subgrade layers that handle the track superstructure of rails and ties. Substructure of tracks affect the stability and performance as well as vehicle dynamics of track superstructure. The fundamental role of the track substructure is to support the applied loads uniformly and without perpetual deformation that might influence the geometry of track. The resulted loads of the railway elements and its transfer way are represented in Fig. 1.

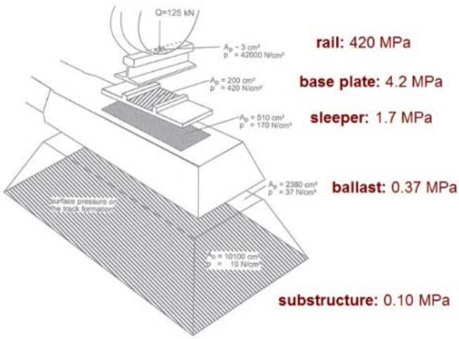

Figure 1. Load distribution in superstructure [3]

The performance of the track substructure is depending on the performance and properties of each layer. The track superstructure transfers the load which comes from the wheel from the highest point of the rail, through the ties and into the foundation. The ballast should offer resilient support for the tie. In any case, the development of the tie under singular wheel loads will be resulted in permanent differential settlement. Thus, the rigid support would be resulted in the failure of other track segments. Ballast of open-graded hard rock gives the vital strength. However, when the voids filled with fouling material and moisture, the flexibility is decreased along with the inter-particle contact stress, which leads to relative movement of the ballast particles and settlement of the tie [4][5].

In case of unfavourable conditions, different kinds of subgrade problems could be developed which in turns could lead to failure or iterative maintenance of railway track. The significant causes that might engaged in the development of subgrade problems could be classified mainly into load factor, soil factor, and environmental factor.

- Load factor

It is the external factor which might lead to subgrade problem. There are different types of loads which are involved in this context: self-weights of material and repeated dynamic loads. The first one could be the main concern that may cause consolidation settlement or massive shear failure and the second type is defined as the repeated traffic loading which has two features characterize it, the magnitude of the individual wheel load and the number of repetitions [6][7][8].

- Soil factor

The impact of soil type on the subgrade is firmly identified with its moisture content and its sensibility to the effects of moisture change. Many soils have no problem if it goes as subgrade depending on its ability of keeping low sufficient moisture content. A significant reason behind why subgrade problems which are regularly connected with fine-grained soils is that this type of soils is generally vulnerable to diminishing in stiffness and strength with increasing water content and do not drain well. In contrast, the performance properties of coarse-grained soils are lesser extent affected by the presence of water, because such soils can drain well so that they typically have low moisture contents.

- Environmental factor

The term environmental factor includes soil moisture and soil temperature. The presence of water in the subgrade can lessen the strength and stiffness of subgrade soils drastically. Additionally, soil temperature is considered as main concern when it causes patterns of freezing and thawing [9][10].

In this study, a comprehensive review of various scientific journal papers about soil substructures special reinforcement techniques. Also, different case studies of railway rehabilitation are considered in this study.

The layout of the rest of this study is coordinated as follows: Section 2 gives an outline of the soil reinforcement. An overview of various methods of soil reinforcement is presented in Section 3. Section 4 illustrate the factors that affecting the soil reinforcement. Reviewing of literature of different scientific papers related to soil reinforcement and railway substructures as well as some case studies which are related to the topic are showed in Section 5. Conclusion, remarks, and future perspective are given in Section 6. Finally, the summary is introduced in Section 7.

2. Soil reinforcement

Generally, soils can be considered as four fundamental sort blends: gravel, sand, clay, and silt. The soil usually has the characteristics of low tensile strength and is exceptionally subject to natural conditions. Thus, the concept of soil reinforcement had been coming out which can be defined as a technique to improve the engineering characteristics of soil, such as shear strength, compressibility, and density. In other word, soil reinforcement can be specified as a method for improving the mechanical properties of the soil like shear, compression, hydraulic conductivity, and density. Therefore, the crucial purposes of reinforcing soil mass could be concluded as improving its stability, bearing capacity, and reducing settlements and deformation. Soil reinforcement can be done by stone columns, root piles or micro-piles, soil nailing and reinforced earth. In other words, soil reinforcement is a technique used to stabilize soil. Essentially, reinforced earth is a composite material comprising of substituting layers of compacted inlay and man-made building up material. The use of reinforcement materials in the soil is resolved as an interaction for improving the characteristics of soil [11][12].

In the following sections, different methods of soil stabilization and reinforcement will be discussed from several aspects such as the benefits of these techniques, general mechanism for applying such methods of reinforcement and its effect on different kinds of soils.

3. Methods of soil reinforcement

During the previous forty years, innovative techniques to improve soil have been reached out to handle soil problems. Several techniques were used for reinforcing the soils to decrease the deformation of soils which undergo applied load. These techniques are viewed as the most practical approaches to improve the conditions of undesirable sites compared to the traditional construction methods. For instance, rope fibers, metal strips, tire shreds, metal bars and geotextiles.

As it was referenced, reinforcement of soil is a technique where characteristic or incorporated added materials are utilized to improve the properties of soils. Various reinforcement techniques are available for stabilizing soils. However, based on reinforcing performance, Fig. 2 presents different methods of soil reinforcement.

3.1. Thermal stabilization

Soil thermal stabilization has gotten more habitually usage in expanding the bearing limit of foundations of a structure. Researchers and specialists have created and introduced a few techniques of thermal stabilization previously by allow roasting soil segments through boreholes of different depths and diameters [13]. Because of heat treatment of soils, its strength increases fundamentally; this increase relies on the monolithic phase of the heated soil.

3.2. Mechanical stabilization

In general, diverse particle sizes are added to existing soil for purposes of changing the uniformity degree and grading size. This process raises friction angle magnitude and cohesion. Considering that such method is used prior to a construction phase to avoid the issues that might occur if we perform it during construction.

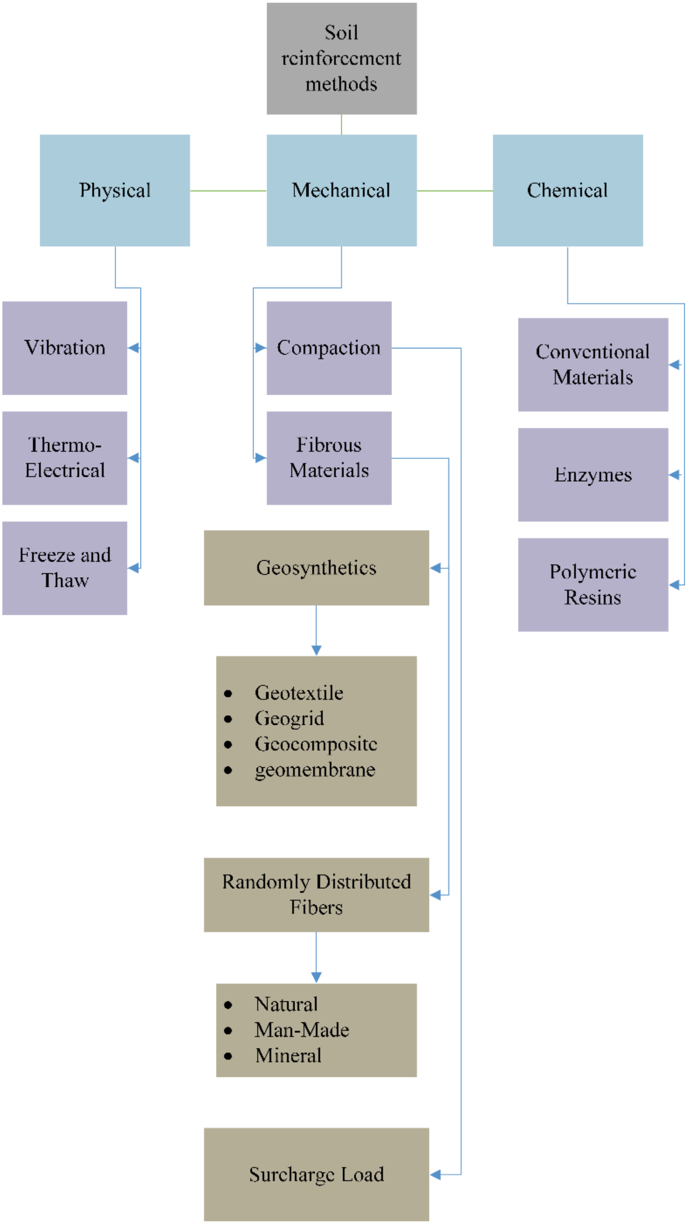

Figure 2. Different techniques of soil reinforcement

3.3. Chemical soil reinforcement

Chemical soil reinforcement has been used broadly applied in last decades in different fields such as foundations and hydraulic constructions. This method of soil reinforcement showed that this technique is truly dependable and in various cases it can be considered as the only method which can be used to strengthen weak soils. Also, it has been utilized to save significant designs and remarkable noteworthy landmarks.

3.4. Geosynthetic reinforcement

These days, geosynthetics are widely used in geotechnical engineering. Numerous construction projects in the world have not utilized of geosynthetic reinforcement which as a result, these projects have not succeeded. Fig. 3 represents one of geosynthetics reinforcement applications which includes replacing the poor soil with better granular fill combined with the geosynthetics reinforcement.

Figure 3. Geosynthetic membrane [14]

3.4.1. Geotextile

Geotextile is one type of geosynthetic. These are materials which comprise of synthetic fibers rather normal ones. Geotextiles, a centre member of geosynthetic family, are broadly utilized to improve soil in civil engineering applications. Geotextiles are not a solitary product; they are manufactured by both synthetic and natural fibers with various aspects and its fundamental objective is separation of aggregate.

3.4.2. Geogrid

Geogrid is generally produced from polymer materials, which might be woven or sewn from yarns, heat-welded from pieces of material, or delivered by punching a standard opening in sheets of material, at that point extended into a lattice. triaxial geogrids reinforcement example is represented in Fig. 4.

Figure 4. Geotextile reinforcement [15]

3.4.3. Geocell

Geocell confinement system is cell structure that gave regulation of compacted fill soils. It reduces the settlement by reducing the soil lateral movement. Besides, it is a useful method for increasing the bearing capacity of the soil. Geocells utilized in many engineering applications such as canals, retaining walls, trenches, embankments, and railways with different preparation conditions of reinforced geocell which are shown in Fig. 5.

Figure 5. Different geocell reinforcement [16]

4. Factors affecting soil reinforcement

There are some factors which could be considered as crucial factors that affecting the reinforced soil such as the distribution of the reinforcement, the state of the soil and soil density. In this section, these influencing factors will be discussed to see its impact on the performance and behaviour of reinforced soils.

4.1. Distribution of reinforcement

- Location

In general, the failure of structures occurs when the applied stresses are greater than the stresses capacity of the structure. Stresses are falling into two categories of which are normal and shear stresses. As a simple definition of these two stresses, we can say that the stress which is perpendicular to a plane is referred as normal stress, while if it parallel to a plane it defined as shear stress and they are anticipated to characterize the strain field. Accordingly, the place of reinforcement is in the tensile region where most deformation occur.

- *Orientation*

The vertical spacing between the reinforcement is playing a major role of peak reinforcement load. However, tiny, or huge spacing could result in an aberration from this direct relationship.

4.2. State of soil

- *Density*

Unique soil states would have various impacts on soil reinforcement, also shifted soils densities directly affect relationships between stress and strain in soil reinforcement.

- *Overburden*

Overburden pressure has direct effects on the friction angle between soil particles and its reinforcement. In fact, the friction coefficient reduces as overburden pressure rises; thus, the shearing stress peak angle of a granular particles soil also decreases with the increasing in normal stress.

- *State of Stress*

In case of reinforced structure, the stress states are dissimilar with growing height. The void ratio diminishes as the height of the soil rises because of increasing in normal stress.

- *Degree of Saturation*

An issue which is related to saturated soil is generally fine-grained material and cohesive soils which are sometimes poor in seepage have a powerful stress transforming that might not be prompt. Therefore, to stabilize the soil, there would be an impermanent decrease in shear strength which diminishes the construction rate.

5. Literature review and case studies

5.1. Literature review

5.1.1. Fibrous material reinforcement

The work depicted in the study of Rowe and Soderman [17] can be considered as a crucial work for amended design procedures of the geotextile reinforced dikes. A technique for assessing the stability of reinforced embankments was discussed in this paper. This methodology kept up the straightforwardness of regular limit equilibrium methods while consolidating the impact of soil-geotextile interaction regarding allowable compatible strain of geotextile. It was showed that this allowable strain might be derived from a design chart and relies on several factors such as geometry and height of embankment, depth of the deposit, and the bed stiffness. The methodology was validated through finite element results which compared with the results of analysis for one benchmark problem. Geosynthetic materials were used extensively in embankments to increase stability. Geosynthetic reinforcement as can be seen in Fig. 6 can be used widely in embankments for purposes of increasing stability.

A study of the resistance to pull-out of geogrid reinforcement had been done by Khalid et al. [19]. Sample's preparation and testing equipment are presented for geosynthetic reinforcements in granular soils. Standard testing equipment was consisting of pull-out boxes which has designed and constructed according to GERL/LTRC-LSU. The study obtained that there were considerable differences in direct shear or pull-out tests used in experimental models of soil-geosynthetic interaction mechanism and performance evaluation of geosynthetics properties. Based on their study, we can sum up the results of their work as:

- the peak pull-out load decreases by the effect of side frictions of the walls, sleeve length and increased thickness of soil.
- In general, the peak pull-out load increases by increasing of densities and confinement which resulted in increasing of passive resistance.

Figure 6. Reinforcement method of embankment [18]

A geosynthetic wall case has been studied by Allen and Bathurst [20] to find the loads in reinforced soil by estimation of strain then convert these data to load through reinforcement material stiffness. The paper summed up these assessed loads, depicted general patterns in the information, and compared those reinforcement loads to apply to wall case histories. It was discovered that reinforcement loads got from strain estimations are, all in all, lower than would be anticipated dependent on current limit equilibrium design techniques that utilization traditional earth pressure theory. This methodology would assist with lessening design traditionalism and would be steady with the way of thinking of forestalling failure of a significant part of the reinforced soil. When the soil has been failed, the wall has been failed also. Uncertainties in the estimation esteems were assessed in the figuring of the loads assessed from estimated strains in contrast with anticipated loads utilizing current design methodologies.

By considering that assessment, it was resolved that the contrasts among estimated and anticipated qualities were huge, both regarding consistency of the expectation and the propensity of the current design methods to considerably overestimate reinforcement loads, justifying re-assessment of the current methods utilized for predicting of reinforcement loads in walls. The authors had also suggested that it would be imperative to evaluate the impacts of toe restriction and facing stiffness on reinforcement loads, just as the impacts of reinforcement stiffness to gauge the reinforcement loads even more precisely of geosynthetic walls as well as their distribution. Hejazi et al. [21] presented a study which aimed to make a review about soil reinforcement by using various kinds of fibers. In addition, a discussion about models used for short composite fibers had been considered.

Natural and synthetic fibers that had been yet utilized to reinforce soil were examined. The importance of using fibers as a soil reinforcement technique was discussed. From the study, it could be noticed that there are several factors that helps in increasing strength and stiffness of soils which could be summed as sand characteristics, test condition and fiber characteristics. Several tests had been performed to approve that shear strength increase when the soil is mixed with discrete fibers. Fiber incorporations likewise hinder the compaction cycle, causing a decrease in the most extreme dry density of reinforced samples with expanding fiber content. It is reported that the mechanism of load transformation still not well understood in case of clayey soils, thus further research required to get better understanding of fibers effect on such kinds of soils. The authors mentioned three significant executive issues engaged with composite soil production which were: clustering and balling of fibers, lack of scientific standards and adhesion between soil and fibers. The technical advantages of soil reinforcement by fibers that were mentioned are: rising hydraulic conductivity, decreasing thermal conductivity, preventing tensile cracks from occurrence, and decreasing the total weight of structure materials. Fig. 7 shows the impact of Polypropylene fiber inclusions which can be observed while implementing triaxial tests.

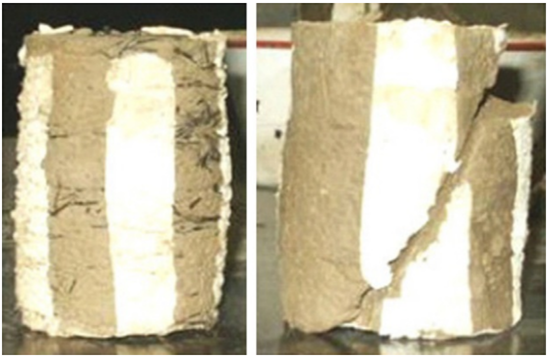

Figure 7. Specimen deformation shape for unreinforced specimen – left and reinforced specimen – right [21]

For purposes of investigating the impact of freeze–thaw on the strength characteristics of geotextile reinforced soil by performing Unconsolidated Undrained (UU) triaxial compressive tests. Ghazavi and Mahya [22] worked on clayey soil with geotextile reinforcement layer which was compacted and tested in the laboratory by applying freeze–thaw cycles. It was found that for unreinforced soil, the triaxial compressive strength decreased as the number of cycles increased. On the other hand, for the reinforced soil samples, exhibited better strength and performance. Additionally, the impact of freeze–thaw cycles on the variations of resilient modulus and cohesion of the soil can be reduced by reinforcement.

A glance at flow rehearses, late advances, momentum research regions, and recommend future headings for the utilization of geosynthetics as reinforcement materials in asphalt frameworks was presented by Perkins et al. [23]. The importance of using geosynthetics as reinforcement of subgrade and their applications fields and purposes was discussed widely in their study. The work which presented in this study would prompt precise design techniques, yet simultaneous with the author's advancement on these turns of events. In addition, geosynthetics ought to be seen as another asphalt material used to impact things such as cracking and rutting.

A methodology was introduced in the study which was done by Leshchinsky and Ralph [24] for stability design and analysis of geosynthetic soil reinforcement. The methodology included external analysis and internal analysis as well. The internal stability analysis depends on variational restricting equilibrium and fulfils all requirements of equilibrium. Two tensile resistance of reinforcement inclination were examined. The orthogonal to radius which defines the geosynthetic sheet and the horizontal which implying the as installed position. The results of both analysis (internal and external) were introduced in a form of design charts that can be used to determine tensile resistance and the profile of reinforcing sheets.

The study which had been done by Brian and Benjamin [25] came out because of upgrades in geosynthetic properties and manufacture methods. The utilization of geosynthetic in soil is expanding and improving. In fact, coastal structures of geosynthetic have accomplished progressed stage regarding applications and proficiency. However, others still actually need specifications and design details based on scientific basis. Subsequently proceeded with test works for better understanding of these geosynthetic coastal structures such as its modes of failure, hydraulic performance, and its stability. Based on this information, this paper came out to review the applications of geosynthetics in soil stabilization, its historical developments, and the techniques of coastal areas protection by introducing significant empirical research data as well as showing the difficulties in the using of geosynthetics in the field of soil stabilization. Laboratory creep test set-up of geosynthetics is shown in Fig. 8.

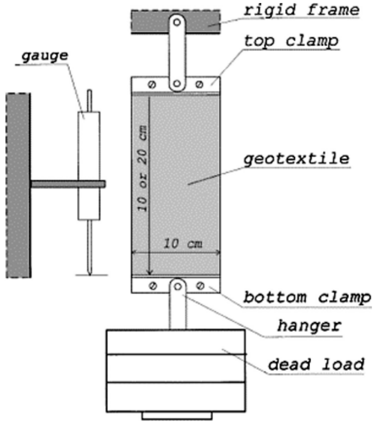

Figure 8. Typical creep set-up of geosynthetics [25]

Venkateswarlu and Hegde [16] presented in their study an investigation of isolation efficiency of geocell reinforced bed which is filled with various materials by several block resonance tests. For testing and experimental purposes, a novel polymeric alloy was used. Different infill cases were considered for testing such as: geocell reinforced sand, geocell reinforced slag, geocell reinforced aggregate, geocell reinforced silty sand, and unreinforced infill. Because of geocell, screening effectiveness of foundation bed has been improved regardless of type of infill material. The greatest isolation proficiency was noted within aggregate presence, among the other infill materials. From the logical investigation, a huge improvement in damping proportion of the foundation bed was seen in the sight of geocell reinforcement also. Field vibration test preparation is shown in Fig. 9.

Using fibers for reinforcing soils considered as ease, proficient and low-cost technique especially in case of recycled fibers usage. Thus, Valipour et al. [26] investigated the impact of using recycled fibers on improving the engineering characteristics of clay soils. The method of this study involved a progression of direct shear tests, unconfined compression and compaction were performed on correctly arranged composite clay soils. In general, 5 mm length of fibers showed better enhancement of clay soils. The results of laboratory tests indicated that the sample ductility increased while the fibers content increased. Thus, higher strength until reaches the optimum content of fibers. Besides, the inclusion of fiber was powerful in increasing cohesion. An example of fibers is shown in Fig. 10 which represents glass fibers.

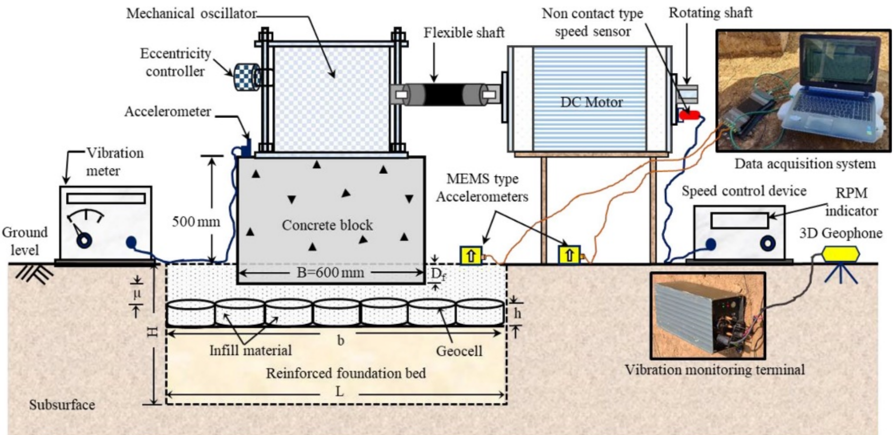

Figure 9. Test setup [16]

Figure 10. Recycled glass fibers [26]

In Alsirawan [27] study, a review of geosynthetic-reinforced pile-supported (GRPS) embankments had presented. The goal of this study was directing an outline of GRPS embankments. Thus, this paper presented a survey about the main boundaries influencing the conduct of geosynthetic-reinforced pile-supported (GRPS) embankments. By considering the design techniques that gauge load efficiency and tensile forces in the geosynthetic layers. In addition, it aimed to cope the problems which resulted because of soft foundations soils such as instability of sliding, excessive settlement and decrease in bearing capacity. Results featured the significance of utilizing GRPS embankments, yet in addition uncover the irregularities between design techniques. At long last, general decisions about the plans and development of GRPS frameworks were introduced. Typical GRPS embankment is shown in Figure 11 which contains piles and platform of load transferring.

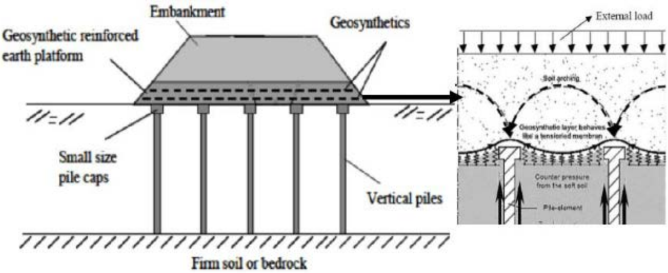

Figure 11. Geosynthetic-reinforced pile-supported embankment [27]

5.1.2. Stabilization and reinforcement of soil

In the article which had done by Salençon and Pecker [28], an extended theoretical framework of yield design theory. In case of shallow foundations assessment, the seismic bearing capacity could be evaluated by implementing yield design theory. That idea which was dependent on in-situ soil reinforcement, was simple to execute, economic and fundamentally improved the seismic bearing capacity for the foundations. The theory validated through series of numerical studies. Much more significant was the way that this foundation concept authorizes philosophy of design capacity in foundation engineering. It looked thusly extremely encouraging for expanding the safety of structures.

A comprehensive review about low-cost soil stabilization methods had done by Ramaji [29] where different methods of expansive soil reinforcement discussed including rewetting, control of compaction and moisture, thermal methods, and chemical stabilization. Each of these techniques might have the disservices of being inadequate and costly. In view of writing, Portland concrete, lime, fly debris and scrap tire were ease and successful to soil reinforcement. According to the study, it was reported that every year a ton of waste rubber are created and consumed an extraordinary space. Thus, it was important to discover an answer for take care of this issue. One of the arrangements is utilization of various size waste rubber in reinforcement of soil.

Shukla et al. [30] made an overview of the essential concepts of reinforcement of soils. Two major groups had classified the reinforced soil which were: randomly distributed fibers and systematically reinforced soil. This study stated that even if the reinforcing technique differs from one type to another, the fundamental concept still the same for all kinds of soils. In other words, the friction/adhesion of soil-reinforcement was basic for all reinforcement. The authors suggested that performing more triaxial tests of large specimens is crucial to show reinforced soil behavior.

Another review had done by Gowthaman et al. [31] which showed the characteristic of plant fibers as situated dispersed fiber- reinforced soil and arbitrarily conveyed fiber- reinforced soil were widely talked about and accentuated the motivation of fiber- reinforced soil dependent on the arising pattern. Review likewise endeavours to investigate the significance of biochemical structure of natural fibers on performance in subsoil reinforced circumstances. The treatment techniques which improved the lifetime and behavior of fibers, were likewise introduced. While illustrating the flow capability of fiber reinforcement technology. Finally, some key research gaps had been featured at their significance. Also, the review clearly showed that there was an impressive research gap because of the absence of large-scale examinations on fiber-soil reinforcing technique, as large portion of the investigations performed up to that day were small-scale laboratory studies.

5.1.3. Stabilization and reinforcement of soil

Eller and Fischer [15] presented a comprehensive review about railway substructures. The authors’ point was to sum up the aftereffects of significant international publications and, in view of these, to give a thorough survey about the advanced ballasted tracks' foundation. The approach which was implemented in this article was doing a summary of the foundation and its protection layers. Besides, the geosynthetic cementitious composite materials were talked about. The main discoveries of the proposed work were that the encounters of the geosynthetics and other protection layers capacities showed that a potential utilizing of geosynthetic cementitious composite mat beneath the ballast could be a decent solution for reestablishing short segments of the railway tracks. After examined the related research, the benefits, and weaknesses of GCCM layers in the railway foundation can be adequately characterized. In addition, factual deterioration interaction can be resolved. Finally, the authors mentioned according to the encounters which was attracted the article that the failures of local track could be solved by using concrete canvas or GCCM.

A cost efficiently techniques to solve the local substructures problems had considered in the study of Eller et. al. [3]. The factors which might cause failures of local substructures were viewed. In addition, the protection layers of railway were viewed as well which are competent for railway structures. By summarizing the material properties and previous experiences, the authors reported that the usually used techniques do not provide cost productively improving solution for substructure issues. However, they researched the implicit qualification of the referenced new advances such as the injection technologies and cementitious geosynthetic mats which can be cost efficiently solutions of the mentioned issues. Some failures of local substructures that lead to track's distortion are presented in Fig. 12.

Figure 12. Local substructure failure [32]

A brief literature review according to the fracture of the railway ballast particles was introduced by Juhász and Fischer [32]. Providing better understanding of the international achievements was the goal of this work. With the assistance of the prepared articles with the principal subject of discrete element modelling (DEM). Rock materials can be examined from a different viewpoint. The components can be analysed in laboratory conditions absolutely from the quarry, or by acquiring previously fragmented particles came from railway tracks. Furthermore, DEM models can be made by utilizing PC programming. This article handled just a small fragment of the literature. Although each DEM theme was interesting, they all elaborate assessment of debasement of particles here and there. This review paid attention to model structure, including particle calibration and construction.

5.2. Case studies

5.2.1. Rehabilitation of railways

Fortunato et al. [33] presented a few aftereffects of exploratory work completed on a deactivated rail stretch, utilized as an experimental site. This examination was acted to evaluate the practicality of some structural solutions, utilizing reinforcement layers worked with unbound granular materials (UGM) and concrete bound granular mixtures (CBGM). Since that diverse structural solutions can be set up for recovery purposes, with respect to the current track conditions. Among different perspectives, the plan of these structural solutions relies upon the hydrogeological conditions that happen along the line, on the attributes of the foundation soils and on the current ballast layer. The non-destructive in situ tests had been considered as helpful tools for the assessment of the current railway and take into consideration the reinforcement condition and its development in time. The qualities of the materials got with in situ testing showed that lab triaxial tests can give appropriate resilient modulus values. The measured deflections of tests are presented in Fig. 13.

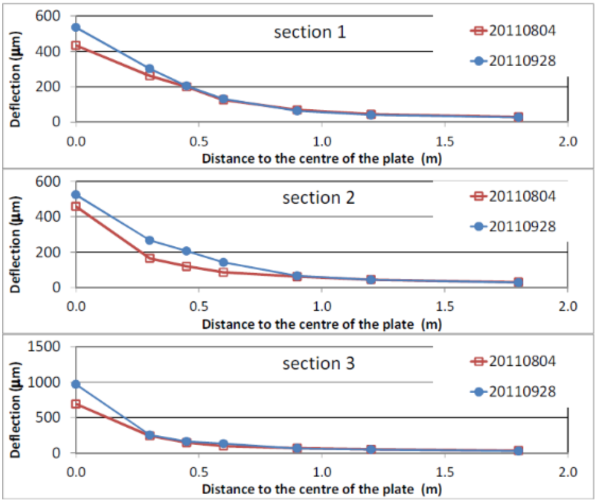

Figure 13. Results of tests [33]

It tends to be reasoned that it is feasible to reinforce the rail track foundation with a moderately dainty layer of aggregate blended in with aggregate. In any case, it ought to be focused on that lone the evaluation of versatile behavior of the materials was finished with these investigations. It was important to gauge the drawn-out exhibition of every one of the arrangements tried. Execution assessment ought to think about the perpetual deformity. Because of CBGM, it is important to assess the chance of cracking and corruption of the layer and the expansion of the permeability, which is lacking to the foundation behavior. Fig. 14 represents test device of ground penetrating radar which contains pairs of air-coupled antennas.

Figure 14. Test equipment of Ground penetrating radar [33]

The research subject of the breakage test for the railway ballast particles with remarkable lab test outcomes was showed by Juhász and Fischer [34]. Since most of railway lines on the planet have purported customary superstructure (ballasted tracks). The authors reported that in the previous few years there were a great deal of railway restoration projects in Hungary, just as abroad. Also, according to their suggestion, we can notice that these days cannot be considered typical that there was enough railway ballast in satisfactory quality, due to the changes and limitations in the connected guidelines in Hungary since 2010.

The principal objective of that study was to have the option to simulate the stress-strain impact of ballast particles in genuine and target path in research facility conditions just as in discrete element modelling. The methodology which was mentioned in the study can be considered as more practical for testing ballast samples than standardized abrasion tests. Different derelictions identified with computation of time spans between ballast screenings have been considered, such as: in the entire ballast cross area tantamount measure of breakage was not figured as the one that was estimated in referred laboratory tests, contaminating impacts on ballast (for example dust and breakage), and the impact of track geometry.

5.2.2. Rail track substructure improvement

Indraratna et al. [35] outlined the benefits of the proposed DEM and FEM models regarding catching the right stress-strain and degradation reaction of ballast with specific accentuation on particle breakage and fouling, just as uses of geosynthetic. Numerical modelling could mimic these perspectives subject to different sorts of loading and boundary conditions for a scope of material properties. So, in this work, the stress strain and degradation reaction of ballast was examined through discrete element (DEM) and limited component (FEM) techniques. In DEM, sporadically moulded ballast aggregates were reproduced by amassing together circles in fitting sizes and positions.

In FEM, a composite multilayer track framework was mimicked and an elastic-plastic model with a non-affiliated flow rule was utilized to catch ballast debasement. These DEM and FEM reproductions showed a decent concurrence with enormous scope lab tests. two distinct instances of subgrades had a match between the FE predictions and the laboratory data which resulted from experimental tests. The discoveries of these numerical examinations at the miniature and full scale, took into consideration a superior comprehension of urgent perspectives, for example, the mechanism of ballast-geogrid interface and long-term distortion and corruption.

In their study, Chawla et al. [36] performed static and cyclic tests on railroad track models. Tests were performed with two distinct thicknesses of subballast layers. Geogrid or geotextile or both were used to reinforce the tracks at appropriate interfaces. The results of tests on supported track models were introduced to assess the impacts of the sort of geosynthetic reinforcements, subballast thicknesses and kinds of subgrades on relocations of and incited vertical weights on each track layer.

Due to low permeability and high plasticity of the clay, it was noticed that mud-pumping was not critical in case of tracks which laid on clayey soil subgrade. For such tracks, the provision of a geogrid alone at the ballast-subballast interface was more effective in reducing the tie displacements, ballast and subballast strains, and subgrade displacements when compared to the provision of a geotextile alone at the subballast-subgrade interface.

6. Conclusion

The current review endeavours to draw out the comprehension of soil reinforcing methods to have better understanding of numerous techniques which are highly important for considerable stabilization. Thus, the aim of this paper was to review the literature of special reinforcement solutions of railway permanent ways' soil substructures. According to various experimental tests such as triaxial and direct shear tests, the shear strength of the soil is increased when the fibers is added to the soil. The significant factors that might lead to the failures of substructures such as excessive water in the subgrade and existence of fine-grained soils were viewed in this paper also.

Based on the review, the following remarks could be obtained:

- There are various reinforcement methods can be considered as effective techniques for enhancing engineering properties of soils.

- Potential utilizing of geosynthetic cementitious mat beneath the ballast could be a decent solution for re-establishing short segments of the railway tracks.
- Subgrade problem might occur because of several factors such as load, environment, and soil factors.
- According to the literature, various methods can be considered as effective techniques for railways strengthening.
- Special reinforcement solutions such as geosynthetic and fibrous reinforcement methods approved that it can be used as crucial methods for support the foundations of the railway tracks.

7. Summary

To sum up, this paper aimed to make detailed review of the previously published scientific journal papers. In general, most of papers that listed in this study approved that strength and stiffness of soils was improved by introducing reinforcement. In other words, as mentioned previously, soils are weak in tension generally, thus the using of different soil reinforcement techniques approved that the load efficiency of the soil increases in case of reinforcement presence.

Many of substructure failures which are related to railway tracks have been considered and cost efficiently solutions have been studied through this literature. Finally, different laboratory and in-situ tests have been considered to show the effects of each reinforcement method.

8. Research gap and future scope

Based on this review, key research gaps have been mentioned. In addition, valued suggestions and recommendations have been given for the future development and promotion of various soil reinforcement techniques. Understanding the behavior of different soil reinforcement techniques at different subsoil conditions is highly essential for reliable improvement of soil properties. Further studies will allow more practical and accurate analysis and consequently spreading reinforced soil techniques.

Up to date, challenges about cost, maintenance availability, drainage and construction restrict the application of the special reinforcement solutions of railway permanent ways' soil substructures. However, some of those problems are settled, further researches are still needed to improve the ballasted track.

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