International Journal of Sustainability in Research (IJSR)
Vol. 3, No. 5, 2025: 317-328

Roadbed Design on Soft Ground: Settlement and Stability Analysis of Cuihua Road, Xi'an

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ARTICLEINFO

Keywords: Roadbed Construction, Road Embankment Design, Road Alignment

Received: 21, July
Revised: 20, August
Accepted: 30, September

ABSTRACT

This research aims to give a general view of a thorough analysis of the while building road embankments on soft ground and suggests a course for future development Roadbed construction is an important part of the road project, and the quality of the subgrade is directly related to the quality of the entire road project. The subgrade works include the subgrade itself, related earth (stone), small bridges and culverts along the line, retaining walls, shoulders, slopes, drainage pipes, and other projects. Depending on whether the roadbed is located in a cut or in an embankment, it has its own specific aspects and a different structure. There is a discussion of frequently employed soft-ground improvement methods. In many parts of the world, particularly along deltas and coastal regions, there exist thick deposits of soft ground, such as soft marine and estuary clay. These soils have bad geotechnical characteristics, such as a high natural moisture content that is almost liquid, a high compressibility, and low shear strength. Embankments on such soft terrain, which are frequently used for highway building, are frequently impacted by edge stability and long-term settlement. The approaches, findings, and historical cases that contribute to the stability of the road embankment are examined. The research demonstrates that the construction of the road embankment is complicated by settlement, slope stability, and soil-bearing capacity. Geometric data is also discovered to be a crucial element in embankment design. This study's findings can be utilized to create design guidance systems, numerical modeling, and to provide an overview and background knowledge to other researchers who are conducting or plan to conduct research in this area. Understanding the behavior of these components is essential for producing a successful embankment. Finally, research directions for the future are related to artificial intelligence-based predictions of the elements that influence the stability of road embankments.

DOI: https://doi.org/10.59890/ijsr.v3i5.156
ISSN-E: 3025-7379
https://dmimultitechpublisher.my.id/index.php/ijsr

INTRODUCTION

A road is a traveled path used by wheels-powered vehicles, animals, or humans to move. Nowadays, a street is a metropolitan thoroughfare, whereas a road refers to a rural, less-used route. The execution of a roadbed in poor-bearing soil is given special consideration, as is the protection of the roadbed from external impact and agents of the terrain [1]. Additionally, the design must take into account the functionality and geometrical characteristics of cars. Additionally, it crucial is that you adhere to these criteria [2]. Highway engineers can use these tools to increase the useful life of this important and complex infrastructure network, whether money is used for new construction or repair [3]. This significantly affects the rise in road building costs, particularly in hilly or mountainous terrains [4]. Three-dimensional problems in x, y, and z coordinates can be used to determine the alignment of a road. It is crucial to understand that a road is a complicated, three-dimensional entity that is tailored to the terrain and challenging for the human mind to comprehend as a whole. Highway engineers frequently work in two dimensions at once, so in the geometric design process, the road is represented by the centerline and the cross-section perpendicular to the centerline, which may be designed independently [5]. A profile image, which provides the elevation of every spot measured along the length of the roadway, represents the vertical alignment [6]. It must be stressed, though, that these factors cannot be taken into account separately, and the coordination of the horizontal and vertical alignment is essential for the road's appearance, which is one of the key factors affecting road safety and driver satisfaction [7]. To show vertical grades are typically depicted on graph paper with a scale that is distorted; the horizontal scale is typically the same as the scale of the view plan, and the vertical scale is chosen based on the local terrain conditions (typically 1/10 of the horizontal scale, for example, 1:200 vertical scale for 1 2,000 horizontal scale). The vertical orientation of the road is designed using the longitudinal section [8].

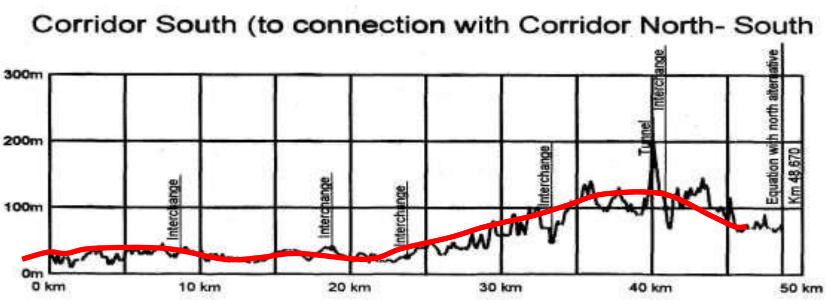

Figure 1. Longitudinal Section (LS)

There are also cross-sections sketched (typically every 20 m) to determine the project's required number of earthworks (cut and fill). Cross-sections are depicted in natural size (1:50, 1:100, or 1:200) without distortion [9].

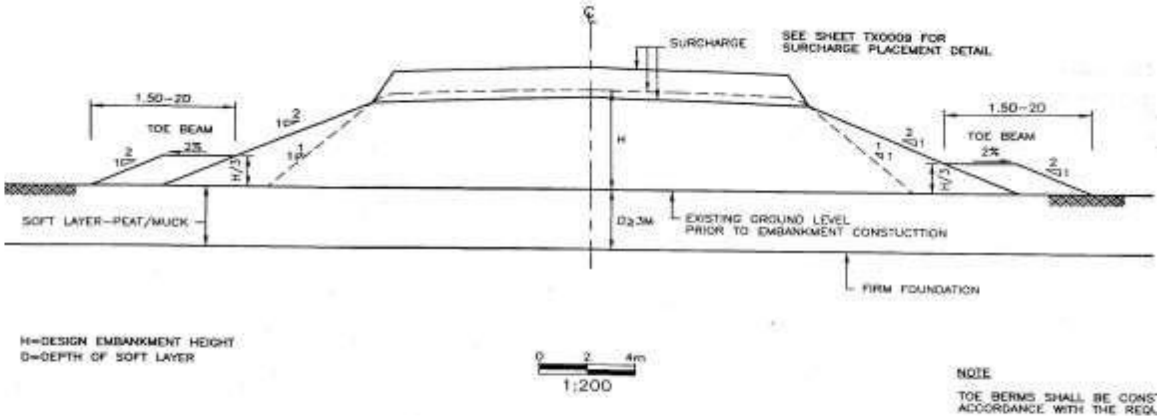

Figure 2. Cross-Section at a Fill Section

LITERATURE REVIEW

With an east longitude of 107°40'-109°49, Xi'an is situated in the Yellow River Basin's Guanzhong Plain, abutting the Qinling Mountains to the south and the Weihe River to the north. at the northern end. The "Eight Hundred Li Qinchuan" is another name for the Guanzhong Plain. The land is fertile, the wilderness is wide, and the natural setting is excellent. Xi'an, which has four distinct seasons and moderate rainfall, is situated in the transitional zone between the monsoon region and the subtropical monsoon climate area. July) The highest maximum temperature is 41.8°C, and the average temperature is 27.0°C. (June 21, 1998). The average annual temperature is 14.1 °C, and the average yearly precipitation is approximately 561 mm. 69.6%. From 1951 to 2013, there were 31 days with daily maximum temperatures below 40°C and 13.8 days with average yearly snowfall. With a total of 54 waterways, Xi'an has a substantial river network. They include the Sichuan River system, the Jinghe River, and the Weihe River. The Qinling Mountains or the southeast hills are the sources of the remaining waterways. Most waterways enter the Weihe River by flowing through the Weihe Plain from south to north. The majority of the study region is situated in high, remote terrain on the second-order terraces of the Weihe River, the 1-41st-order terraces of the Haihe River, and the L-III terraces of the Zaohe River [10]. Previous studies highlight the importance of addressing settlement and slope stability in embankment design on soft ground. Common solutions include soil replacement, reinforcement using geotextiles, and slope protection with vegetation such as vetiver grass. Despite advancements, challenges remain in predicting long-term settlement and optimizing drainage. This study contributes by applying numerical modelling to assess stability under realistic site conditions in Xi'an. The terrain of Xi'an rises in steps from northwest to southeast. According to the genetic types and characteristics, the terrain of the whole area can be divided into alluvial plains, loess tablelands, and loess beam depressions. Microscopic landforms include beams, depressions, and steep ridges. Slopes, gullies, paleo channels, etc. The alluvial and flood plains are the most widely distributed (see Figure 2.1), accounting for two-thirds of the area, with an elevation of 380-420m, flat terrain, and are closely related to groundwater resources and rising water levels. The breakdown is as follows:

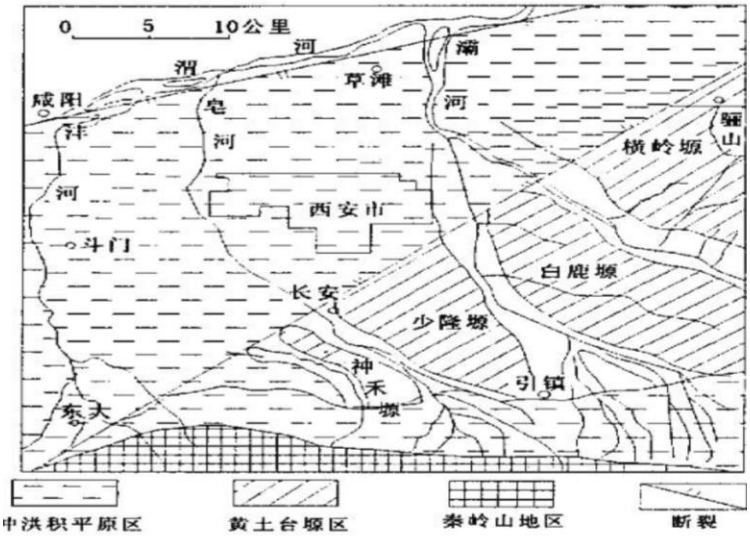

Figure 3. Topographic and Geomorphic Distribution in Xi'an (Quoted from Shi Hai, Historical Research on the Loess Plateau

Subgrade

Since the subgrade forms the foundation of the road, it is both the smallest and most crucial Road Structure. Substandard materials ought to be reasonably priced, readily accessible, and capable of supporting the weight.

The following are the Construction steps of subgrades:

1) The surface is reduced to the suggested subgrade surface if the natural surface is higher than the formation level.
2) The subgrade will be above the ground level if the native surface is below the formation level. Road pavement layers.
3) It should be built at least 60 cm (2 feet) above the area's greatest flood level.

The following are functions of the subgrade.

1) Supports the entire weight, serving as the road's foundation.
2) Transfer load by coming into contact with grains.

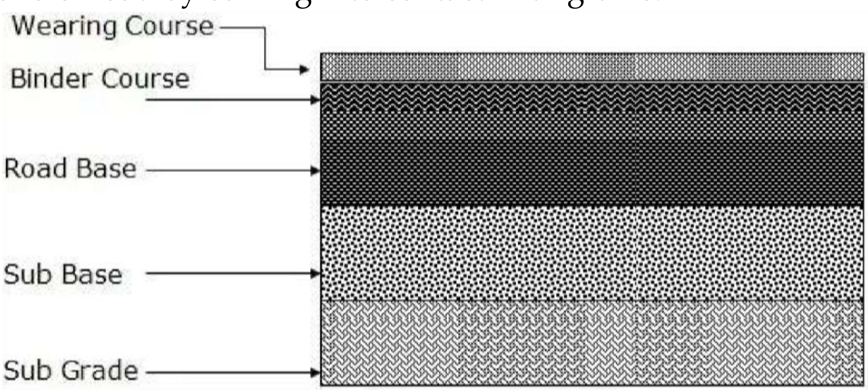

Figure 4. Functions of Subgrade

Sub Base

Consists of the upper base course and the lower base course. The material should be superior to Subgrade Substances, Sand, rubble, and stone that make up the Upper Base Course. Rock and stone, which are readily accessible materials at low cost, make up the Lower Base Course.

The following is the Construction of the subbase:

1) Built higher than the subgrade. Not necessary if the subgrade is extremely strong.
2) Upper and lower base courses are separated with various materials in flexible pavement cases.
3) Only the top base course is offered in the event of rigid pavement.
4) The range of thickness is 7.5 (3 in) to 15 centimetres. (6in).

Road Base

As a result of the material's quality, the road base is split into the Base of the Upper Road and the Base of the Lower Road. The Construction will be built on top of the sub-base. The material is of high quality in the instance of Upper Road Base because the load intensity is high. Lower Road Base uses high-quality materials because of the decreasing load strength [10].

The following are Functions of the Road Base:

1) Because of its adequate density, the wearing course won't distort.
2) Aids in donning the course.

Surface Course

The layer that comes into direct contact with traffic loads is known as the surface course, and it typically has materials of the highest caliber. Typically, dense graded asphalt concrete is used to build them. (AC). The duties and specifications of this stratum are as follows:

1) It offers qualities like draining, smoothness, friction, etc. Additionally, it will stop excessive amounts of surface water from entering the base, sub-base, and sub-grade.
2) To withstand distortion under traffic and provide a smooth, skid-resistant riding surface, it must be sturdy.
3) It must be waterproof to prevent deterioration of the complete base and sub-grade due to the impact of water.

The following are the Functions of Road Surfacing:

1) Prevent water from penetrating the ground.
2) The Binder Course connects the Wearing Course and the Road Base.
3) Smooth cycling is provided by wearing courses.

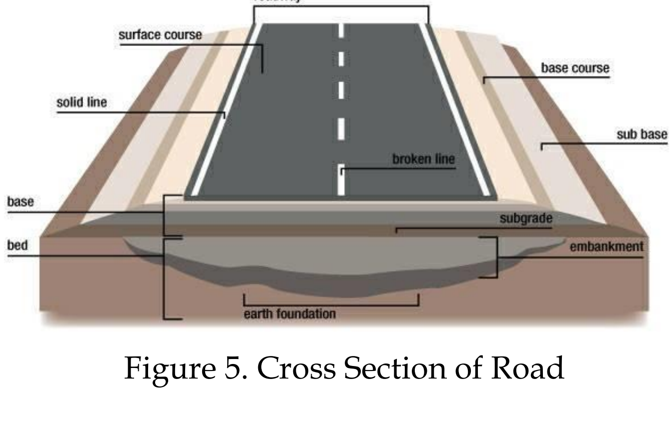

Figure 5. Cross Section of Road

Roadside-Slope Protection

A variety of techniques are used in civil engineering to stabilize slopes, including those along roads, in quarries, on gullies, and along stream banks. Its utilization of living greenery sets it apart from other designs. This can be done either independently or in conjunction with non-living plant elements and civil engineering constructions. Erosion prevention and the reduction of shallow-seated unstable slopes are the goals. Being a key component of civil engineering, vegetation's beneficial mechanical and hydrological properties are used to ensure the stability of slopes along roads and other surfaces. To preserve roadside slopes, measures including stone pitching, gabions, and putting soil-cement layer have been used. Civil engineering is a substitute technique that is extremely successful and relatively inexpensive and suited to environments where vegetation grows quickly [11].The least expensive method of safeguarding earth embankment steep slopes is vegetation. The vegetable used frequently is vetiver grass. This resilient group naturally grows in many humid regions of the planet. It is incredibly durable and can withstand significant flooding of up to 6 meters. (Howell 2008). Since it has a longer lifespan, a robust, lengthy, finely structured root system, and a great resistance to harsh climate conditions, vetiver grass is often utilized as an effective biotechnology for protecting slopes. Recently, this method has been successfully used in some regions of side-slope protection against the wind- and rain-induced erosion. In brackish rivers and canals as well as freshwater rivers, vetiver effectively controls erosion. Farmers might also use it as a supplement for animal feed, or a tie-up for rice straw and seedlings (Dung et al. n.d.). According to studies, applying vetiver is around eight times less expensive than protecting masonry walls and about five times less expensive than installing a revetment stone-slope protection system. So, vetiver grass plantations for slope protection may be an affordable, environmentally friendly, and long-lasting bioengineering solution [12].

Figure 6. Vetiver Grass on Road Embankment Slopes

METHODOLOGY

The study focuses on the analysis of the Straightened soft ground embankment Roadbed design. Using Beijing Lizheng (Leading) Software, the Roadbed design was conducted, which required the collection of necessary data from teachers through the software. The purpose of this study was to find out the Roadbed Design in China and offer a solution. The chapter deals with the explanation of the Data, construction of instruments, and statistics used to analyze the data.

Research Design

This research study was conducted to find out the Roadbed Design in China. The researchers prepared a software and research Design to help the researchers, and were filled by the teachers of the undergraduate level of Civil Engineering. Primary as well as secondary sources were used for the data collection. Beijing Lizheng (Leading) Software was used as a primary source, and Internet books were used as a secondary source. The software was used to find the Embankment Design mean of collected data and for the analysis of data. It was a quantitative study that was descriptive in nature. It was used for the Roadbed Design. The descriptive design of the research produces the maximum information with minimum resources of time, expenses, and money.

Population of the Study

The population of the study consisted of Beijing Lizheng (Leading) Software Embankment Design in China, Cuihua Road in Xi'an.

Sampling Technique

Convenient sampling was used by the researcher. The researcher took Beijing Lizheng(Leading) Software Embankment Design in China Cuihua Road in Xi'an as the sample. The sample consisted of Embankment Design in China, Cuihua Road in Xi'an.

Instrument for Data Collection

This Software was designed and used as a research tool to collect data. This instrument was designed for teachers of intermediate and advanced levels. His instrument was designed under the guidance of a supervisor. Embankment Design in China, Cuihua Road in Xi'an included in the instrument under the supervision of a researcher with the help of the research. Through the engineering design of the roadbed, students of civil engineering can comprehensively apply and deepen the theoretical knowledge which has been learned, so that students of civil engineering can receive the basic training of engineers.

Validity of the Instrument

To check the validity of the instruments in terms of content and format, the instruments were discussed with an expert in the relevant field. After a detailed discussion, some items of the instrument were dropped, some were added some were modified; the instrument was improved in light of their comments, to make them more comprehensible, and ambiguity if any ambiguity was removed. The next important step was to test the validity of the Beijing Lizheng (Leading) Software Embankment Design. In order to validate Items, it was requested of the supervisor was requested to refine the items in format and language in order to make them simple and understandable. The Beijing Lizheng (Leading) Software Embankment Design was administered to teachers at the graduate and undergraduate levels.

Data Collection

The data collection stage was very difficult for the researchers. Researchers personally visited the Cuihua Road in Xi'an. The Software was distributed to respondents selected for data collection by the supervisor of the researcher. Before introducing the Software among the teachers, the nature and purpose of the study were explained to them; moreover, they were assured strongly that their responses would be kept confidential. The researcher gave instructions to fill out the Software. The entire Software Design was returned on the same day. The return rate is one hundred percent. It was assured that the information provided by them would be kept confidential and used only for research purposes.

Data Analysis

After the collection of data, the data were tabulated, and findings were drawn on the basis of a statistical procedure by using Beijing Lizheng (Leading) Software Embankment Design. Analysis of data is given at the end of the tables. The pattern of Software was based on which the researcher made the design of the Embankment in China Cuihua Road in Xi'an. The conclusion was stated in the form of the Software design of Embankment Beijing Lizheng (Leading), restricted by the researcher.

Procedure of Study

The use of the Beijing Lizheng (Leading) Software Embankment Design in China Cuihua Road in Xi'an data was analyzed and found the percentage and tables about the design. The results were discussed and explained logically, and the conclusion was presented in a design. Precise way so that every reader would comprehend the aims of the study. The conclusion suggested some suggestions for further.

RESULT AND DISCUSSION

Embankment Design

1. Original Condition

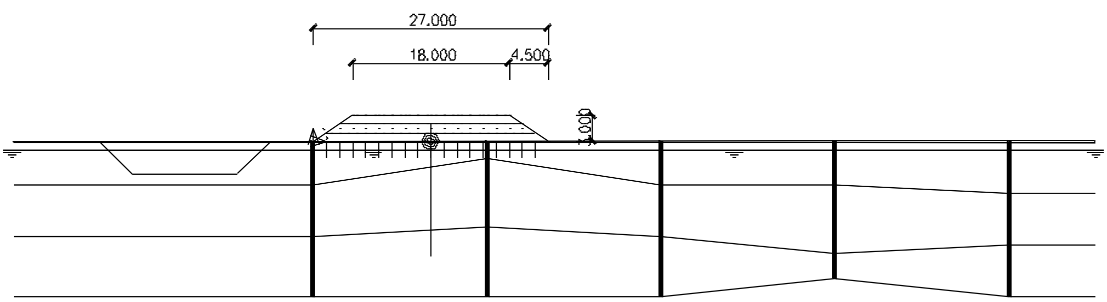

Figure 7. Complex Soft Ground Subgrade Design

Calculation Target: Calculate settlement and stabilization
Embankment design height: 3.000(m)
Embankment design top width: 18.000(m)
Embankment slope: 1:1.500

End time of post-work settlement base period: 166 (months). Number of load application stages 2.

Table 1. End Time of Post-Work Settlement Base Period

Serial number	Start time (Months)	Termination time (months)	Fill height (m)	Whether to make a stable calculation
1	0.000	6.000	3.000	Yes
2	10.000	14.000	0.000	Yes

Table 2. Number of Embankment Soil Layers: 3 Number of Overloads

Serial number	Layer thickness(m)	Severe (kN/m3)	Cohesion (kPa)	Internal friction angle (degrees)
1	1.000	18.000	17.000	30.000
2	1.000	22.000	17.000	30.000
3	1.000	17.000	25.000	5.000

There are earth extraction pits at the edge of the embankment

Take the X coordinate of the lateral edge of the subgrade of the earth pit -5.000(m)

Pit depth 3.800(m)

Pit bottom width 12.000(m)

Take the pit slope (1:m) 1.000

Number of foundation layers: 3 Groundwater depth: 1.000(m)

Number of drill holes: 5

Drilling position (m): 0.000 20.000 40.000 60.000 80.000

The embankment for Cuihua Road was designed with a height of 3.0 m, a top width of 18.0 m, and a slope ratio of 1:1.5. The post-construction settlement base period was estimated at 166 months with two load application stages. The design incorporated three embankment soil layers with no overloads. Earth extraction pits were located at the lateral edge of the subgrade at an X-coordinate of –5.0 m, with a depth of 3.8 m, a bottom width of 12.0 m, and a slope ratio of 1:1. The foundation consisted of three layers, with groundwater at a depth of 1.0 m, and five drill holes positioned at 0.0, 20.0, 40.0, 60.0, and 80.0 m. A sand cushion with a thickness of 3.0 m, a unit weight of 20.0 kN/m^3, cohesion of 0.0 kPa, and an internal friction angle of 32° was used. Additionally, a fly ash embankment layer with a unit weight of 15.0 kN/m^3, cohesion of 10.0 kPa, and an internal friction angle of 28° was included. Consolidation parameters indicated that the bottom surface of the foundation soil layer was not a drainage layer, and the degree of consolidation was determined using the numerical solution of differential equations.

This study's first goal is to discuss the elements that support the stability of road embankments on soft terrain. Current research has discovered that settlement, slope stability, and bearing capacity are crucial elements for the stability of road embankment. These findings are based on literature reviews and some historical cases. The results of a historical case study that has been provided by academic researchers clearly show that these elements are contributors to road degradation. Additionally, during the design process, these soil characteristics call for the installation of instruments and regular lab and field tests. The most recent technological advancements, such as artificial intelligence, allow for quick and accurate soil property predictions, eliminating the need for extensive field or laboratory testing. Today's most popular artificial intelligence techniques include support vector machines (SVM), artificial neural networks (ANN), and adaptive neuro-fuzzy inference systems (ANFIS).

The discussion of the variables influencing the design of road embankments is the study's second goal. In this investigation, it was discovered that geometric data was crucial to the design. This is due to the fact that geometric information like embankment height, side slope, and crest width should be established before performing a stability study. The majority of academics seem to be more concerned with determining the height of the embankment, which is noteworthy to note from the literature. However, the majority of regulations published by enforcement bodies in many nations place emphasis on the need to adhere to slopes and side loads as prescribed. This study's discussion of practical soft soil improvement methods is its ultimate goal. Preloading and prefabricated vertical drains and geofoam as light-weight fill materials are utilized frequently today based on research and observations from a few historical occurrences. Both strategies are environmentally friendly, according to the study. However, the construction times for both of these methods are lengthy.

CONCLUSIONS AND RECOMMENDATIONS

The major objective of the current study was to review the difficulties encountered when building highway embankments on soft ground and offer recommendations for future research. This study has discovered that, generally speaking, there are two main difficulties that engineers must overcome while building road embankments on soft ground during the stability design and technology selection phases. Additionally, it identified three elements—bearing capacity, settlement, and slope stability—that engineers must take into account when analyzing the stability of embankments. However, these elements are influenced by earthquakes, rainfall rates, and ground characteristics. The research that has been presented on the side slope and crest width was also limited in comparison to the height of the embankment, according to more significant findings in recent studies. Therefore, future development studies must take into account criteria like critical, safe, and reasonable to be broadly understandable on these three geometric data. This study discovered that the FEM approach is helpful in figuring out settlement rates and slope stability in order to shorten construction time. The most evident conclusion from this study is that preloading with PVDs and geofoam is frequently used as a soft soil improvement strategy since it is cost-effective, time-saving, and ecologically benign. The results of this study add to the body of knowledge in various ways. First, it deepens our comprehension of the most recent problems with building embankments on soft terrain. Second, it contributes to the growing body of knowledge on the stability of road embankments. Finally, it identifies the research gap that has to be filled by future investigations.

1) Unexpectedly, it was discovered that the problem is also influenced by soil characteristics and rainfall rates. The country's or region's weather has an impact on the rate of rainfall. These two elements are what lead to sediment buildup, bearing capacity loss, and slope failure.

2) This finding's implications include the fact that improving soft soil qualities is expensive.
3) A road embankment stability prediction system that takes into account the crucial elements of settlement, soil bearing capacity, and slope stability based on soil parameters has to be developed.
4) When it comes to side slope determination criterion based on embankment height, the majority of the current recommendations are somewhat restrictive. In order to create new advice with critical, safe, and fair side slope requirements, it is crucial to address this issue in future studies.
5) In the future, it may be possible to explore the connection between crest width, side slope, and embankment height to establish a standard level or value range with necessary, safe, and appropriate standards.

It takes 6 to 12 months for the preloading and prefabricated vertical drains technology to consolidate the soft ground. The installation of geofoam is extremely challenging and necessitates the lengthy creation of a connected network. This issue may have an impact on construction costs. As a result, this is a crucial topic for current and future research and development.

FURTHER RESEARCH

The Authors declare no conflict of interest. The research lacks any kind of funding. All authors contributed equally from the write-up, data collection to final drafting.

ACKNOWLEDGMENT

The authors acknowledge the support from the local people who provided a timely response with regard to the data collection.

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