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A Case Study of Mechanically Stabilized Earth (MSE) Retaining Wall Failure in the State of Tennessee; Recommendations for Future Design and Constructions

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Abstract

This study presents an investigation into the failure of a Mechanically Stabilized Earth (MSE) retaining wall in Tennessee, USA. The wall was constructed to support an embankment development, but it failed catastrophically, causing damage to the road and posing a significant safety risk to the public. The investigation involved a comprehensive site visit, field data collection, laboratory testing, and numerical modeling. Our investigation revealed that the failure of the retaining wall was caused by inadequate construction practices. Specifically, the wall was not constructed in accordance with design specifications, and the backfill material used was not properly compacted. The construction issues resulted in the differential settlement of the wall, which ultimately caused it to fail. Based on our findings, we propose a set of recommendations for the design and construction of future retaining walls in similar geotechnical conditions. The recommendations include the proper selection and use of backfill material, proper compaction of backfill, and adherence to design specifications. The results of this study are expected to contribute to the development of improved design standards and construction practices for MSE retaining walls in Tennessee and other regions with similar geotechnical conditions. (DOI:https//**doi.org/10.52547/JCER.5.1.52**)

Keywords: Type your keywords here, separated by semicolons ;

1. Introduction

Retaining walls are an essential component of civil engineering projects, providing support to the soil, rock, and other materials that are prone to collapse or erosion [1]. However, the failure of MSE retaining walls can be attributed to various factors such as poor design, improper construction, inadequate drainage, substandard materials, poor site preparation, overloading, and natural disasters. Inadequate design specifications, selection of materials, and calculation of loads and forces can impact the wall's strength and durability. Non-compliance with design specifications can also lead to the inability of the wall to withstand the forces it is subjected to, resulting in failure. The absence of proper drainage systems can cause water to accumulate behind the wall and exert pressure on it, leading to failure. The quality of materials such as soil, reinforcement, and geosynthetic fabrics can also

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impact the wall's strength and durability [2]–[4]. Insufficient site preparation can lead to soil instability, causing the wall to shift or settle over time. Overloading due to changes in the use of the area adjacent to the wall or an increase in the weight of stored materials can also cause the wall to fail. Natural disasters such as earthquakes, landslides, or heavy rainfall can also contribute to the failure of MSE retaining walls. Regular inspections, proper design, construction, and maintenance procedures must be followed to prevent the failure of MSE retaining walls. Several studies have investigated the causes of retaining wall failures and proposed remediation plans. These plans include reconstruction with improved design, construction techniques, and installation of drainage systems or geosynthetic reinforcement.

Poor construction quality is the most common cause of retaining wall failures, which include issues such as inadequate compaction, poor drainage, and inadequate reinforcement. H. Binici, et al. (2010) [5] investigated the failure of a case study retaining wall and found that poor construction quality was the primary cause of the failure. The retaining wall was constructed using poor-quality materials, and the construction techniques used were not in accordance with the design specifications. In another study, Kong et al. (2021) [6] illustrated that inadequate design was the primary cause of retaining wall failure in their case study. The study proposed a remediation plan that involved reconstructing the retaining wall with improved design and construction techniques.

Other researchers, such as [7]–[12], investigated retaining wall failures and identified poor construction quality and inadequate drainage as the primary causes. They proposed various remediation plans, including the installation of a new retaining wall with improved construction techniques and materials or the installation of geosynthetic reinforcement, reconstruction of the foundation, and installation of additional reinforcement.

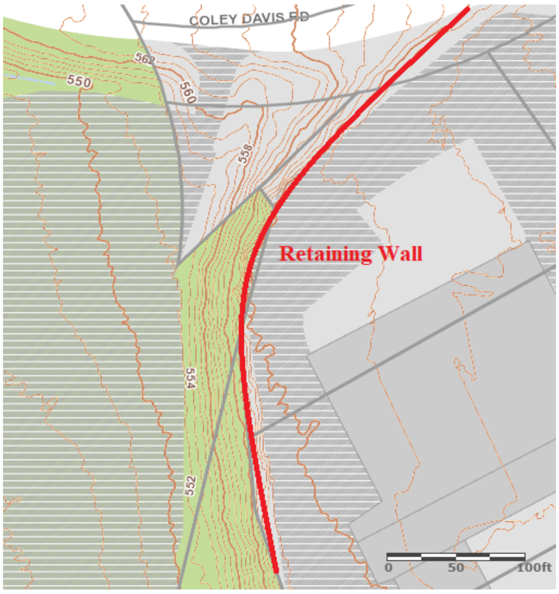
In other studies, researchers such as [13]–[17] investigated retaining wall failures and identified inadequate design and construction as the primary causes. The proposed remediation plans involved reconstructing the retaining wall with improved design and construction techniques, installation of drainage systems, and use of higher quality materials and additional reinforcement.

Further research conducted by [18]–[22] investigated retaining wall failures and identified poor drainage, inadequate reinforcement, poor compaction, inadequate soil reinforcement, and poor maintenance as the primary causes. The proposed remediation measures included reconstruction of the retaining wall, installation of a new drainage system, or installation of a new retaining wall with improved construction techniques and materials.

This case study aimed to investigate the causes of the retaining wall failure that occurred in the state of Tennessee, USA, where a retaining wall constructed using Mechanically Stabilized Earth (MSE) blocks failed, resulting in significant damage to an embankment road and posing a threat to public safety and propose appropriate remediation measures. This paper discusses the factors that led to the retaining wall failure, the assessment methods used to determine the cause of failures, and the remediation measures taken to repair the retaining wall. The study also highlights the importance of proper design and construction, regular inspection and maintenance, and the use of appropriate assessment methods to prevent retaining wall failures. The results of this study are expected to contribute to the development of improved design standards and construction practices for MSE retaining walls in Tennessee and other regions with similar geotechnical conditions.

2. Methodology and Background

The case study involved a comprehensive investigation that combined field data collection, laboratory testing, and numerical modeling. A site visit was conducted to assess the damage caused by the retaining wall failure, and the wall's design and construction were analyzed to identify potential weaknesses. Field data collection involved conducting geotechnical investigations to assess the engineering properties of the soil and rock strata in the area [23]–[27]. The laboratory testing program



a) b)

Figure 1 a) site location map b) topographic layout of the site and the retaining wall's position from Metro GIS

a) b)

Figures 2a and 2b) The current state of the failed retaining wall

included assessing the properties of the soil and rock strata and examining soil samples in accordance with the Unified Soil Classification System (USCS) [28]. The USCS classification system is widely used in geotechnical engineering and provides a framework for describing the physical and mechanical properties of soils. Numerical modeling was conducted to simulate the behavior of the retaining wall under different loading conditions. The numerical models were validated using field data, and the results were used to identify potential causes of the retaining wall failure. Finite element analysis was used to model the retaining wall and simulate the behavior of the wall under various loads and conditions. The finite element analysis revealed that the retaining wall was well-designed to resist the lateral earth pressure and vertical loads from the roadway above and utilized low-quality materials or construction were the factors that led to the retaining wall failure.

The location of this case study project is situated in Davidson County, TN, to the southeast of Nashville, and encompasses an existing development, infrastructure, and a retaining wall. The project area, as mapped by metro GIS [29] topography, is characterized by a general slope from east to west, with the retaining wall situated at an elevation of approximately 578 to 580 feet, MSL, near the top, and around 582 feet at/near the existing building. The ground in front of the wall sharply descends to the west, with an elevation range from approximately 572 feet at the top to 551 feet MSL at the bottom of the slope, creating a slope height of up to 21 feet along the wall and 26 feet in areas where no wall exists. The site location map and topographic layout of the site and the retaining wall's position are depicted in figures 1a and 1b respectively.

The retaining wall at the site has experienced partial failure along a section of its length, resulting in a loss of retained materials and consolidation of adjacent pavements. This mechanically stabilized earth (MSE) retaining wall was constructed using precast concrete panels interlocked with an anchorage system comprising concrete stretchers in the upper part of the wall and tandem epoxy-coated rebars with concrete deadman anchors in the lower portions. The approximate exposed height of the wall is estimated to be up to 10 feet tall. The wall was constructed to support new fill associated with the original grading of the existing development. However, a large portion of the wall has either failed or had its stability compromised. In some locations, the wall has completely collapsed, with the obvious failure of the wall anchorage system at its connection to the precast concrete facing panels. Figures 2a and 2b illustrate the current state of the failed retaining wall.

In order to support the recommendations outlined in this study and to gain insight into the construction of the current retaining wall, we conducted both geotechnical borings and excavated test pits to collect subsurface information regarding material stratification and strength. The field exploration program involved six borings, each extending to a depth of 30 ft or until auger refusal, and three pits, each excavated to a depth of 10 ft or until refusal, located in the backfill zone of the retaining wall. The subsurface exploration plan is presented in Figure 3, while Figure 4 a and b illustrate the excavated test pits and subsurface conditions found in the backfill of the retaining wall.

A truck-mounted rotary drill rig equipped with continuous flight augers was utilized to advance the borings, while the test pits were excavated using an excavator. The final logs for both borings and test pits were prepared by the Geotechnical Engineer, based on the field logs, and included modifications based on observations made during the exploration program. Soil samples collected were described and classified in accordance with the Unified Soil Classification System (USCS), and laboratory tests were performed to determine the backfill soil water content and Atterberg limits.

The investigation conducted in the backfill of the retaining wall revealed the presence of fill material up to a depth of 22 feet. The composition of the fill was highly variable, ranging from predominantly rock fill (with a majority of rock size <6") containing a small amount of clay to mostly clay with some limestone fragments. Additionally, occasional large-size rocks were observed during test pit excavations. Out of six borings, four were obstructed by large-size rocks before reaching the natural ground. At one of the boring locations, asphalt debris/pieces were encountered within the fill at a depth of approximately 13½ feet below the existing grade. The Standard Penetration Tests (SPT) conducted within the existing fill indicated erratic N-values, ranging as low as 4 to 5 bpf, indicating the presence of poorly compacted (compressible) material in some layers. Below the existing fill, the soil was found to consist of stiff to very stiff natural residual clay (lean clay) extending to a depth of about 30 feet without encountering bedrock.

3. Geotechnical Overview

Based on our subsurface exploration and observations, the MSE retaining wall comprises precast concrete panels that are interconnected using some form of interlocking mechanism. Additionally,

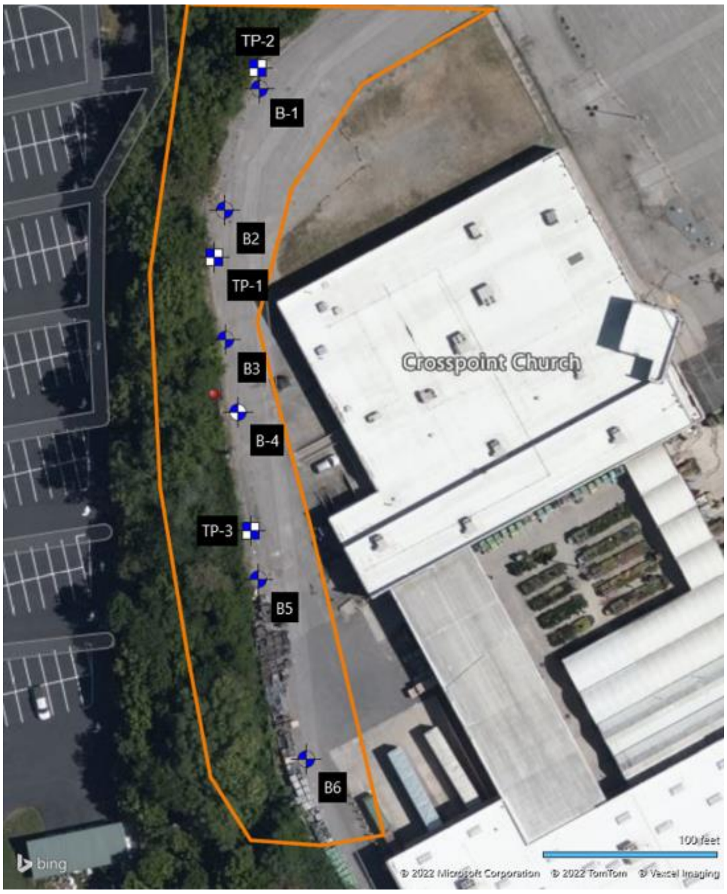


Figure 3 subsurface exploration plan

a) b)

Figures 4a and 4b) Excavated test pits and subsurface conditions found in the backfill of the retaining wall an anchorage system consisting of concrete stretchers in the upper part of the wall and tandem epoxy-coated rebars with concrete deadmen anchors in the lower portions of the wall is used. The height of the exposed wall varied along its length and was observed to be as tall as 10 feet. However, our findings indicate that a significant portion of the wall has either failed or is compromised in terms of stability. At several points, we also observed a complete collapse of the wall, indicating an obvious failure of the wall anchorage system at its connection to the precast concrete facing panels.

The assessment of the retaining wall failure revealed additional concerns beyond just wall movement. Both vertical settlement and lateral movement of the asphalt pavement and concrete curbs were observed over the reinforced backfill zone of the retaining wall. Our investigation suggests that the accumulation of surface water runoff from the parking lot, illustrated in figure 2a, has been directed towards the wall over time, instead of flowing into the designated site stormwater drainage system. The failure of the retaining wall seems to have occurred due to a connection failure at the facing panels, where the anchorage system pulled out of or sheared off the panels as illustrated in figure 2b. This failure may have been caused by backfill settlement and the added hydrostatic pressure imposed on the wall from the migration of surface water runoff into the backfill. Our examination also revealed anchor system failures both at the wall panel connection locations as well as within the concrete deadmen anchors, where rebars appeared to have pulled out from the concrete anchor block.

The intrusion of water into the soil rock mixture has resulted in the loss of strength in the backfill material, which has settled over time. It is noteworthy that most MSE wall systems of this type are designed using a free-draining granular backfill material. However, at several locations, the wall backfills contained significant amounts of clay that hindered the drainage of water entering the reinforced zone. As a consequence, lateral earth pressures acting on the wall system may increase, not only due to the added weight of the backfill material but also due to the likelihood of hydrostatic pressures imposed on the wall. Additionally, we observed the absence of any drainage system in the retaining wall such as weep holes, perforated drainage pipes, or other similar features. It is possible that a chimney drain system is located at the back of the reinforced zone, which was unable to be detected during our exploration, or a drainage system may run underneath the wall and empty onto the slope below, which was obscured by vegetation.

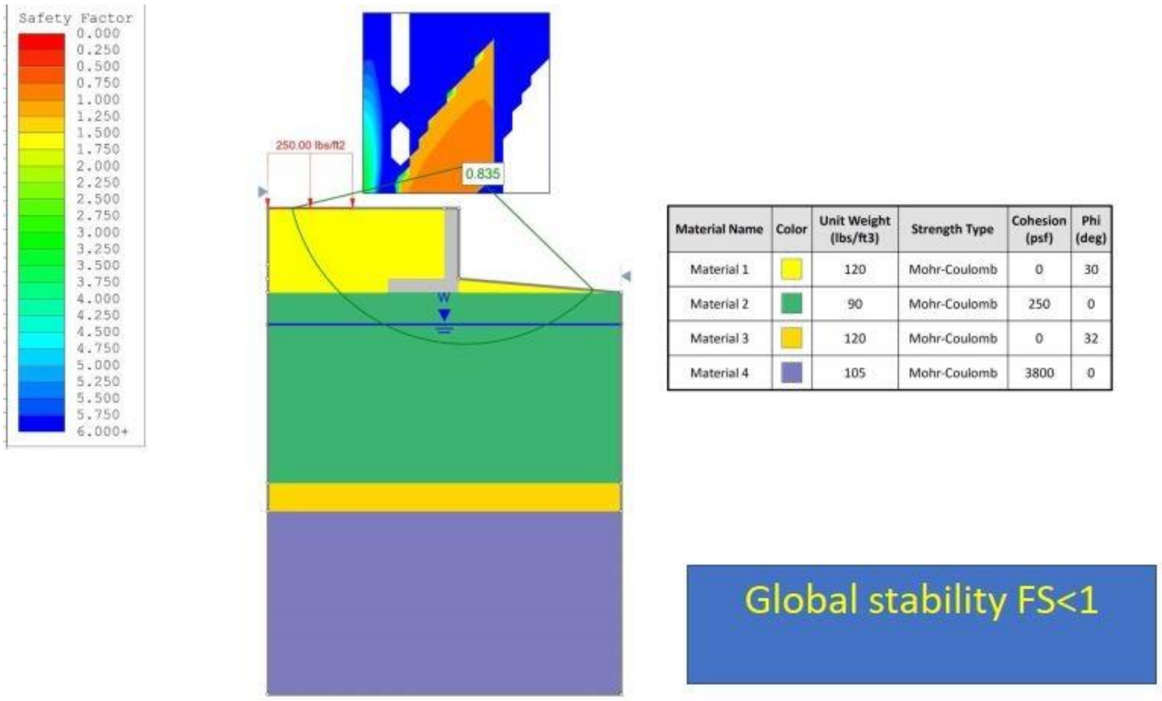
4. Numerical Modelling

One method of analyzing the behavior of retaining walls is numerical modeling, which involves simulating the behavior of the wall using computer software. In this research, we use the SLOPE/W software to model the behavior of an MSE (Mechanically Stabilized Earth) retaining wall under different conditions and loads. The numerical models were validated using field data, and the results were used to identify potential causes of the retaining wall failure. Finite element analysis was used to model the retaining wall and simulate the behavior of the wall under various loads and conditions.

The numerical modeling in this research was performed using the SLOPE/W software, which is a powerful tool for analyzing the stability of slopes and retaining structures. The software uses finite element analysis to model the behavior of the retaining wall, taking into account the properties of the soil, the wall geometry, and the loads it will be subjected to. The numerical models were validated using field data, which were collected from the site of a retaining wall failure.

The MSE retaining wall that was analyzed in this research was constructed using low-quality materials, and it failed due to a combination of factors, including inadequate drainage, poor compaction, and overloading. The numerical models were used to simulate the behavior of the wall under different loads and conditions, including different angles of internal friction, different wall heights, and different surcharge loads.

The finite element analysis revealed that the retaining wall was well-designed to resist the lateral earth pressure and vertical loads from the roadway above. However, the use of low-quality materials and



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Material 1		120	Mohr-Coulomb	0	30
Material 2		90	Mohr-Coulomb	250	0
Material 3		120	Mohr-Coulomb	0	32
Material 4		105	Mohr-Coulomb	3800	0

Figure 5 simulated MSE retaining wall using SLOPE/W software

poor construction practices led to the retaining wall failure. The numerical models showed that the wall was most susceptible to failure under high surcharge loads, which caused the wall to tilt and lose stability. The models also showed that the use of geogrid reinforcement and proper compaction of the soil could significantly improve the stability of the wall.

The finite element analysis revealed that the retaining wall was well-designed to resist the lateral earth pressure and vertical loads from the roadway above and utilized low-quality materials or construction were the factors that led to the retaining wall failure.

5. Recommendations

When dealing with retaining wall failure, several factors must be considered in order to make informed decisions and provide effective recommendations. Firstly, the type and cause of the failure must be determined in order to choose the appropriate solution. Common causes of retaining wall failure include poor construction, soil erosion, inadequate drainage, and seismic activity. Secondly, the severity of the failure will dictate the course of action, as minor damage may only require minor repairs, while a complete reconstruction may be necessary for significant collapses. Site conditions, such as soil type, slope, and groundwater level, must also be taken into account when developing a repair or replacement plan. Environmental factors like rainfall, temperature, and seasonal changes can also impact the performance of the retaining wall and must be considered when developing a solution. Additionally, the available budget and resources will determine the feasibility and scope of any repair or replacement work. Compliance with local regulations and requirements is also critical to ensure the safety and structural integrity of the retaining wall. Finally, the planned future use of the area may influence the design and construction of any repair or replacement work.

There are several methods used to assess the causes of retaining wall failures, including visual inspections, soil testing, and structural analysis. Visual inspections involve examining the wall for signs of damage or distress, such as cracks, bulges, or leaning. Soil testing can help determine the soil's properties, including its shear strength, compaction, and moisture content. Structural analysis involves using mathematical models to analyze the wall's behavior under various loads and conditions. All these assessment methods are important and necessary to identify the root cause of the failure [30]–[39]. Once the cause of the retaining wall failure is identified, remediation measures can be taken to repair the wall and prevent future failures. These measures may include reinforcing the wall with additional materials or support structures, repairing any damage, improving drainage, and implementing regular inspection and maintenance programs. The remediation measures taken should be based on the specific cause of the failure and should be designed to address the underlying problem. Proper design and construction, regular inspection and maintenance, and appropriate assessment methods are all critical to preventing retaining wall failures [40]–[46]. A well-designed and constructed wall that is regularly inspected and maintained is less likely to fail. If a failure does occur, appropriate assessment methods can help determine the cause of the failure, and remediation measures can be taken to prevent future failures. It is important to recognize that retaining walls are complex structures that require expertise in design, construction, and maintenance. Therefore, it is essential to hire qualified professionals who have experience in these areas to ensure the safety and stability of the retaining wall.

Retaining walls can fail if not constructed correctly, leading to property damage, personal injury, and legal disputes. One critical factor that can prevent retaining wall failure is the proper selection and use of backfill material. Backfill is the material placed behind the retaining wall to provide support and counteract the force of the retained soil. The choice of backfill material depends on several factors such as soil type, groundwater level, and wall height. The backfill material should be free of debris, large rocks, and organic matter that can create voids and affect the wall's stability. Moreover, the backfill material should be compacted correctly to minimize settlement and lateral movement. The backfill material should be placed in layers and compacted using appropriate equipment and techniques to achieve the required density and moisture content. The use of geotextiles and drainage systems can also improve the backfill's performance and prevent water build-up and hydrostatic pressure.

The Backfill material required to achieve design grade should be classified as structural fill. Structural fill is material used below, or within 10 feet of the retaining wall, pavements or constructed slopes. Compacted structural fill should meet the material property requirements mentioned in table 1.

Another critical factor in preventing retaining wall failure is adherence to design specifications and proper compaction of the backfill material. The retaining wall's design should be based on the site's soil conditions, slope angle, and anticipated loads. The design should include details on wall height, thickness, reinforcement, drainage, and backfill material. The contractor should follow the design specifications and use the appropriate construction methods and materials. Proper compaction of the backfill material is crucial to prevent settlement and lateral movement, which can affect the wall's stability. The compaction should be done in layers, using the appropriate equipment, and testing the density and moisture content. The contractor should also monitor the wall's performance during and after construction to detect any signs of movement, cracking, or distress. Regular maintenance and inspection can also prevent retaining wall failure by identifying and addressing any issues before they become critical. Backfill Compaction Requirements should meet the requirements in table 2.

In this case study, the retaining wall on the north side has failed and requires complete removal and reconstruction to support the pavement and backfill. Various retaining wall systems are available for construction, a gravity wall concept was recommended for this site, such as Redi-Rock or gabion basket wall systems, or an MSE retaining wall system over traditional cast-in-place concrete retaining walls, soldier pile or secant pile walls for their cost-effectiveness. To ensure suitable bearing

Table 1 Structural fill material requirements

Soil Type [1]	USCS Classification	Acceptable Parameters (for Structural Fill)
Low Plasticity Cohesive	CL	Liquid Limit $\leq$ 45 Plasticity index $\leq$ 25 Not recommended for reuse below and behind wall
High Plasticity "Fat" Cohesive [2]	CH	Liquid Limit $\geq$ 50, Plasticity index $\geq$30 not recommended for reuse
Granular	GW [3]	Less than 5% Passing #200 sieve, can be used at all locations and elevations. Terracon recommends any fill material used within the geogrid reinforced wall backfill should be granular fill with rock size less than 3 inches. The actual wall backfill material should be as specified by the designer of the retaining wall.
Existing Fill	CL	A large portion of the existing fill may not be suitable for reuse due to the presence of clay in the rock fill. However, if the fill contains predominantly clean well-graded rock (particle size $\leq$6") this material can be reused as engineered fill below the wall bearing or beneath the pavement area in the retained zone of the wall if approved by the geotechnical engineer
Clean well graded processed rock, surge stone (max. rock size 6 inches) [4]	--	Can be used at all locations and elevations except in the reinforced backfill zone of the retaining wall

1. Structural fill should consist of approved materials free of organic matter and debris. Frozen material should not be used, and fill should not be placed on a frozen subgrade. A sample of each material type should be submitted to the Geotechnical Engineer for evaluation prior to use on this site.
2. CH soils should not be used.
3. Similar to TDOT Section 903.05 Type A, Grading D crushed limestone aggregate, limestone screenings, or granular material such as well-graded gravel or crushed stone.
4. Approval of surge stone should be made prior to placement. Any rock fill containing clay fines should not be used as engineered fill.

and limit settlement to tolerable limits, the new retaining wall should be supported on engineered fill, and the existing fill must be undercut and replaced with approved engineered fill. However, a portion of deeper fill (below 15') may not require replacement if it can be recompacted to a non-yielding state and reinforced with a layer of geogrid prior to the placement of newly engineered fill and any wall construction. It is crucial to compact each lift of new fill, not exceeding 9 inches, according to our recommendations.

Additionally, a proper drainage system is imperative for the long-term performance of the retaining wall. Incorporating relief drains at the bottom of the rock fill is recommended, which may be daylighted on the face of the slope to bleed off any trapped water within the backfill. Furthermore, pavement near and around the retaining wall should slope away from the wall and collect into the site stormwater drainage system. All grades must provide effective drainage away from the wall during and after construction and should be maintained throughout the life of the wall.

The results of borings and test pits conducted in the wall backfill area revealed that the fill was placed up to a depth of 22 feet against and below the retaining wall. During drilling, Standard Penetration Tests (SPT) conducted within the existing fill indicated the presence of poorly compacted and compressible material layers. Consequently, in this case study it is recommended to excavate the existing fill to a depth of 15 feet below the existing grade or

Table 2 Backfill compaction requirements

Item	Structural Fill
Maximum Lift Thickness	9 inches or less in loose thickness when heavy, self-propelled compaction equipment is used 4 to 6 inches in loose thickness when hand guided equipment (i.e. jumping jack or plate compactor) is used
Minimum Compaction Requirements [1, 2]	98% of the material's standard Proctor maximum for granular fill material The surge should be placed in max. 9-inch thick lifts. and compacted with a heavy-duty vibratory smooth drum roller or D-6 class dozer Each lift of shot rock or surge fill should be compacted using a minimum of ten passes, five in one direction and five that are at a right angle to the initial passes. A complete pass consists of complete coverage of the surface with the tracks (roller).
Water Content Range [1]	Cohesive: -1% to +3% of optimum Granular: -2% to +2% of optimum

1. Maximum density and optimum water content as determined by the standard Proctor test (ASTM D 698 [47]).
2. If the granular material is coarse sand or gravel, or of a uniform size, or has a low fines content, compaction comparison to relative density may be more appropriate. In this case, granular materials should be compacted to at least 70% relative density (ASTM D 4253 and D 4254 [48]).

until stiff natural clay is reached, whichever comes first. The recommended undercutting should extend laterally at least 5 feet beyond the wall-bearing footprint on both sides. The exposed existing fill should be scarified or over-excavated and recompacted to a minimum of 95 percent of the material's standard Proctor maximum dry density. Next, a single layer of geogrid should be placed directly on top of the recompacted fill subgrade, followed by at least 12 inches of crushed rock-engineered fill. Any subsequent fill above this layer should consist of either crushed rock engineered fill, well-graded clean surge stone (rock size <6 inches), or material specified by the designer of the new retaining wall.

It is essential to ensure that retaining walls are constructed with high-quality materials, appropriate foundations, and proper drainage systems. Regular inspections and maintenance can help identify any signs of deterioration or structural weaknesses, allowing for timely repairs or replacements to prevent failure [49]–[56]. The use of appropriate assessment methods, such as geotechnical evaluations and structural analysis, can provide valuable insights into the integrity of the retaining wall, identifying potential problems before they become major issues. Proper design, construction, inspection, maintenance, and assessment are all critical components in preventing retaining wall failures and ensuring the safety and longevity of the structure and the people who rely on it. By prioritizing these factors, we can create a safer and more sustainable built environment.

6. Construction of New MSE Retaining Wall

In this journal paper, we provide recommendations and parameters for the construction of a new MSE wall. Our proposed design assumes that the wall will be supported on an engineered fill that meets the outlined recommendations. When designing the retaining wall foundations, a maximum net allowable bearing pressure of 2,000 psf can be used in this case study, while the recommended net allowable bearing pressure should provide a factor of safety of 3 (2 for MSE Wall) with respect to anticipated shear strength.

MSE retaining walls are typically composed of modular concrete block face units, geogrids for reinforcement, and compacted soil or select granular material that creates a reinforced soil mass acting as a gravity-type retaining wall. Design considerations for

Table 3 Recommended MSE wall soil strength parameters – foundation soils

Material Type	Moist Unit Weight (pcf)	Total Stress (Undrained) Parameters		Effective Stress (Drained) Parameters	
		c_u, psf	ϕ, degrees	c', psf	ϕ', degrees
New engineered granular fill	110	0	32	0	32

Table 4 Recommended MSE wall soil strength parameters – backfill materials

Material Type	Moist Unit Weight (pcf)	Total Stress (Undrained) Parameters		Effective Stress (Drained) Parameters	
		C_u, psf	ϕ, degrees	c', psf	ϕ', degrees
No. 57 Stone or Surge Stone	105	0	34	0	34
Crushed rock engineered fill [1]	135	0	32	0	32
1. Fill should be compacted to at least 95% of standard Proctor maximum dry density.					

the MSE wall should include geotechnical parameters such as the unit weight and strength of in-place native materials, compacted soil for the reinforced zone, and foundation subgrade. The parameters used in the design and global stability analyses of the MSE retaining wall should not exceed those outlined in provided tables 3 and 4. It is also important to consider any surcharge loading that will be placed on the completed wall. It is crucial to exercise caution in the design and construction stages to establish and sustain swift and positive drainage away from the retaining wall area. Also, an effective surface drainage is necessary to prevent water from flowing over the wall face and saturating the fill behind the wall or subgrade soils at the base of the wall.

Before commencing construction of the MSE wall, it is essential to collect and analyze samples of the fill material proposed to be used in constructing the reinforced zone for the wall. This laboratory testing is critical to confirm that the engineering properties of the backfill align with the assumed properties utilized in the design. Additionally, it is recommended that qualified geotechnical personnel conduct field testing and observations during the MSE wall's construction. Table 3 illustrates recommended MSE wall soil strength parameters for foundation soils and table 4 shows recommended MSE wall soil strength parameters for backfill materials.

The retaining wall failure under investigation was found to be caused by construction practices. The wall was not built to withstand the lateral forces exerted by the embankment and soil retention. Other factors, such as unsuitable backfill materials, inadequate compaction, and poor drainage, were also found to have contributed to the failure. A remediation plan was proposed based on our findings, which involved reconstructing the retaining wall using improved design and construction techniques. The proposed design included additional reinforcement and drainage systems to prevent the accumulation of water and soil pressure. This study's results are expected to contribute to the development of better design standards and construction practices for retaining walls in Tennessee and other regions with similar geotechnical conditions. The study emphasizes the importance of proper design, construction, and maintenance practices in ensuring the long-term stability and safety of retaining walls. The value of a comprehensive investigation that combines field data collection, laboratory testing, and numerical modeling to identify the causes of retaining wall failure and propose appropriate remediation measures is also demonstrated by this study.

7. Conclusions

In conclusion, the case study involved a comprehensive investigation that combined field data collection, laboratory testing, and numerical modeling to identify potential causes of a retaining wall failure in Davidson County, TN. The investigation revealed that the retaining wall was well-designed to resist the lateral earth pressure and vertical loads from the roadway above; however, utilizing low-quality materials or construction was the factor that led to the retaining wall failure. Based on the subsurface exploration and observations, it was evident that the retaining wall in question was compromised in terms of stability. The assessment of the retaining wall failure revealed additional concerns beyond just wall movement, such as the presence of poorly compacted (compressible) material in some layers and the occurrence of occasional large-size rocks. The findings from this investigation highlight the importance of proper design and construction of retaining walls. The study provides insights into the need for careful consideration of soil properties and design loads, as well as the use of appropriate materials and construction techniques. The investigation also underscores the importance of regular monitoring and maintenance of retaining walls to identify and address potential issues before they result in catastrophic failure. Overall, this case study provides insights into the investigation of retaining wall failures and highlights the importance of proper design, construction, monitoring, and maintenance of retaining walls. The study findings can be useful for geotechnical engineers, contractors, and developers involved in the design and construction of retaining walls.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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