Lecture Notes in Civil Engineering

Thomas Kang
Youngjin Lee *Editors*

Proceedings of 2021 4th International Conference on Civil Engineering and Architecture

Springer

Lecture Notes in Civil Engineering

Volume 201

Lecture Notes in Civil Engineering (LNCE) publishes the latest developments in Civil Engineering - quickly, informally and in top quality. Though original research reported in proceedings and post-proceedings represents the core of LNCE, edited volumes of exceptionally high quality and interest may also be considered for publication. Volumes published in LNCE embrace all aspects and subfields of, as well as new challenges in, Civil Engineering. Topics in the series include:

- Construction and Structural Mechanics
- Building Materials
- Concrete, Steel and Timber Structures
- Geotechnical Engineering
- Earthquake Engineering
- Coastal Engineering
- Ocean and Offshore Engineering; Ships and Floating Structures
- Hydraulics, Hydrology and Water Resources Engineering
- Environmental Engineering and Sustainability
- Structural Health and Monitoring
- Surveying and Geographical Information Systems
- Indoor Environments
- Transportation and Traffic
- Risk Analysis
- Safety and Security

To submit a proposal or request further information, please contact the appropriate Springer Editor:

– Pierpaolo Riva at pierpaolo.riva@springer.com (Europe and Americas);
– Swati Meherishi at swati.meherishi@springer.com (Asia - except China, and Australia, New Zealand);
– Wayne Hu at wayne.hu@springer.com (China).

All books in the series now indexed by Scopus and EI Compendex database!

More information about this series at https://link.springer.com/bookseries/15087

Thomas Kang · Youngjin Lee
Editors

Proceedings of 2021 4th International Conference on Civil Engineering and Architecture

Springer

Editors
Thomas Kang
Department of Architecture
and Architectural Engineering
Seoul National University
Seoul, Korea (Republic of)

Youngjin Lee
Boston Architectural College
Boston, USA

Sasaki Associates, Inc.
Watertown, USA

ISSN 2366-2557 ISSN 2366-2565 (electronic)
Lecture Notes in Civil Engineering
ISBN 978-981-16-6931-6 ISBN 978-981-16-6932-3 (eBook)
https://doi.org/10.1007/978-981-16-6932-3

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Conference Committees

Conference Chair

Thomas Kang, Seoul National University, South Korea

Program Chairs

Alireza Afshari, Aalborg University, Denmark
Adnan Ibrahimbegovic, University of Technology of Compiègne, France
Dario Pedrabissi, University of Portsmouth, UK
Youngjin Lee, Boston Architectural College and Sasaki Associates, Inc., USA

Technical Committee

Alberto Gonzalez, University of Utah Asia Campus, South Korea
Allan Alzona, National University—Manila, Philippines
Bakhriev Nuritdin, Samarkand State Architectural and Civil Engineering Institute, Uzbekistan
Bernard Villaverde, Mapua University, Philippines
Changsoo Kim, Shandong Jianzhu University, China
Chavanont Khosakitchalert, Chulalongkorn University, Thailand
Chompoonut Kongphunphin, Thammasat University, Thailand
Dante L. Silva, Mapua University, Philippines
Deuckhang Lee, Nazarbayev University, Kazakhstan
Emina Hadzalic, University of Sarajevo, Bosnia and Herzegovina
Fadi Hage Chehade, Lebanese University, Lebanon
Gokhan Tunc, Atilim University, Turkey

Haryati Yaacob, Universiti Teknologi Malaysia, Malaysia
Hazrina Haja Bava Mohidin, University of Malaya, Malaysia
Hosein Nadepour Hosein Naderpour, Semnan University, Iran
Hyeon-Jong Hwang, Hunan University, China
Junior Didi Orihuela, Universidad Peruana de Ciencias Aplicadas, Peru
Junwon Seo, South Dakota State University, USA
Karol Slawomir Sikora, University of Wollongong in Dubai, UAE
Khan Zaib Jadoon, International Islamic University Islamabad, Pakistan
Leonardo Maximiliano Massone, University of Chile, Chile
Lyazat Aruova, Eurasian National University, Kazakhstan
Manat Srivanit, Thammasat University, Thailand
Manny Anthony Taguba, National University—Manila, Philippines
Marcelo Villacis Ormaza, Universidad Tecnológica Indoamerica, Ecuador
Mohammad Arif Kamal, Aligarh Muslim University, India
Mohammad Ichsan, Binus University, Indonesia
Muneerah Jeludin, Universiti Teknologi Brunei, Brunei Darussalam
Norhidayah Abdul Hassan, Universiti Teknologi Malaysia, Malaysia
Ryan Ahn, Texas A&M University, USA
Satawat Doungpan, Sukhothai Thammathirat Open University, Thailand
Shaoyun Pu, Southeast University, China
Shavkat Buriboev, Samarkand State Architectural and Civil Engineering Institute, Uzbekistan
Suppachai Sinthaworn, Srinakharinwirot University, Thailand
Taki Eddine Seghier, School of Architecture and Built Environment, UCSI University, Kuala Lumpur, Malaysia
Tamara Kelly Kelly, Abu Dhabi University, UAE
V. V. N. Prabhakara Rao, VR Siddhartha Engineering College, India
Wardah Fatimah Mohammad Yusoff, National University of Malaysia, Malaysia
Wonseok Chae, University of Wuppertal, Germany
Woosuk Kim, Kumoh National Institute of Technology, South Korea
Zhmagul Nuguzhinov, KazMIRR at Karaganda State Technical University, Kazakhstan

Preface

The 4th International Conference on Civil Engineering and Architecture (ICCEA 2021) was held from July 10 to 12, 2021. ICCEA aims to become a premier international conference for an in-depth discussion on the most up-to-date and innovative ideas, research projects, and practices in the field of civil engineering and architecture. Given the current global outbreak of the virus, this year's conference, which was supposed to be held in Seoul, was organized as a fully virtual conference.

This year, 4 keynote speeches have been delivered by myself, Prof. Atsuko K. Yamazaki (Japan), Prof. Youngjin Lee (USA), and Prof. Jorn Altmann (South Korea). More than 60 presentations were given from about 20 countries/regions, making this conference truly international. The whole conference was held online in Zoom, and we also had tests for each presenter in advance to ensure the success of delivery of the conference. For those who had Internet problems, a pre-recorded video presentation is accepted as an alternative. Meanwhile, the whole conference had been recorded for conference backup only.

ICCEA 2021 proceedings span over created 8 topic tracks including *geological survey and road engineering, earthquake engineering, concrete structure design and performance analysis, building materials and structural engineering, architecture and environmental engineering, urban space planning and development, project construction and management, and ancient architecture and architectural history,* which are well balanced in content and manageable in terms of many contributions, and create a discussion space for trendy topics.

Efforts taken by peer reviewers contributed to improving the quality of papers provided constructive critical comments; improvements and corrections to the authors are gratefully appreciated. We are very grateful to the international/national advisory committee, session chairs, and administrative assistants who selflessly contributed to the success of this conference. Also, we are thankful to all the authors who submitted papers, because of which the conference became a story of success. It was the quality of their presentation and passion to communicate with the other participants that made this conference a grand success.

We sincerely hope that the academic community and industrial practitioners will continue to support us in our attempts to provide even more meaningful conferences with numerous critical idea exchanges, diverse opportunities for fruitful networking, and future collaborations between the delegates.

Warmest regards,
Dr. Thomas Kang
Conference Chair, ICCEA 2021
Professor
Seoul National University
Seoul, South Korea

Contents

Earthquake Engineering

Concrete Structure Design and Performance Analysis

Geological Survey and Road Engineering

Stability Analysis Using the Finite Element Method of a Slope in the Virgen de Fátima Sector of the San Juan de Lurigancho District of Lima, Peru

N. Carrizales, R. Rodriguez, and J. Vasquez

Abstract The geometric alteration of slopes is a reality that can be observed in several districts of the Peruvian capital. The construction of houses, roads, and other infrastructure can produce some slope instability and cause tragic events. Thus, a stability analysis was carried out for a slope located in the San Juan de Lurigancho district, specifically in the Virgen de Fátima sector. Therefore, for the present investigation, two models were made with the help of Phase2 software to identify the resistance reduction factors (SFR), which is a finite element-based program. To start the analysis, possible failures were identified, demonstrating that the slope does not present any possibility of failure. For the first model, we worked with a dip of 30° and identified an SFR = 19.26 for static conditions and an SFR = 9.66 for pseudo-static conditions. For the second model, we worked with a dip of 55°, this change in slope geometry shows a possible wedge failure, according to the kinematic analysis. Also, an SFR = 0.89 was identified for static conditions and an SFR = 0.48 for pseudo-static conditions. The results show very considerable changes and are due to the geometry of the slope, the presence of discontinuities, and the participation of seismic forces.

Keywords Finite elements method · Kinematic analysis · Rock slope · Slope stability

N. Carrizales · R. Rodriguez · J. Vasquez (✉)
Universidad Peruana de Ciencias Aplicadas, Lima, Perú
e-mail: pccijiva@upc.edu.pe

N. Carrizales
e-mail: u201417184@upc.edu.pe

R. Rodriguez
e-mail: u201414727@upc.edu.pe

T. Kang and Y. Lee (eds.), *Proceedings of 2021 4th International Conference on Civil Engineering and Architecture*, Lecture Notes in Civil Engineering 201,
https://doi.org/10.1007/978-981-16-6932-3_1

1 Introduction

A current problem in one of the most populated districts of Lima is the construction of housing on the slopes of the hillsides by families in need of a home of their own. This context translates into the alteration of the slope, through cuts or the intervention of machinery, intending to create flat spaces for the construction of housing, access roads, or common areas such as the construction of a sports slab. For this reason, the way of cutting the slope, without any engineering criteria, often generates instability, leading to a latent risk such as rockfall and thus causing very important damages such as human and material losses.

In this study, although an analysis will be made on a slope that is potentially stable, it is necessary to know the behavior of stability with the change of slope, due to the geometric variation caused by the cuts in the slope. In addition, it is important to mention that most of the constructions in this type of places lack a technical study due to the lack of advice from a specialist and the absence of State institutions to improve the quality of life of the population.

The study area is located in the Virgen de Fátima sector, in the district of San Juan de Lurigancho, Lima, Peru. To carry out the investigation, an identification of the fractures present is made, and then the analysis is carried out to determine the types of rupture that can be generated, and which are the intervening fractures. Previously, a geotechnical study was carried out by INGEMMET [1], in which a geomechanical classification of the slope under study was performed. On this occasion, in general, what is intended to be done is a model of the slope before and after cutting. For this purpose, a slope stability analysis will be performed using the finite element method, where the representation of the models will be done with Phase2 software. The objective is to identify the vulnerability of the slope after making cuts or geometric changes in its surface.

2 Current State of Knowledge

Mithresh et al. focused on the rock falls that may occur along the hill slopes on a busy road, as these problems cause both as loss of money, inconvenience to travelers and sometimes there are human losses due to these natural phenomena. Thus, the authors investigated the mechanism of such faults to control such problem, for this the respective analysis of a rock slope located in the Himalayas of Sikkim are carried out. These analyses consist of 3 steps, which were performed through a kinematic analysis, a limit equilibrium analysis, and a numerical analysis that focuses on the finite element method. The purpose of the study was to obtain the safety factor which was obtained by the shear strength reduction (SRF) method, therefore, the results obtained show that the numerical analysis was the one that gave a result more related to the kinematic analysis and showing that the slope is not stable, which ends up failing due to its respective explicit discontinuities [2].

Anangsha et al. evaluated the fault mechanisms in a basalt rock slope which is located on the Deccan State Highway in western India. For their respective analysis, they were made through a kinematic analysis which focuses on being able to visualize the possible failures that occur in the basalt rock slope and numerically based on the finite element method with the technique of reducing shear strength parameters (SSR). The shape was also applied to represent the three-dimensional orientation to a two-dimensional orientation of said slope in order to represent an efficient analysis in a 2D model thanks to the "Phase 2" program. Finally, it was announced that the slope presented stability risk because of the safety factor (SFR) that was obtained [3].

Fumming used the resistance reduction method associated with the finite element method with the purpose of not having error and low analysis efficiency of a rock slope, the case study is of a rock slope of the Danjiangkou reservoir with which a simulation must be obtained to know if it is more precise in the results and better satisfy the needs of the geotechnical analysis of slope stability. Given the final results of the research, it was identified that, compared to the traditional method, the safety factor (SFR) is more related to the real data with less analysis error and greater efficiency in less time [4].

Ahmed and Seshagiri focused on how to improve the behavior of rock mass stability under static and dynamic conditions through analytical analysis. The stability of the slope of the slope is generally affected by the material property of the rock in conjunction with the discontinuities in the rock mass. It also depends on the angle of the slope, the height of the slope, the surcharge, the groundwater conditions, the rain, and the dynamic forces such as an earthquake. Block and core samples were collected from each category of rocks and their respective geotechnical properties were experimentally measured and presented. The rock slope stability analysis was performed using numerical modeling techniques, two-dimensional analysis based on the fine element method (FEM) (RS2), or Phase2 9.0 software from Rocscience. The slope of the rock having four different qualities of rock mass was analyzed under static and pseudostatic conditions. Therefore, the optimal support measurements were provided using shotcrete (fck = 35 MPa and 100 mm thick) and fully bonded bolts (32 mm diameter, 10 m long with 3 3 m spacing) because the factor safety for the most critical section which was increased from 0.48 to 1.2 under dynamic load conditions [5].

3 Tools

To carry out the research, a geotechnical study of the slope and three computational tools were used.

3.1 Geotechnical Study

One of the main characteristics in any research process is the field work to collect the corresponding and necessary data. Therefore, for this document, the geotechnical study carried out by INGEMMET [1], is taken as the starting point, where it makes a geological description of the place and the geomechanical classifications of the slopes that were considered for said report, where the characteristics of the rocky matrix and discontinuities.

3.2 Software Dips

Within the analysis it is necessary to identify the possible failure mechanisms and to achieve this characteristic a kinematic analysis is carried out. For this reason, the Dips software is a tool that helps to represent the orientations of the planes based on their dips, dip direction and heading. It also helps to identify the type of failure whether it be planar, wedge or overturning, with the data of the slope and the friction angle.

3.3 Rocdata V3

This software was used to determine the input parameters for the application of the finite element method in the Phase2 software. From the compressive strength of the intact rock (σci), the parameter (mi), geological resistance index (GSI), the disturbance factor (D) and the consideration of the Generalized Hoek Brown criterion, a constitutive method suitable for an analysis in a rocky massif [6], it identifies the cohesion and friction angle values, as well as parameters of the rock mass tensile strength, global compressive strength, deformation modulus and the uniaxial compressive strength of the massif rocky.

3.4 Phase2

It is a finite element program that allows slope stability analysis, whose main characteristic is the shear strength reduction method to determine the safety factor [7]. Phase2 allows evaluating the risk of slope failure and for this purpose, the geometry, geological conditions of the study site and the results or identified parameters of the constitutive model found with Rocdata were identified. In addition, within the modeling, the most representative fracture families or systems are considered.

Table 1 Orientation characteristics of discontinuities

Kind structure	Orientation	
	Dip	Dip direction
J1	59	299
J2	67	85
J3	86	162
Slope	30	242

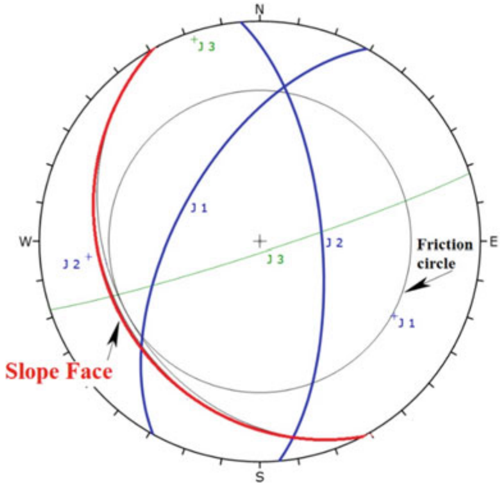
4 Geological Description of the Study Area

The study area is in the "Cerrito Rico" human settlement, in the Virgen de Fátima Sector, San Juan de Lurigancho, Lima, Peru. The geological aspect of the place is represented by intrusive rocks covered by deposits of different physical and mechanical properties. Within this category of rocks is the presence of gray granodiorite, in slightly weathered outcrop with xenolites, with a high degree of fracturing [1]. On the other hand, the slope has two main joint families and a secondary family as detailed in Table 1.

5 Methodology

5.1 Kinematic Analysis

For the present analysis, it is important to know the orientation of the discontinuities since it is one of the most influential aspects in determining stability. The slope understudy presents two main families J1, J2, and a secondary family J3 with the orientation of their discontinuities indicated in Table 1 and a friction angle of 32°. In addition, the stereographic projections of the DIPS software [3], show that there is no presence of wedge, planar and direct toppling, with a dip of the slope equal to 30° as shown in Fig. 1, characteristics of the natural slope. On the other hand, the geometric alteration of the slope, specifically the change of slope, where at first, we worked with the slope dip of a value of 30°, which did not present possible failures. For a second kinematic analysis where the slope dip has a value of 55°, added to the characteristics of the discontinuities present in the slope, a possible wedge failure is observed due to the intersection of the main plane and a secondary plane, J1 and J3 respectively, as shown in Fig. 2.



Symbol	Feature
▫	Critical Intersection

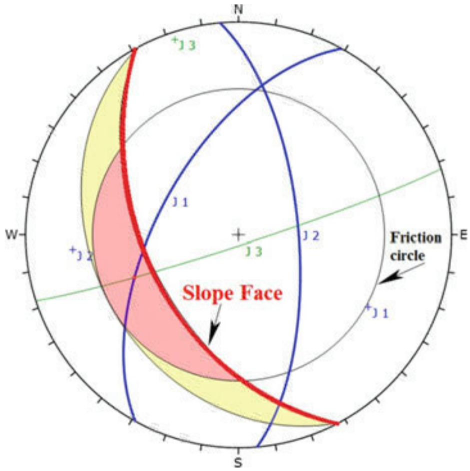
Kinematic Analysis	Wedge Sliding
Slope Dip	30
Slope Dip Direction	242
Friction Angle	32°

	Critical	Total	%
Wedge Sliding	0	3	0.00%

	Color	Dip	Dip Direction	Label
User Planes				
1	■	59	299	J 1
2	■	67	85	J 2
3	■	86	162	J 3

Plot Mode	Pole Vectors
Vector Count	3 (3 Entries)
Intersection Mode	Grid Data Planes
Intersections Count	3
Hemisphere	Lower
Projection	Equal Area

Fig. 1 Kinematic analysis model 1, natural slope. *Source* DIPS



Symbol	Feature
▫	Critical Intersection

Kinematic Analysis	Wedge Sliding
Slope Dip	55
Slope Dip Direction	242
Friction Angle	32°

	Critical	Total	%
Wedge Sliding	1	3	33.33%

	Color	Dip	Dip Direction	Label
User Planes				
1	■	59	299	J 1
2	■	67	85	J 2
3	■	86	162	J 3

Plot Mode	Pole Vectors
Vector Count	3 (3 Entries)
Intersection Mode	Grid Data Planes
Intersections Count	3
Hemisphere	Lower
Projection	Equal Area

Fig. 2 Kinematic analysis model 2, wedge failure. *Source* DIPS

5.2 Numerical Analysis for the Rock Slope

In this present investigation, the finite element method was used to be able to analyze the stability of the ET-002 slope by calculating the safety factor by means of the shear strength parameter reduction (SRF) method, which represents a linkage between the resistance of the system at failure and the resistance found.

With the help of the Phase2 program, it was possible to represent the two-dimensional model of said slope with its respective geometry, this is observed in

Table 2 Slope input parameter ET-002

Parameters	Values
Uniaxial compressive strength (σ_{ci}, MPa)	157
Geological resistance index (GSI)	54
Intact rock (mi)	30
Disturbance factor (D)	0.7

Table 3 Properties of the ET-002 slope both intact rock and the discontinuities

Properties	
Intact rock	Specific weight = 0.026 MN/m^3
	Young's modulus (E, MPa) = 8183.02
	Poisson's ratio = 0.25
	Friction angle (°) = 61.56
	Angle of dilatation (°) = 0
Discontinuities	Apparent dip/direction (Set 1, °) = 42.19/299
	Apparent dip/direction (Set 2, °) = 65.24/85
	Apparent dip/direction (Set 3, °) = 68.07/162
	Friction angle (°) = 61.56
	Cohesion (C, MPa) = 0
	Average apparent separation (Set 1, m) = 1.10
	Average apparent separation (Set 2, m) = 0.65
	Average apparent separation (Set 3, m) = 3.46

Fig. 2. To determine the properties of said rocky material found in the slope under study (ET-002), they were found using the ROCDATA V3 program, in which the following initial parameters were introduced, which are observed in Table 2.

Once the data has been entered into "ROCDATA", the following output parameters are obtained, which are shown in Table 4.

Also, the intact rock properties and discontinuities of slope ET-002 were identified, as detailed in Tables 3 and 4.

Once having the necessary properties and parameters, the slope is designed with its respective geometry, which is shown in Table 5.

Table 4 Slope output parameter ET-002

Parameters	Values
mb	2.396
s	0.0013
a	0.504
Cohesion (C, MPa)	0.821
Friction angle (°)	61.56
Young's modulus (E, MPa)	8183.02

Table 5 Geometry for the design of model 2 of slope ET-002

Geometry for the design of the slope ET-002	
Slope height	10 m
Slope toe length	10 m
Slope head length	10 m
Horizontal length of slope	17.32 m
Slope angle	30°

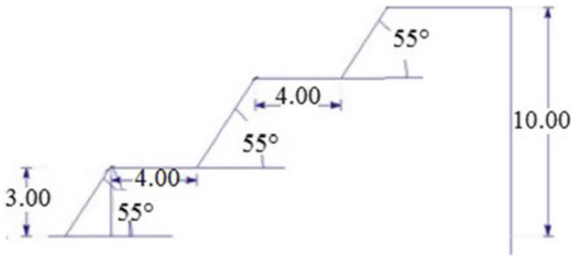


Fig. 3 Design of the ET-002 slope model with benches. *Source* Phase 2

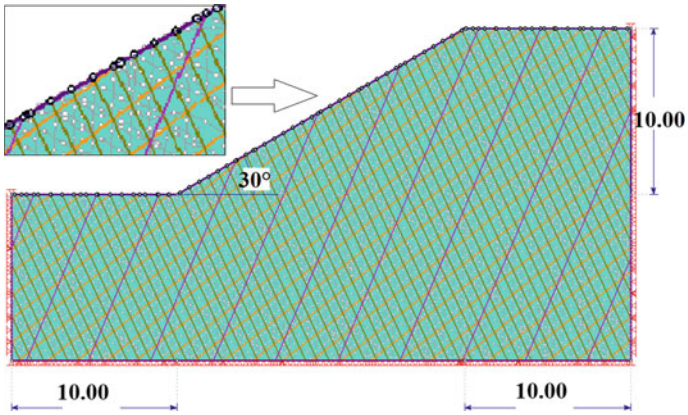


Fig. 4 Slope ET-002 (model 1) meshed and discretized. *Source* Phase 2

For this investigation, 2 cases were considered in relation to the ET-002 slope. The first model consists of a slope without the presence of banks while, in the second model, the slope is presented with the presence of 2 banks.

In the slope under study, 2 banks were considered which were produced by cuts, these banks have a height of 3 m and a length of 4 m, the respective angle of cut is 55°. It is necessary to emphasize that the banks implemented in the slope represent areas for the construction of houses and roads in certain cases.

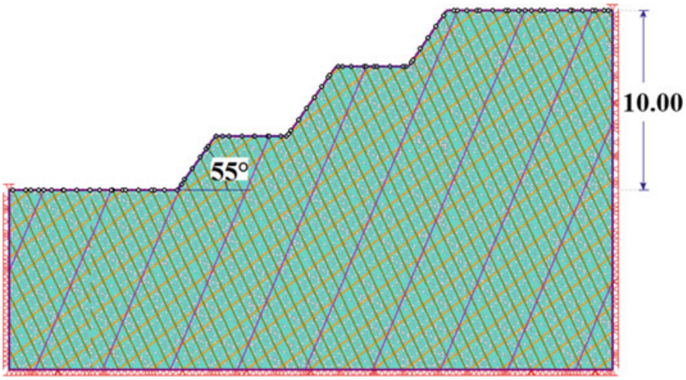


Fig. 5 Slope ET-002 (model 2) meshed and discretized. *Source* Phase 2

Figures 3 and 4 show the design of the two-dimensional models with their corresponding mesh made by the using the Phase 2 program (Fig. 5).

6 Results and Discussion

In this section, the results of the cases proposed in this investigation are shown in Table 6. For model 1, the safety factor (SFR) was statically calculated which resulted in “19.26” and it was also calculated pseudostatically giving as a result a safety factor of “9.66”, using the Phase2 software which applies the numerical method of finite elements. For both cases, the system is stable, this can be seen in Figs. 6 and 7.

In this model 2, the safety factor (SFR) was statically calculated which resulted in “0.89” and it was also calculated pseudostatically resulting in a safety factor of “0.48”, using Phase2 software which applies the finite element numerical method. For both cases the system is unstable, this can be seen in Figs. 8 and 9.

Table 6 shows the results of the two models under study of the ET-002 slope that have been analyzed statically and pseudostatically.

The result in the kinematic analysis due to the change in geometry in the dip due to the implementation of banks within the system generates a possible wedge failure due to the participation of the families of discontinuities J1 and J3. Due to the more representative participation of the main families, J1 and J2 compared to the discontinuities J3, it becomes a second family, which would not have a greater influence on

Table 6 Results of the safety factor of the slope ET-002

Slope ET-002 cases	SRF (static)	SRF (pseudostatic)
Model 1	19.26	0.89
Model 2	9.66	0.48

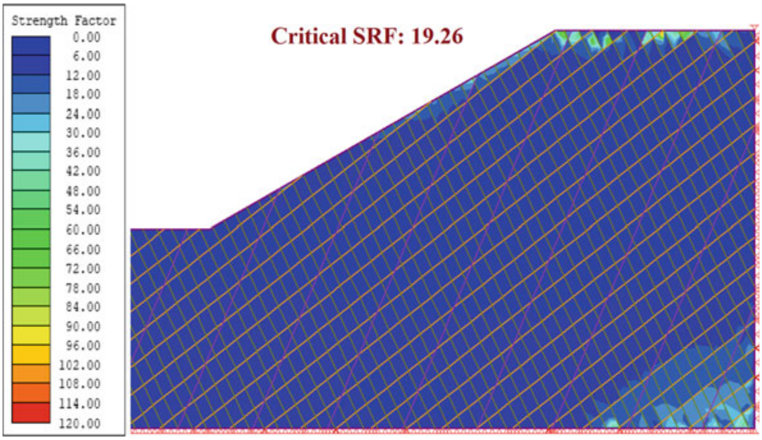


Fig. 6 Critical SFR of the ET-002 slope for statically analyzed model 1. *Source* Phase 2

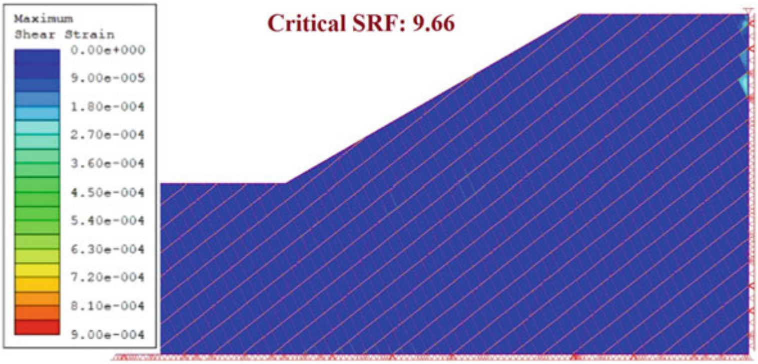


Fig. 7 Critical SFR of the ET-002 slope for model 1 analyzed pseudo statically. *Source* Phase 2

the occurrence of a wedge fault. On the other hand, the representation of said discontinuities by Phase2 shows a tendency to planar failure due to the participation of J1 in the slope understudy, but according to the conditions according to the kinematic analysis, the slope has a dip of 55° which is less to the dip of discontinuity J 1 (59°), where it would be failing as a planar fault. One of the aspects that were noticed was the direct influence of the sudden change in geometry to determine possible failures and thus obtain slope stability.

One of the criteria by which the investigation was carried out was to witness how much difference there could be between a slope without banks and with banks since these cases can be a bit like our problem.

On the other hand, the study area is in the Pacific Ring of Fire, an area of seismic activity. Therefore, static, and pseudo-static analysis was performed for both models under study, considering a seismic coefficient of 0.3 because the Phase2 program

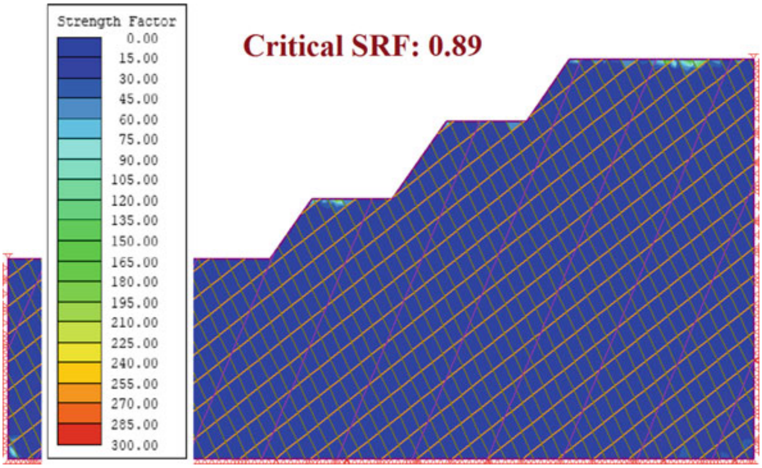


Fig. 8 Critical SFR of the ET-002 slope for statically analyzed model 2. *Source* Phase 2

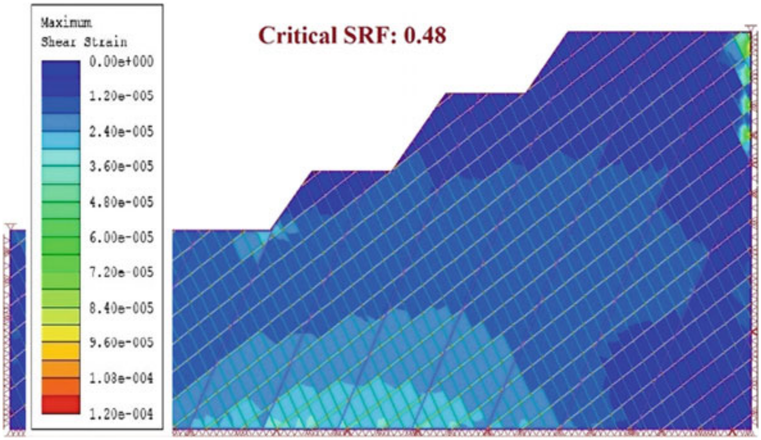


Fig. 9 Critical SFR of the ET-002 slope for model 2 analyzed pseudo statically. *Source* Phase 2

only accepts this coefficient as the maximum value. Therefore, an approximate value was used according to Technical Standard E.030 Seismic-resistant Design of the National Building Regulations, where Lima is in zone 4 with a seismic coefficient of 0.45 [8].

According to the results of the ET-002 slope for static analysis, an SFR = 19.26 (model 1, inclination angle 30°) and an SFR = 0.89 (model 2, inclination angle 55°) is obtained, Figs. 6 and 7, respectively. On the other hand, for a pseudo-static analysis of the same slope understudy, an SFR = 9.66 (model 1, inclination angle 30°) and an SFR = 0.48 (model 2, inclination angle 55°) are obtained, Figs. 8 and 9, respectively.

7 Conclusions

Based on the results mentioned above, the following can be concluded:

The research base is supported by a kinematic analysis and a finite element numerical method. On the one hand, the first method identified the type of failure and the behavior of the discontinuities, and thus have an idea in numerical modeling of the Phase2 software, considering the parameters of the intact rock and its discontinuities present on the slope, to later identify the safety factor of the study area.

In model 1, by means of a kinematic analysis of the slope under study "ET-002" it was identified that there are no possible faults that affect said slope.

In the kinematic analysis of model 2 with a dip of 55°, a possible wedge failure is observed due to the intersection of two discontinuities consisting of a principal one (J1 and J3).

Given the results of the safety factors with reduction to shear (SFR) obtained by the Phase 2 program, the decrease in "SFR" can be evidenced. For an inclination angle of 30° with the participation of the seismic coefficient, it has an SFR = 9.66, a value less than the SFR = 19.26 in static conditions. On the other hand, for an inclination angle of 55° with the participation of the seismic coefficient, it has an SFR = 0.48, a value lower than the SFR = 0.89 in static conditions.

The abrupt change in slope that occurs for both cases under study is given by the inclusion of a bank. Having a considerable change in the geometry of the slope and the presence of discontinuities can generate considerable variations with respect to the stability levels (going from stable to unstable) observed through the calculated safety factors.

One of the causes that lead to the alteration of the slopes of the hills is due to the intervention of families or people who are looking for a place where they can build their own home. In addition, the lack of knowledge and technical advice for an evaluation with respect to stability can cause future risks, thus the importance of this type of analysis since many of these places do not have institutional support from the state.

For future research, it would be good to compare the numerical methods of discrete and finite elements to see how much difference one method can influence to model the fractures and the other for the rest of the domain.

References

1. Ingemmet (2011) Geological geotechnical study and susceptibility to mass movements in the Virgen de Fátima sector, energy and mining sector. Lima
2. Mithresh KP, Amalesh J, Arindam D, Murali A (2017) Evaluation of the stability of a rock slope using finite element modeling. Civil Engineering Department, India
3. Anangsha A, Seema P, Amalesh J (2017) A methodology for modeling an effective two-dimensional plane deformation analysis of articulated rock slope. Civil Engineering Department, India

4. Fuming L (2020) Stability analysis of geotechnical slope based on strength reduction method. Geotech Geol Eng
5. Ahmed S, Seshagiri R (2020) Rock mass slope stability analysis under static and dynamic conditions in Mumbai, India. J Civ Eng
6. Hoek E, Carranza-Torres C, Corkum B (2001) The Hoek-Brown failure criterion. ResearchGate
7. Rocscience (2020) Finite element analysis for excavations and slopes. Rocscience Inc., Toronto
8. Ministerial Resolution N°. 043-2019-HOUSING (2019) Technical standard E.030 earthquake-resistant design of the national building regulations. Lima

The Environmental Performance of Earth Construction Systems in Jordan's Mediterranean Climatic Zone

Zahra Al-Shatnawi

Abstract The aim of this paper was to investigate the thermal and energy performance of different earth construction methods, particularly in Jordan's Mediterranean climatic zone. An IES-VE simulation was conducted to compare five proposed earth construction methods against historic and conventional construction methods used in Jordan, in terms of indoor air temperature performance and operational heating and cooling demand. The findings from the simulation analysis show that a double compressed earth block (CEB) wall constructed model and a hybrid wall constructed model consume the smallest amount of operational energy and have the best thermal winter performance. Moreover, the historic earth wall construction methods perform slightly better than other options during summer. It is concluded that if the appropriate earthen construction method is adopted and combined with suitable passive strategies, earth construction can perform better than conventional building methods used in Jordan's Mediterranean climatic zone, resulting in energy-efficient and comfortable structures.

Keywords Earth construction · Thermal and energy performance · Jordan

1 Introduction

Earth been used as a natural building material for thousands of years. More than half of the population of the developing countries currently lives in earth-constructed dwellings [1]. This method is now attracting attention in industrialized countries, due to its low carbon footprint and low thermal conductivity, as combining earth as a natural building material with advanced construction techniques can result in modern ecological buildings [1–3].

Earth has long been used as a construction material in Jordan. The two construction methods primarily used in the past were adobe and mud with stone [4–6]. Dwellings in the Jordan valley were built using sun dried mud-bricks, while some in the mountainous regions of Jordan were constructed using stone and mud [7].

Z. Al-Shatnawi (✉)
Oxford Brookes University, Oxford OX3 0BP, UK

T. Kang and Y. Lee (eds.), *Proceedings of 2021 4th International Conference on Civil Engineering and Architecture*, Lecture Notes in Civil Engineering 201,
https://doi.org/10.1007/978-981-16-6932-3_2