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To cite this article: E Karapa *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **841** 012004

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Early study of slope strength modeling of block type x

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Abstract. The development of slope strengthening forms requires innovative efforts. One way is to make a particular prototype or model by performing laboratory-scale testing. Slope failure with the use of the riprap method is still frequent; therefore, it needs to be supported by a block to maximize this riprap method. This research is a preliminary study in making the type x block model a form of slope reinforcement. This study has three types of material: clay as slope making material, crushed stone as riprap, and concrete for making type x blocks. This study aims to determine the index value of the soil properties used as slope-making material and to measure the value of the x-block type tensile strength test. The soil properties index shows that this soil is clay with a plasticity index of 10.51%, clay content 42.79%, Friction Angle (ϕ) of 23.24°, and Specific Gravity (G_s) of 2.728. Whereas the tensile strength test results of 4 type x blocks, namely type x brace 1, type x locked 1, type x brace two, and type x closed 2, are 0.293 MPa, 0.128 MPa, 0.205 MPa, and 0.128 MPa, respectively. The test results show that the Block x brace model's tensile strength is greater than the locked Block X model.

1. Introduction

Landslides are natural disasters that often originate from steep slopes. Expanding urbanization areas and changing land-use practices can increase the potential for landslides. Despite efforts to improve, predict, and mitigating measures, natural landslide disasters and engineered slope failures still have many social, economic, and environmental impacts [1]. The fundamental aspects of studying the problems related to landslides and slopes include a trigger, and runout mechanisms are mobility analysis and countermeasures approaches. Because slopes consist of native or transported soil material, the engineering's nature and behavior vary greatly and cannot be predicted to the right extent. Attention to this subject is emphasized in the theoretical study and practice of geotechnical engineering [2]. In practice, slopes often experience significant increases and decreases in water levels due to various causes such as rainfall, tides, and the operation of large reservoirs. Many landslides are induced by drawdown [3].

The process of erosion on the surface of a slope is often the beginning of an avalanche. The erosion process is a natural process that is easily recognizable. Still, in most places, this incident is compounded by human activities in low land use, deforestation, mining, plantation and cultivation activities, construction/development activities that are not well ordered, and road construction. One method of handling slopes is by reducing the erosion of slope surfaces. Plant media or vegetative methods have been widely carried out as one way of controlling slope surface erosion [4]. The non-vegetative process for handling slope erosion can also be done with a type of flexible slope safety riprap building [5].



Riprap is included in the type of flexible revetment, which is a building that protects the cliff from scouring with rock layers. The use of riprap as a retaining wall protects the peak with rock layers following the cliff shape slope. But in its implementation, the use of riprap buildings often also fails due to particle erosion, the slope movement of the rock mass, and the mass movement of material along the internal slip surface in the riprap blanket [6]. To prevent failure, the authors strengthen the riprap with x type concrete block supports. This type of concrete block is a concrete block that looks like an x-shaped front. This block will be installed following the installation of riprap stones along the slope. The use of type x concrete blocks aims to withstand heavy loads and lock the installed stone riprap so that no movement occurs. This research is a preliminary study that aims to study the reinforcement of slopes with the support of type x concrete blocks in an example of a laboratory-scale model. From this study, it is expected that slope reinforcement with type x blocks can be an alternative to increase the riprap function's effectiveness as a slope reinforcement.

2. Literature Review

2.1. Slope Stability

Slope stability is the potential for land-covered slopes to survive and experience movement. Stability is determined by the balance of shear stress and shear strength. Previously stable slopes may be initially influenced by preparation factors, making the slopes unstable conditionally. The trigger factors for slope failure can be climate events, making the hill dangerous, leading to the mass movement. The main internal regulating factors are; slope geometry, potential failure fields, surface drainage, and groundwater conditions [7], where external factors are rainfall, seismicity, and human-made activities [8]. These factors, in combination, will be responsible for determining slope stability conditions. A mass movement can be caused by an increase in shear stress, such as loading, lateral pressure, and transient forces. The shear strength can be reduced due to weathering, pore pressure changes, and organic matter.

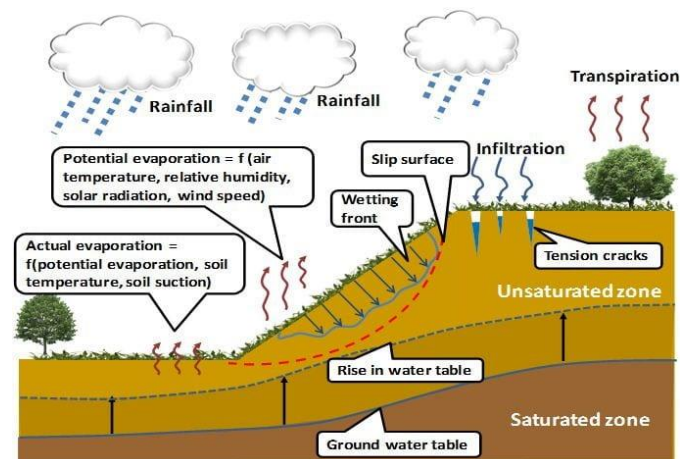


Figure 1. Mechanisms of rainfall-induced slope failure, Rahardjo et al. 2012

Many slope failures occur on steep slopes of residual soil with deep groundwater levels during rainfall. The significant thickness of the unsaturated soil zone above the groundwater level is a common characteristic of steep slope residual soils. Negative pore water pressure in unsaturated soils is greatly influenced by changes in flux boundary conditions (i.e., infiltration, evaporation, and transpiration) resulting from variations in climatic conditions. The mechanism of slope failure due to rainfall is shown in Figure 1. In other words, the unsaturated zone is the dynamic interface of the slope with the environment, and as a result, the slope safety factor is dynamically influenced by climate change [9].

2.2. Index Soil Properties

Slope stability analysis is a geotechnical problem characterized by many sources of uncertainty. Some uncertainties are related to the variability of soil properties involved in the study [2].

Slope failure implies that the slope safety factor at the time of failure is unity. Based on this information, reverse analysis is often done to increase knowledge about slope stability parameters, such as soil shear strength parameters and pore pressure parameters at the time of slope failure. Using back analysis, important factors that might not be well represented in laboratory testing, such as soil heterogeneity and the effect of fissures and fabric structure on soil shear strength, can be included [10]. Criteria for soil properties index parameter based on ASTM and AASHTO is presented in Table 1

Table 1. Soil Property Index Parameters (ASTM, AASHTO) [11]

Index Properties		Unit
Specific Gravity (Gs)		-
Naturale State (Soil Indeks)	Water Content (w)	%
	Wet Density (ρ_{wet})	gr/cm ³
	Dry Density (GDRY)	gr/cm ³
	Void ratio (e)	-
	Porosity (n)	%
Atterrberg Limits	Degree of Saturation (Sr)	%
	Liquid Limit (LL)	%
	Plastic Limit (PL)	%
	Plasticity Index (PI)	%
	Shrinkage Limit (SL)	%
Grain Size	Gravel	%
	Sand	%
	Silt	%
	Clay	%
USCT	Soil Classification	-
UCT	UCT (Unconfined Compressive Test)	kg/cm ²
	Direct Test	Cohesion (C)
Compact Test	Friction Angle (ϕ)	degree
	Optimum Moisture Cont. (w_o)	%
	Maximum Dry Density (ρ_{dm})	t/m ³

2.3. Riprap and Revetment Blocks

Rock riprap protects soil from erosion due to concentrated runoff. It is used to stabilize slopes that are unstable due to seepage. It is also used to slow down the speed of concentrated runoff, which increases the potential for infiltration [12].

Riprap is a building that protects the cliff from scouring with layers of rock. The grind that occurs is generally due to erosion at the bottom or bottom of the cliff. Rock layers can slow down or stop the deterioration that occurs due to the runoff of water flowing at a cliff's base. Riprap rock layers resist erosion through a combination of stone size and weight, rock durability, and gradation and thickness of riprap blankets. Interlocking rock angles provide resistance to movement between protective stone blocks. Flow characteristics also significantly affect the stability of the riprap protector. Local scouring, which is influenced by flow characteristics and bed loads, determines the protective base's protection. The slope of the channel generally follows from the slope of the existing cliff.

Rock riprap is widely adopted as an economical method to prevent dykes, embankment dams, and other riparian structures from runoff. Riprap stone layers having the right size and thickness are essential to reduce the destructive impact of erosion and protect the system from hydrological events [13].

Even though the riprap method is relatively easy to do, it also has weaknesses that can cause slope failure. Combining riprap and block is an exciting thing to do in overcoming the slope problem—the use of revetment structures in general to overcome erosion problems. The revetment structure consists of a cover layer and a filter layer. The revetment cover may be porous or permeable and rigid or flexible, depending on the material used for its construction. A filter is a transition layer made from geotextiles, granular materials (e.g., gravel, broken stones), or both. Concrete blocks have been used as one of the overburden materials for the past decade with large variations such as shape, placement system, etc. Permana [14] says that in all variations, modification to make the block revetment surface more permeable (with gaps or porous) is an attractive technique to increase the stability of the revetment block.

2.4. Tensile Strength Test

Concrete is an aggregate conglomerate (such as gravel, sand, and crushed stone), water, hydraulic cement (such as Portland cement), and other components and additives. It is generally liquid when first made, allowing it to be poured or placed into shape, then hardened, and never again fluid, in general, Sense. Usually, moisture is present in standard raw concrete (i.e., has a high pH). Alkaline materials can be supplied by cement, aggregates, additives, and even environments where hardened concrete exists (such as salt, placed on concrete to melt ice) [15]. One of the most popular concrete used is a mixture of Portland cement, mineral aggregates, and water. The mechanism of concrete is that concrete hardens because cement hydrates and glue all the other components together. Because concrete has become a familiar and increasingly broad construction material, concrete specifications such as durability, quality, compactness, and substantial optimization are critical. This fact leads to significant research and development regarding its design and preparation [16].

For evaluating concrete tensile strength, there are three well-known methods: (i) direct tensile strength, (ii) tensile strength, and (iii) flexural tensile strength [17]. Tensile strength is the main material parameter in the analysis of concrete structures. This is usually determined using either the direct tensile test or the separation test arrangement [18]. Tensile strength testing is one of the necessary mechanical tests performed on a material. This test is done by putting pressure on the material and measuring the material's reaction to the forces applied to it. Tensile testing applied to the material causes the material to elongate. When a material can no longer withstand the pressure applied to it, it causes failure or deformation [19].

Tensile strength is related to compressive strength, although this relationship depends on several factors such as, for example, aggregate type and particle size distribution, concrete age, curing process, and air content. The tensile strength of concrete is about 10 to 15% of the compressive strength [20].

3. Methodology

The research methods carried out include the design of the study, testing the soil property index, and making test specimens to test the tensile strength.

3.1 Research Design

This study's design was the loading test on slopes made from clay medium covered by riprap with type x block supports, as shown in Figure 2.

3.2. Testing the Soil Property Index

The type of soil used to make the slope is soft ground (medium clay). The background used is first checked in the soil mechanics laboratory to determine grading data, moisture content, Atterberg limit (liquid limit, plastic limit, plastic index), dry weight maximum, optimum moisture content, and proctor compaction test.

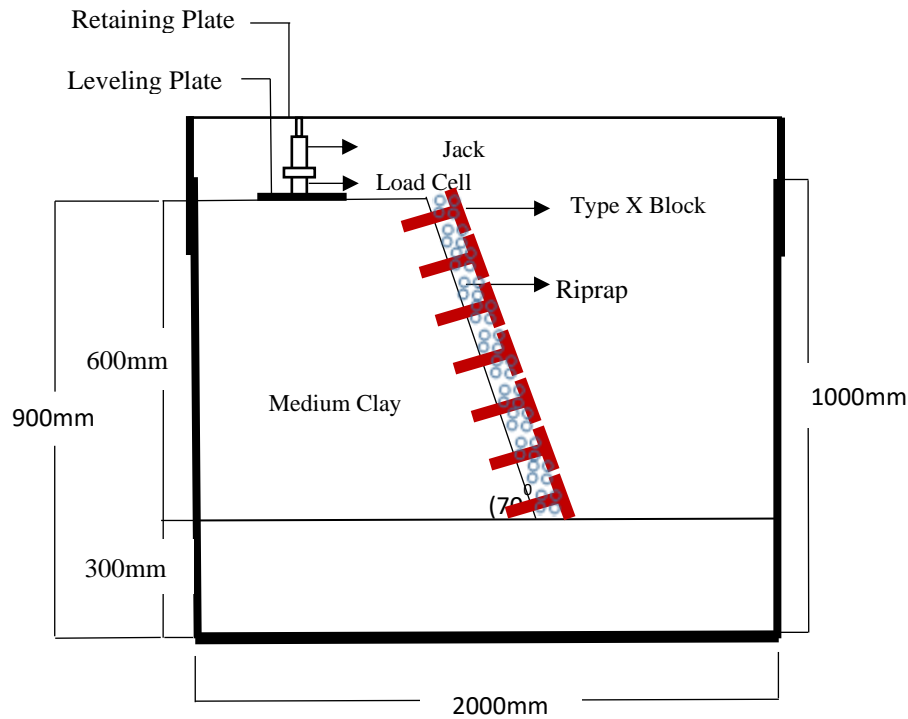


Figure 2. Illustration of slope strengthening research design with x-type block

Table 2. Soil Index Properties

Index Properties		Unit	Value
Specific Gravity (Gs)		-	2.73
Naturale State (Soil Indeks)	Water Content (w)	%	29.17
	Wet Density (get)	gr/cm ³	1.72
	Dry Density (GDRY)	gr/cm ³	1.33
	Void ratio (e)	-	0.01
	Porosity (n)	%	0.51
Atterberg Limits	Degree of Saturation (Sr)	%	75.67
	Liquid Limit (LL)	%	40.26
	Plastic Limit (PL)	%	30.11
	Plasticity Index (PI)	%	10.15
	Shrinkage Limit (SL)	%	25.99
Grain Size	Gravel	%	0.00
	Sand	%	24.60
	Silt	%	32.61
	Clay	%	42.79
USCT Soil Classification		-	CL
UCT UCT (Kuat Tekan Bebas)		kg/cm ²	0.177
Direct Test	Cohesion (C)	kg/cm ²	1.63
	Friction Angle (φ)	degree	23.24
Compact Test	Optimum Moisture Cont. (w _o)	%	26.37
	Maximum Dry Density (g _{dm})	t/m ³	1.37

3.3. Making Block Type X

The making of type x blocks is done in two types: type x brace blocks and locked type x blocks. The work steps of manufacturing are as follows:

Making formwork of each class using a 6 mm thick triplex (Figure 3) and then install reinforcement using a 2 mm wire size. After weighing material for sand, coarse aggregate, cement, and water using the K 300 concrete strength standard are set up. Manufacture of type x brace and type x locked concrete for the tensile strength test. Making the frame for the tensile strength test using 14 mm and 8 mm iron (Figure 4).

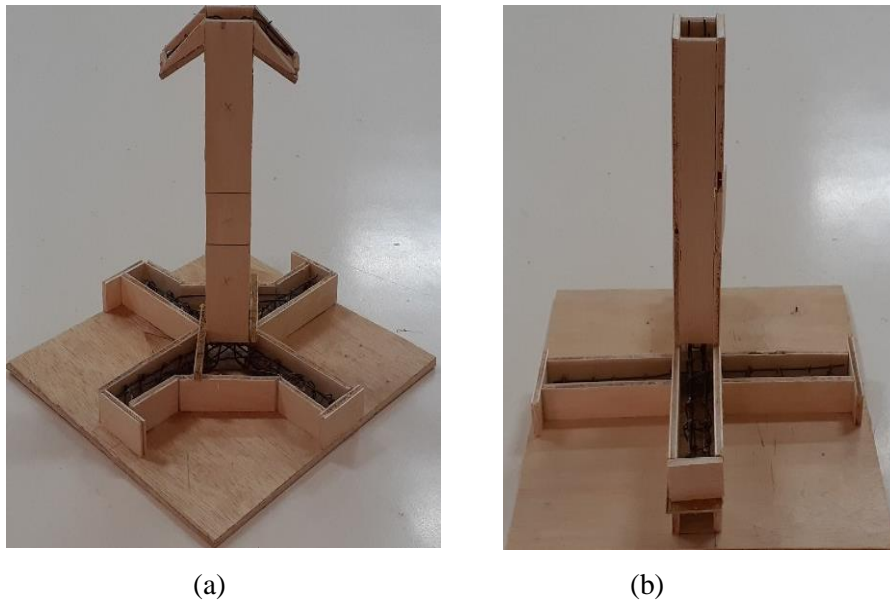


Figure 3. Mall type x brace block (a), locked type x block (b)

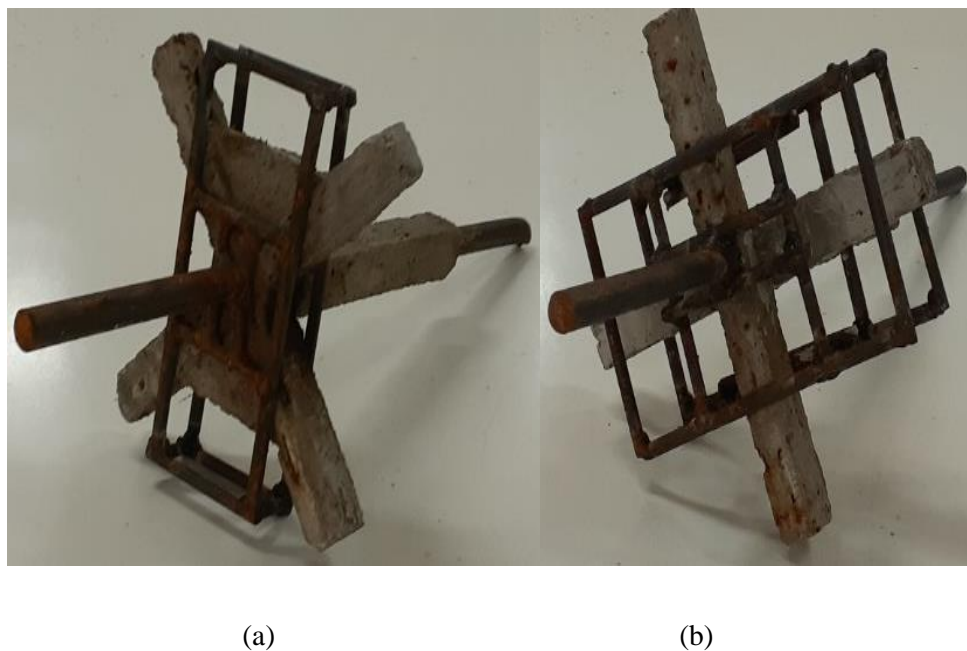


Figure 4. Making concrete blocks and frames for tensile strength test, a. concrete block type x brace, b. locked type x concrete block

3.4. Testing

Tensile strength testing is carried out in a structural laboratory using a Universal Tensile Testing Machine, Type YU100CS-TTM. The samples tested were four samples, two samples of each type (Figure 5)

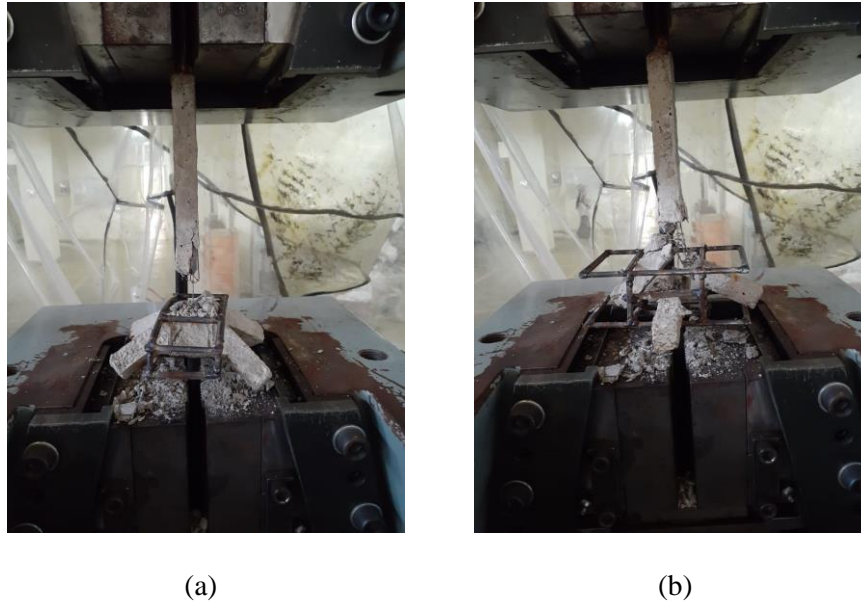


Figure 5. Tensile strength testing of type x brace block (a), locked x type block (b)

4. Results and Discussion

From the results of testing of 4 samples (Figure 6), it appears that the tensile strength of the block x Brace model is greater than that of the locked x block model. This is due to differences in the cross-sectional shape of the two blocks. The cross-section of type x brace blocks together while the type x block is locked apart in tiers.

Table 3. Tensile and Compressive Strength Results

Test Objects	Load (N)	Cross-sectional area (mm ²)	Tensile strength (MPa)	Compressive strength (MPa)
Blok x brace 1	2.048	7000	0.293	1.953
Blok x locked 1	1.024	8000	0.128	0.853
Blok x brace 2	1.434	7000	0.205	1.367
Blok x locked 2	1.024	8000	0.128	0.853

The loading test will be carried out in 2 types of reinforcement by the research design, namely reinforcement type x brace blocks and locked type x blocks. The type x block that will be used in the loading test is by the results of the tensile strength test. The assumed scale of the model or prototype is 1:10 scale. So the value of the tensile strength assumption of type x block results of the test are type x brace 1 (2.93 MPa), type x locked 1 (1.28 MPa), type x brace 2 (2.05 MPa), and type x locked 2 (1.28 MPa).

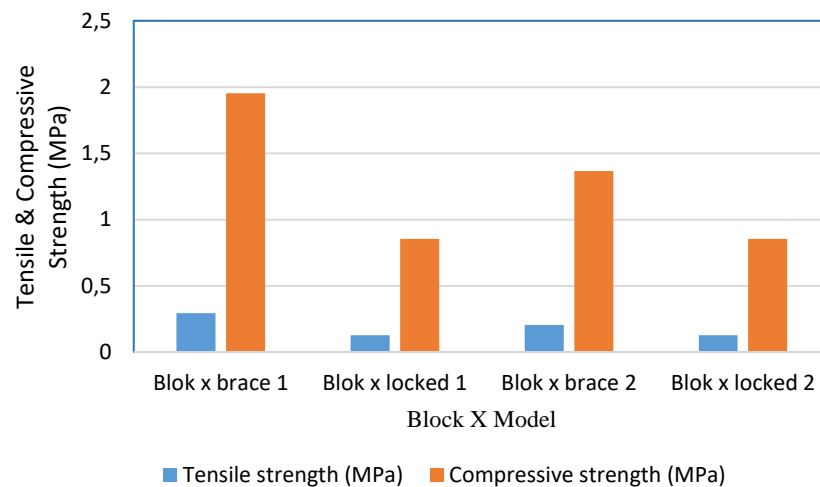


Figure 6. Graph of tensile strength and compressive strength of type x blocks

5. Conclusions

The analysis of the soil properties index shows that this soil is clay with a plasticity index of 10.51%, clay content of 42.79%, Friction Angle (ϕ) 23.24°, and Specific Gravity (G_s) 2.728. Whereas the tensile strength test results of 4 type x blocks, namely type x brace 1, type x locked 1, type x brace two, and type x closed 2, are 0.293 MPa, 0.128 MPa, 0.205 MPa, and 0.128 MPa, respectively. The test results show that the block x Brace model's tensile strength is greater than the locked block x model; this is due to differences in the cross-section of the two blocks. The cross-section of type x brace blocks together while the type x block is locked apart in tiers.

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