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Analysis On Seepage Through Senggarang Coastal Embankment in Johor, Malaysia.

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Abstract: Seepage is one of the most common problems experienced with embankments. Due to soil permeability and pore pressure inside the porous medium, seepage is a critical phenomenon that occurs at Senggarang Coastal Embankment (SCE). In this study, seepage occurred in the inland region, causing flooding and harming the crops. The goal is to monitor and record the seepage rate along the chosen point of the embankment. This point was chosen based on the severity of the seepage and the location's accessibility. A seepage profile and its relationship to the tidal effect on the embankment were derived from the acquired result. A direct shear test was conducted in the laboratory to determine the shear strength of the soil for the SCE. During the arrangement of the field investigation, two distinct points with the most significant seepage were identified. The seepage analysis was conducted on November 11 and 12, 2022, during the highest chart tide of the month. This also applies to collecting the soil sample for the direct shear test to determine the slope's cohesion value. The analysis reveals that the seepage rate appears proportional to the rise in tide height and the volume of water discharged by seepage at points 1 and 2. The direct shear test evaluates the amount of cohesion which leads to the findings that the embankment has a very low cohesion value which causes the seepage issue to happen. This study, found that the seepage condition for SCE is alarming and requires immediate attention to prevent the embankment from collapsing. Changing the soil profile to a better cohesive type of soil will eventually decrease the amount of seepage.

Keywords: Embankment, Coastal, Seepage Profile, Slope, Tide,Monitor.

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1. Introduction

Senggarang is a district located in Batu Pahat, Johor. Seepage that occurs at Senggarang Coastal Embankment (SCE) are concerning which has never met it solution until these days. Due to the enormous dilution factor and the difficulty in detecting this discharge, less attention has been made to seepage discharge as a possible source of dissolved components to the oceans [1]. As shown in figure 1, 10 kilometers of coastline consisting of Sungai Lurus and Pantai Terus have been divided into 21 locations for analysis. Based on their accessibility, these 21 points between points 14 and 21 have been chosen, as this is where the seepage occurs. The area of study consists of 4KM of the coastline. The sea's rising water level has an impact on the accretion and erosion processes that impact the coastline. Embankment is to support the raising of a roadway above the level of the existing ground surface in the surrounding area, an embankment is an artificial mound that is constructed using earthen materials such as stone and soil, and then properly compacted [2]. Unfortunately, the embankment has an unanticipated seepage problem that allows sea water to flow through it and into the river, and as the sea level rises, this problem becomes more severe. However, if seepage becomes too concentrated or uncontrolled, it will cause water loss, reduce shear strength, and perhaps cause the embankment to fail [3]. Along this coastline, seepage indicates that seawater is leaking through the embankment, causing crop damage on the land. Seepage is a fundamental process in earth fill dam engineering, occurring due to soil permeability and pore pressure in porous media [4].

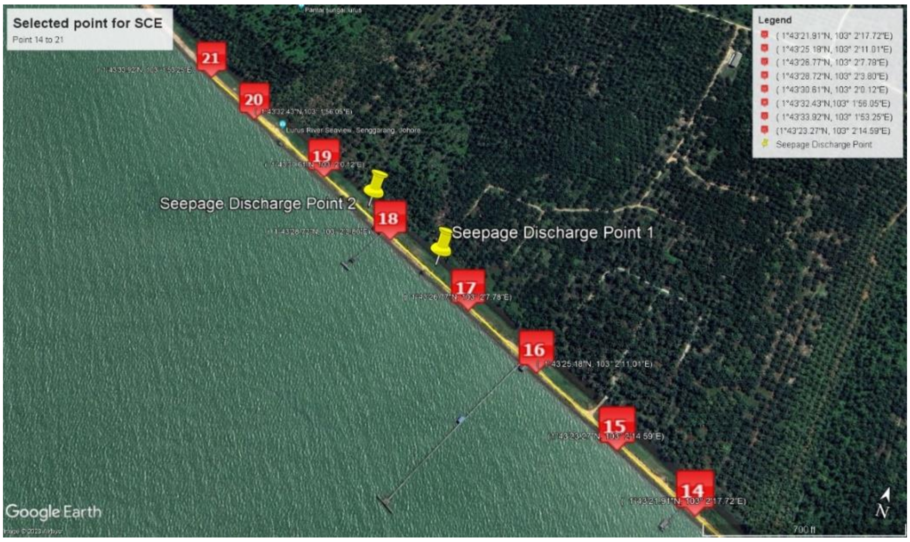

Figure 1: Area of study

Figure 2: Embankment along the coastline

In this study, the primary issue is poor embankment along the Senggarang coast, which is the last line of defense against the sea during the rainy season. This seawater could leak through particular flaws in the embankment, causing a seepage problem. As the water level begins to rise, this occurs. Consequently, it is necessary to investigate and find a solution before the embankment completely fails and affects the local inhabitants. The Senggarang coastal embankment is currently suffering failures such as seepage, which will lead to potholes on the service road and floods inland during high tide. Reducing porewater pressure through improved drainage could possibly ensure longer life of embankments [5].

As part of the project, seven areas along the 4-kilometer-long Senggarang Coastal Embankment will be investigated for seepage problems. By analyzing these subdivided locations, the site of seepage may be determined, and the related seepage discharge values are easily obtained, as the seepage discharged points are difficult to access. The examination focused on positions 14 to 21 because seepage only occurs between these locations. The seepage discharge locations at SCE are both horizontal and vertical, however only the horizontal discharged points are evaluated in this study. To evaluate seepage, it is necessary to examine the ocean's rising levels for a whole 12-hour tide cycle. This cycle indicates the pace and duration of seepage because it is tied to the tidal height, which will cause the embankment to failed.

In addition, a soil test was undertaken to analyses the seepage-related characteristics. The soil cohesion test being conducted by using direct shear test because seepage of water not only influence soil suction but also can cause changes in microstructure in soil that can subsequently affect soil–water retention and shear strength of soil [6] The objective of a direct shear test is to evaluate the shear strength of a soil by forcing the soil to shear at a consistent rate along an induced horizontal line of weakness. The obtained result was then used to purpose mitigation measure to eliminate seepage discharged through the embankment.

The aim of this study is to investigate the seepage profile by monitoring and recording the seepage at Senggarang Coastal Embankment (SCE). Soil cohesiveness parameter are gather by conducting laboratory study and the obtained result are used to provide mitigation measure for the embankment to deduced seepage rate. This result will lead to seepage profile which then is used by Jabatan Perairan dan Saliran (JPS) that will be utilized to decrease the seepage problem.

2. Materials and Methods

Figure 3 show the methodology flow chart of this study.

2.1 Embankment of Senggarang coastal

Embankments made of strongly compacted soil or rock pieces are known as earthen dams [7]. According to a field investigation, the existing embankment has been damaged by the coastal tides which lead to seepage. This location's coordinates are 1°42'58.77"N to 1°43'33.92"N, 103° 3'5.03"E to 103° 1'53.25"E, as determined using Google Earth. Embankments are frequently used along rivers to prevent flooding, which has become more likely in recent years as the intensity of extreme weather events has increased [8]. This is the subject area of the study.

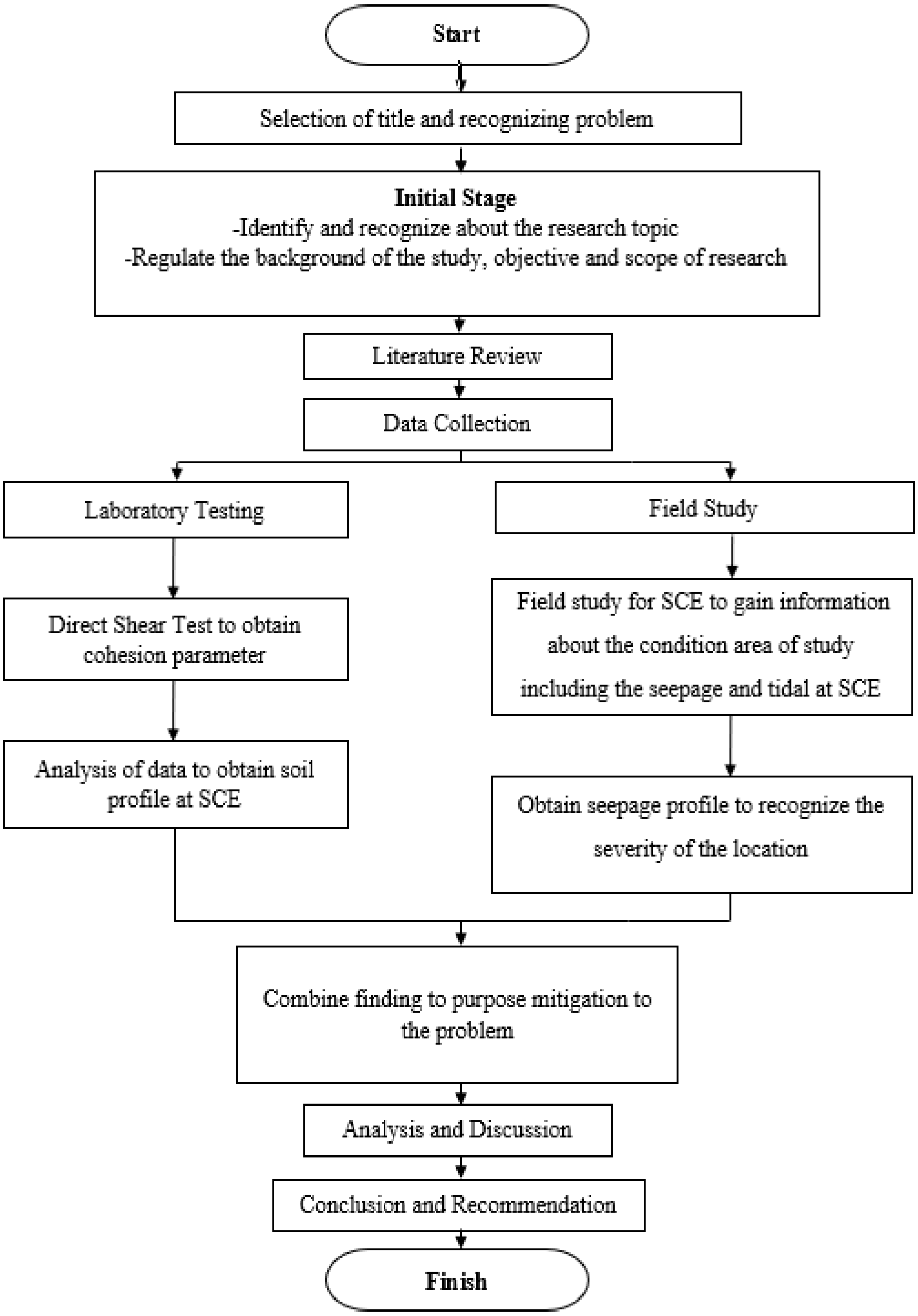

Figure 3: Methodology Flow Chart

2.2 Laboratory testing

Soil and rock samples were collected and preserved with care in the field for accurate results. The majority of testing procedures were conducted according to the international standards. The stability of the slope is related to the water, load, slope and soil parameters, and the soil parameter determines the engineering properties of the slope itself [9]. To determine the cohesiveness, which is related to the issue of seepage, a direct shear test will be conducted (Figure 4). For better evaluation of engineering properties of soil, it is important to analyze the changes in soil microstructure [6].

Figure 4: Direct Shear Test for SCE

2.3 Field Study

The change in water levels can induce seepage in the slope, which may result in the reduction of slope stability and even landslides [10]. The field study is to monitor and record the seepage rate along the selected point at the embankment, as well as draw correlations between the tidal effect and seepage rate profile, as well as how the soil profile may influence the behavior of the embankment.

2.3.1 Tidal Height

Sea level rise will impose a substantial burden on people and societies, especially for a country like Malaysia as it is located in lowlands areas [11]. The tidal height was observed to determine the significant time to obtain the seepage value and rate. Table 1 shows the tide level fluctuations from 11 November 2022 till 12 November 2022. This specific date is selected as they have the highest reading of the month. On the first day of monitoring at SCE, high tide and low tide occur twice daily at the shore.

Table 1: Tide reading at SCE for 11 and 12 November 2022

Date	Low Tide		High Tide	
11 November 2022	0.55m (5:14AM)	0.4 m (6:16PM)	3.04m (11:12 AM)	2.16m (11:29PM)
12 November 2022	0.57m (5:37AM)	0.58m (6:50PM)	2.97m (11:45 AM)	2.05m (11:57PM)

These readings will indicated the presence of seepage because the subject appears to be present only during high tide. The highest tide measured during SCE field research was 3.04 metres on the first day of field testing. On 12th November, it takes 5 hours and 8 minutes to tide height reach from 0.57 meters to 2.97m. While for the tide to goes down it takes about 7 hours and 5 minutes from 2.97m back to 0.58m.

2.3.2 Seepage determination

Seepage, in soil engineering, is the movement of water in soils, often a critical problem in building foundations [3]. It is possible for water to infiltrate into the body of the embankment as a result of an increase in excess pore pressure caused by rising water levels and saturated material. At SCE, a test will be conducted to determine the quantity of seepage flow at the highest monthly tidal level on November 11 and 12, 2022. A few critical spots being assess using piezometer alike method. The output of water flow is collected during the test. To determine the seepage rate, two points (Figure 5) are picked between point 17 to 19 based on the severity of seepage and the accessibility at SCE. These 2 points are about

150m apart from each other.

Figure 5: 2 Points are selected based on the severity of seepage

These two points are subsequently fitted with half-inch PVC pipe (Figure 6), at which point the leak becomes visible to the naked eye. The time interval is 20 minutes, which means that water is collected and recorded every 20 minutes.


Figure 6: Setup for seepage analysis

Figure 7: Severe seepage point causing flood inland area

2.3.3 Calculation

Water collected from the basin are calculated with the formula of:

$$\mathbf{Q = V/T} \quad (4.1)$$

The volume of water collected (V) is divided by the 20-minute interval of time (T) to determine the seepage rate of water collected (Q). Variations in the flowrate may be seen when doing the evaluation. This discovery demonstrates a significant relationship between tide height and water velocity.

3. Results and Discussion

3.1 Direct Shear Test

Roads, dams, embankments, and other important engineering constructions and infrastructure all use soil as a fundamental component [12]. Cohesion of the soils is one of the most essential factors by which a soil's suitability for building foundations, or in this case the embankment, is evaluated. In reality, the safety of slope depends on the shear strength of the soil [13]. The figure of shear stress vs. horizontal displacement (Figure 8) gives the maximum shear stress for a vertical confining tension. For each test, the maximum shear stresses vs. normal vertical confining stresses were plotted. The graphic gives a straight-line approximation of the Mohr-Coulomb failure envelope curve, f, and shear strength for cohesionless soils. From data below (Table 2), a graph has been drawn (Figure 9) to produce the cohesion value of the sample soil taken from SCE. The data shown that the value of cohesion is 0.4 kPa which it is classified as low. Depending on the kind of slope and other soil factors, an increase in cohesiveness will reduce slope stress, strain, and displacement.

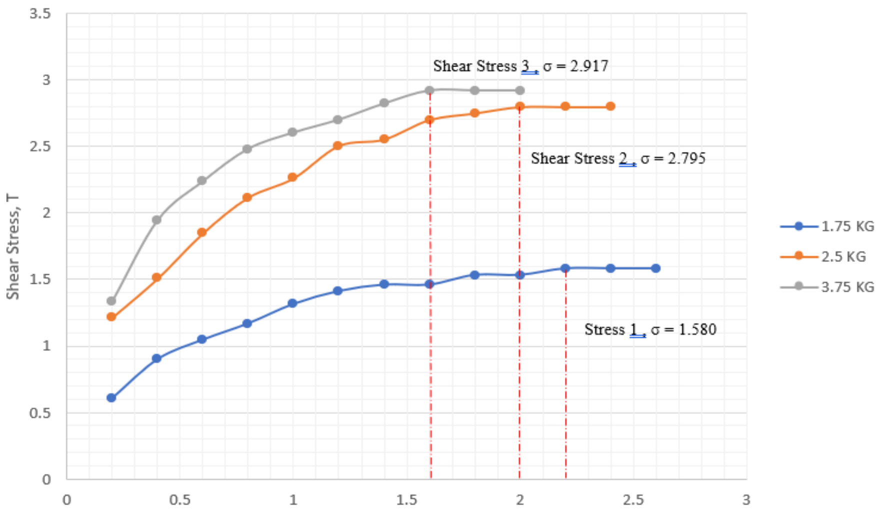

Figure 8: Shear Stress VS Displacement

Table 2: Normal stress and shear stress reading

Loading (kg)	Normal Stress (kN/m2)	Shear Stress τ (kN/m2)
1.75	4.77	1.58
2.5	6.81	2.795
3.75	8.86	2.917

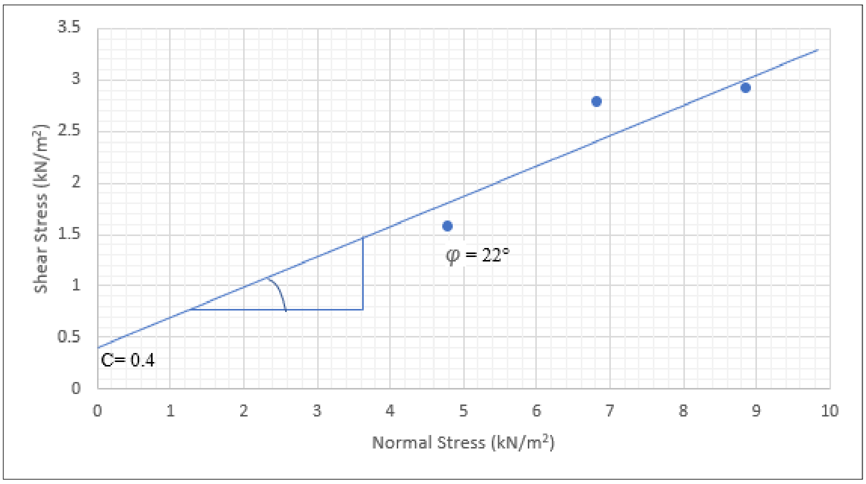

Figure 9: Normal Stress VS Shear Stress

3.2 Seepage analysis and tidal height

At SCE, the study will run a test to evaluate the amount of seepage flow on the highest tide level in a month that is on 11 and 12 November 2022. A few critical spots being assess using piezometer alike method. The output of water flow is collected during the test. Some other conventional observation tools such as piezometers and observation wells also provide valuable information about the water level at the reading points and presence of potential leaks [14]. Table 4 shows the reading of volume of seepage and the seepage rate for SCE seepage analysis. From this table, the seepage starts at 9:40 AM and ends at 2:20 PM for point 1 while point 2 starts at 10:00 AM and ends at 2:00 PM. From this data, assuming that both points have slightly different sea level which affect the seepage flow rate and the volume of seepage. The amount of volume discharge is 243.45 L for point 1 and 333.88 L for point 2 which are will be increasing from time to time if the seepage problem is not focused on. Failure of embankment will lead to failure of embankment because of erosion.

Table 4: Volume of seepage and seepage rate reading point 1 and 2

Date: 12 November 2022	Volume (L)		Seepage Rate (l/s)		
Time	**Point 1**	**Point 2**	**Point 1**	**Point 2**	**Tidal Height (cm)**
5:00 AM	0	0	0	0	84.52
5:20 AM	0	0	0	0	73.24
5:40 AM	0	0	0	0	61.96
6:00 AM	0	0	0	0	75.00
6:20 AM	0	0	0	0	88.04
6:40 AM	0	0	0	0	101.08
7:00 AM	0	0	0	0	114.12
7:20 AM	0	0	0	0	127.16
7:40 AM	0	0	0	0	140.20
8:00 AM	0	0	0	0	153.24
8:20 AM	0	0	0	0	166.28
8:40 AM	0	0	0	0	179.32
9:00 AM	0	0	0	0	192.36
9:20 AM	0	0	0	0	**205.40**
9:40 AM	10.40	0	0.00866	0	**218.44**
10:00 AM	23.00	6.13	0.01916	0.005108	231.48
10:20 AM	29.90	15.80	0.02491	0.013160	244.52
10:40 AM	31.75	25.85	0.02645	0.021540	257.56
11:00 AM	30.30	34.40	0.02525	0.028660	270.60
11:20 AM	33.19	37.10	0.02575	0.030910	283.64
11:40 AM	30.76	37.50	0.02563	0.031250	296.68
12:00 PM	19.30	42.35	0.01608	0.035290	291.48
12:20 PM	12.65	46.85	0.01054	0.039040	280.20
12:40 PM	7.23	33.00	0.00602	0.027500	268.92
1:00 PM	4.33	28.10	0.00361	0.023410	257.64
1:20 PM	3.86	19.60	0.00322	0.016330	246.36
1:40 PM	3.67	7.10	0.00310	0.006920	235.08
2:00 PM	2.13	0.10	0.00177	0.000100	223.80
2:20 PM	0.98	0	0.00081	0	**212.52**
2:40 PM	0	0	0	0	**201.24**
3:00 PM	0	0	0	0	189.96
3:20 PM	0	0	0	0	178.68
3:40 PM	0	0	0	0	167.40
4:00 PM	0	0	0	0	156.12
4:20 PM	0	0	0	0	144.84
4:40 PM	0	0	0	0	133.56
5:00 PM	0	0	0	0	122.28
5:20 PM	0	0	0	0	111.00
5:40 PM	0	0	0	0	99.72
6:00 PM	0	0	0	0	88.44

From the seepage rate and volume table, the rate of tidal height increase at SCE is 0.652 cm/min, and seepage begins once the height reaches 2.1 meters. It takes approximately 6 hours for the tide to rise from 0.6m to 3m, or from 5:37 AM to 11:45 AM. Seepage begins at 9:40 a.m. and 10:00 a.m. at both points, which have nearly the same tidal height of approximately at 2.1 meters. Same goes with the seepage to stop at between 2.1m. However, the amount of reduction in tidal height varies. It takes around seven and a half hours for seepage to cease at a rate of 0.564cm per minute. The tide height decreases from 11:45 a.m. at 3 meters to 6:50 p.m. at 0.6 meters.

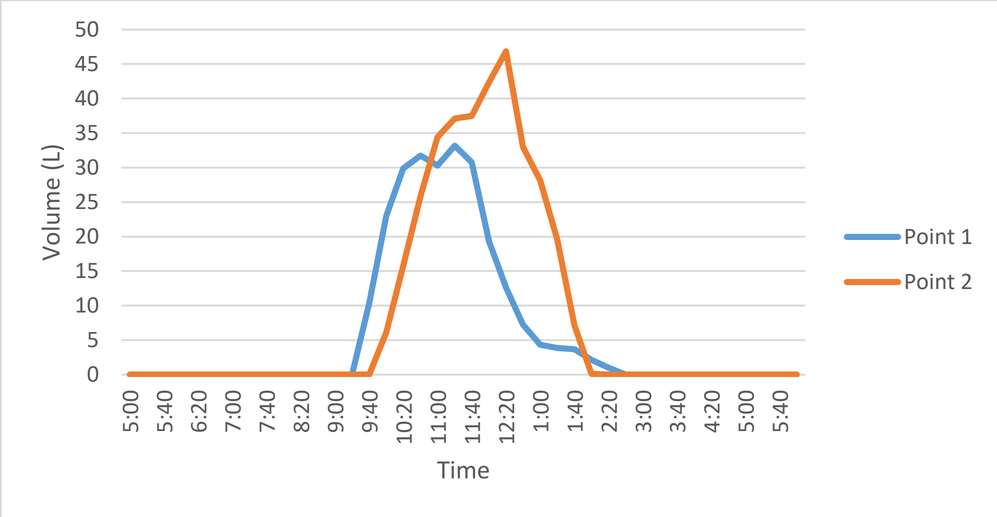

Figure 10: Graph of volume for point 1 and point 2

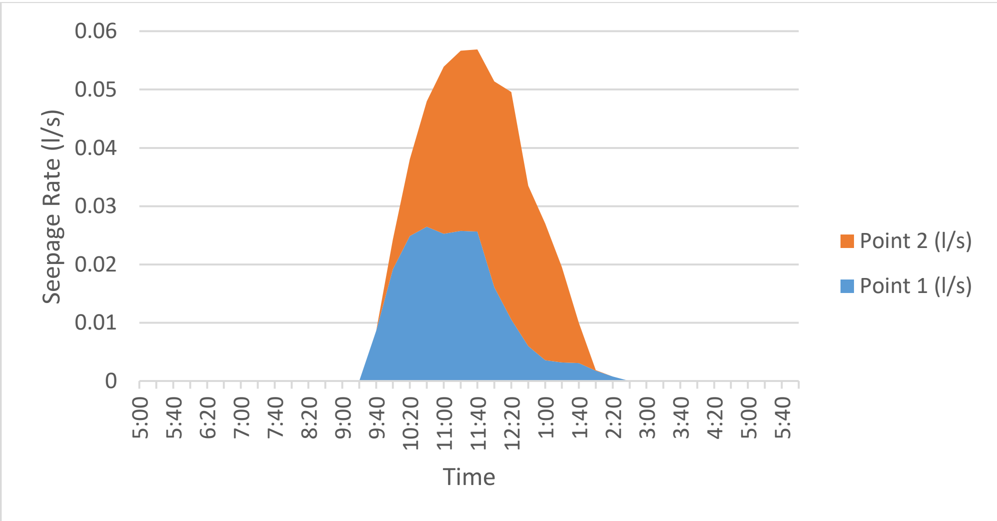

Figure 11: Graph of seepage rate for point 1 and point 2

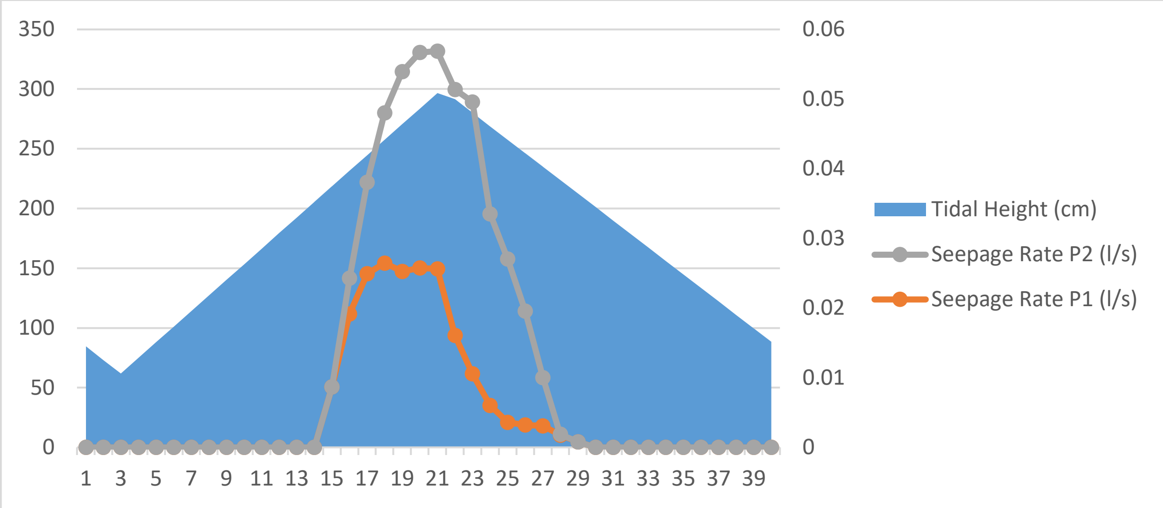

Figure 12: Graph for relationship between tidal height and seepage rate for point 1 and 2

From the graph obtained, it is proven that the highest reading of volume and seepage rate occurs while the tide height at its peak. According to Bakari [15], by raising pressures within the soil pores or by flooding the slope, seepage may cause the slope to collapse. This seepage rate is quite concerning as it produces huge amount of discharged which lead to failure of embankment.

4. Conclusion

A successful experiment was undertaken to quantify the volume and rate of seepage related with tidal flow in order to establish a seepage profile for a particular place that will be utilised in the future for mitigation purposes. The seepage profile can then be used to determine the problem's severity. Monitoring, analysing, and documenting the seepage at Senggarang Coastal Embankment (SCE) induced by tidal action are the primary objectives of this study project. The conclusion that can be derived from the findings is that the rate of seepage is worrying and requires immediate action to prevent the collapse of the embankment. The majority of the SCE's crops are sterile as a result of the salt water inhibiting their growth.

The direct shear test conducted on embankment soil for SCE to determine the cohesiveness value revealed that the result is poor. Depending on the kind of slope and other soil factors, an increase in cohesiveness will reduce slope stress, strain, and displacement. Increase the slope safety factor. The slope's design and construction should be based on changes in soil cohesiveness in order to adopt the relevant design concepts and engineering solutions

The solution recommended are that the seepage causes needed to be appraised as the study have verify the presence of seepage. Finally, transforming the soil profile into a more cohesive type of soil to reduce seepage.

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