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# Groundsill stability in downstream of bridge "Besi" in body of water at River Garang Semarang city, Indonesia

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**Abstract.** During the dry season the elevation of the flow at crest groundsill is the same as the elevation downstream, which is assumed that the dimensions of the groundsill are not large enough. These less large dimensions cause the groundsill weight to be small, so its stability is very doubtful. It is this doubt on the groundsill stability that led to this research. The aims of this study were to analyze the stability of the Groundsill Bridge in the Garang River channel on the force of overtuning, sliding, eccentricity, bearing capacity of the soil, and piping. This research employed survey method. Data collection methods used were observation and secondary data. Analysis of the data were rainfall design of a 50 years return period; flood discharge design with a 50 years return period; the forces acting on the groundsill, and the groundsill stability. The results of the study indicate that: the groundsill were safe against overturning forces, eccentricity, and piping under normal flow and flood conditions; the groundsill were not safe against sliding forces under normal flow and flood flow conditions; the bearing capacity of the groundsill subgrade were safe against forces that occur during normal conditions and unsafe during flood conditions.

## 1. Introduction

Scour that occurs on the abutments and pillars of the bridge is a total scour, which is a combination of local scour and general scour; it can also be a combination of local scour, general scour and localized scour / constriction scour. The local scour that occurs around abutments of bridges or pillars is caused by a vortex system as a result of obstruction of flow patterns from obstacles, and localized scour occurs due to a narrowing of the cross section of the river by the placement of hydraulic buildings [1]. General scour which occurs cross the river along the canal and causes degradation of the base is caused by the energy of the water flow [2].

Groundsill is one type of water structure built across the river to control the riverbed [3]. It is one of the efforts to control the river bed to maintain the river bed so that it does not experience severe settlement, returning the river bed to the elevation before degradation, or obtain a new river bed slope according to the design slope. The excessive settlement in the river bed is partly due to the reduced supply of sediment from the upstream caused by the construction of a river structure such as a dam, checkdam, crib, sabo dam, or other structures [4].

Calculating the stability of Groundsill should be reviewed during normal and extreme conditions such as flooding. The structure can achieve stability if these following things are performed, the control of the forces at work does not cause the building to displace, tilt or overturn. There are several forces that must be calculated to determine the stability of Groundsill. The forces acting on the

building that are important in planning are: (1) water pressure or hydrostatic forces; (2) the building's own weight, (3) sediment pressure; (4) uplift pressure force; and (5) earthquake force. Furthermore, the forces acting on the building are analyzed and controlled for its stability for its safety factors.

The Garang River's upstream and downstream have different roles, but they are equally important. The upper part of the Garang River plays an important role in accommodating surface runoff, while the downstream part is used as a source of fresh water for the Municipal Waterworks of Semarang and as a canal that serves to accommodate the drainage channels of the surrounding area [5]. In 1990, the link between the South Semarang sub district and Gunungpati sub district was opened through Sukorejo village until Gunungpati village known as east Gunungpati arterial road. West Gunungpati arterial road has already existed before the establishment of the Universitas Negeri Semarang campus. Because the west part of Gunungpati subdistrict was developed first [6]. Sampangan Village, Gajah Mungkur Sub District and Sukorejo Village, Gunungpati District are connected by "Besi" Bridge. "Besi" Bridge connects those villages through Garang River located on the Colonel HR Hadijanto street, Sukorejo, Gunungpati, Semarang, at coordinates  $7^{\circ} 1' 10''$  South  $110^{\circ} 23' 21''$  East. "Besi" Bridge construction is equipped with a pole, because the river is quite wide which is 51.30 m.

The pole of "Besi" Bridge in the middle of the Garang river is threatened by total scour. In addition, the total scour is influenced by sand mining activities downstream of the bridge pole. Therefore, the Department Public Works of Water Resources and Spatial Planning (Dinas Pusdataru) of Central Java Province built Groundsill at the downstream of the "Besi" bridge's pole. The groundsill structure does not function optimally because the overflow always sinks even when water discharge is at the base flow, which is  $\pm 1.98 \text{ m}^3/\text{s}$ . Therefore, the construction of Groundsill at the downstream of the "Besi" Bridge's pole must be evaluated especially regarding the stability of the structure [7].

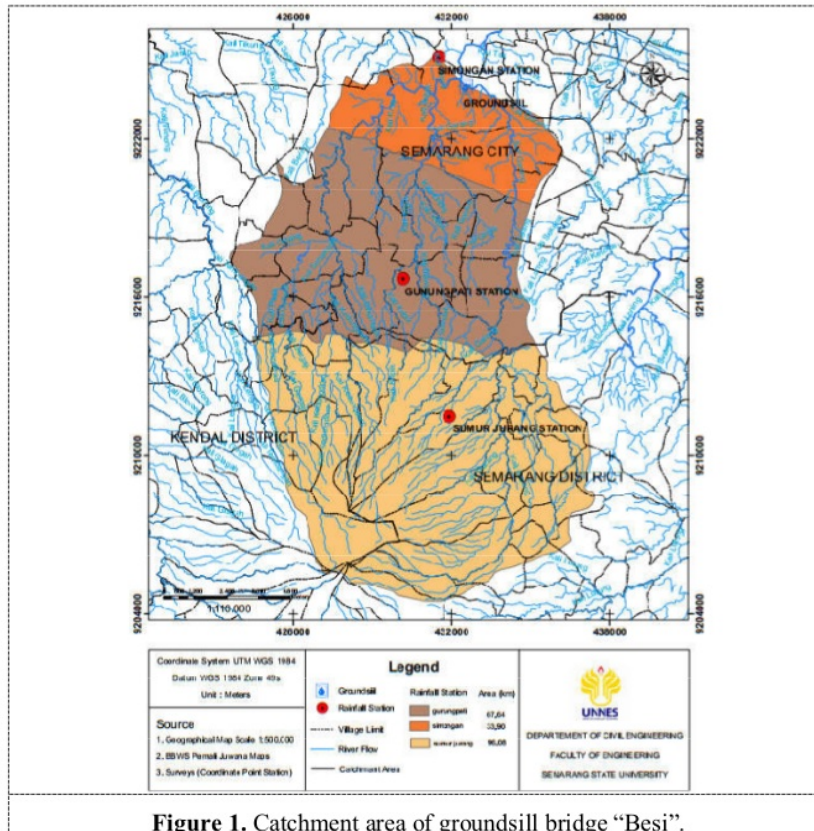
The aims of this study were (1) to analyze the stability of Groundsill based on the overturning moment during normal water condition and flooding; (2) to analyze the stability of the Groundsill based on its shear or sliding during normal water conditions and flooding; (3) to analyze the stability of Groundsill based on its eccentricity during normal water conditions and flooding; (4) to analyze the stability of Groundsill based on its bearing capacity of the land at the time of normal water conditions and flooding; and (5) to analyze the stability of Groundsill evaluated from underground erosion (piping) during normal water conditions and flooding.

## 2. Research method

The study on the Groundsill Stability at the Downstream of the "Besi" Bridge of Semarang City was carried out at Garang river, Sampangan, Semarang City, Central Java, which was located at a coordinate point of  $7^{\circ} 1' 10''$  South  $110^{\circ} 23' 21''$  East. The "Besi" Bridge is located on Colonel HR Hadijanto street, Sukorejo, Gunungpati, Semarang City, which is known as Gunungpati east arterial road. In Figure 1 was presented Catchment area of groundsill bridge "Besi" [8].

This research employed survey method. The data were collected using the method of observation, and documentation. Primary data of this research were parameters of Groundsill soil foundation which were collected using laboratory tests. Secondary data consisted of topographic maps, daily rainfall data, river width data or length of Groundsill's weir are the documentation from the Pemali Juana River Center. (BBWS).

The data required in this study consisted of (1) the topographic map with the scale of 1: 250000 obtained from Geography Department, Faculty of Social Sciences, Universitas Negeri Semarang; (2) daily rainfall data for 10 years obtained from the office of Central Java Water Resources Management (PSDA); (3) data on river width or length of Groundsill's overflow obtained from observation in the Garang River and matched with Groundsill design drawings obtained from the Pemali Juana River Center (BBWS); and (4) the specific gravity of the sediment, the depth of the sediment, the weight of grain volume, the shear angle, and the dry soil volume weight were obtained from laboratory tests at the Geotechnical Laboratory, Faculty of Engineering, Universitas Negeri Semarang.



Groundsill stability analysis based on the stability to the overturning force is calculated based on [9]. Stability analysis of the groundsill based stability against the sliding force is calculated based on [9]. Ground <sup>12</sup> stability analysis based on stability against eccentricity is calculated based on [10]. Groundsill stability analysis based on the stability of the bearing capacity of the soil is calculated based on [9]. Analysis of Groundsill stability based on stability for underground erosion (piping) is calculated based on [10].

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### 3. Results and discussion

#### 3.1. Design Rainfall

Rain data used in the hydrological analysis were taken from 3 rain stations located in the Garang watershed, the Rain Station used was the Simongan rain station, Gunungpati and Sumur Jurang rain stations. The duration of data from the three rain stations is 10 years including daily rainfall data with an observation period from 2008 to 2017.

The rainfall data used is the annual maximum daily rainfall from the three rain stations, after which a monthly maximum daily rain recapitulation is conducted, after obtaining monthly, daily data, annual rainfall data is collected.

**Table 1.** The calculation results of average maximum daily rainfall per year

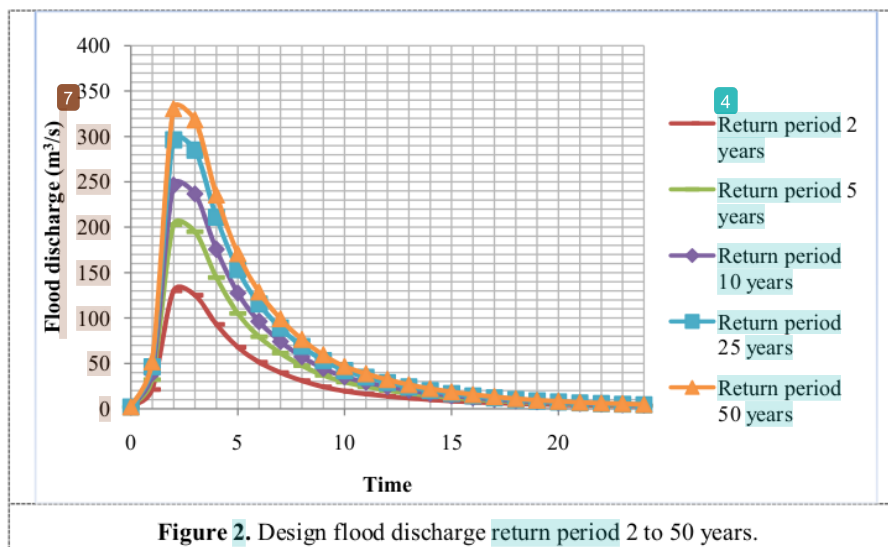
Years	Simongan Station		Gunungpati Station		Sumur Jurang Station		Maximum Rainfall (mm)
	Rainfall (mm)	Cathment area (12.24 Km <sup>2</sup> )	Rainfall (mm)	Cathment area (6.64 Km <sup>2</sup> )	Rainfall (mm)	Cathment area (68.64 Km <sup>2</sup> )	
	(1)	(2)=(1)*12.24	(3)	(4)=(3)*6.64	(5)	(6)=(5)*68.64	(2+4+6)/87.52
2008	169	2068.56	114	756.96	165	11325.6	161.6901
2009	216	2643.84	108	717.12	35	2402.4	65.85192
2010	110	1346.4	165	1095.6	121	8305.44	122.7998
2011	83	1015.92	200	1328	90	6177.6	97.36654
2012	80	979.2	99	657.36	55	3775.2	61.83455
2013	111	1358.64	146	969.44	124	8511.36	123.851
2014	125	1530	148	982.72	72	4942.08	85.17824
2015	177	2166.48	106	703.84	79	5422.56	94.75411
2016	98	1199.52	152	1009.28	82	5628.48	89.54845
2017	89	1089.36	110	730.4	68	4667.52	74.1234

(Source: Calculation Results, 2019)

8 The results of the Rain Design calculations using Log Pearson Type III distribution are (1) in the return period of 10 years is 135.96 mm; (2) in the return period of 25 years is 152.69 mm; and (3) in the return period of 50 years is 163.968 mm.

### 3.2. Design Flood Discharge

11 Analysis of the design flood discharge on the “Besi” Bridge Groundsill is determined based on the results of the design rainfall analysis. The design flood discharge is a flood discharge when it is 50 years period. The flood discharge calculation method for the 50 years return period used is the Nakayasu Synthetic Hydrograph Unit (SHU).



Resume of Maximum Discharge Return Period for “Besi” Bridge Watershed using SHU are (1) in the return period of 10 years is 246.15 m<sup>3</sup>/s; (2) in the return period of 25 years is 296.35 m<sup>3</sup>/s; and (3) in the return period of 50 years is 330.78 m<sup>3</sup>/s.

### 3.3. Analysis of the forces acting on the Groundsill under normal and flood water level conditions

The forces acting on Groundsill are analyzed under normal water level condition based on the assumption that this condition is achieved especially during the dry season where the flowing water is at the base flow. This condition can occur mainly from April to October.

The forces acting on the Groundsill are analyzed under flood water condition based on the assumption that this condition can be achieved especially during the rainy season where the flowing water is the flow of the flood. This condition can occur mainly in November to March.

**Table 2.** Resume of the results of analysis on forces acting on the groundsill on condition of normal and flood water level

No	Force	Normal Water Level				Flood Water Level			
		Force (ton)		Vertical Moment (M <sub>F</sub> ) (ton.m)	Horizontal Moment (M <sub>G</sub> ) (ton.m)	Force (ton)		Vertical Moment (M <sub>F</sub> ) (ton.m)	Horizontal Moment (M <sub>G</sub> ) (ton.m)
		Vertical (R <sub>v</sub> )	Horizontal (R <sub>h</sub> )			Vertical (R <sub>v</sub> )	Horizontal (R <sub>h</sub> )		
1	Weight	-15.68		-35.47		15.69		-35.48	
2	The earthquake Hydrostatic pressure		3.38		4.11		3.39		4.11
3	Sediment Pressure	-0.72		-1.36		27.13	4.09	-69.66	13.29
4	Uplift force	3.15	2.04	1.87	6.99	39.24	26.78	22.09	16.07
5	Passive soil pressure		0.42		0.19		0.42		0.19
6	Active soil pressure		-1.66		-0.78		-1.66		-0.78
7	Total	-13.25	4.47	-34.97	11.08	-3.58	33.31	-83.05	32.73

Description: (+) and (-) indicate the direction of force and moment

(Source: Calculation Results, 2019)

### 3.4. Stability analysis groundsill on condition normal water level and flooding

Groundsill stability analysis must be taken into account during the flood condition, the normal water condition. The analysis on the (1) “Besi” bridge’s groundsill safety on overturning force; (2) “Besi” bridge’s groundsill safety on shear forces; (3) “Besi” bridge’s groundsill safety on eccentricity force; (4) “Besi” bridge’s groundsill safety on bearing capacity of the soil; and (5) “Besi” bridge’s groundsill safety on the danger of piping.

**Table 3.** Resume of the results of analysis on forces acting on the groundsill on condition of normal and flooding water level

No.	Stability (S <sub>i</sub> )	In normal water conditions		In flood water conditions	
		Parameter	Information	Parameter	Information
1	Overturning (S <sub>i</sub> )	M <sub>F</sub> =34.970 t.m M <sub>G</sub> =11.075 t.m	S <sub>f critical</sub> =1.5 S <sub>f calculated</sub> =3.157	M <sub>F</sub> =83.047 t.m M <sub>G</sub> =32.726 t.m	S <sub>f critical</sub> = 1.25 S <sub>f calculated</sub> = 2.537

		$S_f = M_T / M_G$ $= 34.970 / 11.075$ $= 3.157$	Stability on overturning is considered as safe	$S_f = M_T / M_G$ $= 83.047 / 32.726$ $= 2.537$	Stability on overturning is considered as safe
2	Sliding ( $S_f$ )	$R_v = 13.259$ $M_G = 11.075$ $S_f = R_v / M_G$ $= (13.259 / 11.075) \times 0.85$ $= 1.02$	$S_{f \text{ critical}} = 1.5$ $S_{f \text{ calculated}} = 1.02$ Stability on sliding is considered as unsafe	$R_v = 3.577$ $M_G = 32.726$ $S_f = R_v / M_G$ $= (3.577 / 32.726) \times 0.85$ $= 0.092906$	$S_{f \text{ critical}} = 1.25$ $S_{f \text{ calculated}} = 0.09$ Stability on sliding is considered as unsafe
3	Eccentricity (e)	$B = 3.9 \text{ m}$ $R_v = 13.259$ $M_G = 11.075 \text{ t.m}$ $M_T = 34.970 \text{ t.m}$ $e = (3.9/2) - (34.970 - 11.075) / 11.075 < 3.9/6$ $= -0.147 < 0.65$	Stability on eccentricity is considered as safe	$B = 3.9 \text{ m}$ $R_v = 3.577$ $M_G = 32.726 \text{ t.m}$ $M_T = 83.047 \text{ t.m}$ $e = (3.9/2) - (83.047 - 32.726) / 3.577 < 3.9/6$ $= -12.11 < 0.65$	Stability on eccentricity is considered as safe
4	Bearing capacity ( $\sigma$ )	$h_p = 1 \text{ m}$ $\gamma = 1.9 \text{ ton/m}^3$ $\phi = 2.5^\circ$ $C = 0.1$ $N_c = 25.1$ $N_q = 12.7$ $N_\gamma = 9.7$ $Q_{ult} = 30.97 \text{ ton/m}^2$ $Q_{min} = 2.626 \text{ ton/m}^2$ $Q_{max} = 4.172 \text{ ton/m}^2$	Koefisien $\sigma_{\text{calculated}} < \sigma_{\text{critical}}$ $(4,172 < 30,97)$ and it is safe for the stability to the bearing capacity of the soil	$h_p = 1 \text{ m}$ $\gamma = 1.9 \text{ ton/m}^3$ $\phi = 2.5^\circ$ $C = 0.1$ $N_c = 25.1$ $N_q = 12.7$ $N_\gamma = 9.7$ $Q_{ult} = 30.97 \text{ ton/m}^2$ $Q_{min} = 442.29 \text{ ton/m}^2$ $Q_{max} = 459.36 \text{ ton/m}^2$	Koefisien $\sigma_{\text{calculated}} > \sigma_{\text{critical}}$ $(459.36 > 30.97)$ and it is not safe to the stability of the soil bearing capacity
5	Weighted-creep-distance ( $L_w$ )	$\Delta H = 1.2 \text{ m}$ $\sum L_v = 3.9 \text{ m}$ $\sum L_h = 4.2 \text{ m}$ $C = 4.0$ (fine gravel) $L_w = \frac{\sum L_h}{3} + \sum L_v$ $L_w = 5.3$ $WCR = \frac{L_w}{\Delta H}$ $WCR = 4.416$	The $WCR_{\text{calculated}}$ coefficient = 4.416, while $WCR_{\text{critical}} = 4$ thus safe against underground erosion (piping)	$\Delta H = 0.875 \text{ m}$ $\sum L_v = 3.9 \text{ m}$ $\sum L_h = 4.2 \text{ m}$ $C = 4.0$ (fine gravel) $L_w = \frac{\sum L_h}{3} + \sum L_v$ $L_w = 5.3$ $WCR = \frac{L_w}{\Delta H}$ $WCR = 6.06$	The $WCR_{\text{calculated}}$ coefficient = 6.06, while $WCR_{\text{critical}} = 4$ is thus safe against underground erosion (piping)

(Source: Calculation Results, 2019)

#### 4. Conclusion

The conclusions of this study are: (1) Stability of the “Besi” Bridge, Garang River of the Groundsill structure is safe from overturning under normal water level and flooding water level conditions; (2) The groundsill structure at the “Besi” Bridge, Garang River was not secure against sliding in the condition of normal water level and flooding water level; (3) The stability of the groundsill structure at the “Besi” Bridge, Garang River is categorized as safe from eccentricity in normal water level and flooding water level conditions; (4) Stability of the groundsill structure at the “Besi” Bridge, Garang River is safe against shears force in normal water level, while the flooding water level conditions is classified as unsafe; and (5) The stability of the groundsill structure at the “Besi” Bridge, Garang River is safe to underground erosion (piping) on the condition of normal water level and flooding water level.

#### 5. Acknowledgment

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