2. Experimental Study of Local Scouring on Porous Concrete of Bridge Pier

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Experimental Study of Local Scouring on Porous Concrete of Bridge Pier

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***Abstract*— Bridge is one of transportation infrastructures that helps to develop the economy growth of country. In addition, infrastructure development must pay attention to existing environmental conditions. Porous concrete allows water to flow through it, therefore it becomes a popular material for a variety of applications, including in stormwater management. Lack of previous research has used porous concrete in bridge piers. The main objective of this research is to study and analyze the depth of local scouring and scouring patterns that occur around the bridge piers by using two scenarios (porous concrete and solid concrete). This study has an average flow velocity of 0.07m/sec within clear water scour condition. As the results, in porous concrete scenario, the smallest percent difference (16.86%) between empirical and experimental analysis is by using Blench-Inglis I formula. While in solid concrete scenario, the smallest percent difference (4.18%) between empirical and experimental analysis by using Blench-Inglis II formula. The local scouring results that occurs due to solid concrete scenario is 5.5 cm while the local scouring that occurs due to porous concrete scenario is 7 cm. It resulted that the percentage difference is about 5%.**

Keywords—bridge piers, experimental study, local scouring, porous concrete

I. Introduction

Local scouring is a phenomenon that occurs in rivers and other bodies of water where the flow of water causes sediment to be eroded from the bed and banks of the channel[1,2]. The factors that contribute to local scouring include the velocity and depth of the water, the size and shape of the sediment particles, the turbulence of the water flow, and the composition of the bedrock and soil in the riverbed[3]. Local scouring can be particularly significant in areas where there are changes in the slope or width of the river, or where there are obstructions such as bridge piers or abutments[4].

As water flows around piers, it can create turbulence that erodes the surrounding bed material[5]. Over time, this can cause the foundation of the pier to become exposed and weaken, potentially leading to structural damage or even collapse[6,7].

The concept of sustainable development has increased over time, aiming to reduce environmental problems[8]. Therefore, infrastructure development also emphasizes efforts to use environmentally friendly materials and planning or design such as porous concrete in many structures. In the meantime, lack of previous research has used porous concrete in bridge piers[9,10]. Therefore, the main objective of this research is to study and analyze the depth of local scouring and scouring patterns that occur around the bridge piers by using two scenarios (porous concrete and solid concrete).

II. Theoritical Background

A. *Porous Concrete*

Porous concrete is a type of concrete that has voids or gaps in it as can be seen in Figure 1. Voids in porous concrete can be produced by adding additives such as fibers or granules to the concrete mix, or by using fillers or expanders such as foam or trapped air in the concrete mix[11]. Porous concrete can be used in piers, particularly for bridge piers or other marine structures as can be seen in Figure 2. Porous concrete is a type of concrete that contains voids or pores that allow water to pass through it. When used in piers, this type of concrete allows water to flow through the pier, which reduces the impact of waves and other hydrodynamic forces[12-13].

Porous concrete in piers can provide several benefits over traditional solid concrete piers. Firstly, they reduce the risk of scouring around the base of the pier caused by the flow of water, which can lead to erosion and the destabilization of the pier. Secondly, porous concrete piers can also help to reduce the impact of waves, which can cause damage to traditional solid concrete piers. Finally, porous concrete piers can be more cost-effective, as they require less concrete to be used in their construction and can be made using simpler construction techniques. However, it is important to note that porous concrete piers may have lower strength and durability than traditional solid concrete piers. Therefore, the design and construction of porous concrete piers should be carefully considered to ensure that they meet the required structural and durability requirements for the specific application[13].

Fig. 1. Difference between solid concrete and porous concrete

Fig. 2. Porous concrete of bridge pier

B. *Local Scouring*

Local scouring refers to the erosion of sediment around the base of a structure, such as a bridge pier, caused by the flow of water. When water flows around a structure, such as a pier, it creates turbulence and eddies that can erode the sediment around the base of the structure as can be seen in Figure 3. Over time, this erosion can cause the sediment to become unstable, which can lead to the destabilization of the structure.

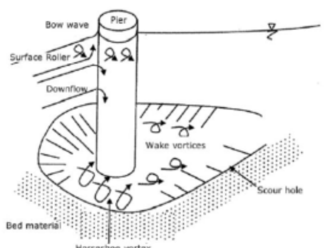

Fig. 3. Local scouring of bridge pier

III. Experimental Set Up and Scenario

An experimental study of local scouring on porous concrete of bridge pier. Figure 4 shows the experimental set up. The flume has 15.2 m length x 0.64 m height with 1 m width. Meanwhile, the size of concrete piers is 60 cm length with 8 cm diameter for this experimental study. According to ACI 522R-10 mix design for 1m^3 of porous concrete in this study consisted of cement (270 - 415 kg), aggregate (1190 - 1480 kg), cement water factor (0,27 - 0,34), weight ratio of sand and gravel (0 to 1 : 1) [14,15].

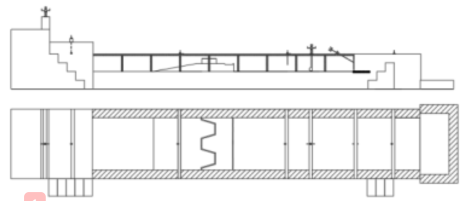

Fig. 4. Experimental set up (Top view and side view without scale)

A. *Flow Velocity Analysis*

Flow velocity that occurs is related to the condition of scour; flow velocity measurements were carried out using a Propeller 6-144981 with certain location can be seen in Figure 5.

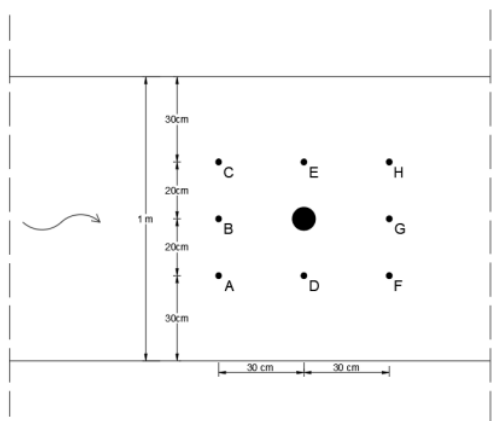

Fig. 5. Flow velocity reading point position

TABLE I. Flow Velocity Analysis Result

Point	A	B	C	D	E	F	G	H
Test 1	122	116	107	125	110	125	74	113
Test 2	121	115	106	125	112	125	75	110
Average	121.5	115.5	106.5	125.0	111.0	125.0	74.5	111.5
n	4.05	3.85	3.55	4.17	3.70	4.17	2.48	3.72
V	0.07	0.07	0.06	0.07	0.07	0.07	0.05	0.07

This study has an average flow velocity of 0.07m/sec within clear water scour condition as can be seen on Table 1.

B. *Sediment Sieve Analysis*

The sediment factor at bridge piers includes particle size distribution, basic sediment type, and the spatial distribution of sediment size. The difference in basic sediment affects scouring behavior. For example for coarse-grain soil and fine grain soil, scouring behavior will be different Salthough the distribution particle. The purpose of sediment sieve analysis to specify the distribution or gradation of the sediment used as can be seen in Table 2 and Figure 6.

TABLE II. SEDIMENT SIEVE ANALYSIS RESULT

No. Sieve	Retained Weight (gram)	Soil Retained (%)
No. 4	16.2	3.95 %
No. 8	80.6	19.66 %
No. 16	53.2	12.98 %
No. 50	87.2	21.27 %
No. 100	38.7	9.44 %
No. 200	123.9	30.22 %
Pan	10.2	2.49 %
Σ Retained Weight	410.0	

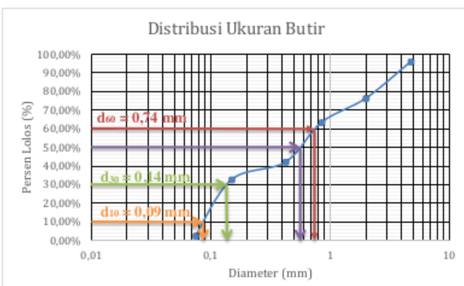

Fig. 6. Sediment grain size distribution chart

By using Soil Classification Chart, it is classified that sediment is categorized in Poorly Graded Sand.

IV. RESULT AND DISCUSSION

The result indicates that the depth of local scouring and scouring patterns that occur around the bridge piers by using porous concrete and solid concrete.

A. *Local Scouring on Solid Concrete*

On solid concrete there is scouring around the piers and has the deepest point of -5,5 cm as can be seen in Figure 7.

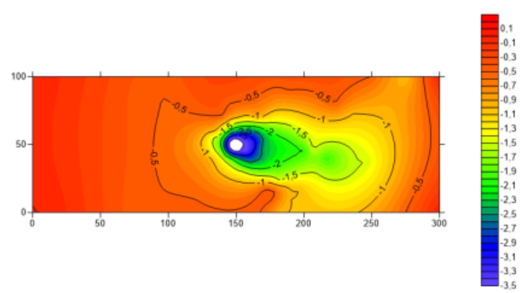

Fig. 7. Scouring Patterns (Solid Concrete)

B. *Local Scouring on Porous Concrete*

On porous concrete there is scouring around the piers and has the deepest point of 7 cm as can be seen in Figure 8.

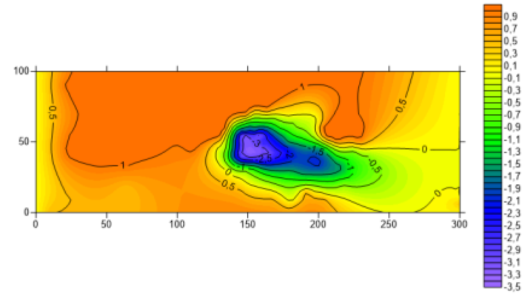

Fig. 8. Scouring Patterns (Porous Concrete)

C. *Empirical and Experimental Analysis*

Local scouring can be calculated using the empirical formula, in this study the empirical formula used includes: Breusers, Laursen and Toch, Blench-Inglis II, Larras, Inglis-Poona I, Inglis II formula.

TABLE III. EMPIRICAL AND EXPERIMENTAL RESULTS (POROUS CONCRETE)

No	Formula	Depth Scour (cm)		Difference (%)
		Experimental Porous Concrete	Empirical	
1	*Breusers*	7	11,2	60,00
2	*Laursen* dan *Toch*		10,15	45,00
3	*Blench-Inglis* I		5,82	16,86
4	*Larras*		15,79	125,57
5	*Inglis-Poona* I		9,09	29,86
6	*Inglis-Poona* II		5,27	24,71

The smallest percent difference between empirical and experimental analysis in porous concrete scenario is by using Blench-Inglis I formula of 16.68 % as can be seen on Table 3.

TABLE IV. EMPIRICAL AND EXPERIMENTAL RESULTS (SOLID CONCRETE)

No	Formula	Depth Scour (cm)		Difference (%)
		Experimental Porous Concrete	Empirical	
1	*Breusers*	5.5	11,2	103,64
2	*Laursen* dan *Toch*		10,15	84,54
3	*Blench-Inglis* I		5,82	5,82
4	*Larras*		15,79	187,09
5	*Inglis-Poona* I		9,09	65,27
6	*Inglis-Poona* II		5,27	4,18

The smallest percent difference between empirical and experimental analysis in porous concrete scenario is by using Inglis-Poona I formula of 4.18% as can be seen on Table 4.

The occurrence of local scour around on pier is the principal factor raising concerns about the stability of porous concrete bridge piers. Therefore, it is important to identify and study the important parameters that affected local scour depth including the horseshoe vortex at the base of the pier and the down flow at its upstream face cause local scour around bridge piers. The so-called wake vortices are also caused by the separation of the flow along the edges of the pier. These unstable vortices alternately shed from the pier's two sides. The sediment particles are lifted off the bed by these tiny vortex-like motions, creating a scour crater all the way around the pier.

V. CONCLUSIONS

Local scouring can have significant impacts on river ecosystems and infrastructure. For example, it can affect the stability of bridge foundations, leading to structural damage or collapse. It can also alter the morphology of the riverbed, changing the flow patterns of the water and potentially causing erosion and sedimentation in downstream areas. As such, understanding and mitigating the effects of local scouring is an important consideration in the design and maintenance of river infrastructure and the management of river ecosystems.

In this study local scouring and scouring pattern of bridge piers has been examined experimentally under clear water scouring. The local scouring results that occur due to solid concrete scenario is 5.5 cm while the local scouring that occurs due to porous concrete scenario is 7 cm. It resulted that the percentage difference is about 5%. In porous concrete scenario, the smallest percent difference (16.86%) between empirical and experimental analysis is by using Blench-Inglis I formula. While in solid concrete scenario, the smallest percent difference (4.18%) between empirical and experimental analysis by using Blench-Inglis II formula. There is not much difference in the pattern scouring that occurs in porous concrete pillars and solid concrete pillars, but in porous concrete pillars there is an accumulation of the bottom sediments at the end of the canal.

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