

RESTORATION ANALYSIS OF KURANJI DAM DUE TO SCOURING AT THE DOWNSTREAM

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ABSTRACT

Sub-dam at downstream of the Gunung Nago Main-dam at Kuranji river in Padang had suffered from severely damage during the flash flood on July 24, 2012. The flood known as 'Galodo' by local people has lead to the scouring at the downstream of the Gunung Nago sub-dam. The scouring was deep and long enough to cause the tail structure of that stone masonry dam suffered from damaged. The damage resulted in malfunction of the dam then needs the restoration work. Besides protecting the main dam, this sub-dam is also used as intake to take irrigation water and drinking water for the right side of the downstream area of the Kuranji river. This paper explains the mechanical analyses to set up the idea of the reparation method the damaged dam. Based on the results of the study, this dam can be repaired without the use of reinforced concrete material. So that simple improvement can be done by filling back the scoured foundation and constructing back with the use of stone masonry materials. To protect against the future scouring this restoration is completed with an apron structure at the downstream of the dam. This study is very useful to design and construction of the small dam in general. In case of restoration it can carry out the reparation work quickly and cheaply.

Key words: Scouring, Masonry Dam, Unreinforced Concrete, Restoration

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1. INTRODUCTION

On July 24, 2012 the flash flood that called 'Galodo' by local people has occurred in Padang. This flood disaster resulted in damage to a number of houses and public facilities (Febrin et al., 2013). One of the facilities damaged by the Galogo is the sub-dam in Batang Kuranji river at Gunung Nago district. The dam with a height of about 3m and

length of about 27m is damaged due to scouring at the downstream foundation. This scoured foundation has caused a lost of support on the tail of dam structure. This condition then led to the load of the flood water and the debris could not be supported hence damaging the downstream of dam structure. This scoured foundation also led to the failure of intake facility of irrigation water and drinking water in the dam. Figure 1 shows the conditions of the sub-dam at before and after the disaster.

The water level during the flash flood in 2012 reached up to 6 meters from the riverbed. This condition had caused uncontrolled overflow and flooding on the left and right side areas of the Batang Kuranji river. The Galodo at this time was triggered by the heavy rainfall is the Batang Kuranji catchment area. There were also landslides on the hills of the upstream of the Batang Kuranji river on where the slopes of the river trunk more than 80° .



Figure 1 The condition of the sub-dam at before and after Galodo 2012

There were also found the degradation or the decrease along Batang Kuranji riverbed. This degradation primarily occurred in the segment between the main-dam in Gunung Nago trough supply water weir in Siteba. There are various important river facilities in endangered if the dam was not repaired immediately. Some river facilities at the downstream section of the river that have been and likely to be damaged are the check-dams and groundsills, water intakes, river cliff protection structures and bridges without protected pillars and abutments.

The main role of the Gunung Nago sub-dam is protecting the main dam of the Batang Kuranji river. In addition, together with the front groundsill construction, it is also used to divert water toward the right side area of the Batang Kuranji. The water is used initially for paddy field irrigation, but later the residents in the lower area have been using it for all the necessities of life, including the drinking water and household water that was taken indirectly through infiltration into wells. The damage followed by non-functioning of the sub-dam has also threated to the lives of thousands of residents of Padang city, especially in the right side area of the downstream of Gunung Nago dam. Thgen, it is necessary to restore the dam quickly and accurately. It is also expected that in the future the similar damage or coming loss from disaster will not happen again.

The sub-dam in Batang Kuranji river can be categorized as a small dam since it has the high only 3 m (FCoLC, 2002). There are some literatures that have described many aspect in small dams which the guidance for designing, constructing and monitoring of small dams can be referred from (Silveira et al, 2011 and US Army CE, 1995). Those references are summaries of past experiences around the world in small

dams which are different from large dams. The small dams in the literatures are usually made of embankment material but the Batang Kuranji dam is made of river stone masonry. This paper explains the experience of rehabilitation of small dam Batang Kuranji based on mechanical analyses to set up the reparation method.

2. METHODOLOGY

Sub-dam of Gunung Nago is a dam that serves primarily to protect the main dam at the upstream section. A typical picture of the sub- and the main- dam used in Batang Kuranji is plotted in Figure 2. The Gunung Nago sub-dam is made of river stone masonry. The riverbed at the dam site consists of sedimentary rocks with the size up to boulder. The rock size can in fact be scoured and transported by strong water currents. In some case the lower side of groundsill can also be eroded so that the foundations of the dam losing the support. This situation makes the tensile stress on the upper side of the dam. The flash flood that carry heavy sediment, may result in a more high tensile stress on the upper side of the dam that may cause the lost bond in the masonry structure.

The river stone masonry and un-reinforced concrete are indeed not susceptible to the tensile force. The tensile strength of concrete and masonry can be estimated based on its compressive strength. For a masonry, where a specified compressive strength is relatively small (about 10 000 kN/m²) will also has a very low tensile resistance. In Indonesia the tensile strength is determined based on the compressive strength with the formula has been imprinted on the concrete code (PBI, 1971) which then is adopted to the new reinforced concrete design procedures (SNI, 2012). The tensile resistance value of river stone masonry can be calculated by adopting the formulation of the code, that is:

$$\tau_b = \sigma_{bk}^{1/2} \quad (1)$$

where:

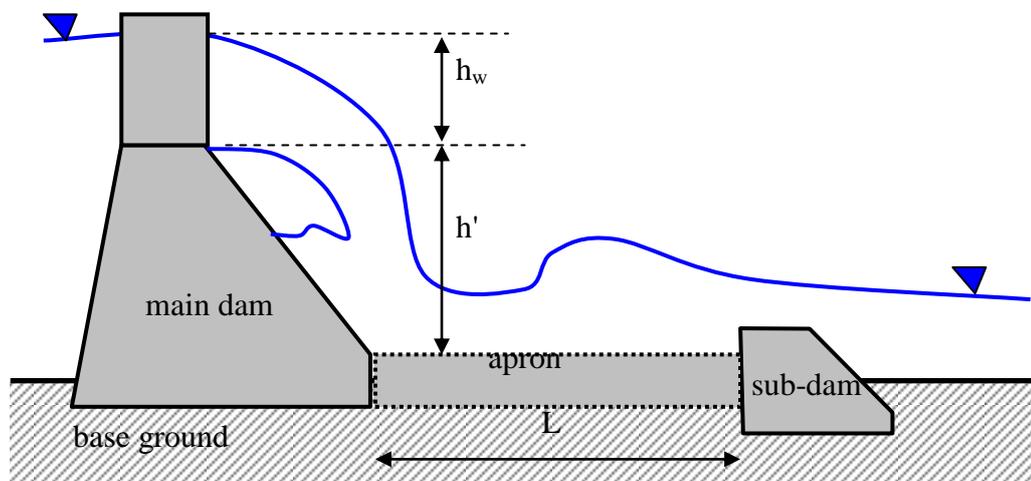
- τ_b : tensile strength (in kg/cm²)
- σ_{bk} : compressive strength of the mortar in masonry (in kg/cm²)

The soil layer under the base of the dam site which consists of sedimentary materials, is dominated by the material composition of loose rocks with other smaller grains filler. So, the strength of the subgrade under the dam is determined by the strength of the rock sediment. The structural simulation for the reparation purpose is based on available technical data of the dam as listed in Table 1. The simulation results are very necessary to take the decision of reparation method of the dam without the use of reinforced concrete which can be done quickly and accurately. Besides the dam strength, the speed of restoration time is necessary since the facility of this dam is very vital to support the lives of thousands of people on the right side of the Batang Kuranji river.

Then using those values in Table 1, it was conducted a series analysis of the dam based on a number of scouring scenarios at the subgrade of the dam. The simulation is aimed to estimate the tensile stress of the unreinforced masonry dam to withstand the scouring on the base of foundation in the downstream. The two dimension finite element PLAXIS program is used as numerical tool to solve the simulation.

Table 1 Values of parameter for analysis

Material type	Parameter		Value
River rock masonry	Unit weight	γ_b	22 kN/m ³
	Compressive strength	σ_{bk}	10 000 kN/m ²
	Tensile strength	τ_b	1 000 kN/m ²
	Modulus of Elasticity	E_t	15 x 10 ⁶ kN/m ²
Subgrade	Unit weight	γ_s	18 kN/m ³
	Standard penetration test	N_{spt}	60 blows
	Internal friction angle	ϕ	45 ⁰
	Unconfined compressive strength	q_u	400 kN/m ²

**Figure 2** Typical scheme of sub- and main- dam (PSDA West Sumatra, 2012)

3. RESULTS AND DISCUSSION

Simulation of the dam structure is done by considering the original of the dam before damage, the initial scouring of the foundation and after damage occurred. The results of the numerical software program are then redrawn to give better illustrations of the problems. In the original condition, it can be seen that the dam of Gunung Nago is in a very good condition. It means that all parts of the dam body in a state of compressive stress. This situation is really ideal for concrete and masonry without reinforcement (Figure 3). The compressive stresses are very small compared to the strength and the dam is still in a safe condition. The maximum stress value is only 5% of the compressive strength of the rock river masonry material.

At the beginning of the scouring conditions at the base of the foundation, the dam of Gunung Nago is still in good condition. Most of the part of the dam structure are in a state of compressed. At this time there is tension stress began on the upper part of downstream tail (Figure 4), but the dam is still in very safe conditions. The maximum tensile stress in that section is only about 10 kN/m² or about 1% of the tensile strength of the masonry material.

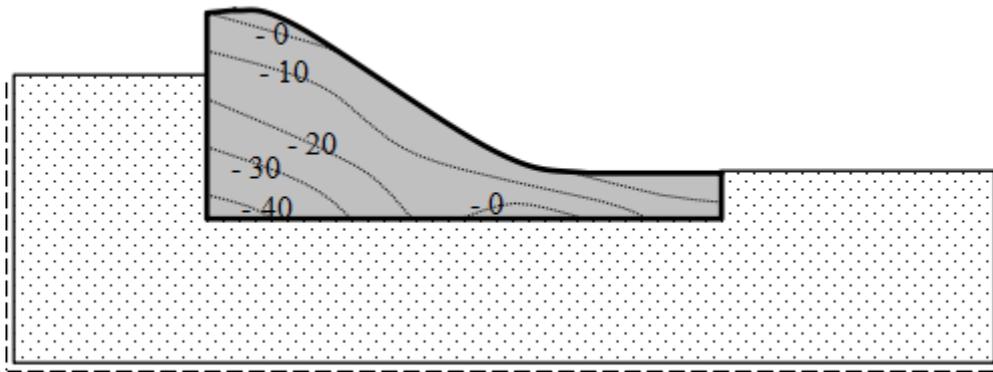


Figure 3 Stress on dam in initial condition

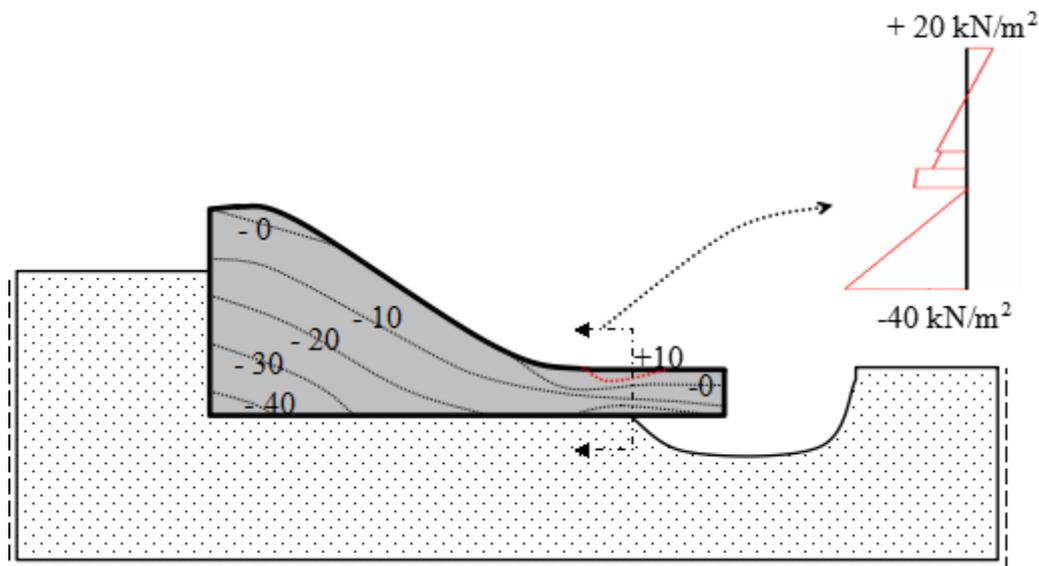


Figure 4 Stress on the dam in beginning scouring condition.

At the scouring state that reaches as long as 1.5m on downstream dam, the stress of the Gunung Nago dam condition has been already on a safe boundary conditions. Even the most part of the dam structure is still in a state of compression, however at this time the are fairly large tensile stress on mid-upper parts of the dam (Figure 5). The maximum tensile stress occurs at the boundary safe condition. The maximum tensile stress value in that section is about 300 kN/m^2 , or about 30% of the tensile strength of the material where the safe limit values for tensile stress is allowed.

When the soil conditions below the dam foundation scoured up to 1.5 m, it can be seen that the upper part of the dam structure was at the limit of safety against tensile. At that time, the upper part of the dam in which its base began to loos the soil support, is started to damage during the flood. Mechanically the values of tensile stresses in this conditions are remain in limit of allowable strength. Theoretically the dam is still able to give the service if it is repaired with the same material that is the river rock masonry.

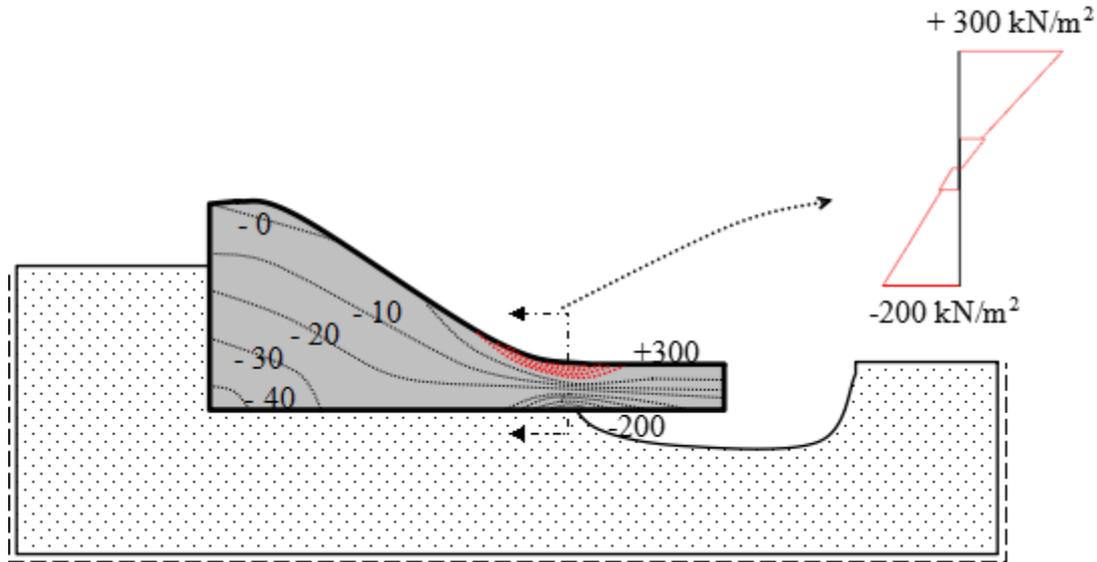


Figure 5 Stress on the dam in limit safe condition.

Based on these results, the appropriate restoration that need to be done only by filling the section below the dam back to the original condition (Figure 6). Then the dam is repaired as same as the original one. Furthermore, to avoid the occurrence of scouring at the base of the dam foundation, it needs to make an additional apron on the downstream side of the dam as a scouring protection.

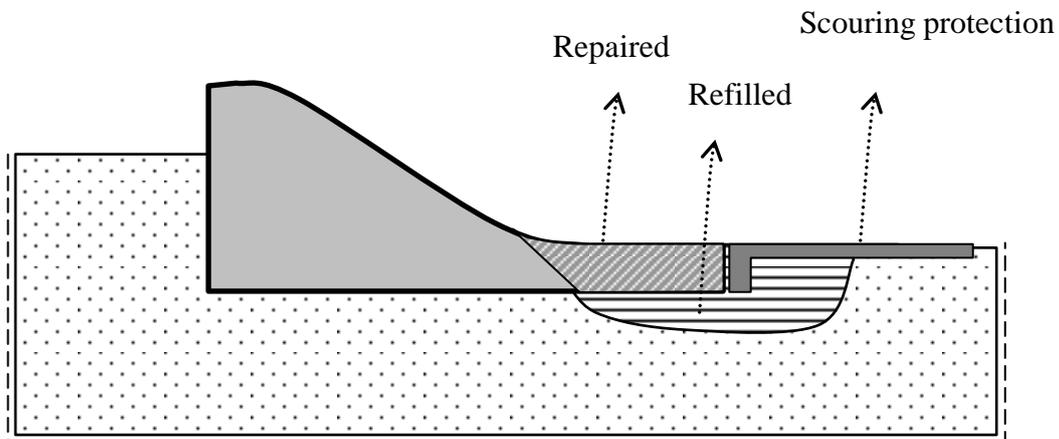


Figure 6 Quick and appropriate restoration for the dam

4. CONCLUSIONS

Based on the observations in the field during Galodo disaster at Batang Kuranji in 2012 and followed by the series analyses of the Gunung Nago dam structure, it can be concluded that the construction of the dam is mechanically strong enough. Although it has been scoured in a large section of the subgrade under the downstream foundation, the stresses that occurred in the dam is still in allowable condition.

Most part of the river stone masonry dam is still stable at post the Galodo disaster. Based on the analyses, Since it was showed that the stresses occurred in the body of the dam is still in safe condition, then the corrective action that is quick and accurate is refilling the soil on the base that has been scoured followed by the reconstructing

the dam with the same material. To protect the dam against the scouring in the future, it needs to build the ground sill on the downstream of the dam as a scouring protection structure.

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