Assessment of Bridges for Tsunami Evacuation Route Plan in Padang: Survey of Existing Condition and Identification of Problems

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ABSTRACT

Padang, as one of the tsunami prone city in the world, had already prepared itself for the upcoming event. Local government already issued tsunami evacuation plan, and assigned several buildings as temporary evacuation facilities or shelters. One important thing in this mitigation plan is the performance of the infrastructures as roads and bridges. Bridges are essential since any damages or failures leads to disruption or even widespread jam of traffic after the big earthquake. Draft of new seismic code for bridges in Indonesia suggests that bridges for evacuation plan must be designed with very limited damage or near elastic design. This study attempts to identify bridges that are included in tsunami evacuation plan route and summarizes the existing condition. The collected data and information are important and could be used as basic for future studies such as retrofit plan.

Keywords: tsunami mitigation, tsunami evacuation plan, bridge assessment

1. INTRODUCTION

Padang City is known as high seismic risk zone, and 5 strong earthquakes with MMI scale between IV-VII hit the region between 2005-2009 [1]. Beside earthquakes, Padang is also a tsunami prone area [2], [3], [4]. The local government already launched several mitigation plan such as issuing tsunami evacuation map in 2010 and building several tsunami shelter. Based on experience from the past big earthquakes, people in Padang City immediately evacuate after the earthquake hit. One of most important thing in evacuation plan is the performance of infrastructures such as roads and bridges. Bridges play essential role, since damage or collapse of bridges may disrupt traffic and cause widespread traffic jam during evacuation process.

The draft of new seismic code for bridges in Indonesia [5] already specify clearly the design earthquake and ductility required based on the importance criteria of the bridge. Bridges that will be used immediately after the earthquake hit, such as bridges in tsunami prone area like Padang, are classified as critical bridges. This is a new clausul for bridge code in Indonesia since the old code [6] does not specify clearly the use of importance factor. This raises question about the performance of existing bridges which are designed with old code against future design earthquake. Especially in Padang City, where several big earthquake already hit since 2005, there are concern about the accumulated damages.

Padang City also has potential for liquefaction [7], [8]. Based on experience from the 2009 big earthquake, liquefaction occured in several locations, mostly near the river and bay area. Therefore, bridges in Padang City are not just have to withstand the large forces to due earthquake but also resistance against liquefaction problems.
2. PROBLEMS STATEMENT AND PURPOSE OF STUDY

Based on the above explanation, questions about the performance of bridges in Padang City regarding next big earthquake are straightforward:
1. How are the condition of existing bridges? Are there any damages resulted from previous earthquakes?
2. Can these bridges withstand the next big earthquake with minor or no damage? What are the expected performance level?
3. If any damages occurred, what are the typical problems and proposed solutions?

This paper tries to summarize briefly the condition of existing bridges. The data are collected from survey that was held on May 26-27, 2015. There are 24 bridges that are related with tsunami evacuation plan, or located in tsunami ‘red zone’ area according to official tsunami evacuation map issued by local government.

The results will be very important as basis for the next step: detail analysis for assessment the capacity of bridges and performance analysis under design earthquake load based on the new code.

3. THEORETICAL BACKGROUND AND LITERATURE REVIEW

Chen & Duan [9] summarized that damages of bridges due to earthquake are affected by:
1. Local condition: soil condition, distance to earthquake source and potential for liquefaction.
2. Year of construction: older bridges are more prone to damages since older codes do not accommodate accurate load or adequate detailing.
3. Change of condition due to lack of maintenance.
4. Structural configurations that are not favorable against earthquake, such as: skewed bridge, large difference of stiffness of piers, lack of redundancies.
5. Inadequate length of support seat. This can results in collapse of upper structure due to large deformation.
6. Inadequate detailing, such as confinement at plastic hinge region or detailing of horizontal stopper.

Draft of Indonesian seismic code for bridges, RSNI 03-2833-201x, has several improvement compared with older code. Some of the differences that are relevant with this paper are:
1. New earthquake map that are based on Indonesia new earthquake map 2010, with dual risk level: return period 500 years and 1000 years.
2. Provision of importance category. Bridges are classified as critical bridges (keep operating right after big earthquake with return period 1000 years for emergency reason), essential bridges (can be operated few days after big earthquake with return period 1000 years) and other bridges (design earthquake has 500 years return period). Critical bridges has lower reduction factor for earthquake load, R=1.5 for all types of piers, implying that they are designed as almost elastic structure.
3. Some detailing like requirements for deck collapse prevention mechanism are defined more clearly.
Figure 1 shows the difference of design earthquake load for single column type piers in Padang City for different code (soil type SD and SE). This figure clearly shows that the capacity and performance of existing bridges that designed with old code are questionable.

Another factor that need to be studied is liquefaction. Liquefaction can produce lateral spreading that induce high pressure on abutments or piles of bridges. Figure 2 shows the location where liquefaction occurred during 2009 big earthquake in Padang. Studies by Hakam & Darjanto [7] and Warman & Jumas [8] confirmed that many area in Padang, especially near bay and rivers, have high potential for liquefaction.

Figure 1: Design earthquake loading for single column pier in Padang City, soil type SD (left) and SE (right)

4. LOCATION AND DATA OF BRIDGES

Location and data of bridges are shown in Figure 2 and Table 1. Figure 2 also shows the border of ‘red zone’ or tsunami inundation risk zone. All of the surveyed bridges are located within the ‘red zone’. The yellow marked area are the location of liquefaction during 2009 earthquake (reproduced from [7]).
**Figure 2: Location of bridges**

**Table 1. Data of Bridges**

| No | Bridge ID.     | Span length (m) | Type of Superstructure | Type of Substructure | Condition of structural element |
|----|----------------|-----------------|------------------------|----------------------|--------------------------------|
| 1  | Duku 1         | 31.7 + 31.8 + 31.7 | Prestressed I Girder   | Single Column        | -                               |
|    | Duku 2         | 31.7 + 31.7 + 31.7 | Prestressed I Girder   | Wall                 | -                               |
| 2  | Muara Kasang 1 | 6.6 + 11.7 + 12.5 + 6.4 | Composite Steel I Girder | Wall                | -                               |
|    | Muara Kasang 2 | 19.5 + 21        | Prestressed I Girder   | Multiple Column      | -                               |
| 3  | Lubuk Buaya 1  | 42              | Steel Truss            | -                    | Damaged horizontal stopper     |
|    | Lubuk Buaya 2  | 45.3            | Steel Truss            | -                    | Damaged horizontal stopper     |
| 4  | Muara Penjalinan 1 | 31 + 31 + 31       | Prestressed I Girder   | Multiple Column      | -                               |
|    | Muara Penjalinan 2 | 30.8 + 30.9 + 30.8 | Prestressed I Girder   | Wall                 | -                               |
| 5  | Tabing 1       | 25              | Composite Steel I Girder | -                    | -                               |
|    | Tabing 2       | 26              | Reinforced Concrete T Girder | -                    | Cracks on girder               |
| 6  | Ulak Karang 1  | 30.5 + 30.6 + 30.5 | Composite Steel I Girder | Multiple Column      | Damaged railings               |
|    | Ulak Karang 2  | 30.7 + 30.7 + 30.7 | Prestressed I Girder   | Single Column        | -                               |
5. TYPICAL PROBLEMS AND PROPOSED SOLUTION

There were no damages or cracks observed on reinforced concrete structural element at piers or abutments, therefore it can be concluded that the structures are in good condition. However, damages or potential problems are observed in detail elements like bearings, horizontal stopper and seismic buffers. Detail typical problems and proposed solutions are summarized as follows:

1. No horizontal stopper
   Almost all bridges with concrete upper structure do not have horizontal stopper. This condition is very serious since the bridges are prone to collapse of upper structure or deck. Additional horizontal stopper structures have to be installed immediately. Ulak Karang bridge shows indication of pounding between railings of adjacent span, and this may be caused by unrestrained deformations in longitudinal direction during past earthquake.

2. Damaged horizontal stopper
   Bridges with steel I-girder or truss deck have horizontal stopper and seismic buffers. Damages of horizontal stopper or seismic buffer element were found in 3 bridges. Repair of these elements need to be done immediately.
Figure 3: Damages at railing due to pounding (Ulak Karang Bridge)

Figure 4: Damages of concrete block for horizontal stopper (Lubuk Buaya Bridge)

Figure 5: Damages of steel bracket for seismic buffer and horizontal stopper (Tamsis-Jati Bridge)
3. Damages of mortar pad and bearing
Siti Nurbaya Bridge, one of the city’s icon and longest bridge, suffers from damage of mortar pad and bearing. This damage need to be repaired immediately, since bearings are the only connection between the bridge’s upper structure and lower structure.

Figure 6: Damages of mortar pad and bearing (Siti Nurbaya Bridge)

Figure 7: Damages of bearing’s bolt (Ganting Bridge)

Beside the condition of existing bridges, other problems that need immediate actions are:
1. No design or construction documents available
Almost all of design and construction documents for bridges in Padang are missing or gone due to the collapse of old Public Works building due to 2009 big earthquake. Therefore, detail calculation for analysis of capacity of existing bridges can not be done due to lack of data.

2. Bridge in liquefaction area
At least 12 bridges (including the longest: Siti Nurbaya Bridge) are within liquefaction area. To the authors knowledge, Padang City still does not have liquefaction map. More detail works to establish liquefaction potential map and analysis of bridges against failure due to liquefaction are needed.
6. CONCLUSIONS

Several conclusions can be pointed out from this study:
1. The design earthquake load for Padang City is increased significantly in the new code compared to older one. The new code also give more clear definition of importance factor and its implication in design. Bridges within tsunami inundation risk zone can be classified as critical bridges. This results in inadequate capacity of existing bridge against future event.
2. Typical problems in bridges in Padang are: no horizontal stopper in bridges with concrete deck, damages in horizontal stopper, damages in bearing.
3. No damages in piers and abutments are found. It can be said that the quality of concrete for piers and abutments are good.
4. More detail and comprehensive studies about liquefaction are needed, and detail analysis about its effect on existing bridges are essential.

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