Bridge Piers Structure Performa Evaluation of Purus at The Time of Strong Earthquake with Finite Elements Method Non Linear Three Dimensional

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Abstract
Currently, the majority of earthquake-resistant structures are planned with the procedures written in the planning regulations. Rules are made to ensure the safety of the infrastructure of the massive earthquake that may occur, to avoid, reduce damage or losses as a result of the earthquake load is received by the structure. However, the procedure used in these regulations cannot directly show the performance of the structure due to earthquake loading has been applied on the structure. Earthquake resistant structural design based on performance (performance-based seismic design) is a process that can be used for planning new structures and retrofitting the existing structure. This performance-based planning will provide a realistic understanding of the safety risk (life), the readiness to use (occupancy) and loss of property (economic loss) that may occur as a result of earthquakes in the future. Planning is used to determine performance-based targets as set out in FEMA 273 (1997), which was the performance of the infrastructure. From the above concept, the calculation of the bridge Purus II can be seen, how the planned infrastructure performance when receiving loads, especially seismic loads that have been planned, using the finite element method.

Keywords: bridge piers; pushover

INTRODUCTION
Indonesia is a country prone to earthquakes because it is located in a region of high earthquake level. The massive earthquake that struck Indonesia occurred on September 30, 2009 in the province of West Sumatra. Epicentrum is located approximately 60 km from the city of Padang. Researchers seismicity predictor that the coastal areas of West Sumatra has the potential to be a big earthquake followed by a tsunami. One of the areas expected to receive the impact of the earthquake and tsunami is Padang. With regard to the foregoing, the Regional Government of Padang have been and are preparing infrastructure to minimize the impact of disasters that might befall the city of Padang. One of the infrastructure in question is the provision of a bridge that connects the region bounded by the river in the city of Padang. Besides, as the infrastructure to support the development of the city of Padang, the bridge is also used as an evacuation path if the city of Padang suffered the earthquake and tsunami.

The purpose of this study was to evaluate the performance of reinforced concrete bridge piers due to the load Purus powerful earthquake that may occur in the city of Padang using pushover analysis, namely by charging models monotonic bridge pillar structure in the horizontal direction. The horizontal load is determined based on the load inertia working on the pillar structure, namely the multiplication of the mass of the structure with the maximum ground motion acceleration that have occurred in the city of Padang. The results of this evaluation are expected to be one of the considerations and input, both in the structural design of bridges in earthquake prone areas, as well as a consideration in the utilization of Purus bridge later.
Performance planned infrastructure needs to be evaluated. In this study, the performance evaluation is done by using a numerical method based on the Finite Element Method. Specifically, in evaluating the analytical performance, the root problems that arise can be given as follows:

1. How to model the structure of the pillars of the bridge Purus with the finite element method?
2. How to evaluate the performance of the pillars when under load due to a strong earthquake?

In order for the process of the analysis conducted in this study could be simpler, analysis to determine the performance of the Purus bridge is only done on the structure of reinforced concrete pillars and floor girder rested the bridge. Selection is done groundlessness pillar analysis the fact that the failure of the pillar structure of the bridge will result in failure of the overall structure of the bridge.

LITERATURE REVIEW

Currently, the majority of earthquake-resistant structures are planned with the procedures written in the planning regulations. Rules are made to ensure the safety of the infrastructure of the massive earthquake that may occur, to avoid, reduce damage or losses as a result of the earthquake load is received by the structure. However, the procedure used in these regulations cannot directly show the performance of the structure due to earthquake loading has been applied on the structure. Earthquake resistant structural design based on performance (performance-based seismic design) is a process that can be used for planning new structures and retrofitting the existing structure. This performance-based planning will provide insight, which is realistic about the safety risk (life), the readiness to use (occupancy) and loss of property (economic loss) that may occur as a result of earthquakes in the future. General criteria used in the planning of infrastructure in earthquake-prone areas have been set in the UBC in 1997, where the criteria are structured to prevent structural failure and loss of lives. The criteria are to be provided as follows:

1. When a small earthquake, no damage at all.
2. When an earthquake happens medium, allowed damage to architectural but not a structural damage.
3. When a strong earthquake occurs, allowed the occurrence of structural and non-structural damage, but the damage done is not to cause the building to collapse.

Planning is used to determine performance-based targets as above in FEMA 273 (1997), which was the performance of infrastructure as given as follows:

1. Immediately usable (IO = Immediate Occupancy),
2. Safety is still guaranteed (LS = Life-Safety),
3. Avoid a total collapse (CP = Collapse Prevention).

The finite element method is a numerical method that is commonly used to analyze problems in the field of engineering. The development of computer technologies and
computational and numerical methods allow the finite element method can solve engineering problems are complicated and complex. As described previously that in evaluating the performance of civil structures, one of them a numerical simulation, which models the structure was analyzed using an analytical approach. Finite Element Method has been widely recognized in the field of engineering that has the ability to simulate the structural model as expected in a performance-based structural design.

The general equation for the finite element method is derived based on the assumption of infinitesimal displacements (infinitesimal displacement) is mathematically written in equation (2.1)

\[
\frac{\partial}{\partial x_i} \sigma_{ij} + \frac{\partial}{\partial y_j} \sigma_{iy} + \frac{\partial}{\partial z_k} \sigma_{iz} = \rho \frac{\partial^2 u_j}{\partial x_i^2}
\]

(2.1)

Wherein voltage components; which is gravity. In tensor notation, equation (2.1) can be written as follows:

\[
\sigma_{ijkl} - \rho g \delta_{ij} = 0
\]

(2.2)

Formulation of the non-linear finite element method in this study is derived by reference to the Weighted Residual Method (WRM), which displacement in the domains that are reviewed u, taken as unknown factors, as outlined in equation (2.3).

\[
\int_{\Omega} \delta u_j \delta \sigma_j \, \mathrm{d}\Omega = 0
\]

(2.3)

The behavior of concrete structures obtained from the experimental nature is as macroscopic and cannot always represented actual conditions on the level of microscopic. Expected condition of macroscopic material behavior can be reflected in the constitutive models of concrete materials. This is because the internal mechanism that determines the behavior of the concrete material has never been directly observed. For example, the process of fracture, slip, friction, crushing, cracks deployment and dilatation in the concrete cracks are not observed directly, but derived from experimental measurements and observations of the surface. This mechanism was later developed into the form of a mathematical equation model using the theory of elasticity, theory of plasticity, and the theory of destruction by extrapolation and certain assumptions. As a result, all models have limitations and are only able to simulate certain aspects of behavior.

In this study, the behavior of concrete damaged plasticity models follow the criteria as set out in the Manual V6.11 ABAQUS. Reliability these criteria, among others.
1. Provide the capability to model the structure of concrete and other brittle material for all types of structures, such as the beam, truss, shell and solid.
2. Applying the concept of isotropic elastic destruction by combining with isotropic tensile and press plasticity to represent the inelastic behavior of concrete structures.
3. Can be used for plain concrete, although its main use is intended for the analysis of reinforced concrete structures.
4. Can be used to model reinforcement in concrete.
5. Designed for applications where the concrete is subjected to load monotonic, cyclic and dynamic.
6. Can control factors influence recovery of material stiffness during cyclic load reversal.
7. Can be defined to be sensitive to the rate of straining
8. Require that the elastic behavior of materials can be isotropic and linear.

The model is based on the criteria of damaged plasticity models assume that the two main failure mechanisms are cracked drag and tap the destruction of the concrete material.
Developments of the destruction of the surface hardening is controlled by two variables, namely the failure mechanism under the influence of tensile and pressure loading.

Criteria damaged plasticity models assume that the uniaxial tensile and press response damaged concrete structures characterized by plasticity, as shown in Figure 2.

![Figure 2](image)

**Figure 2.** Pull and Press uniaxial behavior of concrete (Source: ABAQUS Theory Manual)

When under the influence of uniaxial tensile load, stress-strain response of concrete follow linear elastic relationship to the value of voltage collapse, is reached. Collapse of the surface associated with the onset of small cracks that occur in concrete structures. Furthermore, the process of forming a voltage collapse on small cracks macroscopically represented by softening the stress-strain response that will produce strain in the structure of the initial concrete, (initial yield) indicates that the response of concrete structures suffered uniaxial compressive load is linear.

**RESEARCH METHODOLOGY**

In this study, the pillars of the bridge Purus Padang taken as objects in the analysis. Purus bridge is one bridge in the city of Padang is one of its functions is as an evacuation route when the earthquake and tsunami struck the coastal city of Padang. It is expected that the bridge is able to work properly. Bridge with spans 80.00 meters divided into three parts with two pillars and two abutments buffer.

The case study is taken from a reinforced concrete pillar with 12:00 meters wide, thick 1:00 meters and a height of 5:00 meters as shown in Figure 3. Pilar riveted by the pile cap and pile foundation. In this study, it is assumed that the foundation remains stable when loaded and when a strong earthquake. On this basis, the analysis in this study is only carried on without a pillar and foundation pile cap, where the basic pillars wedged perfectly assumed the pile cap.

![Figure 3](image)

**Figure 3.** Pilar Model Bridge Purus

Pillar reinforcement is shown in Figure 4. To ease the problem, reinforcement were reviewed did not include the reinforcement on the wing pillars. Construction of concrete on the
wings of strong assumed in accepting the existing load. However, analysis by reviewing the reinforcement in reinforced concrete construction would require large memory in the analysis process by using computer software. In addition, the analysis process will also require a relatively long time to get the expected results. So that analysis can be performed more simply, in this study, the reinforcing steel in the construction of reinforced concrete bridge piers is modeled in the form of steel sheet with the same volume as the real steel bars as shown in Figure 4.b. The relationship between concrete and reinforcing steel terekat assumed perfect (perfectly bonded) in view of reinforcing steel used is a steel and concrete screw with the quality of K-350, so expect no slip between concrete and reinforcing steel.

![Figure 4. Model Analysis of Reinforcement Pilar](image)

Finite element model is made by dividing the pillar structure be more than 2682 solid elements 8 meeting points (8-node hexahedron element), 6082 meeting points to 12882 degrees of freedom, as shown in figure 5.

![Figure 5. Finite Element Model](image)

**ANALYSIS AND DISCUSSION**

Finite element model has been discussed in the previous chapter, then analyzed using ABAQUS software. To determine the performance of reinforced concrete pillars of the bridge, in this study, the discussion will be presented in the form of numeric, graphic and distribution contours that are relevant to the discussion undertaken. As also previously discussed that the analysis carried out by applying a load monotonic against bridge piers construction model (load control)

The relationship between base shear acting on the base of the pillar to pillar head displacement is shown in Figure 7. The position where a reference point for the movement of the head of the pillar is shown in Figure 6. (Point A). The graph in Figure 7 shows that the displacement of the head of the pillar relatively small, only about 0.5 cm on the loading of up to 200% of the existing loading plan. The results of the analysis in the form of displacement of the head pillar looks unstable, especially when approaching a loading of 200% of the design load.
Distribution mains voltage (pull) construction of concrete at the end of the applied load is shown in Figure 8. As expected, the stress concentration starting from the base of the pillar and spread to the upper center pillar. History of the mains voltage to the loading time given, shown in the graph in Figure 9. From the graph shown that along with the addition of load, tensile stress to the tensile strength of concrete is allowed. This condition indicates that the area has been fractured.
However, after reaching the point of tension licenses, permits voltage back on concrete decreased. Instability of the results of this analysis is believed to be because the concrete material models do not include conditions permit after reaching the tensile stress, the condition of the collapse of the drop on concrete. This condition must also be directly explain the instability of the pillar head displacement behavior described in the previous section.
Contras with the behavior of concrete, during the loading condition of the reinforcing steel is still in elastic, where the maximum voltage happens is still below 100 MPa. This condition is understandable considering the condition of the concrete is still in a state with no damage, so almost all of the applied load is received by the concrete.

Figure 11. Main voltage behavior (Pull) Steel Construction

CONCLUSIONS AND RECOMMENDATIONS
This conclusion is drawn based on the analysis and discussion described in the previous chapter as summarized as follows:
1. Transfer of the head of the pillars were relatively small so that when subjected to strong earthquake loading, bridge girder rested on the heads of the pillars will not experience significant changes in the position. Thus it can be stated that, if the girder bridge was not damaged during the earthquake is strong, bridge Purus can still function properly, either at the time a powerful earthquake, and after a powerful earthquake that may occur.
2. Some parts in concrete construction has undergone plastic initial condition, but has not reached its limit conditions. Thus, it can be predicted that the fractured concrete construction just beginning and without suffering significant damage.
3. Conditions reinforcing steel is still in the elastic region due to the applied load. This is understandable considering the condition of the concrete construction is still in the early stages of plastic, so most of the applied load is received by the concrete construction.

Pushover analysis results in this study show an unstable condition if pushover performed by applying a load loading control. In this regard, it is suggested in the pushover analysis should be done with the loading system based on displacement control. The analysis also showed that the constitutive model used in this study is not fully adequate to simulate the behavior of concrete material. This is particularly noticeable after the tension has reached its license tensile stress. It is recommended to use a constitutive model which includes material behavior of concrete post-tension permission.

REFERENCES


