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RELIABILITY ANALYSIS FOR DYNAMIC BEHAVIOR, STIFFNESS, AND STRENGTH OF EXISTING STEEL TRUSS BRIDGE BH77

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ABSTRACT

Railway bridges are old, especially on the Sumatra Island and according to earthquake map on 2017 version show an increased risk, it is necessary to analyze the reliability of dynamic behavior to extend the bridge life and damage can be detected early. The bridge reliability was assessed in terms of natural frequency, deflection, and internal force. The study was conducted on the BH77 Railway Bridge in Tegineneng-Lampung, a through truss type. Reliability analysis with a non-deterministic approach, using the probability concept, the variability used is the dimensions of steel profiles based on fabrication drawings and field measurements. The research uses secondary data, one of which is the measurement of the circumference of the steel cross section, that influenced by the paint layer, where the paint thickness sample to correct and obtain the actual dimensions. Dynamic behavior analysis, consisting of modal analysis, Fast Fourier Transform, time history, and First Order Reliability Method. The analysis results showed the effect of steel dimension correction compared to the fabrication drawings did not have a significant effect on the changes in the values of natural frequencies, mode shapes, deflections, and internal forces. The reliability of the dynamic behavior obtained was 99% at all reviews. Which indicates that the bridge is safe against potential resonance, the bridge stiffness is still high, and the axial+moment capacity is still sufficient against static & earthquake loads, as well as good bridge maintenance. The largest deflection point as a reference for placing strain and vibration gauges on structural health monitoring systems.

KEYWORDS *Bridge; Earthquake; Dynamic; Behavior; Reliability.*

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INTRODUCTION

Referring to the National Railway Master Plan Review issued by the Ministry of Transport (2018), the railway has many advantages over other modes of transport, including: large transport capacity, fast, safe, energy efficient, and environmentally friendly. According to the Decree of the Transportation Minister Number KP2128 (2018), the national railway masterplan is prepared by taking into account the railway network masterplan per island, including the railway network masterplan for the islands of Sumatra, Kalimantan, Sulawesi, Java, Bali, and Papua. The policy for future technology transfer in 2030 and the development of the railway industry is to increase technological mastery of facilities and infrastructure, such as bridges, rails, and concrete sleepers. Based on data from the Ministry of PUPR (2019), 307,715 km out of 537,991.2 km (57.20%) of bridges in Indonesia are in good condition, 46,124.90 km (8.57%) are in minor damage, while 1.21% are in collapse condition. So a method is needed to determine the amount of capacity that can still be provided by the existing bridge structure. The remaining capacity can be obtained through structural reliability analysis.

According to Dewi et al. (2018), structural reliability is the chance of a structure not failing or collapsing when withstanding working loads. Structural reliability analysis with non-deterministic approach, which uses the concept of probability using variable distribution data. In this approach, all elements of uncertainty or parameter diversity are taken into account. Diversity that may arise such as load diversity, structural element dimensions, and structural models. The probability of failure exists because there is always an uncertainty factor in all structural data in terms of load, material grade, dimensions, and other factors. These uncertainty factors through statistical theory are used to calculate the probability of failure (P_f), then the value of structural reliability (R_o) is $R_o = 1 - P_f$.

The case study of this research is the existing railway bridge BH-77 located near Tegineneng Station, Natar District, South Lampung Regency, Lampung Province (see Figure 1 and Figure 2).

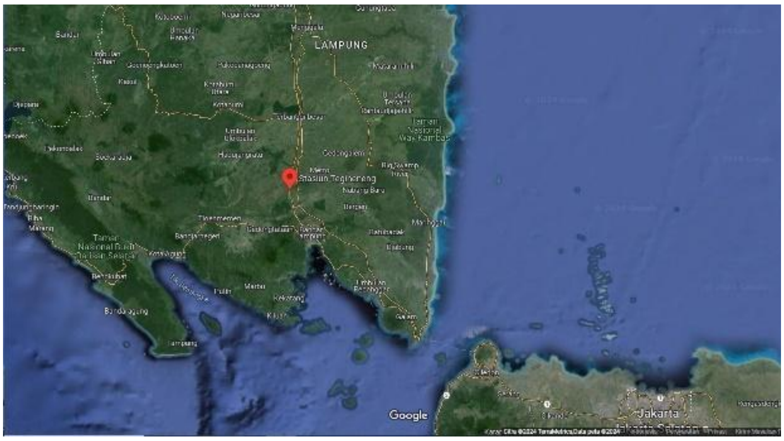


Figure 1. Location of Tegineneng Station
Source : Google Earth

Figure 2. Location of BH-77 Railway Bridge
Source : Google Earth

From the above background, several problem identifications were obtained, including that the location of the bridge in remote areas and rarely passed, making it difficult to know its maintenance. Railway bridges in Indonesia are old, especially on the island of Sumatra, so it is necessary to check the reliability of the dynamic behavior of the structure. According to the earthquake map on 2017 version, the area around Bandar Lampung has a high peak acceleration of bedrock (PGA) value, indicating an earthquake risk area. The reliability of the BH-77 bridge structure under static loading has been investigated in previous studies, so it is necessary to analyse the reliability of the dynamic behavior of the structure. And to extend the service life of the bridge and damage can be detected early.

Reliability analysis of the BH-77 bridge with static loading was investigated by Larasati et al. (2022) using a non-deterministic approach and monte carlo method. The variability used is the steel profile dimensions (width & height), based on data from fabrication drawings and direct measurements in the field. Nurfaizi et al. (2022) conducted research on the possibility of resonance in the BH-77 bridge based on the characterization of site effects around the bridge with microtremor data. From it data, the natural frequency value and site amplification factor at the location were obtained, then compared with the natural frequency of the bridge structure to determine the potential for resonance.

Referring to previous research, dynamic loads have not been included in the study, so in this study a reliability analysis of the dynamic behavior of bridge structures against earthquake loads is carried out, and using the First Order Reliability Methods (FORM) method.

The hypothesis of this study is that there is an influence between the steel cross-section of an old existing bridge structure on the reliability of its dynamic behavior, in terms of natural frequencies, internal forces, and deflections. Dynamic analysis with earthquake acceleration data scaled to the response spectrum of the bridge site, will provide more conservative structural analysis results, compared to the original accelerogram data. That the natural frequencies, deflections, and reliability of dynamic behavior can be used to determine the health of bridges in structural health monitoring systems (SHMS).

The purpose of this research is to answer the formulated problems, among others, to obtain the dynamic behavior of the bridge structure in terms of natural frequency, based on the mass and stiffness of the bridge structure. To get the dynamic behavior in terms of deflection and force in the rod due to load. To obtain the reliability value of dynamic behavior based on the natural frequency of the structure, deflection, and internal force using a probability approach with the First Order Reliability Methods (FORM) method.

RESEARCH METHOD

This study was conducted on the existing BH-77 steel truss bridge at Tegineneng, Tanjungkarang-Martapura, Lampung. To examine the effect of the steel frame cross-section of the old bridge structure on its dynamic reliability, in terms of natural frequencies, deflections, and internal forces. According to the Department of Transportation (1995) in the document The Design, Fabrication, and Supply of Steel Railway Bridges for Java and Sumatra, the bridge geometry has a length of 61.6 m in the bottom truss section, 53 m in the top truss, a width of 4.8 m, and a height of 8 m. This bridge type is a closed wall truss (through truss). Figure 3 to Figure 5 which displays a structural model view of the bridge.

The research uses secondary data, because the data is used from previous researchers. Data collection techniques by documenting the data. Bridge geometry and steel profiles refer to fabrication drawings from the Department of Transportation (Departemen Perhubungan, 1995). For changes in the dimensions of steel profiles following field measurements from previous researchers, Larasati (2022). The accelerogram data of the Padang-West Sumatra earthquake (Mag. 7.5) on 30 September 2009 was taken from the book of Earthquake Engineering & Earthquake Resistant Structural Systems, Amrinsyah Nasution (2016). For the main loading specifications refer to the Regulation of the Minister of Transportation Number: 60 (2012) about the technical requirements of railway track, and BSN: SNI 2833 (2016) concerning Design of Bridge against Earthquake.

The research variables consist of independent variables that present the cross-sectional dimensions of steel profiles (width and height). For the dependent variable which is the dynamic behavior of the bridge structure, the parameters are the natural frequency of the structure, deflection, force in the bar, and reliability.

The data analysis technique used to evaluate the performance of the bridge structure is variance analysis for free vibration of the structure, an analytical process to determine the dynamic characteristics of the structure, namely the natural frequency and mode shape. Earthquake load analysis with Fast Fourier Transform (FFT), to obtain the magnitude of the load frequency. Non-linear analysis of time history dynamic response to obtain deflections and forces in members. As well as dynamic reliability analysis of structures using the FORM method.

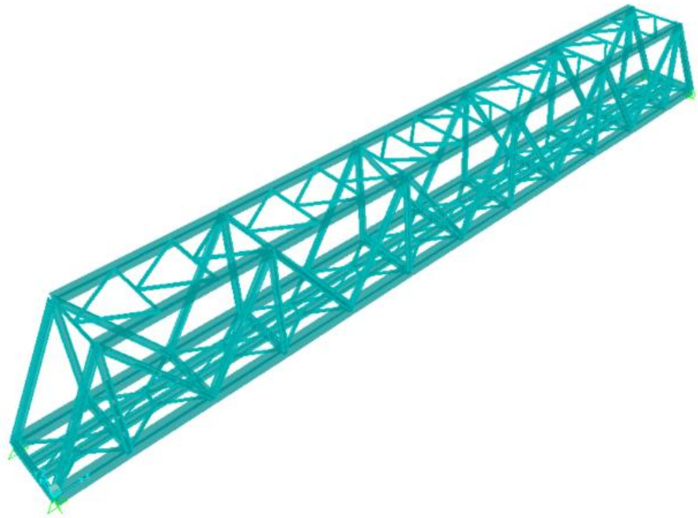


Figure 3. Three-Dimensional View of The Model

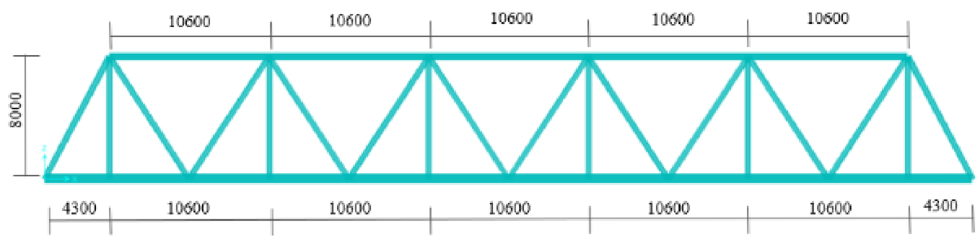


Figure 4. Side View of The Model

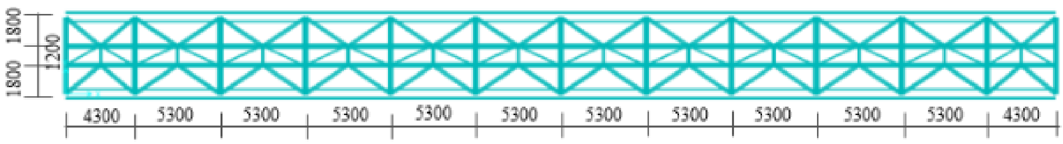


Figure 5. Top View of The Model

Structural modelling using SAP2000 V22 program. Based on previous research by Larasati (Larasati, 2022) from the results of dimensional correction due to the thickness of the paint layer, there are 173 steel members with corrected cross-sectional circumference (P") greater than the circumference on the fabrication drawing (P). Meanwhile, the corrected circumference that is smaller than the circumference in the fabrication drawing is 89 members. Therefore, in order to obtain a conservative model, the members whose circumference is greater than the fabrication, continue to use the dimensions based on the fabrication, and are combined with the members with smaller corrected circumference or dimensions.

The following Figure 6 is a flow chart for this research:

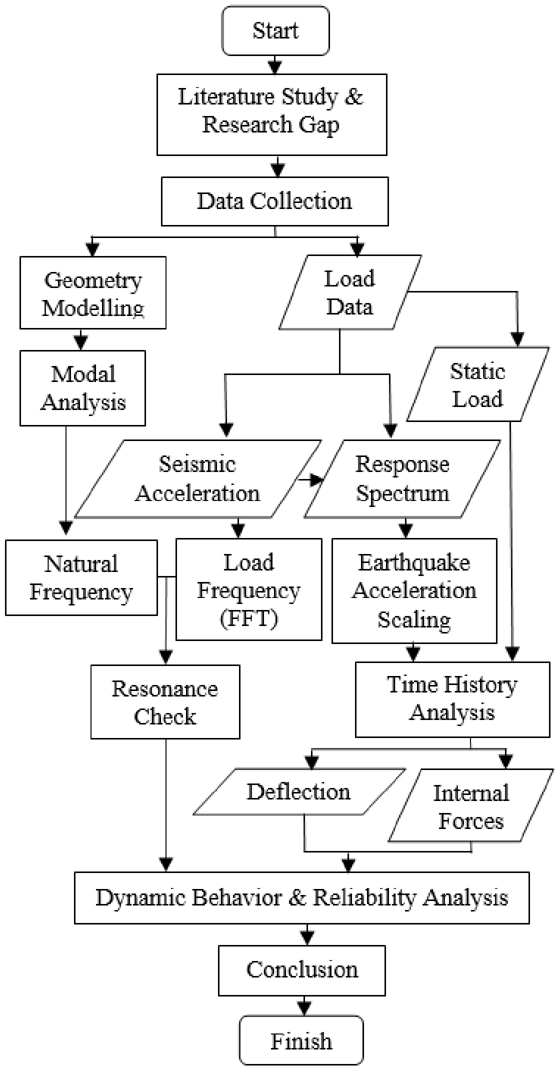


Figure 6. Research Flowchart

The types of static loads in this study include dead load (DL) which is the self-weight of the structure. The weight of bolts, plates, and stiffeners is taken as 15% of the total weight of the steel structure. Additional dead loads (SDL) are wooden rail sleepers with dimensions 180mm (t) x 220mm (l) x 1800mm (p), and steel rails type R54. Live load (LL) is the train load, consisting of CC202 locomotive load (108 tonnes) and KKBW carriage (72 tonnes), and is analysed as a moving load. The moving load consists of 2 schemes, namely when the bridge is passed by 3 CC202 Locomotives + 1 KKBW Carriage, and also when the entire bridge section is passed by KKBW Carriages. The impact load (I) is obtained by multiplying the factor i by the train load. The train lateral load (LR) is 20% of the train load. Braking and traction load (B) are 25% of the train load. And the temperature load (ΔT) refers to BSN: SNI 1725 (2016), the amount is based on the difference between the maximum and minimum temperatures, taken $\Delta T = 30^o$ C. These static loads will be placed on 2 stringer beams (longitudinal girders).

The earthquake load (EQ) used the acceleration recordings of Padang earthquake on 30 September 2009. According to BSN: SNI 2833 (Badan Standarisasi Nasional, 2016), the time history recordings in each direction must be scaled with the local spectrum response. These spectrum response parameters used the earthquake hazard map on 2017 version, which represents a potential 1000-year earthquake hazard with a 7% probability of exceedance in 75 years. To make it easier to determine the acceleration of the spectrum response, use Lini Application from Directorate of Road and Bridge Engineering (Bina Marga), by entering the coordinates of the bridge location. Due to the unavailability of soil investigation data, such as N-SPT values, it is assumed to use the soft soil (SE) site class. The values of the response spectrum parameters of the spectrum in bedrock consists of, the peak ground acceleration (PGA) = 0.256g, acceleration at 0.2 second vibration period (S_S) = 0.521g, and acceleration at 1 second vibration period (S_1) = 0.236g. Meanwhile, the value of the spectrum response parameters on the ground surface, namely, the peak acceleration of the ground surface (A_S) = 0.364g, acceleration at the 0.2 second vibration period (S_{DS}) = 0.864g, and acceleration at the 1 second vibration period (S_{D1}) = 0.721g. Amplification factors F_{PGA} = 1.420, F_a = 1.658, F_V = 3.056. After that, scaling was carried out with the Seismo Signal programme version 2018, and Table 1 is the result of comparing the maximum acceleration value from the original accelerogram data and after scaling.

Table 1. Comparison of Maximum Acceleration

No	**Direction**	**Maximum Acceleration**	
		Original Data (g)	**Scale Data (g)**
1	East - West (EW)	0,000265	0,437760
2	North - South (NS)	0,000314	0,684640
3	Top - Bottom (TB)	0,000417	0,506320

Loading combinations refer to BSN: SNI 1725 (Badan Standardisasi Nasional, 2016). Table 2 based on the service limit state method, to obtain the deflection of the structure. And Table 3 is based on the ultimate method, to obtain the force in the steel member.

Table 2. Load Combination (Service Limit)

DL	**SDL**	**LL**	**I & LR**	**B**	**ΔT**	**EQ**		
						TB	**US**	**AB**
1,0	1,0	1,0	1,0	1,0	1,0	-	-	-
1,0	1,0	1,0	1,0	1,0	-	1,0	0,3	0,3
1,0	1,0	1,0	1,0	1,0	-	0,3	1,0	0,3
1,0	1,0	1,0	1,0	1,0	-	0,3	0,3	1,0

Table 3. Load Combination (Ultimate Load)

DL	SDL	LL	I & LR	B	ΔT	EQ		
						TB	US	AB
1,1	2,0	1,8	1,0	1,8	1,2	-	-	-
1,1	2,0	0,5	1,0	0,5	-	1,0	0,3	0,3
1,1	2,0	0,5	1,0	0,5	-	0,3	1,0	0,3
1,1	2,0	0,5	1,0	0,5	-	0,3	0,3	1,0

RESULT AND DISCUSSION

Referring to the research method above, there are three analyses: modal analysis, dynamic behavior analysis, and structural dynamic behavior reliability analysis. Based on the variance analysis, the natural frequency value is obtained as shown in Table 4 Here. In the first mode out of a total of 70 modes, there is a difference in natural frequency between the structural model based on fabrication drawings and dimensional correction of 0.037%.

Table 4. Natural Frequency Values

Mode	Natural Frequency (Hertz)	Natural Frequency (Hertz)	Deviation of Natural Frequency (%)
	(Fabrication Drawing)	(Dimensional Correction)	
1	3,50953	3,50823	0,037
2	6,44807	6,44584	0,035
3	6,98546	6,98456	0,013
…	…	…	…
68	56,70298	56,69282	0,018
69	57,41292	57,40643	0,011
70	57,72166	57,71602	0,010

At Table 5 shows the mode shapes for mode-1, 2, and 3. The conditions based on the fabrication drawings and dimensional correction, it show the same mode shapes. In the first mode, the mode shape is a translation in Y-direction (lateral), with a mass participation values of 69.404% (fabrication drawings) and 69.330% (dimensional correction). The second mode is a rotation in X-direction (lateral), with a mass participation values of 46.147% (fabrication drawing) and 46.089% (dimensional correction). The third mode, translation in Z-direction (vertical), with a mass participation values of 78.762% (fabrication drawing) and 78.767% (dimensional correction). The mass participation value at the mode-70 has reached more than 90% for each direction UX, UY, UZ, RX, RY, & RZ, in accordance with the requirements referring to BSN: SNI 1726 (2019).

To obtain the load frequency from the ground acceleration due to Padang earthquake, Fast Fourier Transform (FFT) method was used, with an excel programme. In the Fourier spectrum, the load frequency is at the largest amplitude.

Table 5. Mode Shape of Truss Bridge

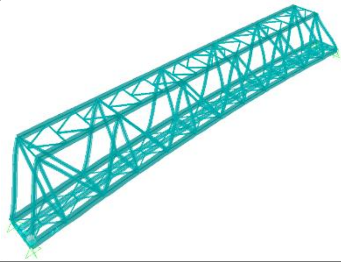
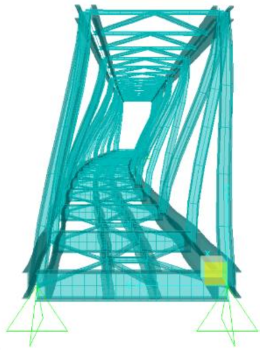
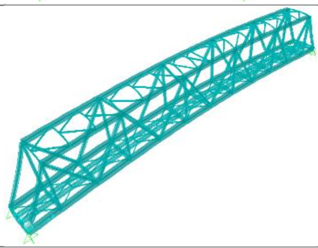
Variety	Shape of Vibration Variety (Fabrication & Dimension Correction)	Vibrating Pattern	
1		Directional translation (Lateral)	Y
2		Directional rotation (Lateral)	X
3		Directional translation (Vertical)	Z

Table 6. Comparison of Frequency Values

No	Frequency of Earthquake Load (Hertz)		Natural Frequency of BH77 Bridge (Hertz)	
			Fabrication Drawing	**Dimensional Correction**
1	East-West	13,672		
2	North-South	14,160	3,50953	3,50823
3	Top-Down	1,953		

Based on Table 6, the natural frequency of the bridge structure does not approach or coincide with the frequency of the earthquake load in each direction, so there is no potential for resonance in the bridge structure. Because a structure will experience resonance or not, if the natural frequency of the structure is close to or equal to the frequency of the load received. According to Kramer (1996) in

Hardiyatmo (2022), the potential for damage due to earthquakes is greatest, when the period or frequency coincides into one between the building structure and ground motion.

Figure 7, Figure 8, & Figure 9 are graphs showing the load frequency values in each earthquake direction.

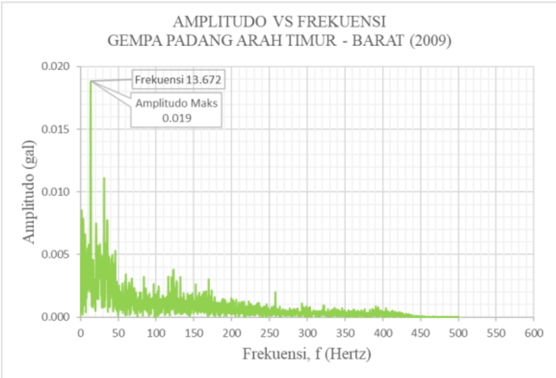


Figure 7. Earthquake Frequency (East-West)

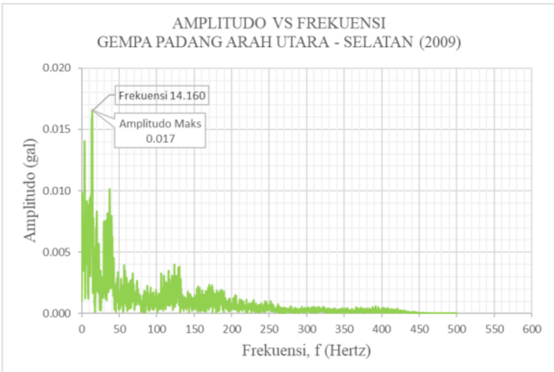


Figure 8. Earthquake Frequency (North-South)

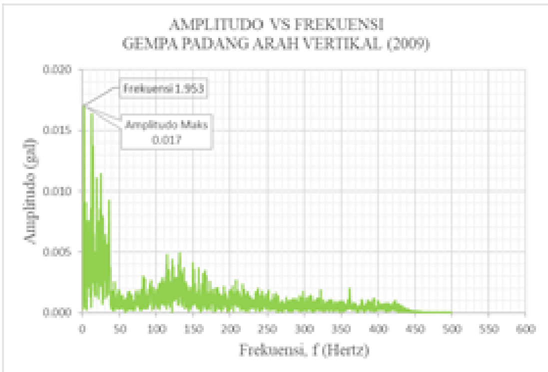


Figure 9. Earthquake Frequency (Upper-Lower)

From the dynamic analysis of structures due to static and earthquake loads using the time history method, one of the analysis outputs reviewed is the deflection of the bridge structure based on a combination of service loads consisting of static loads and earthquake loads. Figure 10 and Figure 11 respectively show the deflection shapes of the structural model based on the fabrication drawings, due to static+earthquake and static+earthquake (scaling) loads. While Figure 12 and Figure 13 show the deflection shapes of the structural model based on the dimensional correction of the steel profile, due to static+earthquake and static+earthquake (scaling) loads.

Figure 10. Bridge Deflection (Unit: mm)

Figure 11. Bridge Deflection (Unit: mm)

Figure 12. Bridge Deflection (Unit: mm)

Figure 13. Bridge Deflection (Unit: mm)

Table 7. Comparison of Bridge Deflection

Service Load Combo	**Deflection (mm)**		
	Fabrication Drawing	**Dimensional Correction**	**Difference (%)**
Static	24,7374	24,7537	0,066
Static + Earthquake	24,7394	24,7557	0,066
Static + Earthquake (Scale)	33,6427	33,6980	0,164

Table 7 shows the comparison of structural deflection between the fabrication drawings and dimensional correction. The value of deflection based on dimensional correction shows an increase, but the avalue is not significant, which is only 0.066% – 0.164%. From these deflection values, the magnitude is still below the allowable deflection L/1000 = 61600/1000 = 61.6 mm, so the stiffness capacity of the existing BH77 bridge structure is still sufficient in terms of deflection.

Table 8. Comparison of Bridge Deflection

Structure Model	**Deflection (mm)**		
	Original Acceleration Data	**Acceleration Data Scaled**	**Difference (%)**
Fabrication Images	24,7394	33,6427	35,988
Dimension Correction	24,7557	33,6980	36,122

From Table 8, the magnitude of deflections referring to the scaled earthquake acceleration data shows greater values than that based on the original acceleration data, with a quite significant difference of 35.988% to 36.122%.

Checking the strength of steel profile cross- sections under earthquake loads from original ground acceleration data and ground acceleration after scaling, based on fabrication drawings and correction of cross-section dimensions, with SAP2000 programme. The checking result is the axial-moment interaction stress ratio (P-M-M). The checking refers to BSN: RSNI T-03 (2005) concerning Steel Structure Design for Bridge, but because it is not yet included in the list of codes contained in the SAP2000 programme, an approximate regulation will be used, namely AISC360-05. For reduction factors (ϕ) consisting of bending, compression, and shear are adjusted to BSN: RSNI T-03 (Badan Standardisasi Nasional, 2005).

Referring to BSN: SNI 2833 (Badan Standarisasi Nasional, 2016), it only defines the response modification factor (R) value for the lower structure and the relationship between bridge structural elements, while the R value for the upper structure has not been defined. So that the R value of the upper structure in this study refers to BSN: SNI 1726 (Badan Standarisasi Nasional, 2019) Table 28, assuming the type of structure is a steel frame with ordinary concentric bracing frame (OCBF), with an R value of 3.25.

Load combination using the Ultimate Limit State method, to obtain the internal force in the steel elements or members. Figure 14 and Figure 15 show the stress ratio (P-M-M) output, with earthquake loads using the original ground acceleration data. The ratio is a comparison from the combination of axial force and ultimate moment that occurs to the capacity of the steel member (demand/capacity ratio).

The largest stress ratio based on fabrication drawings and dimensional correction is 0.91516 & 0.91549, at the lower chord element (double C-680x160x30x30) and is still below the allowable stress ratio of 1.00. This means that the axial force and ultimate moment that occur are still less than the capacity of the steel profile. The maximum ratio difference between the model based on fabrication drawings and dimensional correction, for all members is still below 1%.

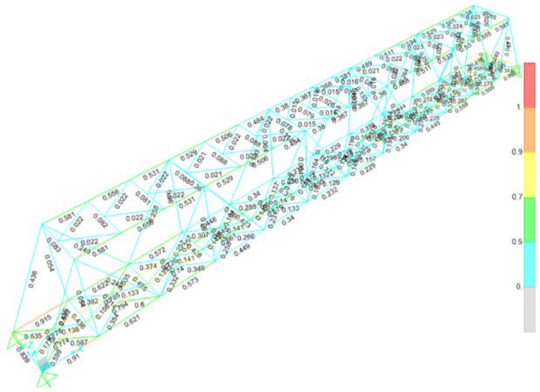


Figure 14. PMM Ratio (Fabrication)

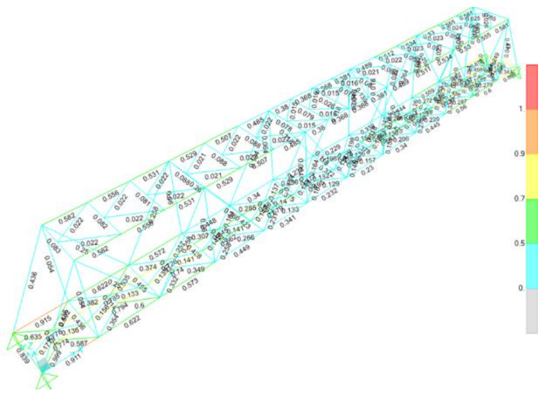


Figure 15. PMM Ratio (Dimensional Correction)

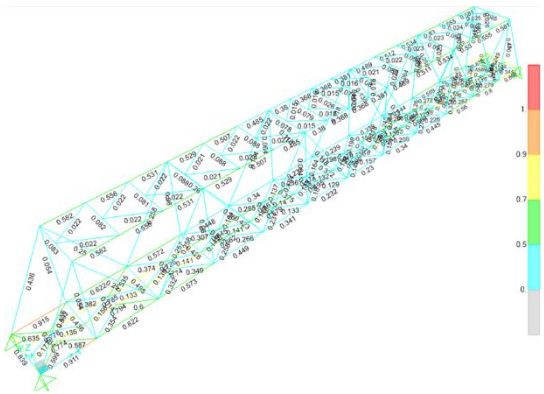


Figure 16. PMM Ratio (Dimensional Correction)

Figure 16 displays the ratio based on dimensional correction, and using the scaled acceleration data. The largest ratio is 0.91549 (<1.00), at the lower chord element (double C- 680x160x30x30). The maximum ratio difference between the model based on the original ground acceleration data and the scaled acceleration is 0%. Which shows that the steel stress ratio is dominantly caused by static loads rather than earthquake loads, because one of the factors is that in this study to check the steel stress ratio, an R value of 3.25 was used.

The dynamic reliability analysis of the structure reviewed are natural frequency, deflection, and steel stress ratio. The method uses the First Order Reliability Method (FORM), which is an analytical method by considering the statistical values of variables. The reliability index (β) is calculated by first finding the limit value for each review. Statistical parameters for resistance and load effect are used to find the β value. Then, using the normal distribution formula based on the mean, standard deviation and β, the probability of failure (P_f) and structural reliability (R_o) are obtained.

In the dynamic behavior reliability based on natural frequency, the resistance parameter (R) is the natural frequency of the bridge. There are two values, namely based on fabrication drawings and dimensional corrections, with a mean value is 3.50888 Hz and a standard deviation is 0.00065 Hz. Meanwhile, the load effect (S) is the frequency value of Padang earthquake-2009 acceleration, which is deterministic. The east-west direction was taken, because the value is closest to the natural frequency of the bridge, which is 1.953 Hz. From these parameter values analysed by the FORM method, the reliability index (β) = 2394 was obtained. Then with the normal distribution formula based on the β value, the probability of failure (P_f) is obtained at $0.54x10^{-11}$%, so the reliability value (R_o) is 99%, which states that the existing bridge structure is still safe against resonance.

Dynamic reliability is based on deflection, the resistance parameter (R) is the allowable deflection which is deterministic, and is 61.6mm (L/1000; L=span). The load effect (S) is the maximum deflection that occurs due to the combination of static load + earthquake (scale). There are two values, based on the fabrication drawings and dimensional correction, 33.6427 mm and 33.6980 mm, with an average value is 33.6704 mm and a standard deviation is 0.0277 mm. Then the reliability index (β) = 1010 was obtained. With a normal distribution based on the β value, the probability of failure (P_f) is $0.54x10^{-11}$%, and the reliability value (R_o) is 99%, which states that the existing bridge structure is still safe against deflection and has a large enough structural stiffness.

Dynamic reliability is based on the steel stress ratio, the resistance parameter (R) is the stress ratio limit (axial + moment) which is deterministic, and the value is 1.00. The load effect (S) is the maximum steel stress ratio that occurs due to the ultimate combination of static load and static load + earthquake (scale). There are two values, based on fabrication drawings and dimensional correction, 0.91516 and 0.91549, with an average value is 0.91533 and a standard deviation is 0.00017. Then the reliability index (β) = 513 was obtained. With the normal distribution formula based on the β value, the probability of failure (P_f) is $0.54x10^{-11}$%, and the reliability value (R_o) is 99%, which states that the existing bridge structure is still safe, with the axial capacity & ultimate moment of the existing truss still greater than the axial force & ultimate moment that occurs.

CONCLUSION

Based on the results of the modal analysis on the BH77 bridge structure, the natural frequency on the structural model with dimensional correction is smaller than the fabrication drawing. Due to the reduction in the dimensions of the steel cross section, the natural period is greater. But this dimensional correction does not have a significant effect, as shown by the percentage difference in natural frequency in the first variation of only 0.037%, and both models have the same mode shape for each mode, indicating that the bridge maintenance is good. Then the natural frequency of the bridge does not coincide with the frequency of the earthquake load, so it does not indicate any potential resonance.

The deflection due to the combination of static service load + earthquake in the structural model based on dimensional correction shows a greater value, due to the reduced stiffness of the structure, but the difference is not significant, only 0.066% ⎯ 0.164%. The deflection due to the scaled earthquake acceleration is greater than that of the original earthquake data, the difference being 35.988% ⎯ 36.122%. And of all the deflection values obtained, the magnitude is still below the allowable value of 61.60 mm, so the structural stiffness is still sufficient.

Based on the time history analysis with the original and scaled earthquake acceleration data, the axial-moment interaction (PMM) steel stress ratio is still below the allowable ratio of 1.00, which indicates that the axial + moment (nominal) capacity of the existing bridge members is still greater than the axial + moment (ultimate) forces that occur. And the dimensional correction factor does not have a significant effect, which is shown by the percentage difference between the maximum ratio value and the fabrication drawing is only 0.003% - 0.628%.

The reliability value of the dynamic behavior of the structure based on the natural frequency is 99%, which states that the existing bridge structure of BH77 is still safe against resonance. The reliability value based on deflection is 99%, which states that the bridge structure is still safe, and shows that the stiffness of the bridge structure is still high. The reliability value based on the steel stress ratio (axial-moment interaction) is 99%, which states that the bridge structure is still safe, indicating that the axial and moment (nominal) capacity of the truss structure is still sufficient.

The acceleration of the 2009 Padang earthquake did not significantly affect the results of structural dynamic analysis, such as deflections and internal forces, because the acceleration value was small. Based on the numerical analysis for matching the original earthquake acceleration to the local response spectrum, a comparison of the peak acceleration values in each direction was obtained, East-West 0.000265g (0.437760g), North-South 0.000314g (0.684640g) , and Top-Bottom 0.000417g (0.506320g). Values in parentheses are scaled peak accelerations, indicating larger values.

The BH77 bridge has a total of 262 steel members, the percentage whose cross-sectional area has changed is 89 members (33.969%). From 89 members, the percentage change (reduction) in cross- sectional area on each member is very small, between 0.062% ⎯ 0.331%. So this also supports that the bridge is still very reliable or has 99% reliability.

Inspection and maintenance of bridges by applying structural health monitoring systems (SHMS), one of which is the measurement of bridge response (static & dynamic). By using strain gauge sensors and vibration sensors (accelerometer sensors). Accelerometer sensors are used to measure vibrations, and can also be used as an alternative to deflection measurements. The sensor is placed at the point of maximum deflection. From the deflection analysis results, the largest deflection point is in the middle of the bridge span, positioned under the stringer beam with the rail above.

The following are suggestions for the development in further research, using earthquake acceleration data that is close to the location of BH-77 bridge in Lampung, and has a quite large magnitude value. Dynamic measurements of passing trains were required, consisting of amplitude and frequency. And a check is carried out between the natural frequency of the bridge and the frequency of the dynamic load of the train.

It is necessary to calculate the degradation value of bridge natural frequency, and its relationship with the actual condition of the bridge from visual bridge inspections based on the BMS-1992 (Bridge Management System). It is necessary to check the bridge structure against wind loads. Also it is necessary to measure the actual steel quality with a Hardness Test on several samples of bridge steel member.

It is required to analyze the reliability of the structure dynamic behavior using other methods, such as SORM (Second Order Reliability Method).

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