

Analysis and Modelling of The Sroyo Village Composite Bridge Superstructure Based on SNI 1725:2016

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Article Information	ABSTRACT
Article History Received : June 27, 2026 Revised : July 16, 2026 Published : July 24, 2026	This study aims to analyze, model and validate the superstructure of the Sroyo Village Composite Bridge to evaluate its structural safety while validating the manual calculation against computer-based modelling. The research method used is manual calculation analysis and computer-based structural modelling with SAP2000, in accordance with SNI 1725: 2016, RSNI T-03-2005 and SNI 2847: 2019. The results of the analysis show an ultimate moment of 991.25 kNm and an ultimate shear force of 304.60 kNm. This value is below the nominal moment capacity of 1365.57 kNm and nominal shear capacity of 648.00 kNm. The highest demand capacity ratio (DCR) is found in the shear connector at 0.98, while other internal force components can maintain safety control with a value of <1.00. The deflection that occurs is 12.36 mm which meets the allowable limit of 15.00 mm. Furthermore, validation of the results of manual analysis and SAP2000 modeling shows a minimum deviation of 0.07% and a maximum deviation of only 4.54% thus indicating the validity of the calculation results. Therefore, the superstructure of the Sroyo Village Composite Bridge is declared to meet structural feasibility according to Indonesian National Standards. However, this study is limited to the superstructure analysis.
Keywords: <i>Manual Analysis; SAP2000 Modelling; SNI 1725:2016; Sroyo Village Composite Bridge.</i>	

INTRODUCTION

The Sroyo Village Composite Bridge connects two villages, Sroyo and Banjaranyar, located in Bojonegoro Regency, East Java. Ideally, a bridge should be constructed of strong materials and in accordance with regulations. However, the materials used in the Sroyo Village bridge do not meet technical standards, posing a risk to users. Comprehensive redevelopment and rehabilitation are needed to support community mobility (Rasita et al., 2026). Unfortunately, in bridge planning processes in rural areas, structural calculations are often not performed, especially for the superstructure. Structural calculations are crucial for validating the safety of the bridge (Solissa et al., 2026).

Many previous studies have been conducted on bridge structural analysis, using both manual analytical calculation methods and software-based modeling. For example, the study by (Laia, 2021) and (Prasetyo, 2018) focused on manual analytical methods for evaluating bridges in rural areas without software validation. Meanwhile, several other studies have used computer-based modeling, such as those conducted by (Syafri et al., 2026), (Widiyanto, 2024), (Momot et al., 2026), (Fauzan et al., 2025), (Hamzah & Basir, 2024) and (Nabiilah et al., 2025). (Abzari et

al., 2025) study attempted to bridge this gap by comparing the results of two different software analyses. However, their analysis remained essentially limited to digital simulations.

A weakness of these previous studies is the treatment of manual calculations and software modeling as separate pathways, rather than as complementary cross-validation tools for analysis results. As a result, the existing literature often presents only numerical analysis results without providing double-checking regarding the structure's service capacity limit (Demand Capacity Ratio/DCR) and the validity deviation between the manual analytical method and software modeling based on applicable standards. This lack of integrated verification creates a significant research gap, particularly for short-span composite bridges in rural areas, where technical data is limited but high structural safety is required. Therefore, this study on the Sroyo Village Composite Bridge addresses the limitations of previous research by presenting comparative analysis results that validate manual analytical calculation methods and modeling using SAP2000 software.

This study focuses on the superstructure analysis of the Sroyo Village composite bridge and aims to manually calculate internal forces and validate them using SAP2000 modeling based on SNI 1725:2016 loading regulations. The choice of composite structural design is based on its efficient load-carrying capacity, where concrete and steel, joined by shear connectors, work together to withstand maximum compressive and tensile forces (Mu & R, 2021). The primary contribution of this study lies in the detailed verification of the comparison between manual analysis results and SAP2000 modeling, measured through strict percentage deviation limits. Ultimately, this research is expected to provide technical recommendations for planning safe bridge superstructures in rural areas as well as serve as a reference for local governments in rehabilitating infrastructure. Therefore, the main objective of this study covers two aspects, namely to evaluate the safety and feasibility of the composite bridge superstructure of Sroyo Village based on SNI 1725:2016 and to validate the accuracy of the calculations by comparing the results of manual analysis and SAP2000 modelling.

RESEARCH METHODS

Field Observations and Bridge Geometric Data

This research begins with field observation and documentation to assess the current condition of the Sroyo Village Bridge. As seen in Figure 1, the existing bridge infrastructure is a makeshift structure built using bamboo material and supported by an inadequate substructure in the form of wooden rods. This structure does not meet civil engineering feasibility standards because it has the potential to experience weathering, which can pose a serious safety risk to its users. Therefore, a complete redesign of the bridge using a composite superstructure is urgently needed to ensure the safety and mobility of the community.



Figure 1. Existing Condition of Sroyo Village Bridge

Based on the results of field observations, shop drawings and Engineering Estimates (EE) from Sroyo Village, the geometric and material parameters used for bridge redesign were obtained, which are summarized in Table 1.

Table 1. General Data of The Sroyo Village Composite Bridge 2026

Parameter	Specification / Dimensions
Location & Span	Sroyo Village, Bojonegoro (Length: 12.00 m, Width: 6.60 m)
Concrete Deck	Thickness: 0.20 m f_c : 30 MPa
Slab Reinforcement	Ø13-150 mm f_y : 420 MPa
Main Steel Girder	I-WF 500 x 200 x 10 x 16 mm Grade: BJ37 Z_x : 2808868 mm ³
Girder Spacing	1.15 m
Diaphragms Spacing	Longitudinal: 1.50 m Transverse: 1.10 m
Cover Plate	8.00 x 0.19 x 0.015 m

Based on SNI 1725:2016, several loads must be calculated for analysis. All of these loads originate from the main bridge load and from external loads. The use of SNI 1725:2016 regulations is in line with the research methods applied by (Ilmiah et al., 2021), (Romadon & Nuranita, 2024), (Wulandari & Sasongko, 2023), (Sapulete, 2020), (Sartika et al., 2019), (Ardhi et al., 2026) and (Bengkalis, 2021). The categories of loads applied in this study are summarized in Table 2.

Table 2. Loads Categories of The Sroyo Village Composite Bridge 2026

Loads Category	Information
Permanent Loads	Dead Load (MS) and Superimposed Dead Load (MA)
Live Loads	Construction Worker and Equipment Loads
Traffic Loads	"D" Lane Load and "T" Truck Load
Environment Actions	Wind Load

Structural Design Equations and Procedures

The structural analysis completion stage is carried out systematically through two stages, namely the non-composite stage (a condition where the steel girder supports the wet concrete load independently) and the composite stage (a condition where the hardened concrete slab works together monolithically with the steel girder in carrying the load). The equations used in the analysis calculations are based on SNI 1725:2016, RSNI T-03-2005 and SNI 2847:2019.

(1) In the flexural capacity control (M_n), the ultimate flexural moment (M_u) must not exceed the nominal flexural capacity of the composite (M_n) calculated through the plastic neutral line conditions located in the concrete compression block. To determine the safety requirements for flexural capacity, the following equation is used: $M_u \leq \phi M_n$. (2) In the shear capacity control parameter (V_n), the ultimate vertical shear force (V_u) must not exceed the shear capacity (V_n). The vertical shear force will be determined by the web area of the steel girder multiplied by the yield stress (f_y) and a coefficient of 0.6. To determine the safety requirements for shear capacity, the following equation is used: $V_u \leq \phi V_n$. (3) The deflection under service load conditions is calculated to determine the level of comfort for bridge users by taking into account the requirements based on the following equation: $\Delta_{max} \leq \frac{L}{800}$.

All load types will be systematically applied, starting with manual analysis and continuing through SAP2000 modeling, to obtain outputs in the form of structural capacity and comparison of analysis results. The research stages are visually explained in the following flowchart:

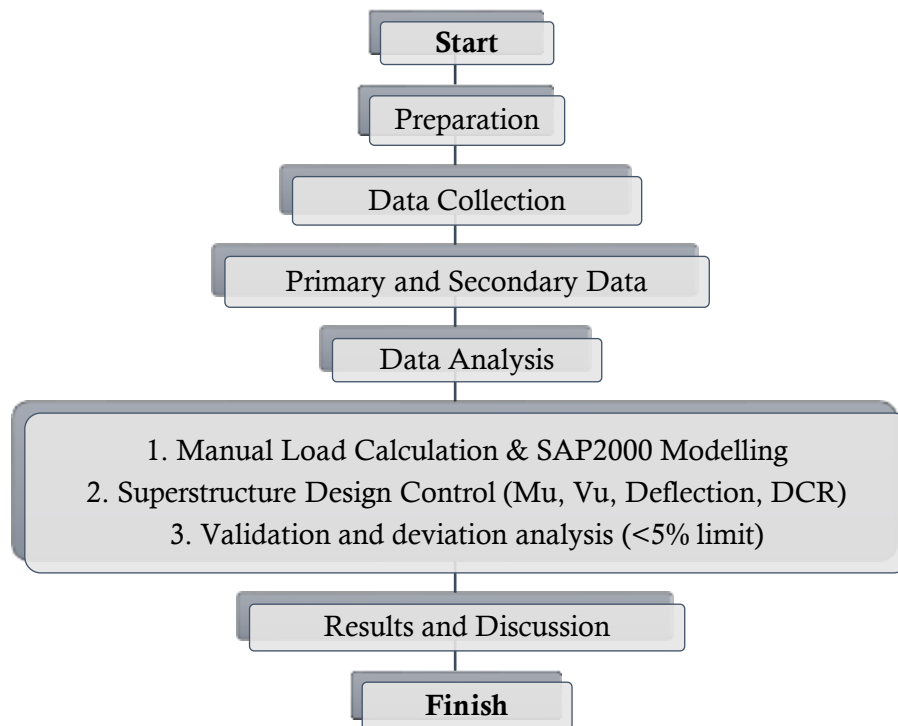


Figure 2. Research Flowchart

SAP2000 Modelling via Section Designer

The superstructure of this composite bridge is modeled using a one-line element approach, namely concrete slabs and steel girders defined monolithically in the section designer feature. The supports used are roller-joint supports to simulate a simple span. Permanent loads are distributed evenly, environmental action in the form of wind is concentrated to the diaphragm point and critical traffic loads are applied centrally which are represented by wheel loads based on actual distances according to SNI 1725:2016. The material in the form of concrete slabs is defined to have a compressive strength (f_c) of 30 MPa combined with BJ37 grade steel ($f_y = 240$ MPa).

Validation of Analysis Results and Limits of Comparison Analysis Results

The validation process of the analysis results was carried out by comparing the SAP2000 modeling results with the results of manual calculations. Previous literature references regarding comparative studies of manual and software structural analysis state that the commonly accepted deviation tolerance limit is below 15% (Nurwahidah, 2026). However, to ensure a high level of precision in modeling the composite bridge superstructure, the tolerance limit was independently set at 5%. The validation test was carried out by reviewing the Demand Capacity Ratio (DCR) value with the condition that the external load acting must not exceed the available capacity. (4)

The DCR equation is stated as follows: $DCR = \frac{\text{Ultimate force } (Mu, Vu)}{\text{Nominal capacity } (\phi Mn, \phi Vn)} < 1.00$.

RESULTS AND DISCUSSION

In general, the analysis of the composite bridge superstructure in this study uses the LRFD (Load and Resistance Factor Design) which is in line with research conducted by (Ode & Frans, 2026) which compares the load Q with the resistance R_n specifically using the equation $\phi R_n \geq \sum \gamma_i Q_i$. R_n is defined as the reduced strength of the structural component while $\sum \gamma_i Q_i$ is the factored load. The analysis is divided into three stages: the non-composite stage, the composite stage, and the SAP2000 modelling stage.

Before describing the process and results of the analysis at each stage, all nominal load components acting on the bridge superstructure, both in the non-composite and composite phases, are summarized in Table 3.

Table 3. Summary of Nominal Structural and Traffic Loads

Analysis Stage	Load Category	Load Component	Nominal Value	Distribution Model	Standart Reference
Non-Composite	Dead Load	I-WF Steel Girder	0.88 kN/m	Uniformly	SNI 1725:2016
	Dead Load	Wet Concrete Slab	5.75 kN/m	Uniformly	
	Dead Load	Formwork	0.31 kN/m	Uniformly	
	Dead Load	Steel Diaphragm	0.20 kN	Concentrated	
	Dead Load	Steel Cover Plate	0.22 kN/m	Uniformly	
	Live Load	Workers	3.83 kN/m	Uniformly	
Composite	Dead Load	I-WF Steel Girder	0.88 kN/m	Uniformly	SNI 1725:2016
	Dead Load	Hardened Concrete	5.75 kN/m	Uniformly	
	Dead Load	Steel Diaphragm	0.20 kN	Concentrated	
	Dead Load	Steel Cover Plate	0.22 kN/m	Uniformly	
	Superimposed Dead	Rain Water	1.15 kN/m	Uniformly	
	Superimposed Dead	Concrete Barrier	1.38 kN/m	Uniformly	
	Superimposed Dead	Steel Railing	0.05 kN/m	Uniformly	
	Traffic Load	Lane Load (UDL)	10.35 kN/m	Uniformly	
	Traffic Load	Lane Load (KEL)	78.89 kN	Concentrated	
	Traffic Load	Truck Axle (Front)	93.43 kN	Concentrated	
	Traffic Load	Truck Axle (Middle)	93.43 kN	Concentrated	
	Traffic Load	Truck Axle (Rear)	20.76 kN	Concentrated	

Non-Composite

At this stage, the steel profiles still function independently as load-bearing structural elements. This is because the concrete slab is still wet and has not yet reached its design compressive strength (f_c). Consequently, the load from the wet concrete and construction activities exerts direct vertical pressure on the main steel girders (Sumajouw et al., 2017). The load components acting during this phase are categorized based on their distribution model and summarized in Table 3. The resulting internal forces are then evaluated using a combination of Strength 1 and Service 1 according to SNI 1725:2016 to ensure safety during the construction process.

The cross-sectional geometry and the position of the Elastic Neutral Axis at this stage are presented in Figure 3. The steel girders used are 500x200x10x16 mm I-WF steel ($f_y = 240$ MPa) combined with a 15x190 mm cover plate on the lower flange to increase its capacity.

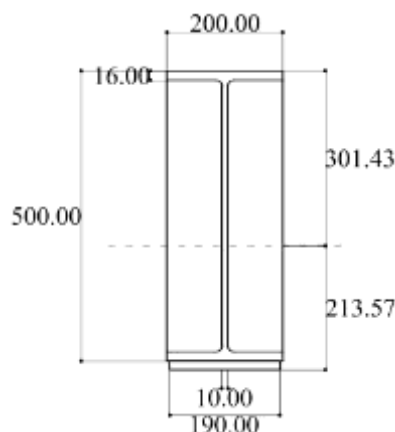


Figure 3. Elastic Neutral Axis Non-Composite Section

Based on the cross-sectional area of the I-WF ($A_s = 11,420 \text{ mm}^2$) and cover plate ($A_{cp} = 2,850 \text{ mm}^2$), the elastic neutral axis is 301.43 mm from the top fiber of the steel profile. Using the parallel axis theorem, the moment of inertia of this combined cross-section is $629,284,658 \text{ mm}^4$. This stiffness value controls the deflection of the structure.

The flexural capacity at the ultimate condition is evaluated using the plastic modulus approach based on Equation (1), which produces a nominal strength of 606.72 kNm. The nominal shear strength of the cross-section is calculated based on Equation (2) with a value of 648.00 kN. Local buckling evaluation is carried out by calculating the slenderness ratio in three steel areas: the upper flange, lower flange, and web, with results of 6.25, 3.23, and 46.80, respectively. All these values are still below the allowable slenderness limit, so the cross-section is categorized as a compact section and no local buckling occurs. The deflection that occurred in the middle of the span due to the service load was 24.01 mm, which still meets the required allowable limit of $L/360$ (33.33 mm). A summary of the analysis results and DCR values for this phase is presented in full in Table 4.

Table 4. Recapitulation of Structural Safety Controls at the Non-Composite Stage 2026

Evaluation Parameters	Factored Demand (R_u)	Nominal Capacity (ϕR_n)	DCR	Status
Flexural Capacity ($M_u \leq \phi M_n$)	290.38 kNm	606.72 kNm	0.48	Safe
Shear Capacity ($V_u \leq \phi V_n$)	97.40 kN	648.00 kN	0.15	Safe
Top Flange Slenderness ($\lambda_p \leq 170/\sqrt{f_y}$)	6.25	10.97	0.57	Safe
Bottom Flange Slenderness ($\lambda_p \leq 170/\sqrt{f_y}$)	3.23	10.97	0.29	Safe
Web Slenderness ($\lambda_p \leq 1680/\sqrt{f_y}$)	46.80	108.44	0.43	Safe
Mid-Span Deflection ($\Delta_{act} \leq \Delta_{all}$)	24.01 mm	33.33 mm	0.72	Safe

Composite

The composite stage is reached after the concrete slab hardens and reaches the design compressive strength (f'_c 30 MPa), resulting in full composite action between the steel girder and concrete slab in carrying the load (Tumimomor et al., 2016). At this stage, the applied load is adjusted to account for additional dead load (MA), traffic loads (lane "D" and truck "T"), and environmental loads in the form of wind. The nominal values and load distribution models are summarized in Table 3. The load combinations used to determine the maximum internal force are Strength 1 and Service 1 according to SNI 1725:2016.

The cross-section geometry and the location of the Plastic Neutral Axis in this phase are presented in Figure 4. The cross-section transformation is calculated using the modulus ratio ($n = E_s/E_c$) considering the effective slab width (b_e) of 1.15 m. This causes the position of the Elastic Neutral Axis to shift toward the concrete slab, drastically increasing the moment of inertia in the composite cross-section and enhancing structural stiffness.

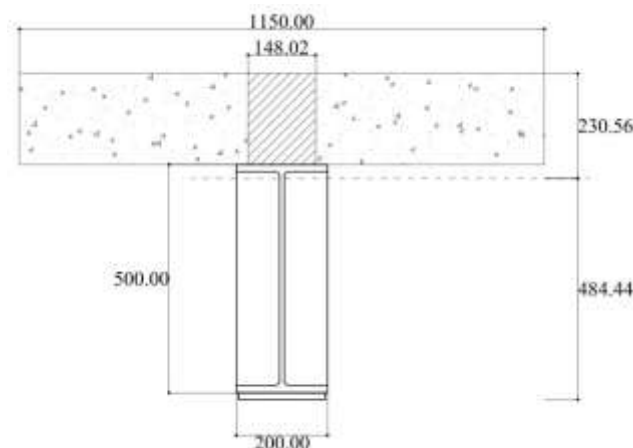


Figure 4. Elastic Neutral Axis Composite Section

Elastic stress evaluation under service conditions showed that the compressive stress in the top fiber of the concrete (5.97 MPa) and the tensile stress in the bottom flange of the steel (141.88 MPa) did not exceed the allowable limits of 13.50 MPa and 216.00 MPa, respectively. The deflection at midspan due to live loads was 12.36 mm, which meets the maximum limit of 15.00 mm. The nominal flexural capacity was calculated using the plastic stress block distribution based on Equation (1), resulting in a capacity of 1365.57 kNm, capable of withstanding an ultimate moment of 991.25 kNm. The nominal shear strength of the cross-section, based on Equation (2), was 648.00 kN, which is sufficient to withstand an ultimate shear force of 304.60 kN.

For the shear connector components, the analysis results calculated using Equation (4) showed a DCR ratio of 0.98. This high value indicates optimal design efficiency in the design drawings. The actual spacing of 100 mm based on the design drawings proved to meet the limit requirements because it was below the maximum required spacing of 101.69 mm. These results indicate that the shear connectors performed optimally to ensure full composite action. However, with a margin of only 0.02%, this suggests that strict work implementation monitoring is necessary to avoid differences in spacing that could trigger horizontal slippage.

Overall, the evaluation of the design control parameters demonstrated a $DCR < 1.00$. Therefore, the superstructure of the Sroyo Village Bridge is deemed structurally sound and safe. However, this safety conclusion is limited to the superstructure components, and this study did not evaluate the suitability of the substructure, such as abutments and foundations. A summary of the strength control results from this phase is presented in Table 5.

Table 5. Recapitulation of Structural Safety Controls at the Composite Stage

Evaluation Parameters	Factored Demand (R_u)	Nominal Capacity (ϕR_n)	DCR	Status
Flexural Capacity ($M_u \leq \phi M_n$)	991.25 kNm	1365.57 kNm	0.73	Safe
Shear Capacity ($V_u \leq \phi V_n$)	304.60 kN	648.00 kN	0.47	Safe
Shear Connector Capacity ($V_h \leq Q_n$)	100 mm	101.69 mm	0.98	Safe
Mid-Span Deflection ($\Delta_{act} \leq \Delta_{all}$)	12.36 mm	15.00 mm	0.82	Safe
Concrete Compressive Stress	5.97 MPa	13.50 MPa	0.44	Safe
Steel Tensile Stress ($\sigma_s \leq 0.9 f_y$)	141.88 MPa	216.00 MPa	0.66	Safe
Connection Bolt Shear Capacity	2.93 kN	79.14 kN	0.04	Safe
Diaphragm Slenderness Ratio ($\lambda \leq \lambda_{all}$)	48.46	200.00	0.24	Safe
Transverse Reinforcement Strength	27.79 kN	48.92 kN	0.57	Safe
Minimum Transverse Reinforcement	360.00 mm ²	885.24 mm ²	0.41	Safe
Longitudinal Reinforcement Strength	27.79 kN	48.92 kN	0.57	Safe
Minimum Longitudinal Reinforcement	360.00 mm ²	885.24 mm ²	0.41	Safe

SAP2000 Modelling

The modeling of the Sroyo Village Composite Bridge uses SAP2000. The principles of SAP2000 are structural modeling, analytical calculations and design optimization (Harmono et al., 2005). This modeling aims to validate manual calculations and simulate the mechanical behavior of the structure due to static loads and traffic loads. The modeling stage begins by defining the composite cross-section in the section designer. IWF steel girders, cover plates, diaphragm and concrete slabs with effective widths are modeled precisely so that the resulting moment of inertia approaches the results of manual analysis. Furthermore, the supports at the ends of the girders use roller-joint supports. The loads input into the model refer to SNI 1725:2016, which includes self-load, additional dead load, "D" lane load, "T" truck wheel load, and environmental action loads in the form of wind. The calculation method by modeling this bridge can produce in-depth output regarding the parameters of shear force, bending moment, and deflection. The modeling results can be seen in Figure 5.

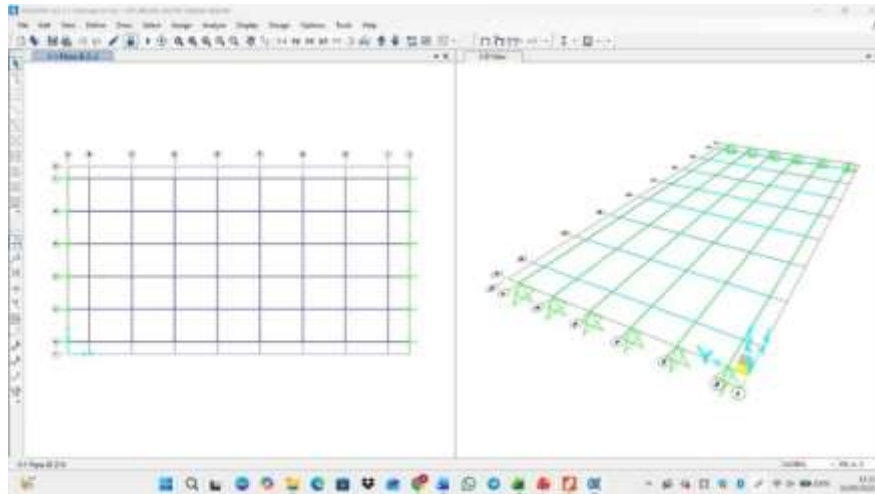


Figure 5. Modelling Results Using SAP2000

IWF steel girders and cover plates are defined as BJ37 grade steel materials with a yield strength of 240 MPa. In addition, the concrete slab is defined as reinforced concrete material with a compressive strength f_c of 30 MPa with a modulus of elasticity of 25742.96 MPa. The bridge is conditioned as a simple span with hinge supports on one side and roller supports on the other side. Meanwhile, diaphragms are modeled in the transverse direction connecting the girders. After the modeling stage is completed, static and traffic loads are applied according to SNI 1725:2016. Based on SNI 1725:2016, there are two load combinations used, namely Strength 1 and Service 1. The existence of this load combination aims to determine the internal forces that occur in the composite cross-section which mainly consist of maximum moments, shear forces and deflections. From the analysis and modeling carried out, the maximum moment value in the Strength 1 condition is 991.90 kNm, the shear force due to the "T" truck load in the Strength 1 condition is 304.23 kN and the deflection due to the Service 1 condition is 12.92 mm. The results of this internal force analysis will determine how big the difference is between the results of manual calculations and modeling with SAP2000. The results of the internal force analysis can be seen in the Figure 6.

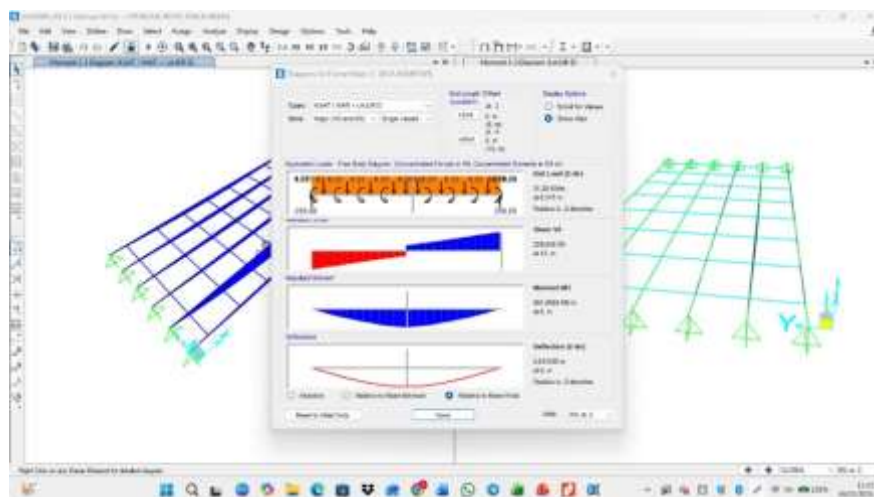


Figure 6. Diagram of Results Analysis Using SAP2000

Recapitulation and Comparison

The results of manual analysis and SAP2000 modeling will be compared to determine the accuracy of the results. The parameters used are the most critical conditions of the combination of Strength 1 and Service 1 which include maximum moment, shear force and deflection. Based on the analysis results, both calculation methods show consistent behavior. The maximum moment value calculated manually is 991.25 kNm while the SAP2000 modeling produces a figure of 991.90

kNm. The difference in the maximum moment results in these two methods is only 0.07%. Furthermore, the shear force in the manual calculation shows a figure of 304.60 kN, while the SAP2000 modeling results show almost the same figure of 304.23 with a difference of 0.12%. In addition to these two parameters, the deflection value is also compared. In the manual calculation, the deflection that occurs is 12.36 mm and in the SAP2000 modeling it is 12.92 mm, the difference in this figure shows a difference of 4.54%. Overall, the difference in the results of the two methods shows a figure below 5%. This difference is due to the rounding of load values in SAP2000 modeling, so the resulting internal force output will show different values but still close to the manual calculation results. With a difference of less than 5%, both methods are declared valid and accurate for application to the Sroyo Village Composite Bridge superstructure. The comparison results are presented in Table 6.

Table 6. Comparison of Analytical Manual Calculations and SAP2000 Outputs 2026

Parameters	Manual Analysis	Modelling SAP2000	Deviation	Status
Maximum Bending Momen (Mu)	991.25 kNm	991.90 kNm	0.07%	Valid
Maximum Shear Force (Vu)	304.60 kN	304.23 kN	0.12%	Valid
Deflection (Δ)	12.36 mm	12.92 mm	4.54%	Valid

The manual calculation approach integrated with SAP2000 software-based modeling serves as a validation tool to ensure the reliability of structural design. This cross-verification method is in line with the methodology previously conducted by (Nurwahidah, 2026) which emphasized that although computer-based modeling offers precise design, manual calculations remain a crucial quality control tool. Research conducted by (Nurwahidah, 2026) applied this cross-verification method to multi-story buildings with deviations in analysis results typically up to 15%. In comparison, the highest deviation obtained in this composite bridge study was much smaller, namely 4.54%, which occurred in deflection control. This very low deviation value indicates that the manual calculations and SAP2000 modeling used can validate each other accurately.

CONCLUSION

Based on the analysis of the Sroyo Village Composite Bridge, it can be concluded that the composite cross-section is capable of meeting all strength control requirements, with a DCR ratio below the safety limit of 1.00. A comparison of the results between manual calculations and SAP2000 modeling shows very similar results, with deviations below the 5% tolerance limit. Specifically, the maximum bending moment differed by only 0.07% (991.25 kNm vs. 991.90 kNm), the maximum shear force differed by 0.12% (304.60 kN vs. 304.23 kN), and the maximum deflection differed by 4.54% (12.36 mm vs. 12.92 mm). This similarity demonstrates the accuracy of the manual calculations and SAP2000 modeling, mutually validating each other, making them reliable in designing similar short-span composite bridges. However, this study has limitations: the analysis was conducted solely on the superstructure based on the loading regulations of SNI 1725:2016. This study did not calculate the bridge's substructure, such as foundations and abutments. Therefore, this bridge is deemed safe only for its superstructure, and further research is expected to conduct a more in-depth analysis of the bridge's substructure.

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