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Analysis of Deflection in Composite Bridge Girder Under Live and Dead Load Using SAP2000

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ABSTRACT

The process of building a transportation infrastructure presents a unique challenge in the field of civil engineering. Bridges play an important role in supporting human mobility and transportation, as well as in delivering goods and services to various locations. A bridge structure must not suffer excessive deflection to have good service capabilities. This research seeks to find the amount of deflection of composite girder under live load and dead load. By inserting the load that occurs, this study wants to identify the deflection that happens using SAP2000 software. SAP200 is a sophisticated software application widely used in the field of structural engineering for the analysis and design of various types of structures. SAP2000 enables engineers to evaluate the behaviour of structures under different loading conditions, including static and dynamic loads, ensuring that designs meet required safety and performance standards. The findings show that based on the RSNI T-03-2005 Standard, the maximum deflection tolerance is L/240, where L is known as the total bridge span, which is 17.5 cm, while after being analysed by SAP2000, it is known that the total deflection that occurred on the composite girder is 17,2 cm. The findings underscore the importance of using advanced simulation tools like SAP2000 to predict structural behaviour accurately. This research highlights the necessity of precise deflection analysis in civil engineering projects to ensure that transportation infrastructure can withstand the loads they will encounter during their service life. This research is designed to serve as a reference for challenges discovered for future research.

1. Introduction

As one of the key components of the transportation infrastructure, bridges are buildings vital for establishing connections between regions [1] . One of the most crucial steps in bridge design is calculating the top structure [2]. This computation considers the bridge's stability, dependability, and strength in addition to the materials' strength [3]. Additionally, the design must account for environmental factors such as wind, seismic activity, and temperature variations to ensure the structure's longevity [4]. Engineers employ advanced simulation and modelling techniques to optimize the bridge's upper structure, balancing functionality with aesthetics and cost-effectiveness [5].

Over the past few years, Indonesia's bridge-building design and construction have also continuously improved [6]. Construction of bridges in Indonesia has standards issued by the Ministry of Public Works and People's Housing (PUPR) [7]. It reduces the possibility of structural failure and guarantees that the bridge satisfies all applicable safety and quality criteria [8]. Periodic inspections are conducted during the building process to ensure that the bridge is constructed in compliance with the intended and stated specifications [8]. The measures above encompass material testing, construction quality monitoring, and ongoing structural evaluation to guarantee the bridge's safety throughout its lifespan [9].

There is a growing demand to design sturdy and resilient bridge structures following requirements [10] [11] [12]. Within the discipline of building materials, steel is one of the technologies. Steel is a common foundation material used in the building of frame bridges in the modern world of construction. Based on its greater steel strength, longer resistance to weather and loads, accessibility in the community, ability to be used for long-distance bridge construction, and improved environmental aesthetics, steel is used as the material for steel frame bridges [13] [14] [15]. Furthermore, steel bridges' structural integrity and longevity have been further improved by creating high-strength alloys due to improvements in steel manufacturing techniques.

Numerous factors must be properly considered while calculating the bridge's upper structure [16]. Every stage of a bridge's design, from load analysis to safety and stability considerations, must be done with great care to guarantee that the structure can support the public's need for efficient, safe, and effective traffic [17] [18] [19] [20]. Bridges may represent technical advancement and serve as a proud piece of local infrastructure when designed with a comprehensive approach and excellent quality [21]. Environmental factors, such as the effect on the ecology and the materials' sustainability, are also considered while designing bridges [22]. Bridges may be a tangible example of dedication to balancing infrastructure advancement with environmental sustainability by combining contemporary technology and sustainable engineering concepts [23] [24] [25].

Transport development is closely linked to the provision of bridge infrastructure. The purpose of this study is to know the concept of bridge calculation with the help of SAP2000 software, especially those relating to the bridge's structure. The study is carried out systematically using the aid of software by first taking a case study, which will then calculate the structure using SAP2000. The analysis emphasizes the load and the moment of the steel frame bridge upper structure in connection with this research article. The concept of calculation of the bridge's upper structure will be discussed.

2. Literature Review

2.1 Steel Frame Bridge

Steel frame bridges represent a substantial progression in the field of bridge engineering. Steel frame bridges have been an integral component of infrastructure development due to their adaptability, longevity, and economical nature [26]. Over time, substantial research has been undertaken to augment our comprehension of diverse facets of the design, construction, and upkeep of steel frame bridges [27]. The objective of this literature review is to present a comprehensive summary of significant research and developments that have occurred in this particular domain.

Steel frame bridges utilize structural steel components, such as beams, trusses, and girders, to support the bridge deck and evenly distribute loads [28]. These bridges can be constructed in several arrangements, such as basic beam, cantilever, arch, and suspension bridges, depending on factors such as the distance to be covered, the landscape, and the desired visual appearance [29]. Steel frame bridges enhance sustainability by optimizing materials, energy, and resources. Steel possesses inherent strength and flexibility, enabling the construction of lightweight yet sturdy bridge structures that can handle substantial loads and dynamic stresses, including traffic, wind, and seismic activity [30].

Recent studies show that selecting appropriate materials plays a crucial role in the performance and longevity of steel frame bridges [31]. Research efforts have focused on evaluating various steel alloys' mechanical properties and corrosion resistance to mitigate degradation and enhance structural durability [32]. Research has examined the impact of multiple coating systems and surface treatments on the corrosion performance of steel bridge parts, offering significant knowledge for choosing materials and maintenance approaches [33].

Advancements in construction techniques have also been a subject of research in the field of steel frame bridges. Studies have explored prefabrication and modular construction methods to accelerate project delivery, minimize onsite disruptions, and improve construction quality [34]. The viability and economic efficiency of modular bridge systems employing steel components showcase possible advantages in terms of rapid construction, efficient use of resources, and strong structural performance.

2.2 Upper Bridge Structure

The arrangement and constituents of the upper bridge structure are key elements of bridge engineering study. Several studies have examined different architectural arrangements, including deck systems, parapets, and railings, in order to enhance structural performance while satisfying aesthetic and functional criteria. In addition, research has prioritized the exploration of novel materials and building methods for the top structural components in order to boost their longevity, decrease maintenance expenses, and promote safety [35].

Gaining insight into the behaviour of upper bridge structures under various loading circumstances is crucial for guaranteeing structural integrity and safety. Scientists have employed sophisticated computer techniques, such as finite element analysis (FEA) and structural dynamics simulations, to examine the impact of various types of loads, such as dead loads, live loads, environmental loads, and dynamic loads, on the different parts of a bridge. Prior research employs load distribution theories and optimization methods to create effective and resilient design solutions for higher bridge structures.

Advancements in design methodologies and construction techniques have also been a research focus in upper bridge structures [36]. Studies have explored modular construction methods, prefabrication techniques, and digital fabrication technologies to streamline project delivery, reduce construction time and cost, and improve construction quality. Recent research has investigated the feasibility and benefits of adopting innovative design-build approaches and integrated project delivery methods for upper bridge structure projects, emphasizing collaboration, innovation, and efficiency throughout the project lifecycle.

The choice of materials for upper bridge structures considerably influences how well they operate and how long they last. Research has assessed the mechanical characteristics, resistance to corrosion, and ecological viability of many construction materials, including steel, concrete, and composite materials [37]. Recent research indicates that new materials and surface treatments can improve the endurance and resilience of upper bridge structures, especially in challenging weather conditions or corrosive environments.

2.3 Truss Bridges

Truss bridges have a rich historical evolution, with advancements in upper structure design evolving over time and notable contributions from influential bridge engineers [38]. Truss bridge upper structure structural analysis and design rely on techniques and software tools that consider loadings, material qualities, safety regulations, and environmental issues. Truss bridge upper structure construction methods include prefabrication, modular construction, and onsite fabrication. These methods must be used while considering site limitations, logistical considerations, and safety concerns. To ensure long-term structural integrity and safety, monitoring and maintenance processes encompass visual inspections, nondestructive testing, and sensor-based monitoring systems [39].

Case studies of notable truss bridges highlight design, construction, and performance characteristics, providing insights into behaviour under static, dynamic, and environmental loads. Future trends may include advanced materials, novel structural forms, and digital technologies like Building Information

Modelling and machine learning, offering opportunities for further research and advancement in truss bridge engineering. Researchers have extensively studied the design and analysis of truss bridge upper structures to ensure structural stability and safety. Various analytical and numerical methods are used to evaluate the performance of different upper structure configurations under different loading conditions.

A comprehensive concept of load distribution within the top structure of a truss bridge is a crucial part of bridge engineering. Properly distributing loads is essential to ensure the bridge can safely withstand different traffic loads, such as live loads from automobiles and people. Studies in this field have explored how loads are transferred across the truss elements of the bridge's upper construction. Researchers analyze load distribution patterns to optimize the structural design, reducing stress concentrations and preventing probable areas of failure.

With the increasing frequency and intensity of natural disasters and climate change effects, researchers focus on making truss bridges more resilient and sustainable [40]. This includes designing bridges to withstand extreme weather events, such as hurricanes and floods, as well as minimizing their environmental impact through sustainable materials and construction practices.

3. Method

The methodology employed in this study involves gathering data profiles from an existing bridge, such as the Mojosongo Bridge. The data is derived from ongoing research issues in the field of civil engineering. In this example, the ongoing research focuses on the deflection that occurs on the girder of the bridge. One of the methodological strategies employed in mapping these subjects utilizes software assistance that specifically emphasizes load input and modelling. The results are then represented as the deflections that can impact the bridge.

In designing the bridge to be used for this research, SAP2000 software was used. The software is used by entering live and dead load data and also the steel profile that is used for the girder. The data generated are the internal force and deflection on the girder of the bridge. SAP2000 was chosen because the application is one of the structural engineering software widely used for designing and analyzing bridge structures.

4. Result and Discussion

4.1 Bridge Planning Results for Upper Structure

This study will give the necessary bridge structure planning data to be inputted into the SAP2000 program for structural analysis and design. This dataset contains precise information on the measurements and composition of the bridge superstructure and other related components. Having thorough and precise planning data is crucial to guarantee that the model developed in SAP2000 can accurately analyze the deflections that occur in bridge girders.

Table 4.1 Bridge Structure Planning Data

No	Details	Value
1	Bridge span	= 42 meters
2	Bridge Width	= 12 meters
3	Sidewalk Width	= 1.2 meters
4	Width of Concrete Road Floor Plate	= 9 meters
5	Extended Girder Distance	= 1.5 meters
6	Height of Concrete Road Floor Plate	= 0.2 meters

7	Sidewalk Height	= 0.15 meters
8	Steel Quality	= BJ 55
9	Fy	= 410 MPa
10	Fu	= 550 MPa
11	Fc	= 25 MPa
12	Modulus el. Steel	= 200000 MPa

4.2 Loading Input Data

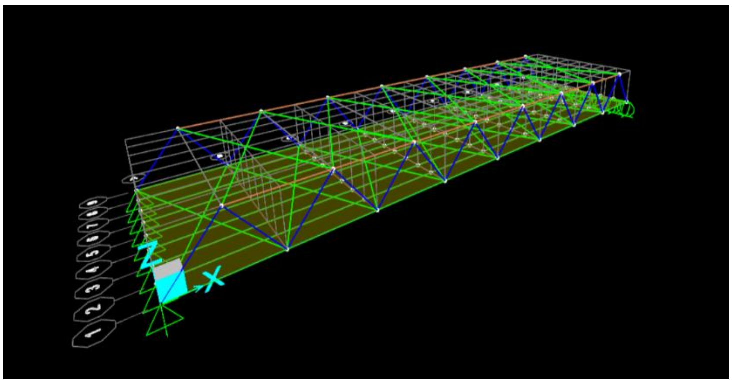
Table 4.2 displays the load data utilized in the structural analysis conducted with SAP2000 software. Within this particular context, the term "loading" pertains to the various types of forces exerted on the structure to replicate the actual circumstances that may arise during the bridge's lifespan. However, in this particular instance, the load applied is only the weight of rain. The rainfall loads refer to the mass of precipitation that can gather on a flat surface. It is crucial to apply this rain load in order to prevent the deflection of the bridge bearings from exceeding the prescribed limit.

Tabel 4.2 Loading Input Data

No	Details	Value
1	Asphalt Height	= 0.05 meters
2	Asphalt Volume Unit Weight	= 1835.49 kg/m3
3	Asphalt Load Factor	= 1.3 (SNI 1725-2016)
4	Concrete Volume Unit Weight	= 2400 kg/m3
5	Concrete Load Factor	= 1.3 (SNI 1725-2016)
6	Rainwater Height	= 0.05 meters
7	Rainwater Volume Unit Weight	= 1019.72 kg/m3
8	Water Load Factor	= 1.3 (SNI 1725-2016)

4.3 SAP2000 Modelling

Figure 4.1 shows the modelling of bridges using SAP2000 software. SAP2000 was chosen for its reliability in the analysis and design of structures for bridges. In the modelling process, structural elements of bridges, such as beams and bracing, are determined and inserted into the program. SAP2000



is then used to simulate the load that works on the bridge and analyze the structure's response to the various load conditions.

Figure 4.1 3D Modelling of Bridge using SAP2000

4.3 Composite Girder Load Analysis

The bridge girder design incorporates a WF profile steel with dimensions of 1200x400x16x32. The girder was constructed using BJ55 steel, which has a yield strength of 410 MPa and an ultimate strength of 550 MPa. The figure displays the self-weight of the steel profile examined with SAP2000 software. Figure 4.2 illustrates that the self-weight of the steel profile measures 565,072 KN/mm.

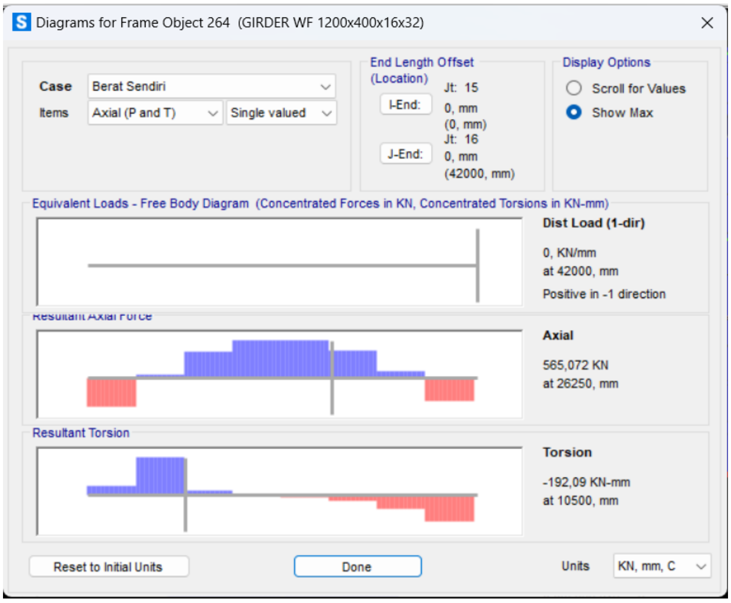


Figure 4.2 Steel Profile Weight

Figure 4.3 depicts the weight of the concrete slab, an important parameter evaluated using the structural analysis software SAP2000. Comprehending this particular weight is crucial for the process of structural design, especially for calculating the necessary specifications for support structures. This guarantees that the girders and other supporting components are capable of enduring the forces and stresses they will experience when the slab is in operation. The imaging data indicates that the concrete plate has a 0.105 KN/mm weight.

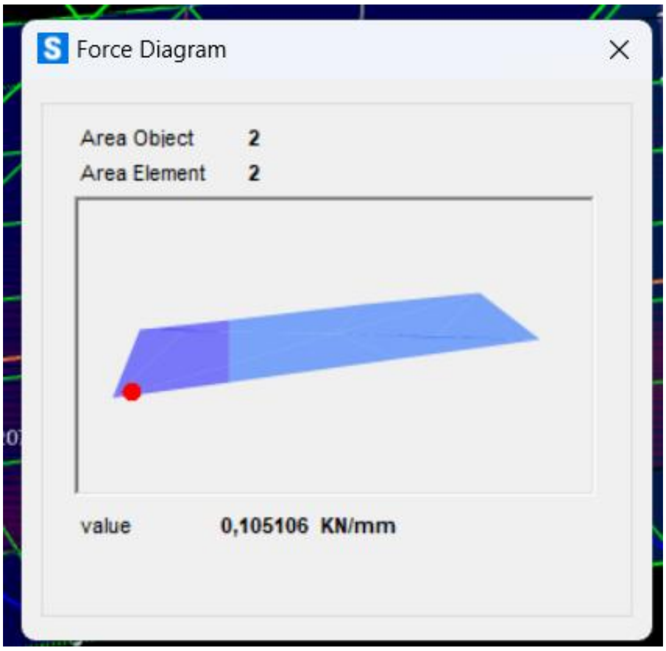


Figure 4.3 Concrete Slab Weight

Asphalt weight is a form of static load, indicating a constant load applied to the bridge continuously. The alteration of the asphalt's weight will result in a modification of the bridge's structural reaction to live loads and focused loads. Effective planning and design are necessary to assure the bridge's safety, durability, and long-term viability while incorporating asphalt into its structure. Figure 4.4 depicts the measured weight of asphalt that has been assessed using SAP2000. The image below illustrates that the asphalt layer on the bridge has a thickness of 0.05 meters and a weight of 0.068 KN/mm. The asphalt weight depicted in the illustration can impact the deflection of the bridge girder.

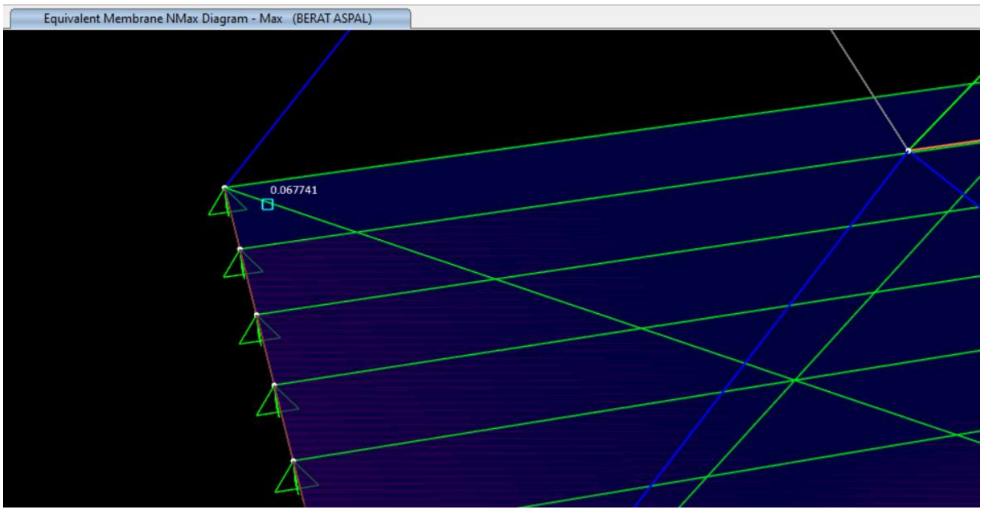


Figure 4.4 Asphalt Weight

The weight of rainwater may vary based on various circumstances, such as the magnitude of the rainfall and the extent of the surface area exposed to the rain. The consideration of this rain live load is crucial in structural design as it can significantly affect the structural capacity and strength. Including rain-live loads in structural design is crucial to ensure the structure's ability to endure these loads without enduring excessive wear or damage. Figure 4.4 depicts the measured weight of rainfall that has been assessed using SAP2000. From the given figure, it is evident that the rain load on the bridge is 0.037 KN/mm, considering a rainwater height of 0.05m and a rainwater volume unit weight of 1019.72 kg/m3. This additional load can impact the deflection of the main girder on the bridge.

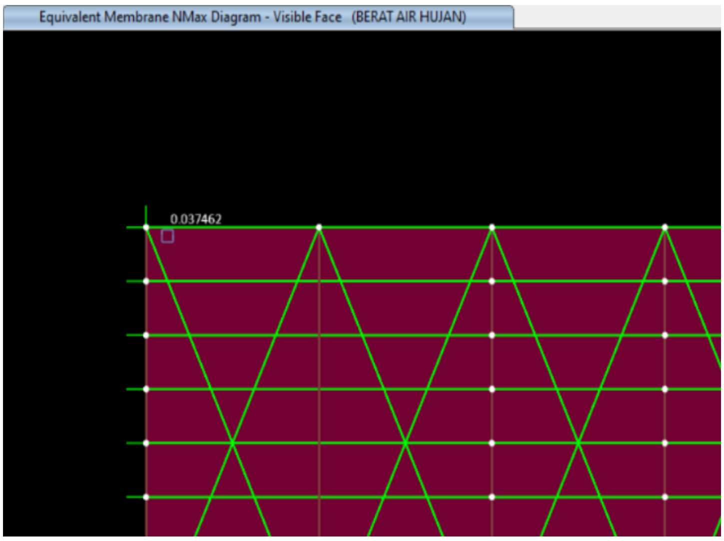


Figure 4.5 Rainwater Weight

4.4 Girder Deflection Analysis

As to the RSNI T-03-2005 standard, the allowable deflection for bridges is L/240, where L represents the length of the bridge. The purpose of this standard is to guarantee that the bridge structure has adequate strength and flexibility to endure loads without undergoing excessive deformation. The bridge's design under discussion yielded a deflection permission result of 17.5 cm. In the SAP2000 study, Figure 4.6 shows a deflection of 11.9 cm due to the dead load. Dead loads refer to permanent loads consistently present in a structure, such as the weight of girders and other structural components.

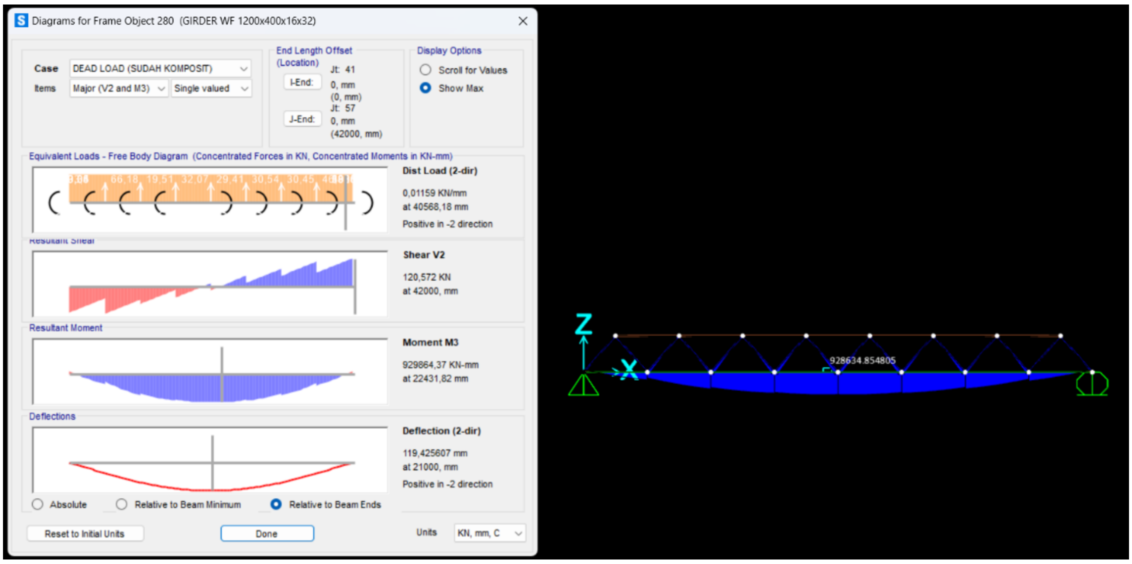


Figure 4.6 Deflection Due to Dead Load

The figure below depicts a deflection caused solely by a live load of 5.3 cm. The living load refers to a transient and fluctuating load that can undergo rapid changes. The total displacement experienced by the bridge girder is the sum of the deflection caused by the dead load and the live load, which amounts to 17.2 cm. Given that the combined deflection caused by the dead load and the living load on the Bridge girder is still less than the specified limit of 17.5 cm, the utilization of the profile for this bridge girder is considered to be safe.

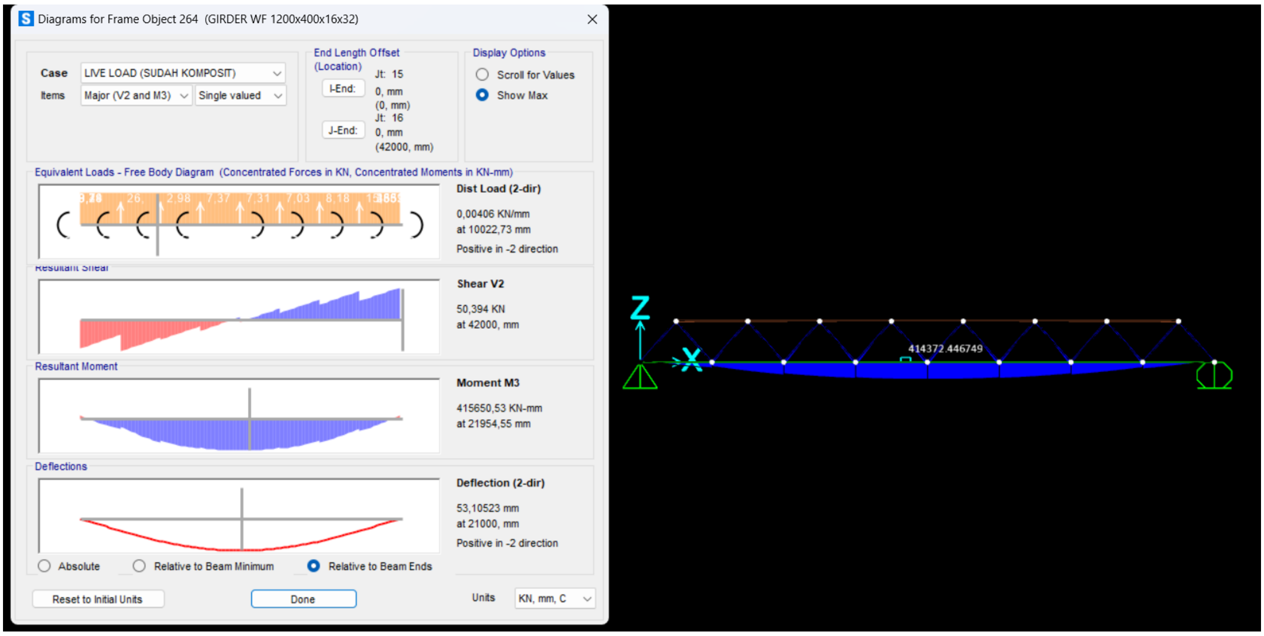


Figure 4.7 Deflection Due to Live Load

5. Conclusion

When combined with pertinent national standards, this research's use of SAP 2000 to demonstrate the deflections that happened on steel bridge girders offers a strong framework for building sturdy and dependable bridge constructions. It is crucial to precisely simulate and analyze the structural reaction of the girder under full load to reduce hazards and guarantee the longevity of vital transportation infrastructure components. The application of SAP 2000 was very helpful in the design and analysis of steel truss bridge deflection. Its advanced modelling tools and visualization features allowed for a thorough assessment of the structural performance under different loading scenarios. The analysis results show that the bridge girder's deflection after the composite is 17.2 cm, which is still less than the RSNI T-03-2005 norm of 17.5 cm. This implies that it is feasible to ensure the steel profile on the bridges is safe.

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