American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN: 2320-0936
Volume-15, Issue-4, pp-18-28
www.ajer.org
Research Paper Open Access

EVALUATION OF THE ARCH BRIDGE STRUCTURE

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ABSTRACT : *The construction of the East Axis Road in the Central Government Core Area (KIPP) of the new capital city (IKN) required a redesign of the bridge structure from a PCI Girder type to a concrete arch bridge due to clashing issues with the Multy Utility Tunnel (MUT). This study aims to evaluate the superstructure of the Concrete Arch Bridge at STA 2+800, with a span length of 100 m and a width of 38.7 m, using Midas Civil software. The evaluation was conducted to examine the section strength, reinforcement requirements, and structural safety factors in accordance with SNI 1725:2016 standards. The research methodology includes modeling the bridge geometry, defining material properties, and applying loads consisting of dead load, utility load, traffic load, braking load, pedestrian load, and wind load. Load combinations were analyzed under the Ultimate Limit State (ULS), Serviceability Limit State (SLS), and extreme conditions. The analysis results demonstrate that the concrete arch bridge at the study site satisfies the requirements of cross-sectional strength and structural stability. The structure recorded a wall support moment of -564.493 kNm, a wall span moment of 434.5 kNm, an arch support moment of -205.70 kNm, and a span support moment of 284.40 kNm. Based on standard design provisions for reinforced concrete bridges, Ø25–150 reinforcement was selected as the appropriate configuration. Furthermore, the calculated safety factor remains within acceptable limits, indicating that the bridge is structurally reliable and suitable for service throughout its intended design life.*

KEYWORDS: *Bridge loading, Concrete arch bridge, IKN, Midas Civil, Structural Evaluation.*

Date of Submission: 20-03-2026 Date of acceptance: 03-04-2026

I. INTRODUCTION

A bridge is a structural system designed to connect two roadway segments separated by obstacles such as deep valleys, rivers, irrigation channels, or drainage systems. Over time, civil engineers have developed and constructed various types of bridges, including arch bridges [1].

The evaluation of existing bridges is essential to assess their residual capacity within their service life [2]. Critical aspects considered in the evaluation process include visual inspection, assessment of residual structural capacity, load-bearing calculations, structural analysis, cross-sectional strength, and foundation capacity, particularly in response to changes in loading regulations. The development of road and bridge infrastructure in the Central Government Core Area (KIPP) of the Nusantara Capital City (IKN) represents a strategic initiative to support national connectivity [3]. One of the key sections is the East Side National Axis Road, which was initially designed as a PCI girder bridge with a span of 100 meters, incorporating exposed steel elements for architectural purposes. However, during the planning stage, significant technical issues emerged, including conflicts between the bridge alignment and the access road to the Ministry of State Secretariat (Kemensetneg), as well as incompatibility with the planned Multi-Utility Tunnel (MUT) corridor [4]. These issues represent major clashes that could not be resolved within the existing design, thereby necessitating a design modification [5].

The selected alternative was a concrete arch bridge [6]. This structural system is considered more suitable as it allows for efficient load transfer to the abutments while accommodating the MUT corridor [7]. Furthermore, concrete arch bridges are known to reduce concrete volume requirements by up to 15% compared to conventional girder bridges, improving both dimensional efficiency and constructability. This research aims to ensure that the proposed structure maintains adequate strength, serviceability, safety, and durability. Structural deterioration, such as cracking or localized damage, can significantly affect performance and long-term reliability [8]. The design parameters of the proposed arch bridge include a total length of 100 meters, a width of 38.7 meters, eight traffic lanes, and a design life of 50 years [9].

The foundation system consists of bored piles with a diameter of 1.2 meters and a depth of 17 meters, arranged in an 11 × 2 pile group configuration, with the central void filled with compacted granular soil. According to the Bridge Engineering Book, this configuration satisfies the requirements of a Class A bridge (LHR > 20,000 vehicles/day, width > 14 meters, and number of lanes > 4) [10].

For the structural assessment, Midas Civil software was employed, providing comprehensive analysis of internal forces, support reactions, and sectional capacity [11]. The purpose of this evaluation is to verify design feasibility in terms of cross-sectional strength, redundancy, and overall safety factors. Therefore, the transition from a PCI girder to a concrete arch bridge at STA 2+800 of the East Side National Axis Road not only addresses the identified design clashes but also enhances structural efficiency and spatial utilization. This study focuses on evaluating the structural performance of the concrete arch bridge as the proposed design alternative [12].

II. THEORETICAL BASIS

a. Bridge Loading

The loads acting on a bridge consist of dead loads, live loads, and environmental loads [10]. Dead loads include the weight of the structure itself and other permanent elements. Live loads originate from vehicle traffic depending on the bridge class, while environmental loads include wind, earthquakes, and temperature effects [13]. The load combinations are determined based on the Bridge Engineering Book [10]. Bridge evaluation in this study is essential to determine the maximum structural performance during its service life [14].

b. Arched Bridge

An arched bridge is a structure in which the arch element serves as the main load-bearing component [15]. Loads from the deck are transferred to the arch and subsequently to the abutments [16]. This type of structure primarily resists compressive forces, making it more efficient than straight girder bridges [17]. An arch bridge generally has a semicircular configuration with abutments at both ends, which stabilize the structure and prevent lateral displacement [12].

Arched bridges can reduce concrete volume by up to 15% and exhibit high lateral stability [18]. Loads acting on the bridge structure induce internal forces, one of which is tension. Excessive tension in arch bridges may cause displacements that exceed the maximum allowable limit [19].

c. Planning Criteria

According to the Bridge Engineering Book, a Class A bridge with an LHR of more than 20,000 vehicles requires a minimum width of 14 m and more than four lanes, with a design service life of 50 years [10]. These criteria serve as the design reference for the concrete arch bridge analyzed in this study [20].

d. Borepile Foundation

Borepile foundations are applied to support bridge loads in deep soil conditions [21]. Their design is determined based on soil bearing capacity and structural load requirements. For the arch bridge at STA 2+800, borepiles with a diameter of 1.2 m and a length of 17 m were used.

e. Analysis with Midas Civil

Midas Civil is a finite element analysis software commonly used for bridge modeling. It enables accurate analysis of internal forces, deformations, and load repetitions, which facilitates structural feasibility evaluations [22].

In this study, a numerical analysis method was conducted using Midas Civil to evaluate the performance of the concrete arch bridge at STA 2+800, Jalan Axis Kebangsaan Sisi Timur, KIPP IKN. The data included bridge geometry (length 94.4 m, width 38.7 m, 11 lanes), material properties (reinforced concrete and granular soil), foundation configuration (borepiles Ø1.2 m, 17 m in length, arranged 11 × 2), and loading conditions based on the Bridge Engineering Book and SNI 1725:2016 [10] [23].

The research stages consisted of: (1) literature review, (2) technical data collection, (3) structural modeling in Midas Civil, (4) analysis of internal forces and deformations, and (5) evaluation of sectional capacity, load repetition requirements, and safety factors according to Class A bridge criteria. The evaluation parameters included sectional strength, load repetition needs, and structural safety factors [24].

III. METHOD

A. Structural Modeling

The modeling of the concrete arch bridge was performed using Midas Civil software [22]. The geometric parameters of the structure are summarized as follows:

Table 1. Data Geometry

Parameter	Spesifikasi
Total Length	94,4 m
Width	38,7 m
Number Of Columns	11 columns
Curve Configuration	4-piece
Curve Diameter	15,45 m
Radius Of Arch	7,725 m
Foundation	Bore pile Ø1,2 m, length 17 m, configuration 11 × 2 columns
Design Service Life	50 years
Bridge Category	Class A

B. Structural Load

The loads acting on the concrete arch bridge were determined based on the Bridge Engineering Book and comply with SNI 1725:2016 and SNI 2847:2019, which govern structural concrete requirements for buildings [10] [23]. The considered loads include dead loads, live loads, wind loads, earthquake loads, and traffic loads. All loads were then combined according to the ultimate load combination criteria.

Table 2. Load recapitulation

No	Type of Load	Notation	Load Value	Unit	Input in Midas Civil
1	**Dead Load of Structure**				Self - Weight
A	Wall				Self - Weight
B	Pier Head				Self - Weight
C	Arch				Self - Weight
2	**Superimposed Dead Load**	**QMA**			Static Load
A	Bottom Pavement Layer		3.405	kN/m²	Static Load
B	Top Pavement Layer		3.405	kN/m²	Static Load
C	Asphalt Base Layer		1.76	kN/m²	Static Load
D	Intermediate Asphalt Layer		1.76	kN/m²	Static Load
E	Wearing Asphalt Layer		0.88	kN/m²	Static Load
F	Concrete Fc 15 MPa		2.94	kN/m²	Static Load
G	Concrete Fc 20 MPa		2.94	kN/m²	Static Load
3	**Additional Dead Load**	**QMS**			Static Load
A	Rainwater Load		0.49	kN/m²	Static Load
B	Asphalt Overlay		1.10	kN/m²	Static Load
C	Street Lighting (PJU)		1.00	kN/m²	Static Load
D	Green Open Space Load		1.76	kN/m²	Static Load
E	Utilities (MUT)		4.75	kN/m²	Static Load
4	**Traffic Load**	**QLL**			
A	Braking Load (TR)	TR	25.37	kN/m²	Static Load
B	Pedestrian Load (TP)	TP	2.36	kN/m²	Static Load
C	Truck Load (TT)	TT	25.37	kN/m²	Live Load
5	**Load Recapitulation**				
A	Superimposed Dead Load		16.65	kN/m²	
B	Additional Dead Load		9.06	kN/m²	
C	Traffic Load		37.40	kN/m²	
D	Earth Pressure Load	TA	65.44	kN/m²	
6	Total Working Load	ΣQ	128.19	kN/m²	

A combination of loading is used to obtain the most critical conditions on the structure. The combination is determined based on the Bridge Engineering Book, as shown in the following table [10].

Table 3. Ultimate load combination

Recap of the Ultimate Load Combination		
Ultimit Limit State	ΣQ	Unit
Strong I	188,48	kN/m²
Strong II	173,50	kN/m²
Strong III	99,40	kN/m²
Strong IV	102,90	kN/m²
Strong V	103,33	kN/m²

Table 4. Extreme load combinations

Extreme Load Combination Recap		
Extrem Limit State	ΣQ	Unit
Extrem I	132,31	kN/m²
Extrem II	139,80	kN/m²

Table 5. Serviceability Load Combination

Serviceability Load Combination		
Serviceability Limit State	ΣQ	Unit
Strong IV	102,90	kN/m²
Strong IV	102,90	kN/m²
Strong IV	102,90	kN/m²
Strong IV	102,90	kN/m²

This load combination represents realistic field conditions, including permanent, traffic, and environmental loads (wind and earthquake). This combination of loading is used as the basis for structural analysis using Midas Civil software [25].

The structural analysis of the concrete arch bridge yielded three primary internal force components: axial force, bending moment, and shear force. These values are obtained from the output of the Midas Civil software based on the load combination according to SNI 1725:2016 [23].

The analysis was performed using Midas Civil, ensuring that the results closely represent the actual structural behavior [22]. Next, the discussion focused on each component of the inner force, starting from the axial force as the dominant force acting on the curved element, then continued with the bending moment, and ending with the shear force.

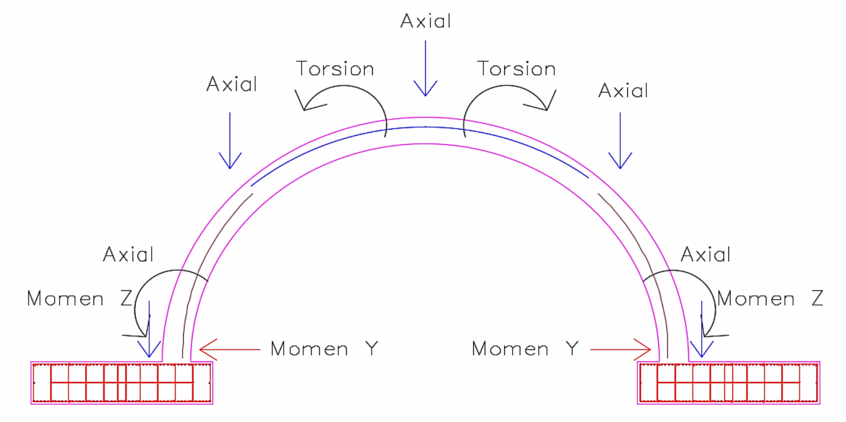

Fig. 1.Illustration of the inner style

C. Axial Force

The analysis results indicated that the maximum axial force in the structural element reached 5730.16 kN/m, while the minimum was 823.39 kN/m. This figure illustrates that arched bridges work effectively as the main pressing element on the structure.

Here is a picture of the axial force working on a concrete arch.

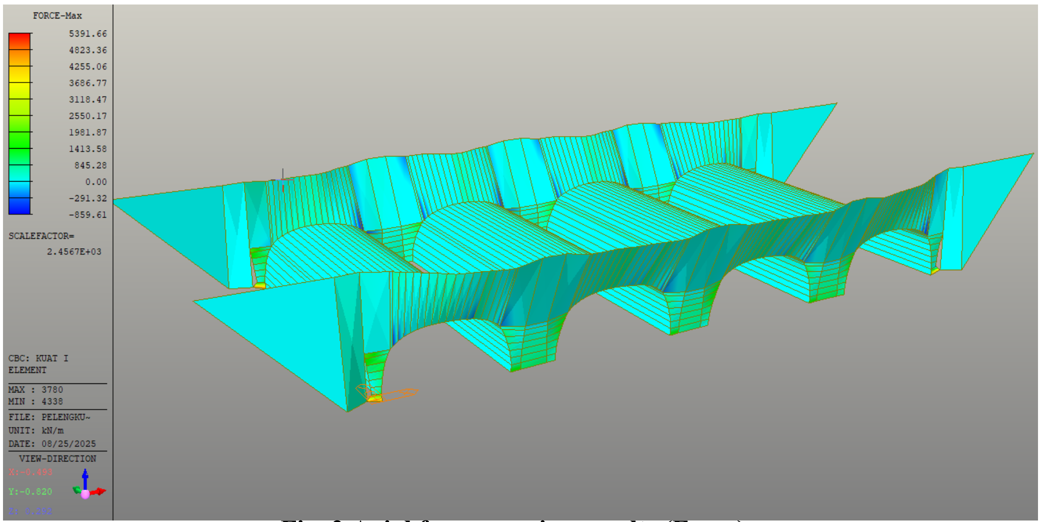

Fig. 2.Axial force running results (Fmax)

D. Bending Moments

In addition to axial forces, structural elements of concrete arched bridges also receive the influence of bending moments due to eccentric loads and non-uniform load distribution. The bending moment is important to analyze because it can cause excessive cracking or deformation in structural elements, especially in the curved part that functions as a force channel. The greatest moment occurred on the wall of the base with a value of -564.49 kNm, while the moment of the wall field reached 434.50 kNm. In the curved element, the moment of focus was recorded at -205.73 kNm, and the field moment reached 287.37 kNm. A negative value indicates a moment that works in the opposite direction, generally occurring in a fixed focus condition.

Here is a picture of the bending moment working on a concrete arch bridge.

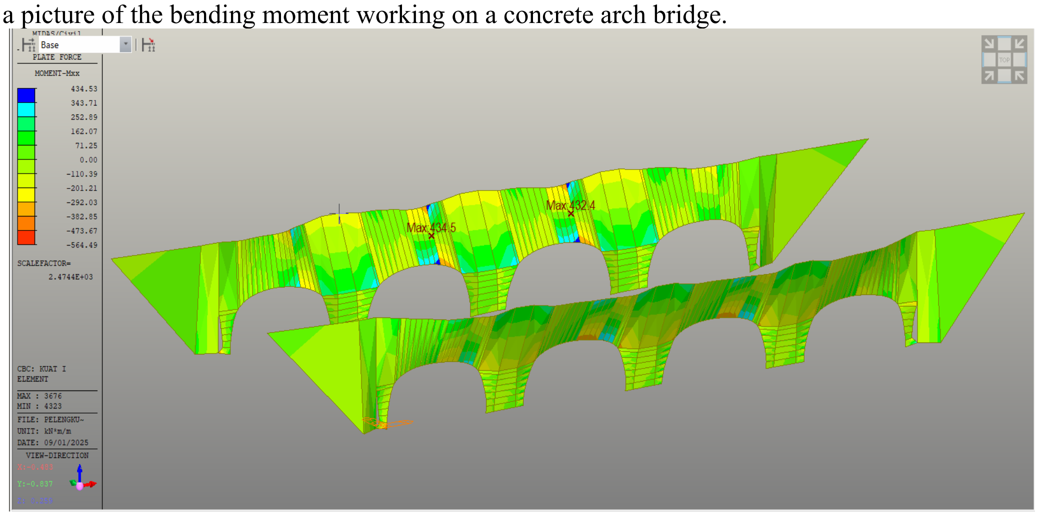

Fig. 3.Positive moment points on the wall

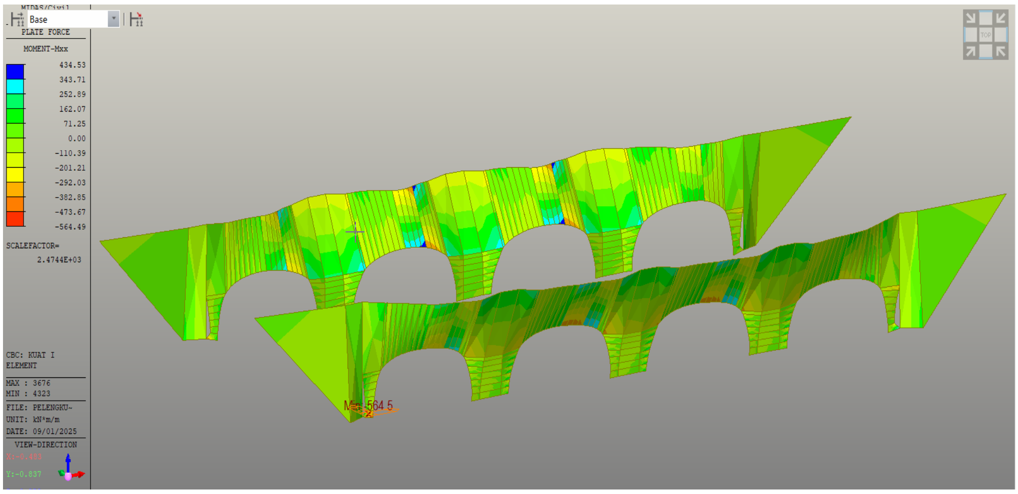

Fig. 4.Negative moment points on the wall

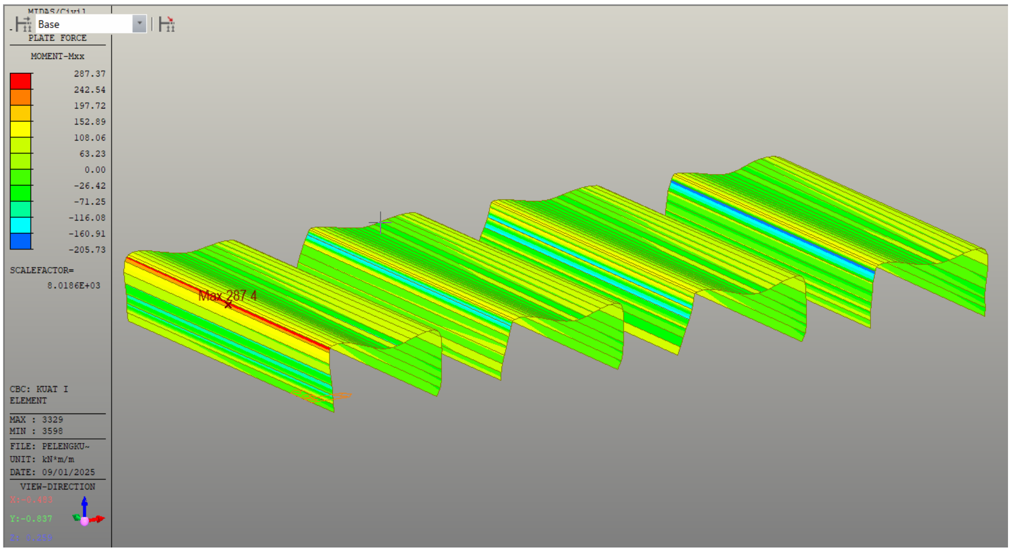

Fig. 5.Positive moment points on the curve

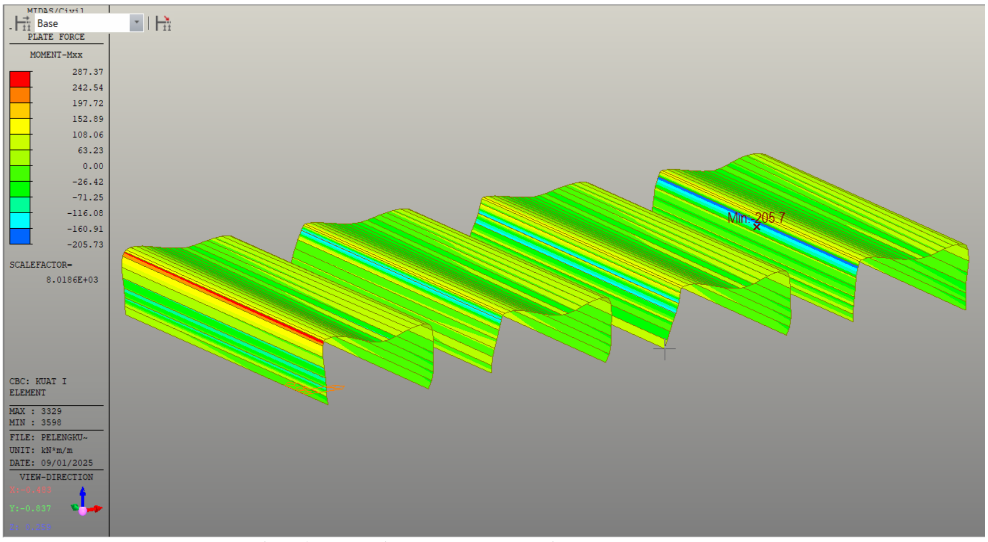

Fig. 6.Negative moment points on the curve

E. Shear Forces

In addition to axial forces and bending moments, shear forces also appear as a structural response to traffic loads and other additional loads. Although the contribution of shear force is relatively small compared to axial force, it remains significant, as inadequate design may lead to shear failure in the structural element. The largest shear force distribution was obtained at the pier head with a maximum value of 501.64 kN/m while on the walls and curves the value was higher, which was 592.17 kN/m. The shear force diagram shows that traffic loads make a dominant contribution to this transverse force.
Here is a picture of the shear force acting on a concrete arch bridge.

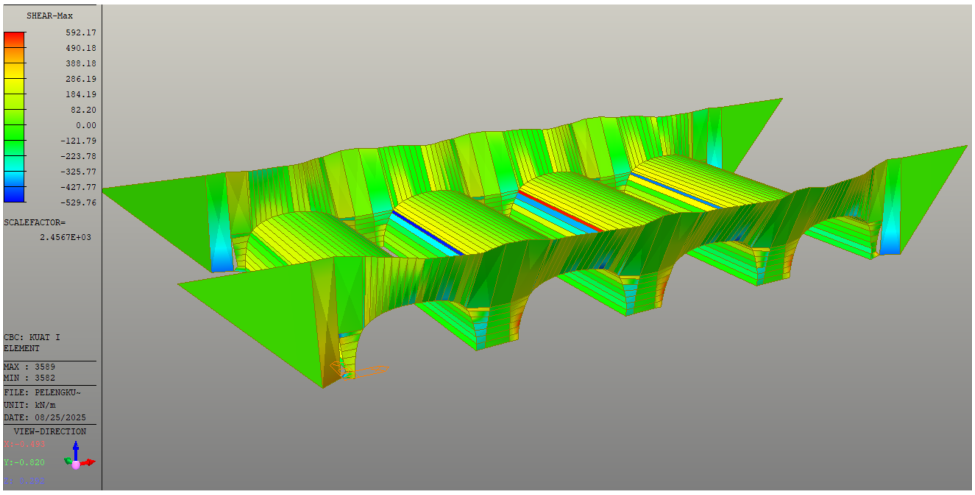

Fig. 7.Shear force running results (Vmax)

Overall, the results of the analysis show that the working inner force can still be held by the cross-sectional capacity in accordance with the provisions of SNI 2847:2019. The moment and the resulting shear force have been taken into account in the repeating design so that the structure is declared safe against the ultimate boundary conditions.

Table 6. Recapitulation of the value of inner style

Elemen	Axial Force (kN)	Momen Flexibility (kNm)	Shear Forces (kN)
Wall (Focus)	5051.94	-564,49	300
Wall (Field)	-1612.03	434,5	220
Curve (Focus)	556.7	-205,7	270
Curve (Field)	-280.38	284,4	180
Pier Head (Focus)	-	146.31	501.64
Pier Head (Field)	-	-292.62	-501.64

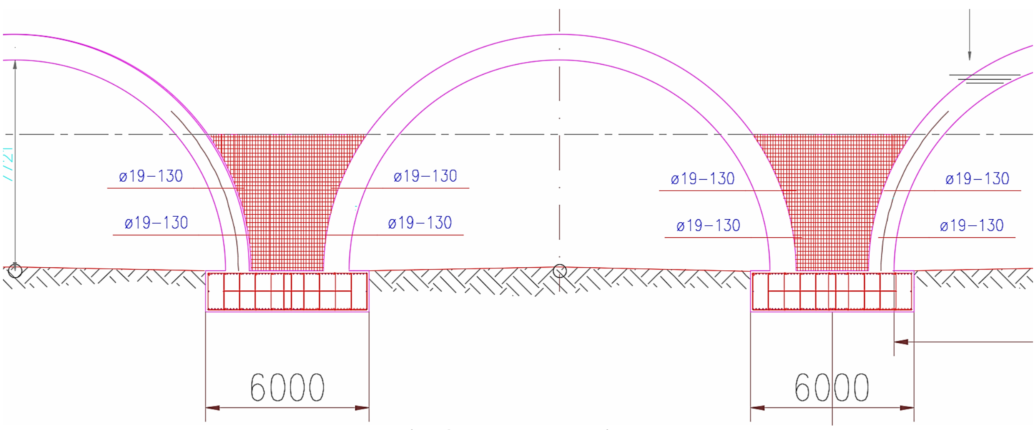

Fig. 8.Wall Repeating

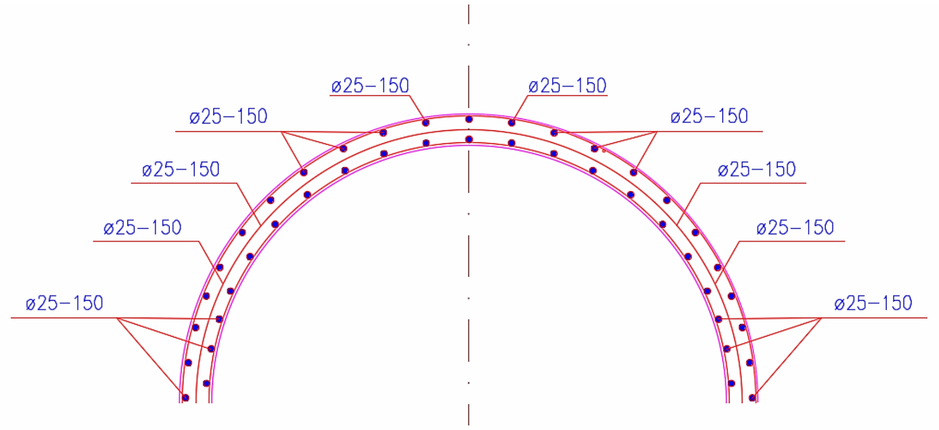

Fig. 9. Curve Repetition

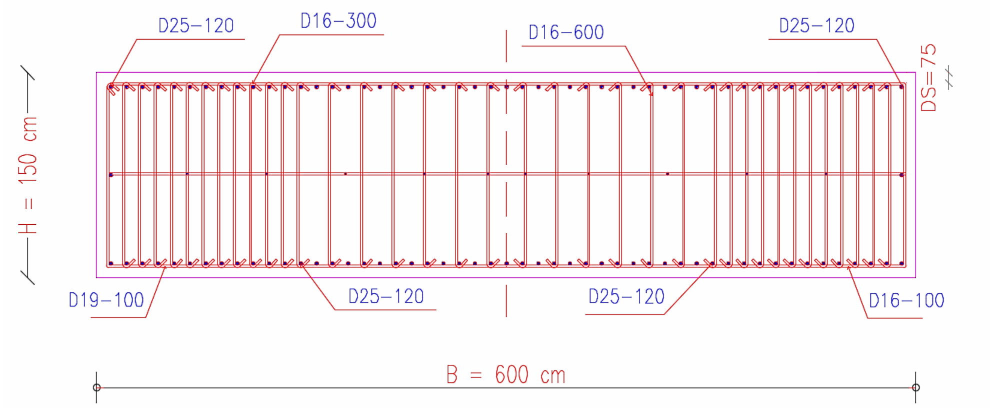

Fig. 10. Pier Head Repeats

The value of the inner force indicates a reasonable load distribution for the arched bridge that dominates the axial force (pressure), the wall holds the greatest moment on the pile, and the pier head becomes the critical point against the shear force. With moment capacity checks such as the data above, the mentioned repeating design (Ø25–150) is potentially adequate—but it must be supported by documentation of cross-sectional capability calculations and connection details for full SNI.

The deflection evaluation was carried out to assess the deformation performance of the concrete arch bridge under the Serviceability Limit State (SLS) condition. Deflections under service loads must not exceed the permissible limits to prevent inconvenience to road users or potential non-structural damage to the bridge.

The results of the analysis showed that the maximum deflection in the concrete arched bridge elements was 1.46 mm, while when compared to the deflection limit set by AASHTO LRFD Bridge Design, which is L/1000 for conditions with moderate foot traffic (equivalent to 20 mm), then the actual deflection value was only about 7.3% of the permit limit.

This relatively very small value proves that the bridge structure has high rigidity and is safe against deformation. This condition also shows that the cross-sectional dimensions and repeating configuration used are efficient in maintaining the stability and comfort of the structure. Thus, from the serviceability aspect, the concrete arch bridge at the study site can be declared to meet the feasibility criteria of the structure.

The calculation of reinforcement needs is carried out to ensure that the cross-sectional capacity of reinforced concrete is able to withstand the inner forces that occur due to a combination of loads in accordance with SNI 1725:2016 and capacity evaluation based on SNI 2847:2019 [23]. The analysis includes the main elements of the bridge, namely the walls, arches, pier heads, and floor.

The results of the evaluation showed that the wall withstood the greatest moments both on the pedestal and the field, so it required a longitudinal reinforcement with a diameter of Ø25 with a tight spacing of 150 mm. In the curved element, the moment is more dominant with a value of 287.37 kNm/m, but still requires a bending reinforcement of Ø25–150 mm to withstand the field momen.

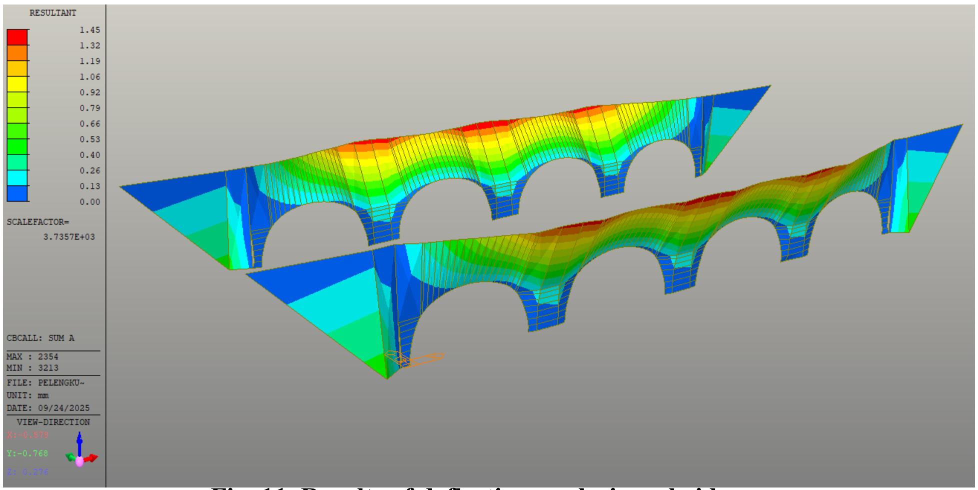

Fig. 11. Results of deflection analysis on bridges

The pier head is the most critical element under shear forces, with a maximum value of 292.62 kN. Therefore, in addition to the longitudinal reinforcement of Ø25–150 mm, a transverse reinforcement of Ø16–300 mm is required to ensure the shear capacity exceeds the design force.

A summary of the reinforcement requirements of each element is shown in the following Table.

Table 7. Recurrence Control

Elemen	Longitudinal Reinforcement	Shear / Transverse reinforcement	Value Inner Style
Wall	Ø25 – 150 mm	Ø25 – 150 mm	Momen max −564,49 kNm& 434,50 kNm
Arch	Ø25 – 150 mm	Ø25 – 150 mm	Momen max −205.73 kNm& 287.37 kNm
Pier Head	Ø25 – 150 mm	Ø16 – 200 mm	Shear max 501,640 kN& Momen 146,310 kNm
Plate	Ø25 – 150 mm	Ø25 – 150 mm	Traffic load distribution (floor plate)

Based on the table, it can be seen that the reinforcement configuration used in each bridge element has met the requirements for cross-sectional strength as well as the minimum and maximum limits of the repetition ratio in accordance with SNI 2847:2019. In walls, the reinforcement needs are mainly controlled by the large bending moment in the pile, while in the curve it is dominated by the axial force of the press. The pier head was identified as the most critical element against sliding, so it required more tight transverse reinforcement to guarantee the safety of the structure. Meanwhile, the floor plate remains safe with relatively smaller reinforcement due to the dominant load in the form of traffic distribution.

Thus, the results of the repetition evaluation show that the design applied to the concrete arch bridge in STA 2 + 800 is in accordance with applicable planning standards, technically efficient, and able to ensure the performance of the structure both in terms of ultimate limit state and serviceability limit state.

IV. CONCLUSION

Based on the analysis and evaluation of the superstructure of the concrete arch bridge at STA 2+800 using Midas Civil software, the following main conclusions were drawn: [22]

1. Internal Forces

The concrete arch bridge experiences significant internal forces. The largest bending moment occurs at the pedestal wall, with a value of −564.49 kNm, and a field moment of 434.50 kNm. In the curved element, the focus moment was recorded at −205.70 kNm, and the field moment at 284.40 kNm. The maximum axial force occurs at the arch, reaching 5730.16 kN, while the maximum shear force is recorded at the pier head with a value of 501.64 kN.

2. Deflection Performance

The deflection analysis revealed maximum values of 1.46 mm at the wall and 0.15 mm at the curve. These values are significantly below the permissible limit of L/1000 = 20 mm, as specified in AASHTO LRFD

Bridge Design for a 100 m span. Thus, the bridge structure is considered safe in terms of the serviceability limit state.

3. Reinforcement Evaluation

The longitudinal reinforcement requirements for wall and arch elements can be fulfilled with Ø25–150 mm bars. For the pier head, in addition to longitudinal reinforcement of Ø25–150 mm, transverse (shear) reinforcement of Ø16–600 mm is required to resist maximum shear forces. On the floor plate, the longitudinal reinforcement is Ø25–150 mm. All reinforcement configurations meet the minimum and maximum spacing requirements according to SNI 2847:2019.

4. Structural Qualifications

Overall, the evaluation results indicate that the concrete arch bridge at the study site satisfies the requirements for cross-sectional strength, structural stability, and safety factors. The structure is deemed safe and feasible as a design solution to resolve clash issues with the Multi-Utility Tunnel line without compromising the strength or reliability of the bridge.

REFERENCES

[1]. Z. Xiang, W. Xu, A. Liu, and F. Meng, "The Origin and Development of Bridges," 2023. doi: 10.1007/978-981-99-2878-1_1.
[2]. "Investigation on load capacity evaluation of existing bridge based on deflection," 2022. doi: 10.1201/9781003322641-41.
[3]. R. Hermawan and M. Pamadi, "Simulation of Tied-Arch Bridge Design on Ibu Kota Nusantara (IKN)," Journal of Infrastructure and Civil Engineering, Mar. 2025, doi: 10.35583/jice.v5i1.97.
[4]. M. A. Ramdani, N. P. Widiya, A. Susanto, and Y. Astor, "Design of The Prestressed Concrete Bridge Structure on The Leuwigajah Bridge," Dec. 2020. doi: 10.2991/AER.K.201221.026.
[5]. J. Propika, Y. Septiarsilia, E. Susanti, and H. Istiono, "Upper Structure of Precast Concretes Comparison: PC-I and PC-U in West Outer Ring Road, Surabaya," Civilla, Sep. 2022, doi: 10.30736/cvl.v7i2.882.
[6]. Y. Lai, "Conceptual design of long span steel-UHPC composite network arch bridge," Engineering Structures, Feb. 2023, doi: 10.1016/j.engstruct.2022.115434.
[7]. S. Palmabas, S. Sariman, and E. Yuniarto, "AlternatifPerancanganJembatanPelengkungStruktur Atas JembatanTawaeliMenggunakanSistemJembatanPelengkung Steel Box Tipe Through Arch Birdge," Deleted Journal, May 2025, doi: 10.56326/jptsk.v3i2.4951.
[8]. T. Treichel, A. Zielstorff, M. G. A. Danish, J. Wimmer, S. Küttenbaum, and T. Braml, "Design of a Digital Twin-based System for Bridges," 2025 IEEE 8th International Conference on Industrial Cyber-Physical Systems (ICPS), Jan. 2025, doi: 10.1109/ICPS65515.2025.11087830.
[9]. J. X. Shi and Y. J. Cheng, "Study on load test of 100m cross-reinforced deck type concrete box arch bridge," Jun. 2018, doi: 10.1051/E3SCONF/20183803011.
[10]. W. Lin and T. Yoda, "Bridge engineering: classifications, design loading, and analysis methods," 2017.
[11]. J. Fang, "Support Load of Tunnel Construction by Crossing Broken Fault and Water-Rich Geological Mine Method by Using MIDAS Software," 2022. doi: 10.1007/978-981-16-8052-6_53.
[12]. C. Huang, Y. Wang, X. Zhou, and L. Yue, "Structural calculation analysis and comparative study of 80m through tied-arch bridge," Jun. 2022. doi: 10.1109/ICAICA54878.2022.9844495.
[13]. S. Zhao, J. Ruan, and K. Chen, "Vehicle Load Model of Highway Bridge and Its Application in Earthquake Prevention and Disaster Reduction," Mar. 2022, doi: 10.1109/icitbs55627.2022.00084.
[14]. Y. Gunawardena, F. Aslani, J. Li, and H. Hao, "In Situ Data Analysis for Condition Assessment of an Existing Prestressed Concrete Bridge," Journal of Aerospace Engineering, Nov. 2018, doi: 10.1061/(ASCE)AS.1943-5525.0000935.
[15]. M. Lagos, M. Elgueta, and M. I. Molina, "Arch and Cable Suspended Bridges," The Physics Teacher, Apr. 2023, doi: 10.1119/5.0070682.
[16]. D. R. Anderson, R. M. Johnson, and R. T. Leon, "Transverse load distribution in a 536-ft deck arch bridge," Transportation Research Record, Jan. 1988.
[17]. J. Bessini, C. Lazaro, J. Casanova, and S. Monleón, "Efficiency-based design of bending-active tied arches," Engineering Structures, Dec. 2019, doi: 10.1016/J.ENGSTRUCT.2019.109681.
[18]. X. Zhang, Z. Deng, G. Fang, and Y. Ge, "Theoretical Analysis of Ultimate Main Span Length for Arch Bridge," Sustainability, Dec. 2022, doi: 10.3390/su142417043.
[19]. J. X. Shi and Q. H. Ding, "Analysis and Test of The boom Tension in a Tied arch bridge," Jan. 2018, doi: 10.1051/MATECCONF/201817502007.
[20]. H. Yu, J. Mao, Q. Zhou, B. Cheng, X. Liu, and C. Du, "Design Research of 600 M Scale Concrete Arch Bridge Based on Mathematical Optimization Method," Aug. 2020, doi: 10.2478/AMNS.2020.2.00030.
[21]. R. Aschenbrenner, "Three-Dimensional Analysis of Pile Foundations," Journal of the Structural Division, Feb. 1967, doi: 10.1061/JSDEAG.0001578.
[22]. J. Li, H.-H. Song, Z. Zhou, C. Yang, L. X. Wang, and H. Li, "A Revit-Midas/Civil conversion approach for bridge superstructures analysis," Engineering research express, Mar. 2024, doi: 10.1088/2631-8695/ad301b.
[23]. M. Yusuf and F. Hermawan, "Comparison analysis of existing bridge design based on bms 1992 and sni 1725-2016," LivaS, Mar. 2024, doi: 10.25105/livas.v8i2.19483.
[24]. C. H. K. Mailangkay, R. S. Windah, and S. O. Dapas, "Analisis dan Desain BalokBetonBertulangMenggunakanTabelBerdasarkan SNI 2847:2019," Tekno (Malang), Jul. 2024, doi: 10.35793/jts.v22i88.57041.
[25]. M. Jagandatta, G. Y. Kumar, and S. S. Kumar, "Analysis and Design of Composite Single Span Psc-I Girder Bridge Using Midas Civil," IOP Conference Series: Earth and Environmental Science, Mar. 2022, doi: 10.1088/1755-1315/982/1/012078.