Structural Quality Comparison of Bungur Bridge T-Girder Using Conventional BJTS 420B and Ultra High Strength Steel (UHSS) Reinforcement

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ABSTRACT

Bungur Bridge in Pamekasan is a 15.00 m short-span bridge on the provincial road network that requires reliable structural quality and controlled constructability. This paper is derived from the first research objective of the thesis and focuses only on analyzing the structural quality comparison of the T-girder between conventional BJTS 420B reinforcement and Ultra High Strength Steel (UHSS) reinforcement. A descriptive quantitative case-study method was used based on bridge geometry, material parameters, load analysis, and reinforced concrete section checks. The analysis applied concrete K-500 or f'c = 41.50 MPa, conventional reinforcement with fy = 420 MPa, UHSS reinforcement with fy = 700 MPa, and the critical ultimate moment of 3,702.46 kNm. The results show that the conventional alternative requires 29-D25 tension bars and produces a flexural capacity of 3,898.00 kNm, while the UHSS alternative requires 17-D25 tension bars and produces 3,810.93 kNm. Both alternatives satisfy flexural, shear, and deflection controls, with maximum calculated deflections of 0.0340 m for conventional reinforcement and 0.0380 m for UHSS, below the allowable limit of 0.0625 m. The UHSS alternative reduces reinforcement congestion and decreases the total reinforcement weight for six girders from 17,473.61 kg to 9,933.21 kg. Therefore, UHSS can be considered structurally feasible for improving the quality and constructability of the Bungur Bridge T-girder, provided that detailing, anchorage, cracking, and field quality control are carefully verified.

Keywords: BJTS 420B, Bungur Bridge, Structural quality, T-girder, Ultra High Strength Steel

1. Introduction

Bridges are critical components of road infrastructure because they connect road segments, maintain traffic continuity, and support public mobility and goods distribution. A bridge failure or reduction in serviceability may generate significant impacts on travel time, safety, maintenance cost, and regional accessibility. For a provincial road network, the structural quality of short-span bridges is especially important because these bridges are numerous and directly influence daily traffic services.

Bungur Bridge is located on the Bts. Kota Pamekasan-Sotabar road section under the service area of UPT Pengelolaan Jalan dan Jembatan Pamekasan. The bridge has a length of 15.00 m and one span. The thesis data indicate that the main girder condition becomes an important concern, particularly because cracking and reinforcement congestion can reduce the quality of concrete placement and long-term durability. In reinforced concrete T-girders, quality is not only represented by compressive strength, but also by flexural capacity, shear capacity, deflection control, reinforcement arrangement, and constructability.

Conventional reinforcement such as BJTS 420B is widely used in Indonesian reinforced concrete construction because it is familiar, available, and supported by common design practice. However, the use of higher-yield reinforcement such as Ultra High Strength Steel (UHSS) provides an opportunity to reduce the required reinforcement area while maintaining the same design capacity. A smaller number of bars may improve concrete compaction, reduce honeycomb risk, increase spacing between bars, and enhance construction quality in elements with limited dimensions.

The application of UHSS must nevertheless be evaluated carefully. High-yield reinforcement may affect ductility, crack width, development length, service stress, and detailing requirements. For bridge structures exposed to repeated traffic loading and environmental effects, the alternative material should be accepted only when it satisfies structural performance checks and remains practical for field implementation. Previous studies on high-strength reinforcement show its potential to improve capacity and reduce reinforcement ratios, but the design must still satisfy code-based strength and serviceability controls (Aldabagh et al., 2022; Eltahawy et al., 2009; Jingfeng et al., 2023).

Therefore, this paper aims to analyze the structural quality comparison of the Bungur Bridge T-girder between conventional BJTS 420B reinforcement and UHSS reinforcement. This paper is limited to the first research objective of the thesis; the duration comparison and Accelerated Bridge Construction (ABC) discussion are not included. The comparison focuses on flexural capacity, shear capacity, deflection, reinforcement configuration, and reinforcement weight as supporting indicators of structural quality and constructability.

2. Methods

This study used a descriptive quantitative case-study approach. The object was the superstructure T-girder of Bungur Bridge. The analysis was based on secondary data from the thesis document, including bridge geometry, material properties, loading assumptions, reinforcement alternatives, and structural calculation results. The calculation was carried out for a 15.00 m span with concrete K-500 or f'c = 41.50 MPa. Two reinforcement scenarios were compared: conventional BJTS 420B with fy = 420 MPa and UHSS with fy = 700 MPa.

The structural quality assessment was conducted through five steps. First, bridge basic data and loading components were identified. Second, ultimate load combinations were reviewed to obtain the critical moment and shear. Third, flexural reinforcement requirements were compared between both alternatives. Fourth, shear reinforcement and deflection controls were checked. Fifth, reinforcement weight was compared to evaluate constructability and reinforcement congestion. The analysis referred to Indonesian bridge and reinforced concrete standards, including SNI 1725:2016, SNI 2052:2017, SNI

2847:2019, and related bridge concrete design provisions (Badan Standardisasi Nasional, 2016, 2017, 2019).

The main strength and serviceability controls used in the paper are expressed as follows:

$$M_u \leq \varphi M_n \quad (1)$$

$$V_u \leq \varphi(Vc + Vs) \quad (2)$$

$$\delta \leq L / 240 \quad (3)$$

where M_u is the ultimate design moment, φM_n is the design flexural strength, V_u is the ultimate shear force, Vc is the concrete shear contribution, Vs is the shear reinforcement contribution, δ is the calculated deflection, and L/240 is the allowable deflection limit used in the thesis calculation.

Table 1 Basic data of Bungur Bridge.

Description	Data
Bridge name	Bungur Bridge
Road section	Bts. Kota Pamekasan - Sotabar (35.118)
Location	KM Surabaya 138+635
Bridge length	15.00 m
Number of spans	1 span
Inspection date	22 January 2026
Bridge management agency	UPT Pengelolaan Jalan dan Jembatan Pamekasan

Source: Author analysis, 2026.

3. Results

The load recapitulation used in the structural comparison is summarized in Table 2. The largest bending contribution comes from traffic loading, while permanent loads contribute substantially to both moment and shear. These values were used as the basis for the ultimate load combinations in Table 3.

Table 2 Load recapitulation per girder.

Load type	Moment (kNm)	Shear (kN)	Description
Self weight (MS)	741.80	197.81	Permanent structural load
Additional dead load (MA)	189.14	50.44	Overlay and water load
Traffic lane load D/T	1,140.00	192.50	Governing traffic effect
Braking force (TB)	60.00	8.00	Longitudinal traffic force
Wind load (EW)	28.35	7.56	Vehicle wind transfer
Temperature effect (ET)	22.50	1.50	Bearing movement effect
Vertical earthquake load (EQ)	57.02	15.21	Vertical seismic effect

Source: Author analysis, 2026.

Table 3 Ultimate moment and shear combinations.

Combination	M_u (kNm)	V_u conventional (kN)	V_u UHSS (kN)	Remark
Combination 1	3,702.46	768.10	748.32	Critical for moment and shear
Combination 2	3,695.44	760.83	741.05	Includes temperature effect
Combination 3	3,605.46	758.24	738.46	Includes vertical earthquake effect

Source: Author analysis, 2026.

Table 4 shows that both reinforcement alternatives satisfy the flexural capacity requirement. The conventional design uses 29-D25 tension bars with an installed area of

14,235 mm², while the UHSS design uses 17-D25 tension bars with an installed area of 8,345 mm². The lower number of UHSS bars indicates a lower reinforcement density while maintaining adequate capacity.

Table 4 Flexural design comparison between conventional reinforcement and UHSS.

Item	Conventional BJTS 420B	UHSS fy 700 MPa	Interpretation
Ultimate design moment, M_u	3,702.46 kNm	3,702.46 kNm	Same design demand
Nominal moment demand, $M_n = M_u/\varphi$	4,628.07 kNm	4,628.07 kNm	Basis of capacity requirement
Yield strength of main reinforcement	420 MPa	700 MPa	UHSS has higher yield strength
Required steel area, A_s	13,495 mm²	8,097 mm²	UHSS requires smaller area
Tension reinforcement used	29-D25	17-D25	UHSS reduces 12 bars
Installed steel area	14,235 mm²	8,345 mm²	Installed area decreases by about 41.38%
Compression reinforcement	12-D25	6-D25	Based on ductility approach
Flexural capacity, φM_n	3,898.00 kNm	3,810.93 kNm	Both are greater than M_u
Status	OK	OK	Both satisfy flexural control

Source: Author analysis, 2026.

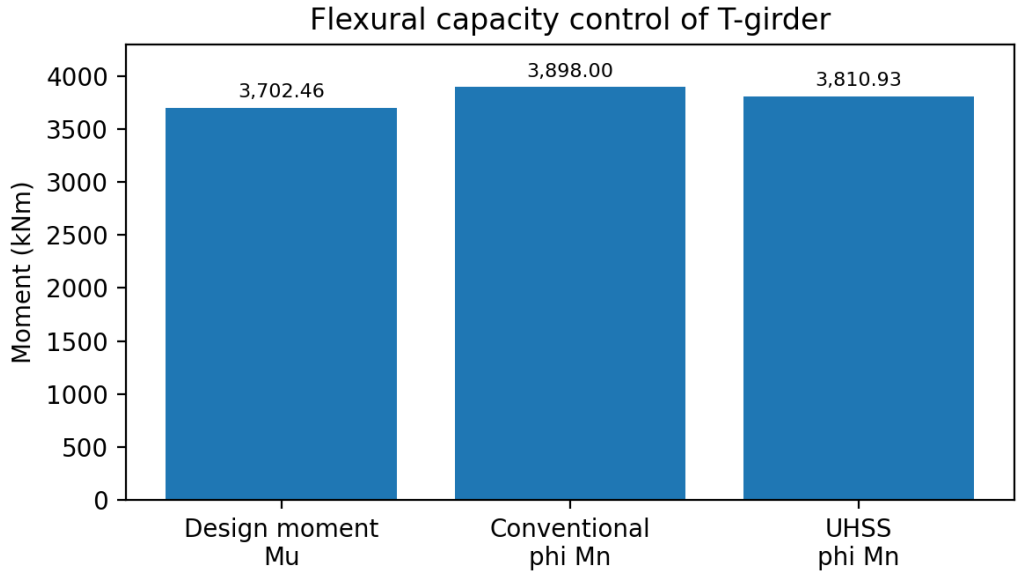


Figure 1 Flexural capacity control of the T-girder.
Source: Author analysis, 2026.

The shear design comparison is presented in Table 5. Since the concrete strength and section geometry are the same, the concrete shear contribution remains identical for both alternatives. The UHSS alternative requires a lower shear reinforcement contribution and allows a wider stirrup spacing in the analyzed configuration.

Table 5 Shear design comparison between conventional reinforcement and UHSS.

Item	Conventional	UHSS	Interpretation
Ultimate shear force, V_u	768.10 kN	748.32 kN	Critical combination
Concrete shear strength, Vc	547.57 kN	547.57 kN	Same concrete strength
φVc	410.68 kN	410.68 kN	Shear reinforcement is still required
Required Vs	476.56 kN	450.19 kN	UHSS requires smaller contribution
Installed stirrups	D13-90	D13-150	UHSS spacing is wider

Vsmax control	OK	OK	Girder dimension satisfies maximum shear control
Status	OK	OK	Both satisfy shear control

Source: Author analysis, 2026.

The deflection control indicates that both alternatives satisfy the allowable limit of L/240, equal to 0.0625 m for the 15.00 m span. Although the calculated deflection of the UHSS alternative is slightly higher because of the lower installed reinforcement area, it remains within the allowable limit for all combinations.

Table 6 Deflection control of the T-girder.

Combination/parameter	Conventional	UHSS	Allowable limit	Status
Combination 1	0.0340 m	0.0380 m	0.0625 m	OK
Combination 2	0.0338 m	0.0377 m	0.0625 m	OK
Combination 3	0.0339 m	0.0378 m	0.0625 m	OK
Interpretation	Controlled	Controlled	L/240	Satisfies

Source: Author analysis, 2026.

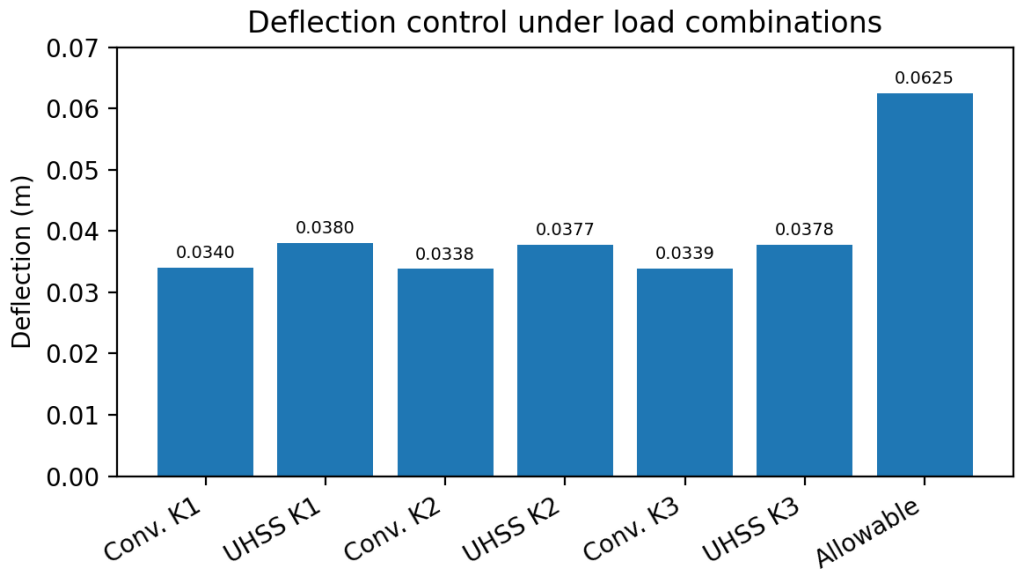


Figure 2 Deflection control under load combinations.
Source: Author analysis, 2026.

The reinforcement weight comparison is used as a supporting indicator of constructability. Lower reinforcement weight and lower bar density can improve bar placement, concrete flow, and compaction quality in the girder section.

Table 7 Reinforcement weight comparison.

Reinforcement component	Conventional per girder (kg)	UHSS per girder (kg)	Conventional 6 girders (kg)	UHSS 6 girders (kg)	Reduction
D25 tension bars	1,676.06	982.52	10,056.33	5,895.09	41.38%
D25 compression bars	693.54	346.77	4,161.24	2,080.62	50.00%
D13 stirrups	542.67	326.25	3,256.04	1,957.50	39.88%
Total	2,912.27	1,655.54	17,473.61	9,933.21	43.15%

Source: Author analysis, 2026.

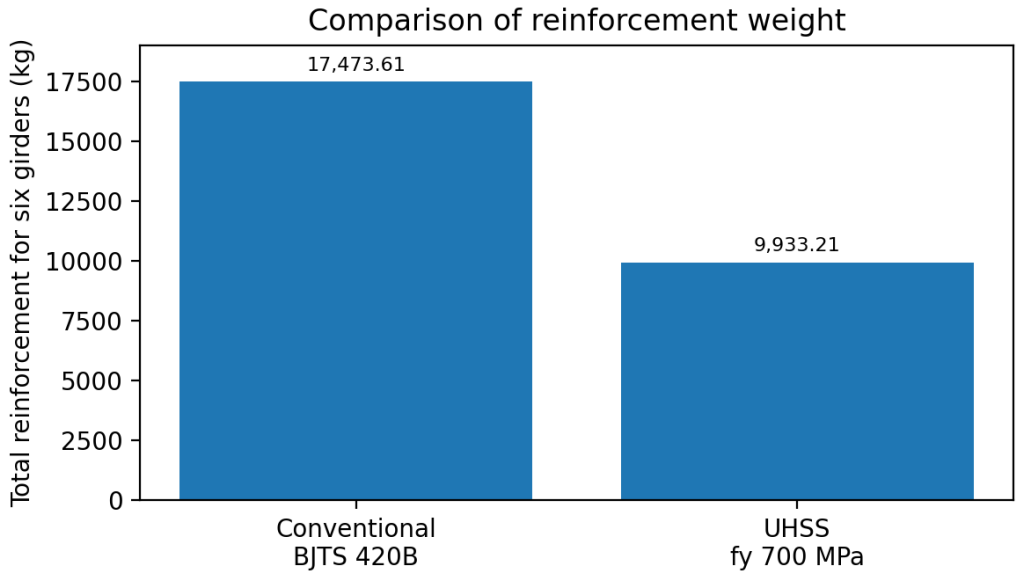


Figure 3 Total reinforcement weight comparison for six girders.
Source: Author analysis, 2026.

4. Discussion

The results demonstrate that UHSS can provide adequate structural capacity for the Bungur Bridge T-girder while reducing reinforcement density. In flexural design, the UHSS capacity of 3,810.93 kNm is still greater than the design moment of 3,702.46 kNm. Although the capacity is slightly lower than the conventional alternative, the difference does not indicate inadequate performance because both alternatives satisfy the required strength check.

From a structural quality perspective, the lower number of tension bars is important. The conventional alternative requires 29-D25 bars, while the UHSS alternative requires 17-D25 bars. This reduction can increase clear spacing between bars and facilitate concrete placement. For field work, reinforcement congestion often becomes a practical source of quality problems such as honeycomb, poor vibration, and voids around bars. Thus, UHSS contributes not only to numerical strength efficiency, but also to the potential improvement of execution quality.

The shear control also shows acceptable performance. Both alternatives require stirrups because φVc is lower than V_u. However, the UHSS alternative allows D13 stirrups at 150 mm spacing compared with D13 at 90 mm in the conventional alternative. Wider spacing may reduce fabrication complexity, but it must still follow detailing requirements, anchorage provisions, minimum shear reinforcement, and inspection control in the field.

The serviceability result shows that the UHSS alternative produces slightly higher deflection than the conventional alternative. The maximum UHSS deflection is 0.0380 m compared with 0.0340 m for the conventional alternative, but both are below the allowable value of 0.0625 m. This confirms that the reinforcement reduction does not cause serviceability failure in the analyzed girder. Nevertheless, crack width, long-term deflection, shrinkage, creep, and fatigue should be considered in further detailed design.

The total reinforcement weight decreases from 17,473.61 kg to 9,933.21 kg for six girders, equivalent to a reduction of 43.15%. This result supports the thesis argument that

UHSS can reduce reinforcement congestion and improve constructability. However, material availability, price, certification, development length, splice detailing, and compatibility with Indonesian standards must be verified before implementation. The UHSS alternative should therefore be considered a technically feasible option rather than an automatic replacement for conventional reinforcement.

5. Conclusion

Based on the first research objective, the structural quality comparison of the Bungur Bridge T-girder shows that both conventional BJTS 420B reinforcement and UHSS reinforcement satisfy the required flexural, shear, and deflection controls. The conventional alternative provides a flexural capacity of 3,898.00 kNm with 29-D25 tension bars, while the UHSS alternative provides 3,810.93 kNm with 17-D25 tension bars. The UHSS alternative remains greater than the design moment of 3,702.46 kNm, satisfies shear control with D13-150 stirrups, and has a maximum deflection of 0.0380 m, which is below the allowable limit of 0.0625 m. UHSS also reduces the total reinforcement weight for six girders by 43.15%, from 17,473.61 kg to 9,933.21 kg. Therefore, UHSS is structurally feasible and improves constructability for the Bungur Bridge T-girder, provided that detailing, anchorage, crack control, material certification, and field quality assurance are carefully addressed in the final design and construction stage.

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