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STRENGTH AND SERVICEABILITY ASSESSMENT OF AN EXISTING REINFORCED CONCRETE DECK ON A STEEL TRUSS BRIDGE

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Abstract

The deck is one of the bridge components that receives traffic loads directly and is therefore vulnerable to repeated loading and environmental deterioration. This paper evaluates the structural performance of the existing cast-in-place reinforced concrete deck of the Citarum Baru steel truss bridge in West Java, Indonesia. The bridge has a 60 m main span, while the deck was represented by a finite-element shell model in SAP2000 using geometry and material properties obtained from project documents and as-built drawings. Loading followed SNI 1725:2016 and included self-weight, asphalt, water ponding, lane load D, and the 500 kN truck load T. The assessment considered flexural demand, shear demand, the demand-capacity ratio, and service deflection. The maximum factored bending moment was 481.34 kN·m and the reported design flexural capacity was 679.27 kN·m, giving a demand-capacity ratio of 0.708. The maximum shear demand was 662.819 kN, and the shear check was reported to satisfy the required capacity. In contrast, the service deflection reached 36.8 mm, which exceeded the allowable limit of 16.67 mm. The results show that the deck still satisfies the reported strength checks but does not satisfy the deflection requirement. For an existing bridge with visible cracking, wear, and local deck damage, this difference is important because a satisfactory strength ratio alone does not demonstrate acceptable service performance.

***Keywords**:* Bridge deck, Reinforced Concrete, Finite Element Analysis, Deflection, Serviceability

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INTRODUCTION

Bridges are expected to remain safe and usable for a long service period, although traffic demand and exposure conditions continue to change after construction. For an existing bridge, structural evaluation is therefore not limited to the main load-carrying system. The deck also requires attention because it receives wheel loads directly and transfers them to the supporting girders. Repeated loading, moisture, surface wear, and local material deterioration can gradually reduce the quality of a reinforced concrete deck even when the main steel truss remains in acceptable condition [1].

The Citarum Baru bridge is a steel truss bridge on the Dayeuhkolot–Banjaran road corridor in West Java. Project documentation indicates that the main truss members are still serviceable, while the conventional cast-in-place concrete deck shows visible deterioration [2]. The observed condition includes worn surfaces, cracking, and locally damaged or perforated areas. Figure 1 shows one of the documented deck conditions. Such damage does not automatically mean that the deck has lost its ultimate strength, but it gives a clear reason to check both strength and serviceability using the current loading standard.

Figure 1. Documented condition of the existing reinforced concrete bridge deck.

For Indonesian bridges, traffic loading is commonly evaluated using SNI 1725:2016 [3]. The standard includes permanent loads, lane load D, truck load T, and dynamic load effects. For concrete members, capacity checks are also related to the strength principles used in SNI 2847:2019 [4]. Numerical analysis can support this evaluation because finite-element models provide internal forces and displacements at locations that are difficult to assess directly in the field. Previous studies have used similar numerical approaches to examine bridge capacity, demand-capacity ratios, and deck deflection [5]-[7].

A common weakness in practical bridge assessment is to stop the evaluation after the member passes an ultimate strength check. For a deck, this can be misleading. Excessive deflection may affect ride quality, cracking, drainage, and long-term durability even when the calculated flexural demand remains below the design resistance. This distinction is relevant to the Citarum Baru bridge because the visible deck damage is more severe than would be expected from a simple flexural demand-capacity ratio below 1.0.

This paper examines the existing conventional reinforced concrete deck of the 60 m steel truss bridge using a finite-element model. The objectives are to quantify the critical bending and shear demands, evaluate the reported flexural demand-capacity ratio, and compare the calculated service deflection with the allowable limit. The main contribution is a clear comparison between strength and serviceability performance using the same structural model and loading framework.

MATERIALS AND METHODS

Study Bridge and Input Data

The assessment used secondary data from the Citarum Baru bridge rehabilitation documents [2], including as-built geometry, material information, and photographs of the existing deck. The bridge has a 60 m longitudinal span and a total width of 9 m. The modeled reinforced concrete deck thickness is 0.20 m. The available documents also specify a 0.04 m asphalt layer and a 0.05 m water ponding depth for additional permanent loading. Concrete compressive strength was taken as 30 MPa and the structural steel grade was BJ 50. Table 1 summarizes the principal input data used in the model.

Table 1. Main geometry and material parameters used in the analysis

Parameter	Value	Unit	Use in analysis
Bridge span	60	m	Overall bridge geometry and lane loading
Total bridge width	9	m	Transverse geometry
Sidewalk width	1	m	Additional permanent load area
RC deck thickness	0.20	m	Shell element thickness
Asphalt thickness	0.04	m	Additional dead load
Water ponding depth	0.05	m	Environmental dead load assumption
Concrete compressive strength, f'c	30	MPa	Concrete capacity calculation
Concrete unit weight	24	kN/m³	Self-weight
Asphalt unit weight	22	kN/m³	Additional dead load
Water unit weight	9.8	kN/m³	Additional dead load

Finite Element Model

The deck was modeled in SAP2000 using area (shell) elements. A representative deck segment was used so that the local response of the slab could be evaluated without modeling every bridge component in detail. Supports were assigned at the deck locations connected to the existing steel stringers. The model used the documented deck thickness and material properties, and the existing reinforcement data were used in the flexural capacity calculation. The main response quantities extracted from the analysis were the shell bending moments, shear forces, and vertical displacement.

The numerical model was treated as a structural assessment model rather than a detailed deterioration model. Cracking, corrosion, fatigue accumulation, and local loss of section were not simulated explicitly. The analysis therefore represents the response of the documented structural section under the specified load combinations.

Loading and Load Combination

Loading was defined according to SNI 1725:2016 [3]. Permanent actions included the self-weight of the concrete deck and additional dead loads from the asphalt layer and assumed water ponding. Traffic actions included lane load D and the three-axle truck load T with a total truck load of 500 kN. A 40% dynamic load allowance was applied to the concentrated traffic effect as stated in the source analysis.

For a loaded length greater than 30 m, the uniformly distributed component of lane load D was calculated from the SNI expression reported in the source document:

$$q = 9.0\,(0.5 + 15/L) \qquad (1)$$

where q is the uniformly distributed lane-load intensity in kPa and L is the loaded length in metres. For L = 60 m, q equals 6.75 kPa. The concentrated line load was taken as 49 kN/m before the stated dynamic allowance. Strength and service load combinations were then evaluated using the LRFD framework in the project analysis.

Performance Criteria

The flexural assessment compared the maximum factored bending moment, Mu, with the reported design flexural resistance, φMn. The demand-capacity ratio was calculated as:

$$D/C = Mu / (\varphi Mn) \qquad (2)$$

A D/C ratio not greater than 1.0 was treated as satisfactory for the reported strength check. Shear demand was evaluated in the same general manner by comparing the maximum shear force with the available concrete shear resistance reported in the calculation.

Serviceability was checked using the deflection limit adopted in the source analysis:

$$\Delta allow = L / 300 \qquad (3)$$

For the 5,000 mm deck-panel span used in the serviceability calculation, the allowable deflection was 16.67 mm. The calculated vertical displacement from the finite-element model was compared directly with this limit.

RESULTS AND DISCUSSION

Internal Force Demand

The SAP2000 results show that the lane-load strength combination controlled the deck response. The maximum bending moment was 481.34 kN·m under Strength I with lane load D, and the corresponding maximum shear was 662.819 kN. The service envelope reached 347.076 kN·m in bending and 473.006 kN in shear. Selected results are listed in Table 2.

Table 2. Selected bending-moment and shear results from the finite-element analysis

Load combination	Maximum moment (kN·m)	Maximum shear (kN)
Strength I - lane D	481.340	662.819
Strength I - truck T	128.092	280.996
Strength II - lane D	377.940	551.599
Service I - lane D	269.526	389.565
Service II - lane D	347.076	473.006
Strength envelope	481.340	662.819
Service envelope	347.076	473.006

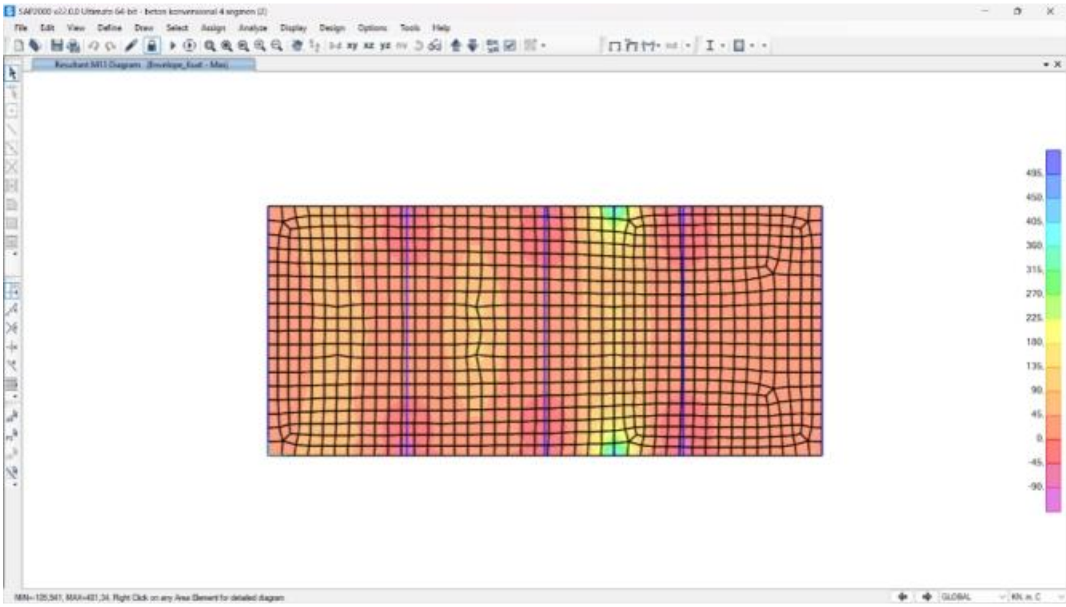

Figure 2. SAP2000 contour used to identify the critical deck bending response (M11).

Flexural and Shear Performance

The source calculation reports a design flexural capacity, φMn, of 679.27 kN·m for the existing reinforced concrete deck. Using the critical moment of 481.34 kN·m gives a D/C ratio of 0.708. In other words, the calculated flexural demand uses about 70.8% of the reported design flexural capacity. On this basis, the deck satisfies the reported ultimate flexural check.

The maximum shear demand was 662.819 kN. The source calculation gives a nominal concrete shear capacity, Vc, of approximately 1,314.534 kN and concludes that the design shear resistance is greater than the applied shear demand. The shear check was therefore classified as satisfactory in the original analysis.

Service Deflection

The serviceability result is different from the strength result. The maximum vertical deflection at the middle region of the deck panel was 36.8 mm. The allowable deflection from

L/300 was 16.67 mm. The calculated displacement is therefore about 2.21 times the allowable value and exceeds the limit by approximately 20.13 mm.

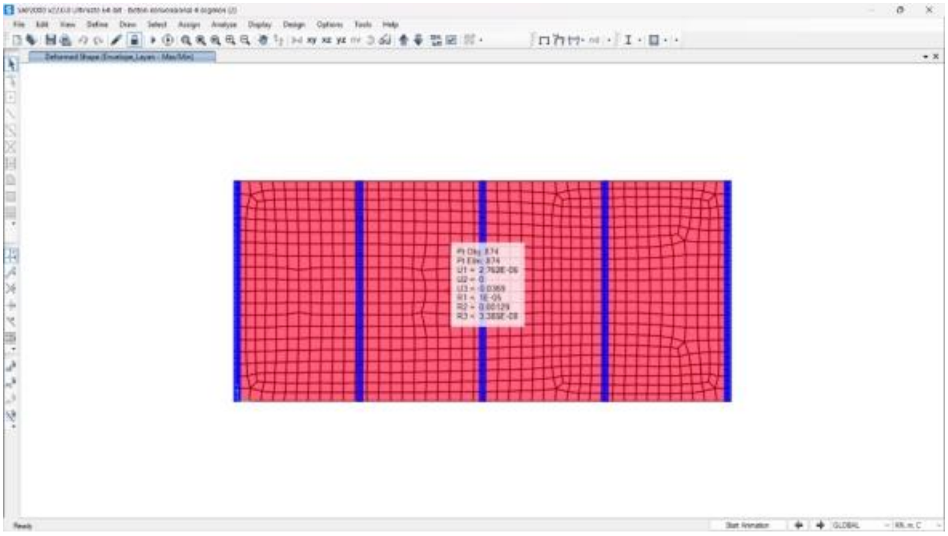

Figure 3. SAP2000 vertical-displacement output (U3) used for the deck serviceability check.

Table 3. Summary of the deck performance checks

Check	Demand	Reported capacity/limit	Ratio	Assessment
Flexure	Mu = 481.34 kN·m	φMn = 679.27 kN·m	D/C = 0.708	Satisfies reported strength check
Shear	Vu = 662.819 kN	Vc ≈ 1,314.534 kN (nominal)	—	Reported as satisfactory
Deflection	Δ = 36.8 mm	Δallow = 16.67 mm	2.21 × limit	Does not satisfy serviceability limit

Stength and Serviceability

The most important result of this assessment is the difference between the ultimate-strength check and the serviceability check. The flexural D/C ratio is below 1.0, and the source analysis also reports adequate shear capacity. If the evaluation were based only on these strength results, the existing deck could be described as structurally adequate under the modeled load combinations. The deflection result, however, shows that the deck response is not satisfactory in service.

This difference helps explain why a bridge deck can show serious field distress even when a simple strength ratio still appears acceptable. Excessive deformation can increase cracking and reduce service performance [5]. For the Citarum Baru bridge, the calculated deflection is more than twice the adopted limit, while visible cracking, wear, and local deck damage were documented in the field [2]. The numerical result is therefore consistent with a serviceability problem, although the model by itself does not prove the exact cause of each observed defect.

The result also shows why an assessment of an existing bridge deck should not rely on a single D/C value. A D/C ratio is useful for checking whether factored force demand exceeds a stated design resistance. It does not directly describe stiffness loss, crack width, fatigue accumulation, local deterioration, or user comfort. These aspects become increasingly important for older or visibly damaged decks.

Implications for Maintenance and Rehabilitation

From a maintenance perspective, the present analysis suggests that immediate attention should be directed to the service condition of the deck rather than to the steel truss as a whole. The reported flexural capacity still exceeds the modeled demand, but the excessive deflection indicates that continued use without corrective action may allow cracking and surface damage to develop further. A practical next step is to combine the numerical assessment with a detailed field survey of crack patterns, concrete delamination, reinforcement condition, and actual deck thickness, consistent with bridge inspection and preservation practice [1].

If rehabilitation is planned, the replacement or strengthening system should be checked not only for ultimate resistance but also for stiffness and deflection. A direct comparison with another deck system would require complete section properties, prestressing data where applicable, connection details, and calculated structural responses for the proposed system. Those quantitative results were not part of the completed conventional-deck assessment reported here.

CONCLUSION

The existing reinforced concrete deck of the 60 m Citarum Baru steel truss bridge was evaluated using a shell finite-element model and bridge loading based on SNI 1725:2016. The analysis produced three main findings.

1. The critical factored bending moment was 481.34 kN·m. Compared with the reported design flexural capacity of 679.27 kN·m, the D/C ratio was 0.708. The deck therefore satisfies the reported flexural strength check.
2. The maximum shear demand was 662.819 kN. The source calculation reported a nominal concrete shear capacity of approximately 1,314.534 kN and classified the shear condition as satisfactory.
3. The maximum service deflection was 36.8 mm, while the adopted allowable deflection was 16.67 mm. The calculated deflection is about 2.21 times the limit, so the deck does not satisfy the serviceability requirement.

The combined result is more informative than the strength checks alone: the deck retains the reported flexural and shear resistance under the modeled loads, but its stiffness-related service response is inadequate. For rehabilitation planning, field verification of the deck condition and a serviceability focused structural check are therefore recommended.

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