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Research on the Small Span Bridge Reconstruction and Expansion Technology

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***Abstract*-The research was performed on the background of reconstruction and expansion project of Shandong 1# expressway, contrastive analyzed the changing status of *Highway Engineering Technique Standard* in regard to the bridge load revision adjustment, particularly computational analyzed the technical requirement and usability of the existing bridge. Combined the analysis of bridge detection and evaluation results, the reconstruction and expansion technology of the existing bridge was theoretical calculated and discussed. Finally, the reconstruction and expansion technical method and suggestion on the mechanical behavior changing character of the small span upper beam-slab and the bottom abutment were proposed. The instance analysis showed that, the small span bridge reconstruction and expansion technology has the advantage of economically feasible, environment protecting and technology feasible. Its specialty of short construction period, small effects, convenient for keeping traffic and meeting the demand of basic functions enables it with a large popularize prospect.**

Keywords-technical standard; bridge load; reconstruction and expansion

I. RESEARCH BACKGROUND

In order to apply the develop of highway traffic, the Ministry of Transport scheduled the revision of *Highway Engineering Technique Standard* (JTG B01-2003) in 2011, and the *Highway Engineering Technique Standard* (JTG B01-2014) was implemented from 1st Apr. 2015. This revision work summarized the latest highway construction experience in our country systematically, and fully absorbed the highway industry scientific research achievements in recent years, learned the relevant standard and the advanced technology from foreign developed country. It fully reflects the traffic development request of "comprehensive, wisdom, green and peace". The revision protects the environment, saves resources and highlights the function of the highway and its facilities in determining the role of technical standards and indicators on the premise of safety. The *Highway Engineering Technique Standard* (JTG B01-2014) revised, adjusted and supplemented the bridge load, and the revision increased the regulations and requirements of safety evaluation, especially the influence of implementation process of highway reconstruction and expansion on the detection evaluation, safety evaluation and technical characteristic of the existing bridge.

A. Bridge Load

Calculated span: the arranging support is the adjacent supports' horizontal distance; No support is the horizontal distance between the centre cross the upper and lower structure.

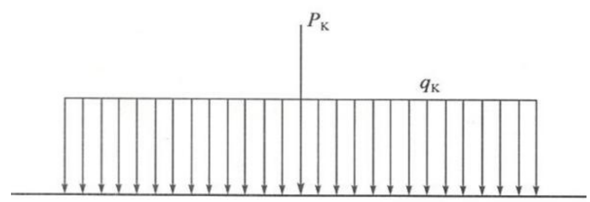

Figure 1. Lane load

TABLE I. THE MAIN TECHNICAL PARAMETERS OF THE VEHICLE LOAD

Item	Unit	Technical parameter
Gravity standard of vehicle	kN	550
Gravity standard of the front axle	kN	30
Gravity standard of the central axle	kN	2×120
Gravity standard of the rear axle	kN	2×140
Wheel tread	m	3+1.4+7+1.4
Wheelbase	m	1.8
The landing width and length of the front wheel	m	0.3×0.2
The landing width and length of the middle and rear wheel	m	0.6×0.2
Vehicle boundary dimension (length × width)	m	15×2.5

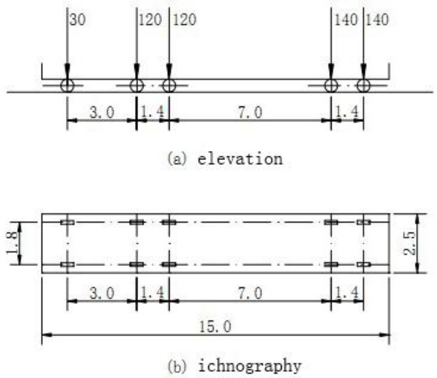

Figure 2. The arrangement diagram of the vehicle load

B. *Highway Engineering Technique Standard(TG B01-2003)*

The grade I highway lane-load uniformly distributed load standard value =10.5kn/m. The concentrated load standard value was selected according to the following provisions:

When the bridge and culvert span ≤5m, =180kN;

When the bridge and culvert span≥50m, =360kN;

When the bridge and culvert span>5m, <50m, was obtained through interpolation. When calculating the shear effect, the coefficient of concentrated load standard values should be multiplied by 1.2.

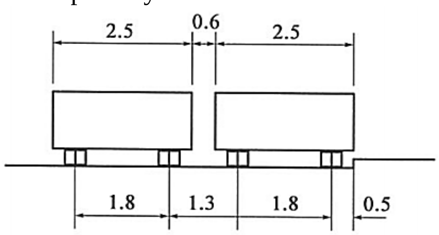

Figure 3. The lateral arrangement diagram of the vehicle load

C. *Highway Engineering Technique Standard(JTG B01-2014)*

The grade I highway lane-load uniformly distributed load standard value =10.5kn/m. The concentrated load standard value was selected according to the following provisions:

When the bridge and culvert span ≤5m, =270kN;

When the bridge and culvert span≥50m, =360kN;

When the bridge and culvert span>5m, <50m, was obtained through interpolation. When calculating the shear effect, the coefficient of concentrated load standard values should be multiplied by 1.2.

D. *Revision Adjustment Results*

According to the seriously reading and analysis of the <standard>, It is not hard to see about the revision of the motor load will adjust mainly concentrated load standard values are increased by 50%. For uniformly distributed load, the standard model, design, number of lanes, horizontal lanes load coefficient, vertical reduction factor, the crowd load standard values are not adjusted.

II. ENGINEERING EXAMPLES

A. *General Situation*

Shandong 1# expressway's total length is 318 km, was built in the 1890s, and it open to traffic has been nearly 15 years, its roadbed width is 26m, its design speed is 120km/h, the original bridge design load is steam-20, the calculation load is hang-120. Precast large bridge, structure is given priority to bridge, tin, and channels, 17% of the total mileage. Transform the success of this kind of Bridges and channels to a great extent will influences the whole project construction schedule and technology control.

TABLE II. STATISTICAL ANALYSIS OF BRIDGE CHANNELS

Type	Span	Substructure	number	Account for all installations
Solid slab	5m	Thin-walled platform/ Gravity platform	132	13.3%
	6m	Thin-walled platform/ Gravity platform	158	15.9%
hollow slab	8m	Thin-walled platform/ Gravity platform	258	26.0%
	10m	Thin-walled platform/ Gravity platform	94	9.5%

B. *Detection and Evaluation Results*

1259 single width bridges were detected, including 40 long span bridges, 99 middle span bridges and 1120 small bridge channels.

The ranking result of general technology state is: class 1 is 39, with the ratio of 3.10%; class 2 is 657, with the ratio of 52.18%; class 3 is 561, with the ratio of 44.56%; class 4 is 2, with the ratio of 0.16%; class 5 is 0, with the ratio of 0.00%.

The main disease form of reinforced concrete hollow (solid) plate and prestressed concrete hollow slab is: transverse cracks of plate wing, vertical cracks, saltpetering, concrete corrosion; transverse cracks of web, vertical cracks, corrosion of reinforcement; transverse cracks of baseboard, longitudinal crack, porous saltpetering, corrosion expansion and exposion of reinforcing bars, the honeycomb pitting surface of concrete and local damage.

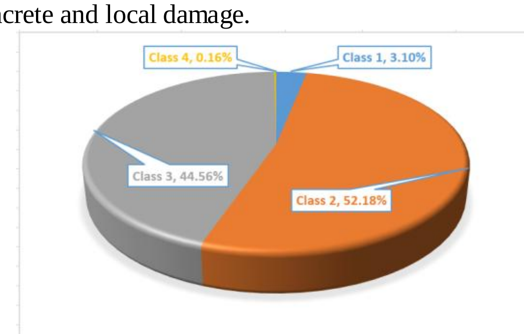

Figure 4. Figure. 4 Distribution of the bridge detection ratio

C. Calculation and Analysis

TABLE III. SMALL AND MEDIUM SPAN BRIDGES UPPER BEAM SHEAR CAPACITY CALCULATION RESULTS

Span(m)	Middle and side plate	Calculated bending moment of mid-span(kN.m)	Resistance (kN.m)	Difference value of bending capacity(%)
5	Sideplate	201.603	179.427	-11.00%
	Middleplate	265.410	175.436	-33.90%
6	Side plate	268.402	203.180	-24.30%
	Middleplate	331.235	198.079	-40.20%
8	Side plate	429.719	335.611	-21.90%
	Middleplate	482.326	329.429	-31.70%
10	Side plate	784.433	422.025	-46.20%
	Middleplate	616.421	546.149	-11.40%

TABLE IV. SMALL AND MEDIUM SPAN BRIDGES UPPER BEAM SHEAR CAPACITY CALCULATION RESULTS

Span(m)	Middle and side plate	Calculated bending moment of pivot(kN)	Resistance (kN)	Difference value of bending capacity
5	Sideplate	393.611	294.815	-25.10%
	Middleplate	400.126	208.066	-48.00%
6	Side plate	409.230	300.784	-26.50%
	Middleplate	417.273	212.392	-49.10%
8	Side plate	448.854	555.232	23.70%
	Middleplate	458.739	433.967	-5.40%
10	Middleplate	535.811	480.247	-10.37%
	Side plate	269.646	282.050	4.60%

Substructure: The abutment body of the gravity abutment was mainly built by rubble concrete or mortar rubble materials. The load has enhanced to 2014 highway Ⅰ level, and even though the abutment body ultimate limit states could satisfy the code requirement, but both the construction of bridge's economic conditions, technical level, such as limit, the foundation safety reserves is very small.

According to the JTG B01-2014, the board height needs increase, then the dead load will increase relatively, so it is bound to add burden to the existing abutment foundation. Through calculation and analysis: the base stress, basal eccentricity can not meet the requirement of the specification.

TABLE V. CALCULATED RESULTS OF THE SMALL AND MEDIUM SPAN BRIDGE SUPERSTRUCTURE

Type	Raw height(cm)	New height(cm)	Type of the beam and slab
5m solid plate	30	36	Reinforced concrete slab
6m solid plate	30	36	Reinforced concrete slab
8m hollow slab	40	46	Reinforced concrete hollow slab
10m hollow slab	40	65	Prestressed concrete hollow slab

III. RECONSTRUCTION AND EXPANSION TECHNOLOGY

A. Upper Beam Slabs

The paper was in line with "the economy, energy saving, environmental protection, recyclable" principle, analog computation was conducted in order to analyze the reconstruction and expansion technology of the 5m-10m small and medium span bridge upper beam slabs. Combined with the detection and evaluation results: except the subordination factor that edge distance of beam-end to abutment capping can not meet the correlation technique requirement of ground motion peak acceleration, the upper beam slab ultimate limit state could not meet the JTG B01-2014 requirement.

B. Substructure

The detection results showed that, the 5m-10m small and medium span bridge presents sub-structural integrity and the structure-globosity is better. The flexural capacity of the pier body and the main structure strength could meet the correlation technical requirements, while the local member could meet the correlation service requirements. In order to avoid waste and reduce the dismantling quantities, the 5m-10m small and medium span bridge substructure had been rebuild for utilization in situ.

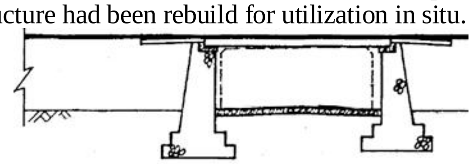

Figure 5. The original abutment design drawing

The distance of simply supported beam-end to pier, abutment cap or bent cap could not meet the aseismatic construction requirement: a≥70+0.5×L; L—Calculated span of upper beam slab(m).

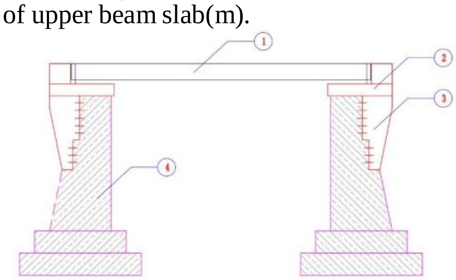

Figure 6. The abutment body reinforcement schematic drawing

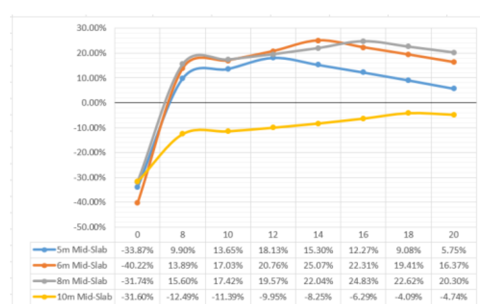

Figure 7. The changing image of the flexural carrying capacity and the mechanical thickness of the bridge pavement

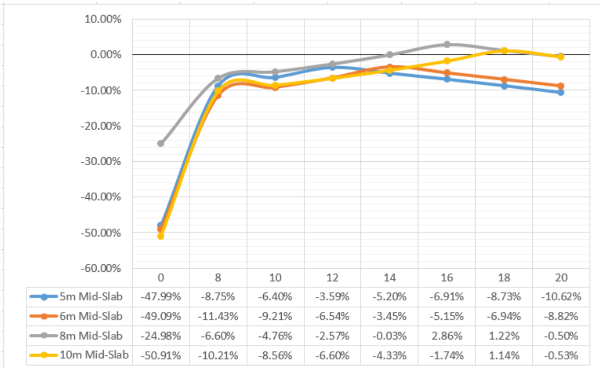

Figure 8. The changing image of the shear carrying capacity and the mechanical thickness of the bridge pavement

Concentrate: ①beam and slab; ②newly build abutment cap; ③newly build parados; ④original abutment body.

After the reconstruction of the abutment, the bridge supports were set behind the original abutment, the superstructure and the motor vehicle load effect were balanced with the earth pressure, the abutment body was equal to the axial compressive force. The basal stress was then more even. Take the original 8m bridge channel as example, if the newly build 8m thickness of slab was being replaced directly, the basement could not meet the force requirement because of the increasing dead load. After the original abutment was reconstructed as Fig. 5, the slab was replaced by 10m, the basement could meet the force requirement. The basement stress checking calculation results were showed in Tab. 8.

IV. CONCLUSION

Upper beam and slab: The working condition of the pavement layer after participating in force can be used for rebuilding and utilization. In order to ensure the participation of stressing reach the optimum condition, the original bridge deck pavement and the hinge joint should be get rid of. After the cross-link reinforcement and the bridge pavement bar-mat reinforcement were added, the hinge joint and the bridge floor concrete pavement layer were overall casted. When the bridge pavement layer participating in the overall stressing of the upper beam slab, it has preferable influence on the flexural carrying capacity, and the efficacious mechanical thickness is 12-16cm, and it presents increase trend with the increase of the increasing span. While it would decrease when the mechanical thickness exceed the efficacious value.

Substructure: The economic and the society of the affect region of Shandong 1# expressway have got rapid improvement, the urbanization concentration significantly, the existing structure has not effectively meet the requirements of regional integrated transportation system, especially the about 10m channel and the separated interchange needs all demolition reconstruction for 2 holes or porous separation overpass. In view of the simple-supported beam end to the edge of pier, abutment capping or bent cap can not meet the requirement of the aseismatic measures, the existing pier and cap could be dismantled to satisfy the requirement of aseismatic measures. Which it can effectively combine the existing working condition requirements for new construction, reinforcement and classification of disposal. The small span bridge reconstruction and Eexpansion technology has the specialty of short construction period, small effects, convenient for keeping traffic and meeting the demand of basic functions enables it with a large popularize prospect.

REFERENCES

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TABLE VI. FLEXURAL CAPACITY CALCULATING RESULTS OF THE SMALL AND MEDIUM SPAN BRIDGE UPPER BEAM SLAB AFTER RECONSTRUCTION

Whether the cast-in place layer participate in the force	Span(m)	Middle and side plate	Calculated bending moment of mid-span(kN.m)	Resistance(kN.m)	Difference value of bending capacity(%)
No	5	Sideplate	201.611	179.434	-11.00%
		Middleplate	265.420	175.443	-33.90%
	6	Side plate	268.478	203.238	-24.30%
		Middleplate	331.265	198.096	-40.20%
	8	Side plate	429.733	335.621	-21.90%
		Middleplate	482.321	329.425	-31.70%
	10	Side plate	784.408	422.012	-46.20%
		Middleplate	616.410	546.139	-11.40%
The cast-in-place layer participate in the force at 8cm	5	Side plate	245.367	298.612	21.70%
		Middleplate	241.509	219.773	-9.00%
	6	Side plate	280.291	292.624	4.40%
		Middleplate	275.056	228.296	-17.00%
	8	Side plate	423.633	417.702	-1.40%
		Middleplate	417.222	360.897	-13.50%
	10	Middleplate	784.481	674.654	-14.01%
		Side plate	616.457	691.048	12.10%

TABLE VII. SHEAR CAPACITY CALCULATING RESULTS OF THE SMALL AND MEDIUM SPAN BRIDGE UPPER BEAM SLAB AFTER RECONSTRUCTION

Whether the cast-in place layer participate in the force	Span (m)	Middle and side plate	Calculated bending moment of pivot(kN)	Resistance (kN)	Difference value of bending capacity(%)
No	5	Sideplate	393.601	294.807	-25.10%
		Middleplate	400.132	208.069	-48.00%
	6	Side plate	409.222	300.778	-26.50%
		Middleplate	417.209	212.359	-49.10%
	8	Side plate	448.761	555.117	23.70%
		Middleplate	458.752	433.979	-5.40%
	10	Middleplate	535.803	462.398	-13.70%
		Side plate	269.656	282.060	4.60%
The cast-in-place layer participate in the force at 8cm	5	Side plate	393.610	375.504	-4.60%
		Middleplate	400.107	264.871	-33.80%
	6	Side plate	381.901	356.314	-6.70%
		Middleplate	417.233	269.533	-35.40%
	8	Side plate	448.086	634.938	41.70%
		Middleplate	491.101	525.969	7.10%
	10	Middleplate	535.883	169.339	-68.40%
		Side plate	269.654	326.821	21.20%

TABLE VIII. SHEAR CAPACITY CALCULATING RESULTS OF THE SMALL AND MEDIUM SPAN BRIDGE SUPERSTRUCTURE

Program	Effect combination	Checking computation contents	Basement maximum compressive stress pmax(kPa)	Bearing capacity admissible value of the foundation γR[fa](kPa)	Whether it meets	Working condition
The program of changing 8m slab	Long-term effect combination	Mean stress	134.6	193.6	Yes	——
		Maximum stress	219.6	193.6	No	Minimum axial force
	Short-term effect combination	Mean stress	134.6	193.6	Yes	——
		Maximum stress	225.7	242	Yes	Minimum bending moment
The program of changing 10m slab	Long-term effect combination	Mean stress	167.5	193.6	Yes	——
		Maximum stress	176.7	193.6	Yes	Minimum axial force
	Short-term effect combination	Mean stress	167.5	193.6	Yes	——
		Maximum stress	176.7	242	Yes	Minimum axial force