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Mechanical properties analysis on incremental launching construction without supporting piers of long-span continuous steel truss bridge[1]

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Abstract. In this paper, mechanical properties analysis of a new railway long-span continuous steel truss bridge that the bridge span is 120 m + 4×180 m + 120 m was done on incremental launching construction without supporting piers was done by finite element method. The length of launching nose affects the force characteristics of structure during incremental launching construction, and decides the feasibility of incremental launching construction without supporting piers. After analysis of strength, stability and displacement that the length of launching nose is 100 m or 120 m, incremental launching construction without supporting piers for this bridge meet requirements and is feasible. Finally, this bridge construction accepted incremental launching construction without supporting piers, and selected 120 m launching nose. This construction case has certain reference significance.

Key words. Design steel truss bridge, incremental launching construction, mechanical properties analysis, finite element method, strength and stability.

1. Introduction

Incremental launching construction technology has been proved to be an economical and convenient method for the building of long-span bridges since Austria's Ager Bridge had been constructed by using this method successfully in 1959. It is of great superiority and particular advantages for bridge sites with deep valleys

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or rivers, or an uninterrupted railway or highway where conventional construction technologies are commonly restricted [1], [2]. In recent decades, the incremental launching construction method has been adopted in many projects [3], [4], [2], such as the Millau Viaduct in France [5], the Ilsun Bridge in South Korea [3], or the Vaux Viaduct in Switzerland [6].

Although many researchers and bridge engineers have investigated the incremental launching method for various types of bridges, mechanical properties such as stability and stress on incremental launching construction without supporting piers of long-span continuous steel truss bridge is not enough. Zhengzhou Yellow River Railway and Highway Shared Bridge that the bridge span is 120 m + 5×168 m + 120 m with cantilever length at 168 m was completed in 2010 [7], witnessing the well-developed application of the incremental launching technology. Up to now, there are few cases for the incremental launching construction to be used in long-span bridges whose cantilever length exceeds 160 m, not to mention those with cantilever length over 170 m. In this paper, Dong-Ying Yellow River Railway Bridge that the bridge span is 120 m + 4×180 m + 120 m, a new railway long-span continuous steel truss bridge, was taken as research object. The bridge adopts through type open deck continuous steel trussed girder, and the two main trusses are triangle trusses with vertical post. Structure of main bridge and general layout of the bridge arrangement and real bridge picture were shown in Fig. 1 and Fig. 2.

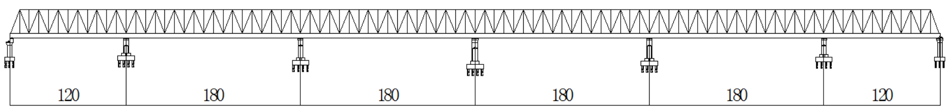

Fig. 1. Structure of main bridge (unit/m)

Fig. 2. Real bridge picture

According to the experience of pushing construction, the launching nose length is generally 0.5–0.7 times that of maximum cantilever length. So the launching nose length is taken as 100 m and 120 m respectively in this paper. Steel truss beam is adopted variable height according to the connection between cantilevers and main trusses. The heights of steel truss beam in front and back of the cantilever are 9 m and 18 m respectively, and all the panel lengths are 10 m. The length of the truss beam in front of the cantilever is 60 m, and the lengths of the truss beams in back of the cantilever are 40 m or 60 m. The truss space is 11.0 m. The top bracing and the bottom bracing are installed on the main truss. The real launching nose that length is 120 m is shown in Fig. 3.

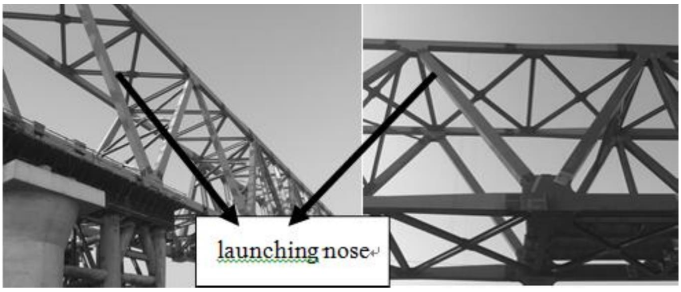

Fig. 3. The real launching nose

The construction process simulation analysis on incremental launching construction without supporting piers was completed when length of launching nose is 100 m and 120 m respectively. The incremental launching truss bridge is shown as Fig. 4.

Fig. 4. The incremental launching truss bridge

2. Mechanical properties analysis

2.1. The most unfavorable condition

Through preliminary analysis, there are two worst conditions during the incremental launching construction without supporting piers. One is the maximum cantilever stage when the launching nose end will support in the next pier, the weight of cantilever will cause huge negative moment at support under this condition. The other is the stage when the launching nose end is supporting at the next pier justly, the structure self-weight causes a large positive moment in the beam and the main structure. The strength and stability of the incremental launching construction about the above two conditions was discussed below.

2.2. Calculating load and material parameters

Three loads were considered in the calculation as following

1) Self-weight, bulk density of steel is as 78 kN/m^3.

2) Temporary construction load is 5 kN/m according to the engineering experience.

3) Wind load, the wind pressure is 955 Pa, calculated according to the standard

4) Two types of steel is Q370 and Q345 are used. The Elastic modulus is $2.1 \cdot 10^5$ MPa. Allowable bending stress is 295 MPa and 260 MPa, respectively. The shear modulus is $0.811 \cdot 10^5$ MPa and Poisson ratio is 0.3.

2.3. Finite element model

The finite element model was established by using of truss elements and beam elements respectively because of each bar's larger section. In fact, true stress characteristics are between calculation by beam element and calculation by truss element. The finite element model by use ANSYS is shown as Fig. 5.

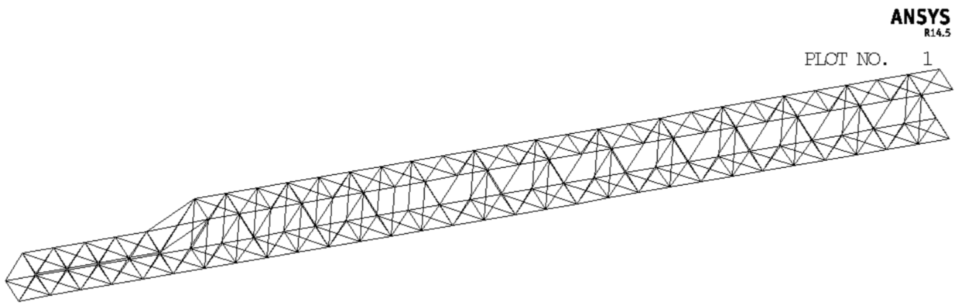

Fig. 5. Finite element model of truss bridge

2.4. Strength analysis

In the condition of maximum cantilever stage, the stress of structure under the combined action of self-weight, temporary load and wind load is shown in Table 1.

The following results are shown from table 1

(1) The maximum compressive stress of the beam elements is 252.0 MPa and the maximum tensile stress is 318.0 MPa, which is out of the allowable stress when length of launching nose is 100 m. While the maximum stress was located in a few bars, those bars should be strengthened to meet the strength requirement.

(2) When the length of the launching nose is reaching 120 m, the strength is to meet the safety requirements under the most unfavorable conditions.

Table 1. Results of strength analysis

Type of launching nose	Maximum stress under action of self-weight (MPa)		Maximum stress under action of self-weight, temporary load and wind load (MPa)	
	Compressive stress	Tensile stress	Compressive stress	Compressive stress
Length is 100 m	218	189	252	318
Length is 120 m	133	160	189	223

2.5. Analysis of stability and natural vibration characteristics

At the condition of maximum cantilever stage, the stability and natural vibration characteristics of structure under the action of self-weight load is shown in Table 2.

Table 2. Results of stability and natural vibration characteristics of structure

Type of launching nose	Stability safety factor			Natural frequency		
	First order	Second order	Third order	First order	Second order	Third order
Length is 100 m	4.9	17.0	40.0	0.42	0.46	0.63
Length is 120 m	4.2	16.1	41.1	0.45	0.66	0.67

Obviously, safety stability meets safety requirements, but natural frequency is lower, incremental launching construction should consider influence of dynamic load, such as wind load.

3. Conclusion

According to mechanical properties analysis of the railway long-span continuous steel truss bridge on incremental launching construction without supporting piers was done by finite element method, some conclusions are following as:

1) The plan of incremental launching construction without supporting piers is feasible under the length of maximum cantilever exceeds 170 m.

2) The length of launching nose affects the force characteristics of structure during incremental launching construction, and decides the feasibility of incremental launching construction without supporting piers. The reasonable launching nose length value range 0.5 to 0.7 times that of maximum cantilever length.

3) The calculation model of finite element method should adopt truss element and beam element respectively, and then compare the two results in order to determine whether to meet the safety requirements.

4) The stability analysis in this paper is based on the linear elastic supposition,

then geometric nonlinearity and material nonlinearity should be considered in the further research.

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