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BIM Modeling Method for Double-Deck Steel Box Girder Construction Stage Based on Cim-Civil Interaction Technology

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ABSTRACT: *A BIM modelling method for double-deck steel box girder in the construction stage withCim-Civil interaction technology is propelled in this paper. Using a 60m equal-height steel box girder as an example by Cim software, a three-dimensional visual information is established and the construction plan is optimized in this paper.When the Cim model is imported into Civil, and through the model interaction of Cim and Civil, the structure behavior of each construction stage can be analyzed to show that it is satisfied with the requirements from the current codes. Compared to the commonly used Revit software, the point, line, and assembly families with Cim are more suitable for establishing bridge-type, one-dimensional, prominent building models.The interaction between Cim and Civil software to carry out structural analysis based on the definition of the construction stage can provide a basis for construction plans and safety management decisions.*

Keywords: *Double-Deck Steel Box Girder BIM Modeling Cim-Civil Interaction Technology*

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I. OVERVIEW

Information-based modeling (BIM modeling) can better simulate the construction process and is integral to intelligent construction. Relevant literature shows that in terms of BIM modeling, there are more application studies on Revit software than on Cim software.In terms of the application of Revit software:Zou, Y[1] and others proposed a new risk visualization and information management method, integrating the Risk Breakdown Structure (RBS) of bridge engineering into 3D/4D BIM;Tian[2] and others combined BIM with Unmanned Aerial Vehicles (UAV), simplifying the hoisting operation plan and construction monitoring;Li, X[3] developed a bridge health monitoring system,using a BIM-supported platform to develop proposed visualization tools for large-span bridges, and inventorying automatic sensor data into the BIM environment;Wang, D[4] and others proposed an effective conversion strategy between the box culvert BIM model and the Midas Civil finite element model, enhancing computational capabilities through bidirectional data exchange between BIM and Finite Element Analysis (FEA)software.Research on the Application of Cim Software:Byun, N[5]and others have constructed a BIM-basedBMS, which includes detailed safety diagnosis and maintenance information. They developed a Web Data Management Program (WDMP) using maintenance data patterns and information systems and connected it with the 3D modelling program Midas Cim; Wang Xiaofang[6]and others used the Midas Cim bridge three-dimensional forward design software to realize the digital interaction from the BIM model in the design phase to the construction phase; Hu Zhimin[7]andothers used Midas Cim software to model a through-type steel box tied arch bridge with a large internal inclination angle. They combined the finite element analysis platform Midas Civil and the two-dimensional CAD platform Midas Drafter to achievea three-dimensional model-assisted design. Moreover, the bidirectional data interface of the Parasolid file provided by Midas Cim can quickly import the solid simulation software Midas FEA NX, thereby avoiding the problem of secondary modeling and improving work efficiency. In terms of model interaction research:He Xiangping[8]relied on the Revit and Midas/Civil software platforms, used the Revit API and C# language in the Visual Studio development environment, proposed an automatic conversion method from the BIM model to a structural finite element model, and designed a model conversion program from Revit to Midas/Civil; Zhang Yonghong[9]made a preliminary exploration of the method of spatial geometric data interaction between Midas Civil and Revit using Dynamo, realized model data sharing, explained the specific method of implementing data interaction in the modeling process through examples, thereby achieving multiple uses with one model; Kang Bin[10] and others used Revit to establish a BIM model of a continuous beam bridge, combined the Midas Civil Link for Revit Structure plugin with the export of plugin section DXF files to carry out finite element analysis of large-span continuous beam bridges, providing a theoretical calculation basis for construction monitoring work;

Jian Li[11]and others proposed a model conversion method that combines Revit and Midas Civil software, using the Visual Studio 2022 platform to establish a secondary development program for converting model information and generating Midas Civil Text files, creating a model conversion interface.

According to the relevant literature, research on double-deck steel box girder hoisting, especially the modelling research based on Cim technology, and there are few related reports. The construction of double-layer steel box girders as an example is taken in this paper. Creating a three-dimensional model to replicate the site addresses challenges in structural design and the selection of construction machinery positions in complex construction environments. Cim with Civil analysis, transferring structural information through converting finite element models and conducting stress calculations for the construction phase is integrated in this study. It explores new methods to provide fresh insights for the future development of construction modeling.

II. STEELBOX GIRDER BIM MODEL BASEDON CIM SOFTWARE

A 60m equal-height steel box girder as an example is used in this paper. The bridge section is on a transition curve from K30+200 to K30+260, with a standard girder height of 2.7m and a total width of 20.5m for the top slab. The pier features a double-layer frame structure with a pile foundation. The elevation view is shown in Figure 2-1, and the cross-section view is in Figure 2-2.

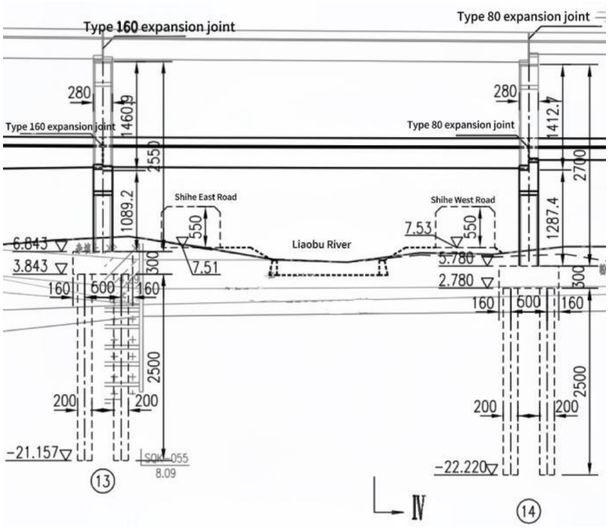

Figure1: Elevation view of the steel box girder

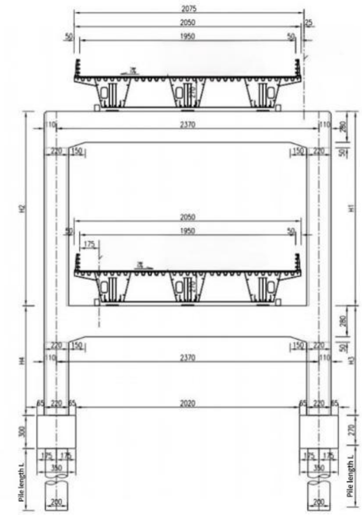

Figure2: Cross-section view of the steel box girder

The Cim modelling process follows: 1. Extract drawing information and create a route. 2. Establishing the line family: The creation of beams and the software come with intelligent components for creating stiffening ribs. 3. Establish a point family: Establish diaphragms, piers, and temporary supports, import the cross-section diagram, determine the orientation to establish the surface, assign corresponding data to its entity after the surface is established, and use function keys such as cut to modify and perfect. 4. Establish an assembly family: Create nodes for the established line and point families to allocate the point family to the line family. 5. Finally, assign the assembly family to the route to complete the allocation combination of the bridge. 6. For auxiliary structures such as street lamps, guardrails, and bridge deck systems, Cim also has its dedicated component library to assist in creating more precise models.

After determining the construction plan, the initial modelling is carried out according to the construction site to determine the hoisting point position, automobile crane operation position, boom lifting angle, rotation range and time. The three-dimensional assembly is carried out in a "building blocks" manner, and the results can clearly show the construction process from multiple angles. This article divides the steel box girder into 12 parts for hoisting simulation. Each half side is divided into three beams for erection in turn. The steel box girder is hoisted in the order of the lower deck on the right, the upper deck on the right, the lower deck on the left, and the upper deck on the left. Observe whether there are collisions and other situations in the construction process. Figures 3 to 6 illustrate parts of the construction process.

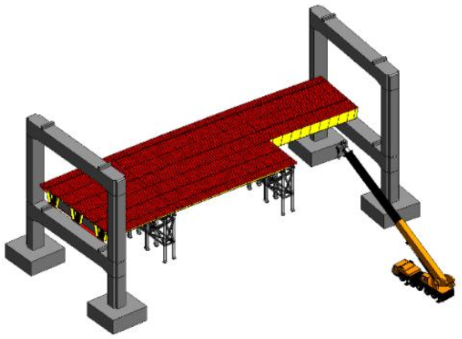

Figure3:Erection of the fifth part on the lower left side

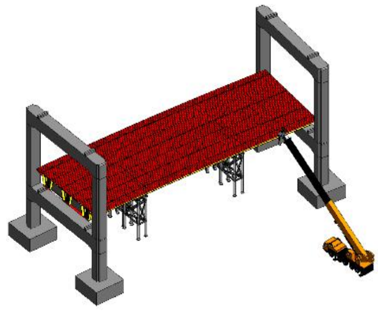

Figure4: Erection of the sixth part on the lower left side

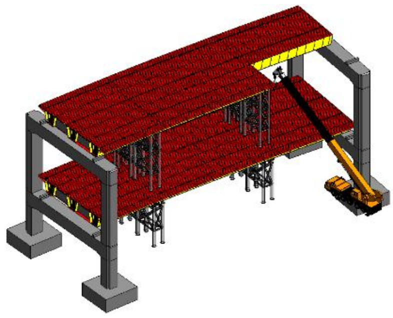

Figure5:Erection of the eleventh part on the upper left side

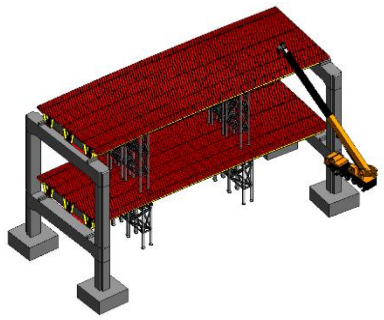

Figure6: Erection of the twelfth part on the upper left side

III. RESEARCHON CIM-CIVIL MODEL INTERACTION TECHNOLOGY

During construction, it is necessary to analyze and verify the mechanical properties. Cim can interact with Civil to consider the parameters required for the analysis, adding material and steel strand information to the Cim model. In the "Model" tab, select the "Boundary" module to add supports and assign rigid connections to create working conditions. Once created, go to the "Application" tab and select the "Analysis Condition" module to define the model's analysis conditions, set the export components and boundary conditions, and configure the element division of the components. The bridge structure can be simplified into a one-dimensional rod system finite element model, as shown in Figure 7.

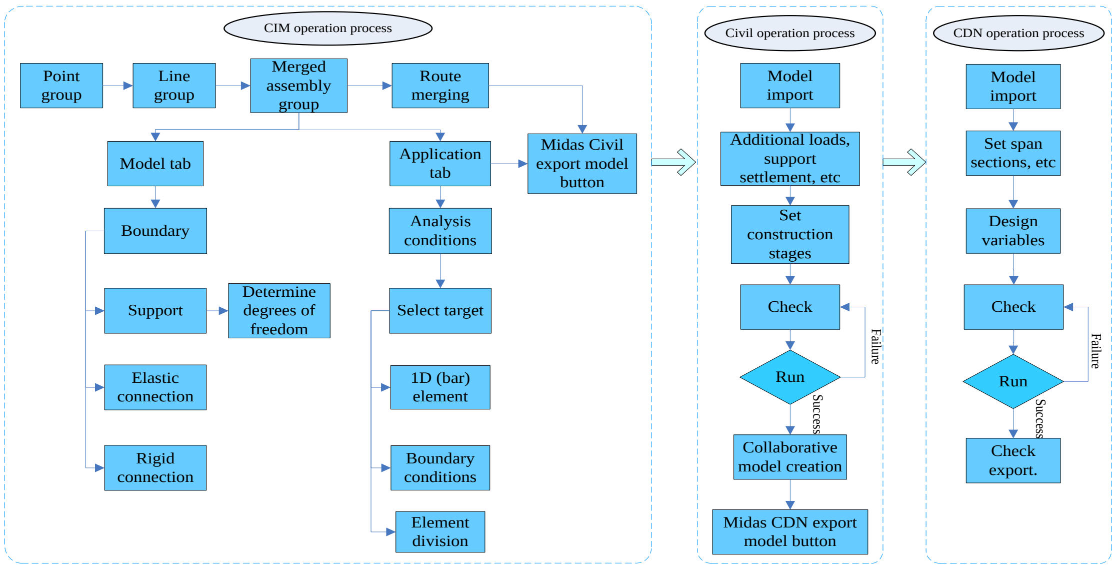

Figure7:Interaction process between BIM and finite element model

Finally, click on Midas Civil in the application, select the corresponding analysis conditions, and complete the creation of the analysis model to import it into Civil for bidirectional communication. Click the Civil icon in Figure 7 to directly open the Midas Civil model, where elements, materials, sections, and boundary conditions will be automatically imported. Enhance and supplement the model in the Civil software, check whether the operation results are correct, click on the "Collaboration" module to interact with the CDN, select the appropriate specifications, determine the span section, generate load combinations, and set design variables such as overturning and deflection to obtain the verification results. Utilize three-dimensional data for structural analysis, ensuring the structure's safety, aesthetics, and economy. As the Cim model changes, the Civil model will also be updated synchronously and seamlessly, facilitating further transformation.

An analysis of the resistance and effects at each construction stage is conducted. It can be observed whether the structure meets the bearing capacity requirements of various specifications according to this construction sequence. According to the 'Specifications for Design of Highway Steel Bridge' (JTG64-2015) and the 'General Specifications for the Design of Highway Bridges and Culverts' (JTG D60-2015), hereinafter referred to as the "Steel Specifications" and "Bridge Specifications," through the collaboration of MIDAS Civil and CDN, the strength, stability, and deflection of the process of steel box girder construction are verified to comply with the specifications. This article considers the working conditions of self-weight, shrinkage creep, temperature, support settlement, and lane offset load combination.

3.1 Strength Calculation Analysis of Steel Box

The overall structure of the steel box girder is calculated, and the stress analysis is carried out according to the ultimate state of bearing capacity under the primary combined condition of load in this paper. According to the "Steel Specifications," the tensile, compressive, and bending strength design values of Q355 steel material are represented as $f_d = 285MPa$. It can be known from formulas 4.2.1 and 5.3.1-1:

$$\gamma_0 S_d \le R_d \text{,that is, } \gamma_0 \sigma sd \le f_d \tag{1}$$

According to the finite element model, the maximum positive stress is 223.118MPa, which can be calculated as:

$$\gamma_0 \sigma_{max} = 1.1 \times 223.118 = 245.43 \le f_d = 285MPa \tag{2}$$

Where in, γ_0 is the importance coefficient of the steel box girder structure, S_d is the design value of the effect of action combination, R_d is the design value of the structure’s resistance, and σ_{max} is the maximum normal stress. The product of the importance coefficient of the steel box girder structure and the maximum design value of the combined action effect is less than the design value of the component bearing capacity. The design of the steel structure is reasonable and meets the specification requirements.

3.2 Stability Calculation of Steel Box Girder

The calculation is carried out according to the formulas 5.3.2-1~2and 5.4.2-1~4 in the "Steel Specifications", and it needs to satisfy formula (3).

$$\min(\sigma_{sd}, y_i, \quad \sigma_{sd}, z_i) \le f_d \tag{3}$$

Formula(3)This means that the minimum design value of tensile stress in the y and z directions is less than that of tensile strength. From Figure 8, we can derive Formula (4), showing that the strength values of the components are all less than the design value of tensile strength, thus meeting the code requirements.

$$\min(\sigma sd, y_i, \quad \sigma sd, z_i) = 227.814\ MPa \le f_d = 285.000\ MPa \tag{4}$$

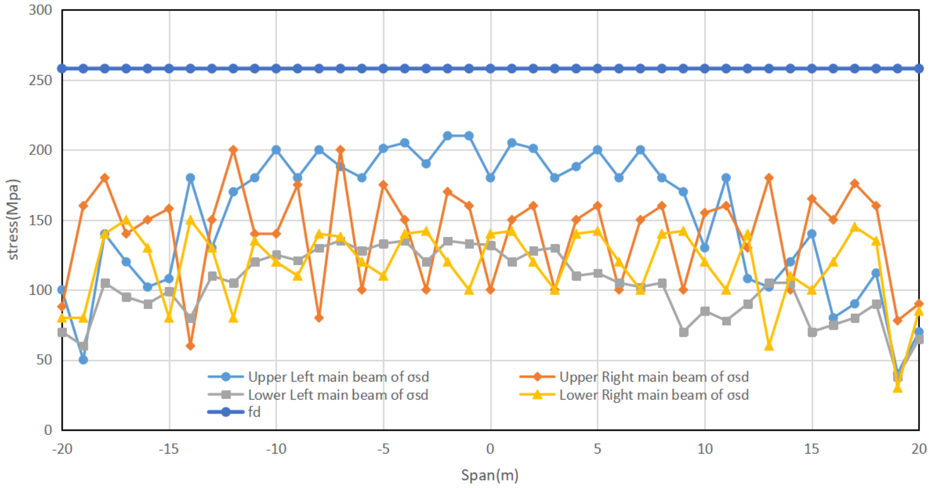

Figure8:Envelope Diagram of Overall Stability Calculation of Tensile/Compressive Bending Components

3.3 Deflection Calculation Analysis of Steel Box Girde

The camber is calculated according to the 4.2.3 clause of the "Steel Specifications." When calculating the vertical deflection, the structural mechanics method and the frequency value of the car lane load without considering the impact force should be adopted, with a frequency value coefficient of 1.0. The calculated deflection value should not exceed the limit value of $fn = l / 600 = 100mm$.

Table 1 Deflection Calculation Table

Beam-Hole	Type	Span(mm)	Node	fa(mm)	fn(mm)	Result
Upper Left Span Center	within the span	59879.977	492	57.817	100	OK
Upper Right Span Center	within the span	59879.977	463	63.749	100	OK
Lower Right Span Center	within the span	59879.977	399	43.920	100	OK
Upper Left Span Center	within the span	59879.977	432	70.865	100	OK

Calculate according to Article 6.5.3 of the "Bridge Specifications"：

As shown in Table 4-1, the four nodes are located in the middle of the beam sections at the top left, top right, bottom right, and bottom left. The maximum deflection design value for the frequently encountered combination of vertical lane load and crowd load, which is fa=70.865mm, is less than the allowable maximum deflection value of fn=100mm.

IV. CONCLUSION AND OUTLOOK

1.Cim can achieve three-dimensional informational modelling of double-deck steel box girders, simulate construction steps, reflect spatial collision points in the construction process, provide an intuitive basis for determining construction schemes, and be used for bridge case teaching.

2.The Cim model can be imported into Civil software for interaction with Civil. Through Cim-Civil interaction technology, the construction phase analysis of the double-deck steel box girder is carried out to study whether its stress at each stage meets the requirements of the specifications.

3.The engineering application of Cim and Civil interaction technology is in its initial stage. This paper uses Cim and Civil interaction technology for the construction scheme of the double-deck steel box girder. However, it can also be extended to the construction modeling of other bridge structures.

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REFERENCES

[1]. Zou, Y, Kiviniemi, A, Jones, S.W. etal. Risk Information Management for Bridges by Integrating Risk Breakdown Structure into 3D/4D BIM. KSCE J Civ Eng 23, 467–480 (2019). https://doi.org/10.1007/s12205-018-1924-3.

[2]. Tian, J, Luo, S, Wang, X, etal. (2021) Crane Lifting Optimization and Construction Monitoring in Steel Bridge Construction Project Based on BIM and UAV. Advances in Civil Engineering, 2021, Article ID: 5512229.

[3]. Li, X, Xiao, Y, Guo, H.etal.A BIM Based Approach for Structural Health Monitoring of Bridges. KSCE J Civ Eng 26, 155–165 (2022). https://doi.org/10.1007/s12205-021-2040-3.

[4]. Wang D, Huang J. Automated Generation and Internal Force Visualization for Box Culvert Based on Building Information Modeling. Applied Sciences. 2024; 14(6):2543. https://doi.org/10.3390/app14062543.

[5]. Byun, N,Han, W.S, Kwon, Y.W, Kang, Y.J. Development of BIM-Based Bridge Maintenance System Considering Maintenance Data Schema and Information System. Sustainability 2021, 13, 4858. https://doi.org/10.3390/su13094858.

[6]. Wang Xiaofang, Yang Hongtu, Li Changzhu.Research on Forward Design of Highway Bridge BIM Based on Three-Dimensional Real Scene Model[J]. Urban Roads Bridges & Flood Control, 2023, (08): 75-79+11.

[7]. Hu Zhimin, Li Meng, Ning Xinmiao. BIM Forward Design of Steel Box Through Truss Arch Bridges. Urban Road and Bridge and Flood Control, 2023, (08): 71-74 + 79 + 11.

[8]. He Xiangping, Wang Hao, Zhang Yiming.Revit-Midas/Civil Model Conversion Method and Application[J].Journal of Southeast University (Natural Science Edition),2021,51(05):813-818.

[9]. Zhang Hongyong.Preliminary Exploration of the Method for Spatial Geometric Data Interaction between Midas Civil and Revit Using Dynamo[J].Gansu Science and Technology,2021,37(04):94-96.

[10]. KangBin,Zheng Yuguo,Huang Junxiang.Analysis of Construction Monitoring Results of Large-Span Continuous Beam Bridge Combined with BIM and Midas[J].Journal of Hunan Institute of Engineering (Natural Science Edition),2023,33(01):79-83.

[11]. Jian Li,Haoxin Song,Zhenwei Zhou,ChaoYang,Liyu Wang,Hongtao Li.A Revit-Midas/Civil conversion approach for bridgesuperstructures analysis.Engineering Research Express,2024,6(1).