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Refined analysis and construction parameter calculation for full-span erection of the continuous steel box girder bridge with long cantilevers

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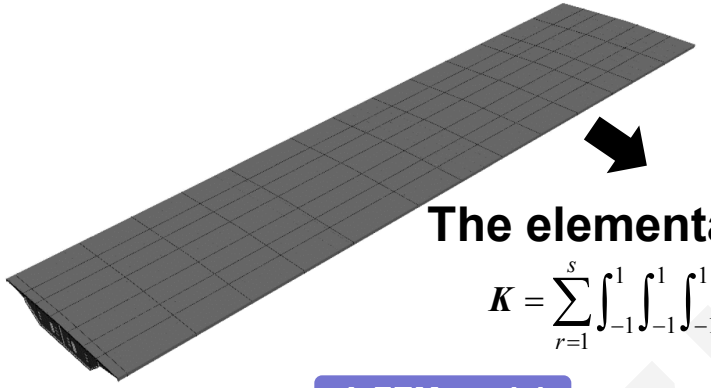
Project Background

The Hong Kong-Zhuhai-Macao Bridge is 22.9 km in length, 70% of which is continuous steel box girders. The application of offshore full-span erection technique has high requirements for the control of construction errors.

Offshore full-span erection of continuous steel box girders

Analytical method

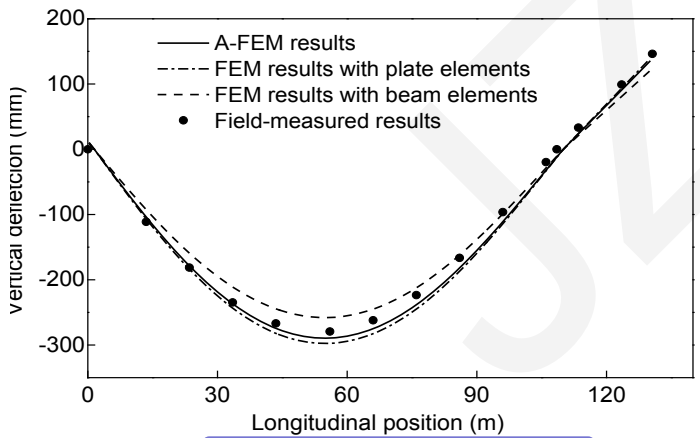
The augmented finite element method (A-FEM) with mesh-separation-based approximation technique breaks through the limitations of conventional FEM on complex boundaries and material composition, so it is more accurate and efficient. Calculation results proved this.



A-FEM model

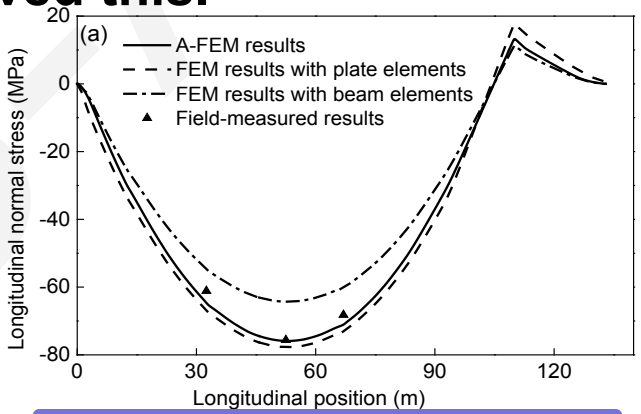
The elemental stiffness matrix:

$$\boldsymbol{K}=\sum_{r=1}^{s}\int_{-1}^{1}\int_{-1}^{1}\int_{-1}^{1}\boldsymbol{B}^{\mathrm{T}}\boldsymbol{D}_r\boldsymbol{B}\left|\boldsymbol{J}\right|\left|\boldsymbol{J}_r'\right|\mathrm{d}\xi'\mathrm{d}\eta'\mathrm{d}\zeta'$$

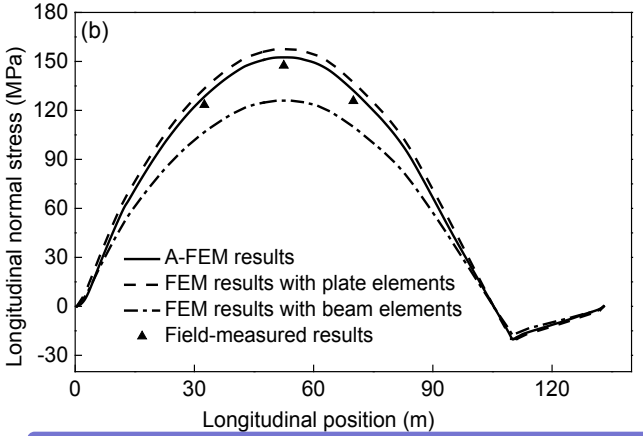


(a) vertical deflections

Comparison of A-FEM, conventional FEM and field-measured results

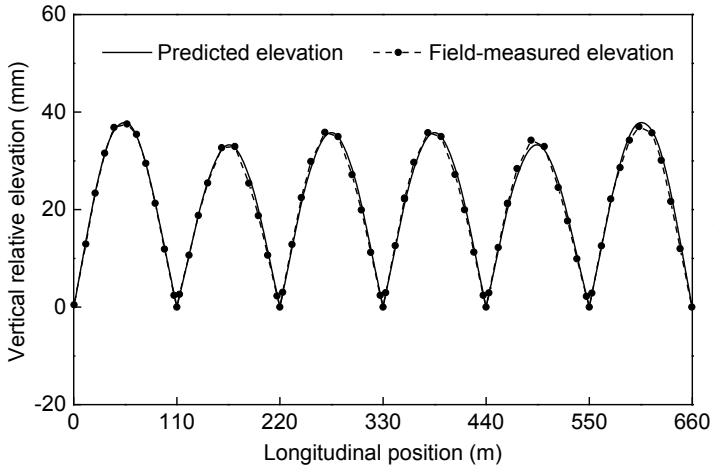


(b) longitudinal normal stress (top)

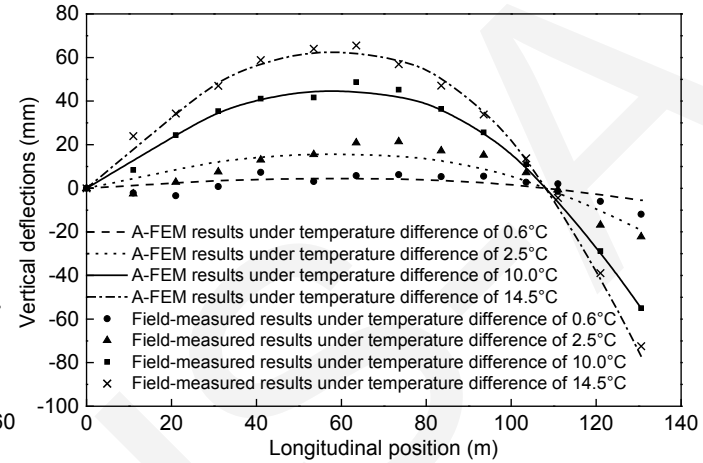


(c) longitudinal normal stress (bottom)

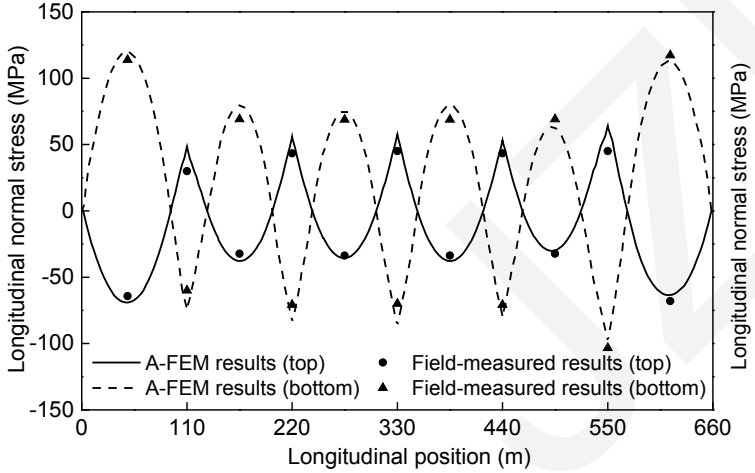
Simulation and control of construction



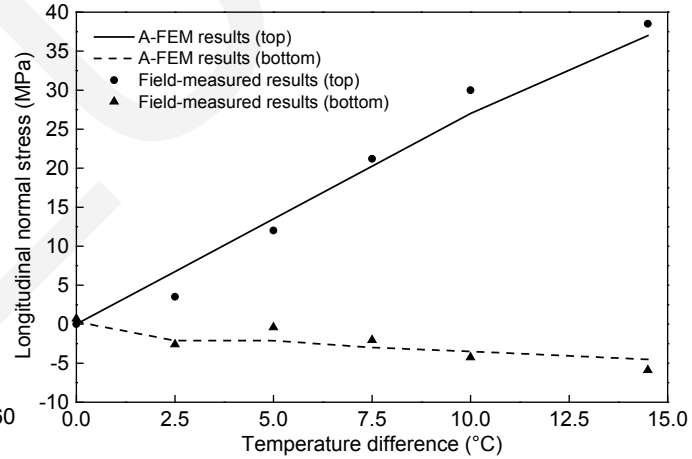
Final vertical relative elevation



Vertical deflections induced by temperature differences



Longitudinal normal stress distribution

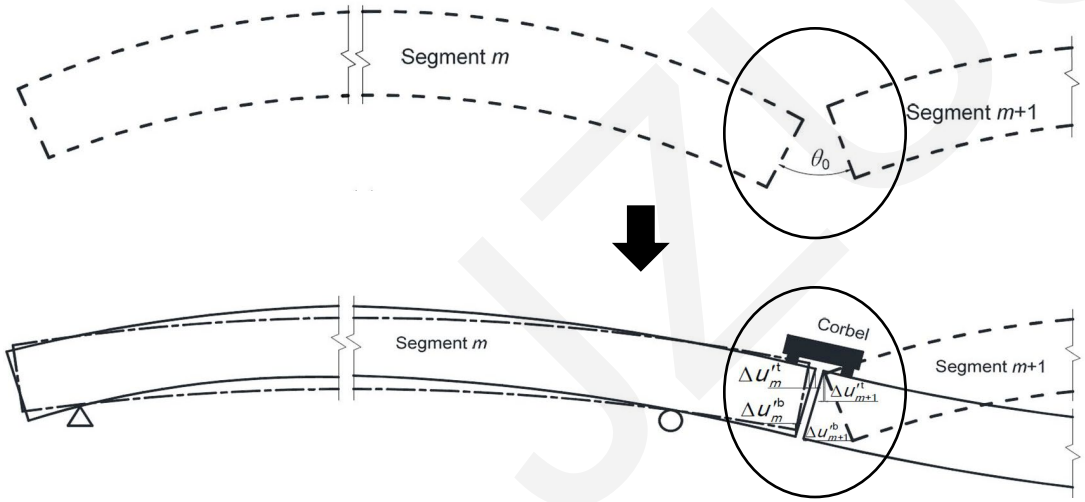


Normal stress at the mid span under different temperature differences

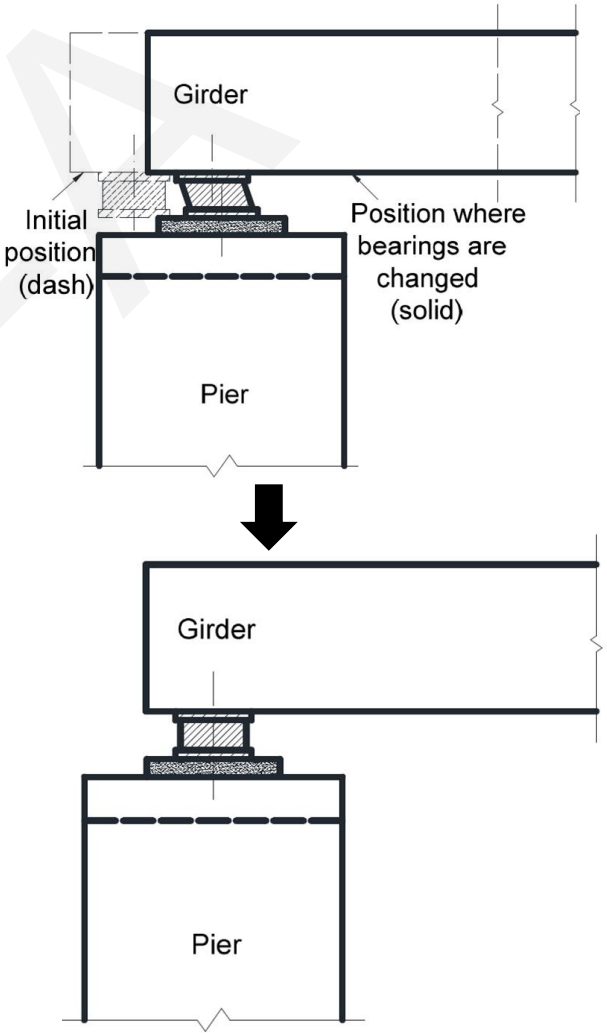
The final vertical relative elevations and longitudinal normal stress of the girder predicted by A-FEM is consistent with the field-measured results, and the errors are controlled within the allowable value. The A-FEM also accurately predicted the effect of temperature differences on vertical deflections and normal stress.

Simulation and control of construction

To control the maximum error of longitudinal distance between two adjacent end-faces of the girder segments within 2 mm before girth-welding, the angle of the two end-faces in the unstressed state must be set based on accurate calculation. The final state of the bearings are affected by the pre-set distance of the girder segment.



The end-face angle between adjacent segments



The pre-set distance of bearings

Conclusions

- Verified by the field-measured data, the accuracy of A-FEM has met engineering requirements.
- Based on the A-FEM results for the deflections and stress of each construction stage, the elevation of girder segments for erection can be precisely controlled, and the most adverse load positions can be identified and checked. The effects of temperature difference are evaluated.
- The end-face angles between adjacent girder segments in their unstressed states are predicted to ensure a smooth connection during construction. The pre-set distance of the girder segment is precisely set to ensure that bearings are still in the specified position under gravity and thermal loads. By controlling these key parameters, the full-span erection of a continuous steel box girder can be effectively guided.