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Design method of the pinned external integrated buckling-restrained braces with extended core. Part I: theoretical derivation

Zi-qin Jiang, Yan-lin Guo, Xiao-an Wang, Bin Huang

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Highlights

☐ The contact force and the bending moment in the external member are deduced.

☐ Strength design criteria of external member and extended core are established

☐ The influence of some parameters is considered in theoretical analysis.

☐ Proposed design method can predict the pinned BRB's overall buckling failure.

☐ Proposed design method can predict the bending failure in the extended core region.

Deformation mode of BRB and corresponding force state of external member

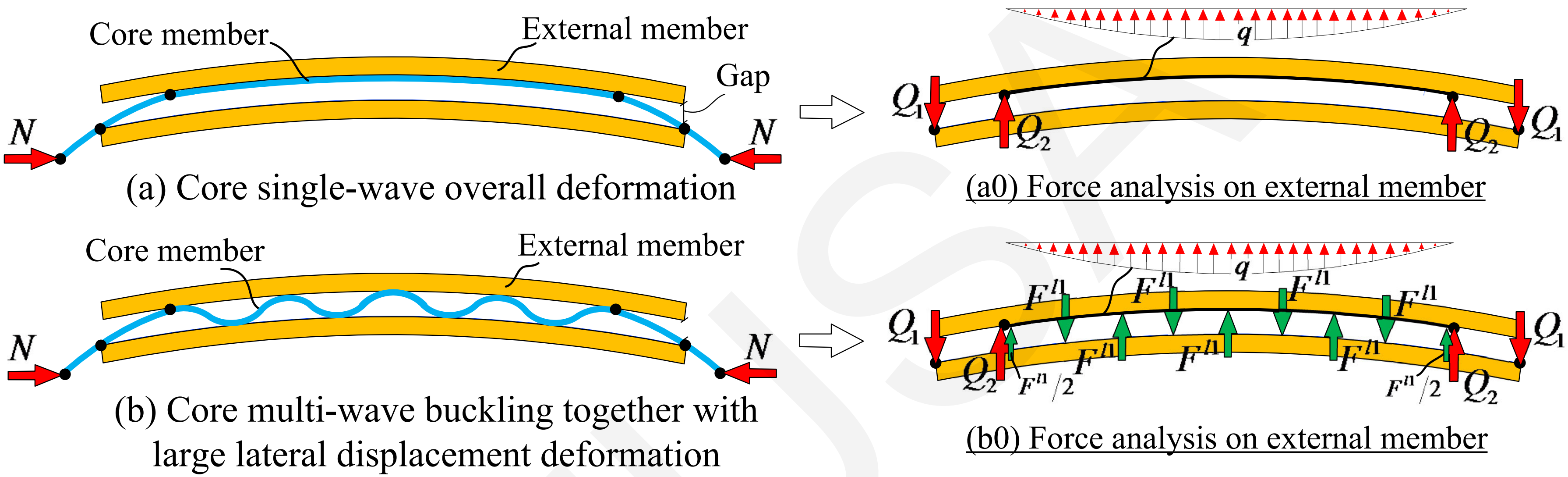

Fig. 1 Deformation mode of BRB and corresponding force state of external member

The core contact force distribution is closely related to the core deformation mode. For pinned BRBs with a single flat-plate core, the core may deform according to two distinct deformation modes, namely, the single-wave overall deformation [Fig. 1(a)] and the multi-wave deformation associated with a single-wave overall deformation [Fig. 1(b)]. And the maximum moment of the external restraining member at the mid-span results only from the core single-wave deformation. Based on this, only the influence of the core single wave overall deformation is considered in this paper.

Stress State of the Pinned BRBs with Core Single-wave Overall Deformation

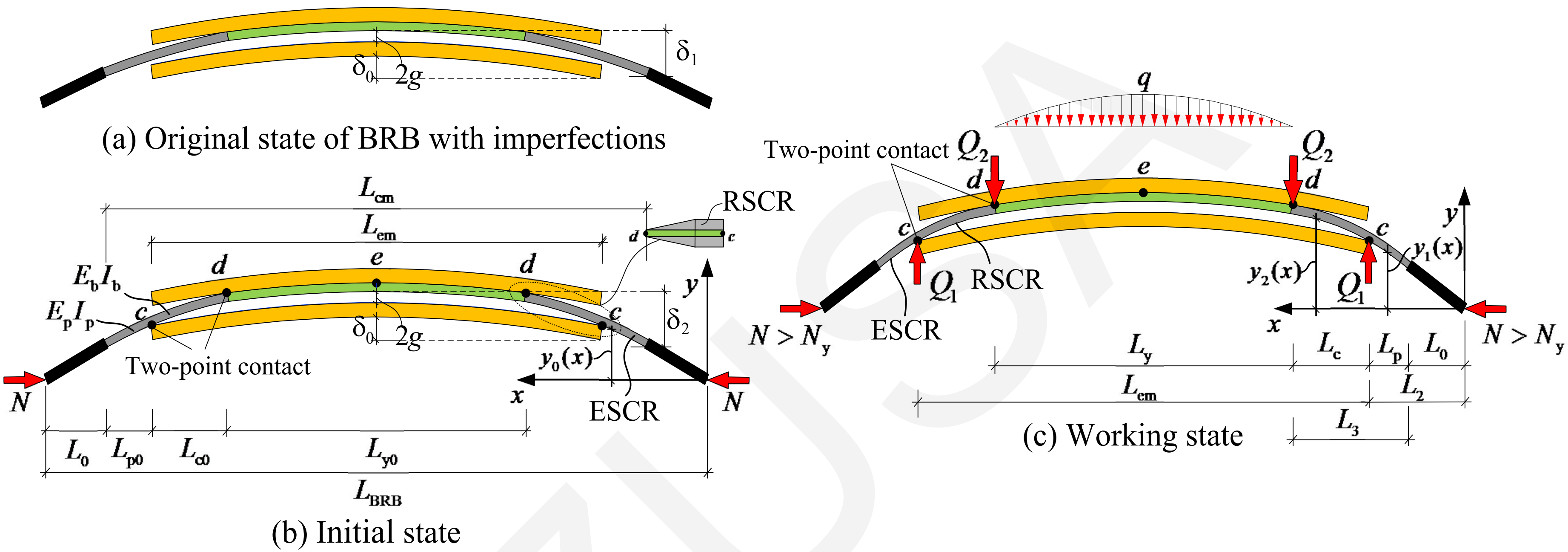

Fig. 5 Changing process of stress state of a pinned BRB

Based on the assumption of core contact force distribution, the equilibrium equations of extended strengthened core region and restrained strengthened core region are established. By employing the deformation compatibility relationship between the core and the external member at some specific contact points, the maximum bending moment acting on the extended core, the contact force distribution and the bending moment distribution acting on the external member are obtained, so as to lay a foundation for developing design criteria of the external member and the SCR.

Design Method of the Pinned External Integrated BRBs

Design Criteria for the External Restraining Member

As the external restraining member only offers lateral support to the core member, it is a flexural member. Accordingly, the sectional bending capacity of the external member can be considered as a control of the BRB restraining ratio in its design method.

$$M_{\mathrm{em,max}} \le M_{\mathrm{em,u}}$$

$$\xi \ge [\xi] = \frac{wL_{\mathrm{y}}^{2}\left(W_{\mathrm{em}} f_{\mathrm{ey}} + \left(\pi^{2}/8 - 1\right) Q_{1} L_{\mathrm{c}}\right)}{L_{\mathrm{BRB}}^{2}\left(W_{\mathrm{em}} f_{\mathrm{ey}} - wN_{\mathrm{y}} x_{1} \delta_{0} - Q_{1} L_{\mathrm{c}}\right)}$$

Design Recommendations for the SCR

Since the ESCR behaves as a typical beam-column, its limit strength is considered as a full sectional yielding and is expressed as an interaction between axial force and bending moment.

$$\left(\frac{N}{N_{\mathrm{p,ec}}}\right)^{2} + \frac{M_{\mathrm{ec}}}{M_{\mathrm{p,ec}}} < 1.0$$

Conclusions

- Taking a pinned BRB with extended core as a research object, this paper presents a theoretical derivation for its design method. Firstly, considering the core single-wave overall deformation mode, the equilibrium equations are established for the ESCR and the RSCR based on the assumed core contact force distribution modes. In addition, by employing the deformation compatibility relationship at some specific contact points, the maximum bending moment acting on the extended core and the core contact force distribution as well as the bending moment distribution acting on the external restraining member are also obtained. In the theoretical derivation, the following factors are considered: the initial geometrical imperfection of the external member, the gap between the core and the external member, the rigidity reduction of the RSCR, the change of contact position, and so on.
- Lastly, based on the stress characteristics of the external restraining member and the SCR, their design criteria are established. The theoretical derivation reliability is verified by finite element numerical analysis in another study as Part II.