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ADVANCED MODELLING OF CELLULAR BEAMS

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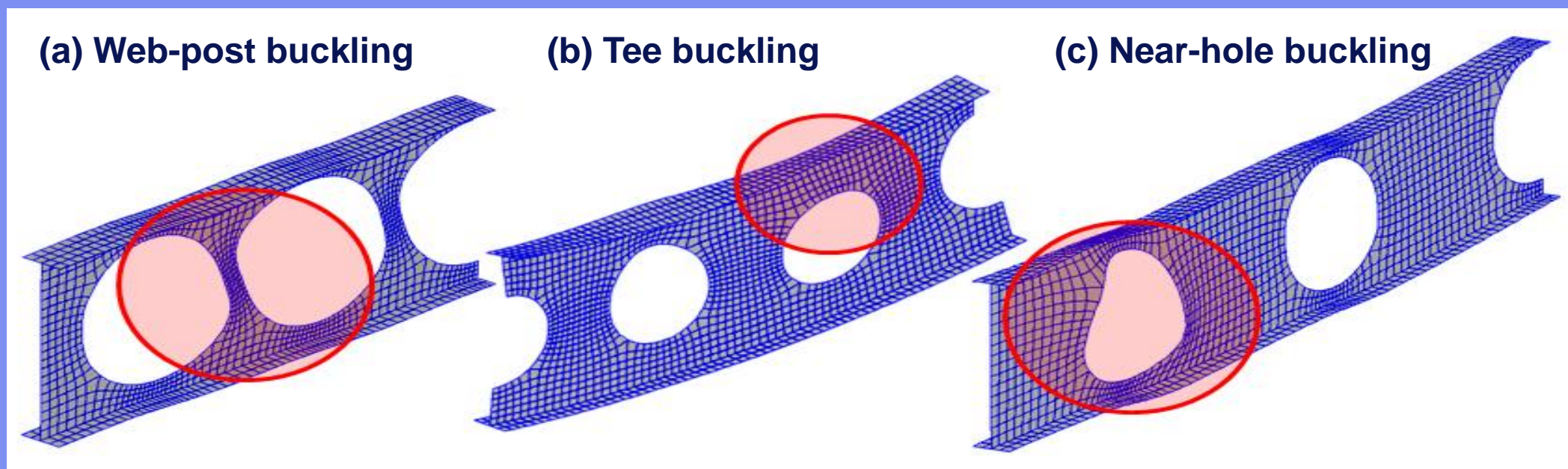Faculty of Engineering, Imperial College London.

CELLULAR BEAMS

Cellular beams, with the ability of withstanding gravity loads over relatively long clear spans while allowing service integration within the beams depth, have become an increasingly common form of construction. However, the presence of web holes leads to the development of local buckling, which is typically most critical in the web-post and in the compressive regions around the openings (Figure 1) [6,7].

FIGURE 1: POSSIBLE MODES OF BUCKLING

(a) Web-post buckling   (b) Tee buckling   (c) Near-hole buckling

CURRENT ASSESSMENT TOOLS

Since the design of cellular beams via detailed numerical models, for example Finite Element Analysis (FEA), continue to be computationally demanding, the current available design approach of such beams is still based on simplified models, which are calibrated against detailed FEA models only for specific geometries including layout and range of dimensions.

OBJECTIVE OF STUDY

The main objective of this work is to develop a more reliable design-oriented model capable of predicting the local buckling response of cellular beams, including interactions between different modes and sub-elements. The model combines the Element-Free Galerkin (EFG) method, originally developed by Belytschko [1], with the Rotational Spring Analogy (RSA) proposed by Izzuddin [2,3].

PROPOSED EFG/RSA MODEL

Consideration is given here to typical simply supported beams under uniformly distributed loading (UDL) applied to the top flange. The critical load factor is evaluated by obtaining the material stiffness (K_E) and geometric stiffness (K_G) of the considered domain (local region that consists of at most 3 unit cells), and then solving via an iterative rank 2 reduced eigenvalue problem [3]. Benefitting from the repetitive cellular beams profile, the planar analysis of the whole beam to determine K_G is simplified through the idea of dividing the system into unit cells and considering these under representative actions [5].
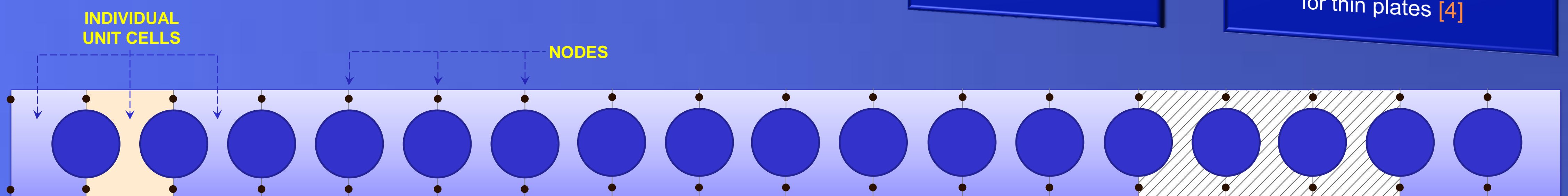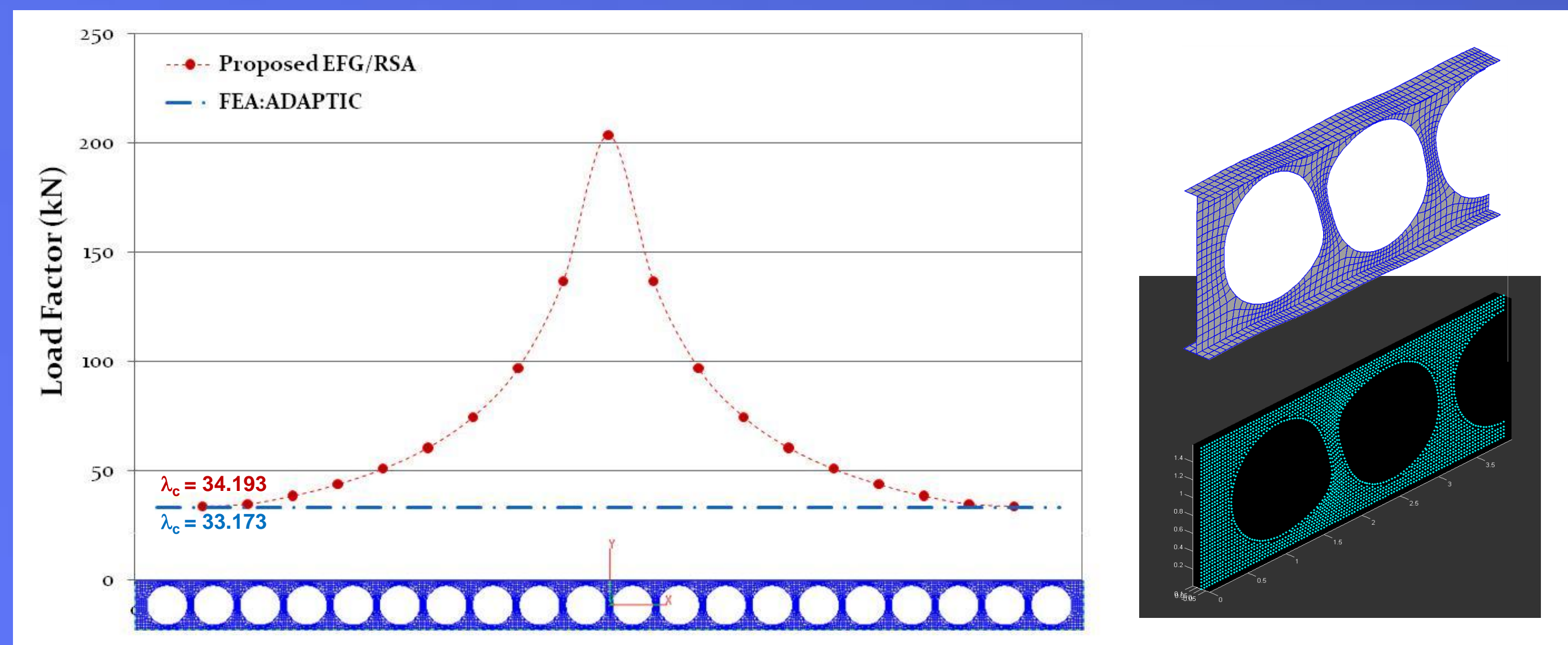
OUT-OF-PLANE BUCKLING
- for simply supported cellular beams under UDL

GEOMETRIC STIFFNESS
- determined from the planar stress field (according to RSA)

MATERIAL STIFFNESS
- directly obtained using the EFG method with Kirchhoff's theory for thin plates [4]

INDIVIDUAL UNIT CELLS   NODES

FIGURE 2: APPLICATION EXAMPLE

- Proposed EFG/RSA
- FEA:ADAPTIC

$\lambda_c = 34.193$
$\lambda_c = 33.173$

A comparison against detailed FEA performed using ADAPTIC is made for verification purposes, considering elastic behaviour. The employed beam is a symmetric cellular beam fabricated from UB1016×305×222 for the upper and lower web-flange sections with 840 mm diameter holes and 1472 mm spacing. The top and bottom flanges are assumed to be prevented from out-of-plane movement due to external restraints from a floor slab on the top and considerable tensile forces in the bottom flange. The results show that the critical mode is web-post buckling at the left end, where favourable comparison is achieved against the detailed FEA model (Figure 2).

CONCLUSION

An efficient method for local buckling analysis of cellular beams, combining the Element-Free Galerkin method with the Rotational Springs Analogy, is presented. The new approach brings particular benefits in terms of efficiency and accuracy with ability to predict accurately the most critical buckling form, and is not only applicable to regular cellular beams with circular holes but also more generally to other forms of cellular beam with different hole shapes and arrangements.

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