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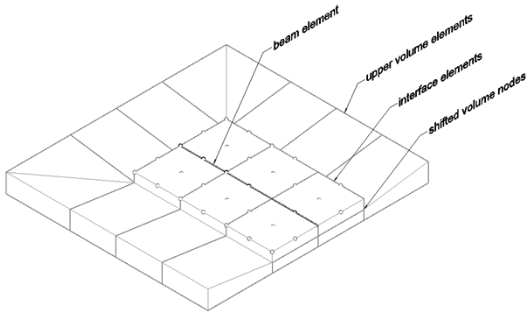
Coupling of Beam and Volume Finite Elements in the Elastic Half-Space

Motivation and objectives

Beams that lie on elastic foundations, under the action of multiple forces and moments, are of particular importance in applied mechanics and especially in civil engineering. Various geotechnical structures such as strip foundations, ground beams, pipelines and railroad tracks can be modelled through this scheme. The objectives are to develop and implement a coupling algorithm between one-dimensional beam elements and a soil half-space model in the finite element software TRIMAS®. For that purpose, interface elements are introduced to provide node continuity within the model. Then beam axial rotations are coupled with the nodal displacements of volume elements. Eventually, the contact pressures are identified and integrated along the geotechnical structure.

Generation of volume interface elements

Interface elements are generated over the soil – structure contact area.

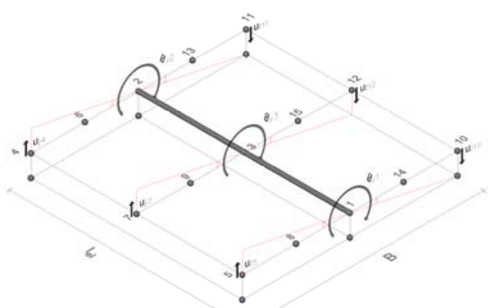


Coupling of rotational degrees of freedom

- Multifreedom constraint are imposed using *penalty method.*
- For each node a new penalty element is generated.

$$\theta_{x1}^{avg} \approx \tan\theta_{x1}^{avg} \approx \frac{u_{z10} - u_{z5}}{B}$$

$$w\begin{bmatrix} 1 & 1/B & -1/B \\ 1/B & 1/B^2 & -1/B^2 \\ -1/B & -1/B^2 & 1/B^2 \end{bmatrix}\begin{bmatrix} \theta_{x1} \\ u_{z5} \\ u_{z10} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

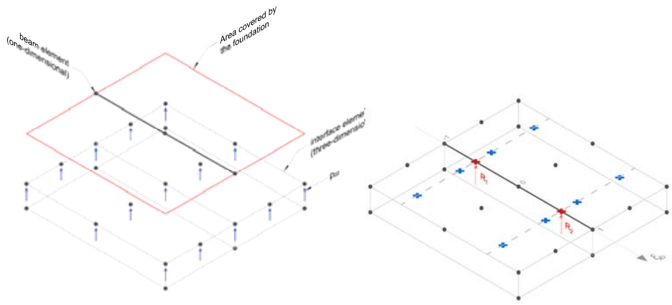


Integration of soil pressures

1D Gauss Integration

$$R_i = \sum_{n=1}^{Nel}\int_{-1}^{1} F_n(\xi) J d\xi = \sum_{n=1}^{Nel}(F_n(-1/\sqrt{3}) + F_n(1/\sqrt{3}))J$$

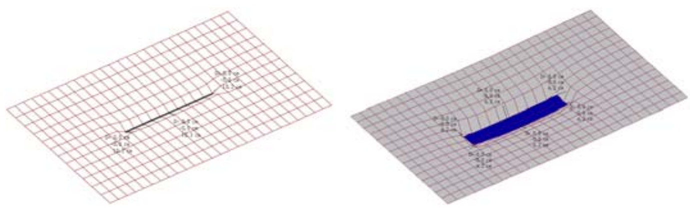
$$f_k = \sum_{i=1}^{2} N_i(\xi_k) R_i J$$



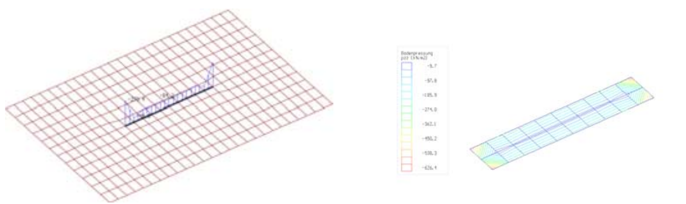
Verification example

→ Strip foundation models using beam elements (left) and shell elements (right).

- Displacements



- Soil pressures



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