Shear forces comparison of various FEM approaches in analysis of passive earth pressures reduced by controlled yielding technique

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Abstract

Passive earth pressure is an important element in integral bridge design. Due to integral connection between bridge deck and abutments, integral bridge expansion and contraction under temperature action causes abutments to move together with the deck. With temperature varying in time, this also causes varying earth pressures acting on the abutments. Abutments are generally being designed to withstand passive earth pressure, because it is significantly higher than active earth pressure. However, using controlled yielding technique, these pressures can be considerably lowered. For this purpose, usually a few centimetres thick layer of expanded polystyrene or other easily compressible material is placed behind abutment, which provides means to potential material saving. In this article, results from 2D and 3D FEM models of integral abutment are presented. Soil - abutment connection was modelled as springs transferring compression only. Varying thickness of EPS layer was used and both linear and nonlinear analyses were performed, with different nonlinear material soil models. Internal forces obtained in 2D and 3D analysis are compared between themselves, and influence of compressible layer thickness on internal forces is also presented.

Keywords: structure - soil interaction ,earth pressure, controlled yielding technique, integral abutment, integral bridge

1. Introduction

Controlled yielding technique provides easy way to lower earth pressures acting on abutment. It can limit active earth pressure up to ca. Ref. [1] 20 percents of its original value. However, when abutment is integral, passive earth pressure is the key design factor.

2D FEM model was created using beam elements representing abutment, and quad elements to represent EPS layer and surrounding soil. Nonlinear material model was used for concrete, reinforcing steel and EPS. However, for soil, only linear material model was available, due to FEM program limitations.

3D FEM model was created using volume elements, with exception of the abutment, where quad elements with corresponding parameters were used instead. For soil Mohr - Coulomb and Drucker - Prager nonlinear material models were used.

Thickness of EPS layer was 0, 50, 100, 180 and 300 millimetres.

Connection between abutment and soil was represented by springs, capable of transferring compression only, for both 2D and 3D model.

Visualisation of model is shown in Figure 1.

2. Results from 2D analysis

Resulting internal forces are presented in Figure 2 and Figure 3 for linear analysis, and Figure 4 and 5 for nonlinear analysis.

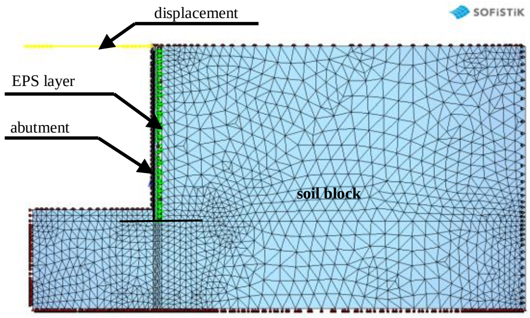

Figure 1: Visualisation

Linear analysis shows very mixed results, with almost no influence of compressible layer on resulting bending moments. Contrary, shear forces have increased when EPS layer was used. Therefore, it is obvious that it is necessary to include nonlinear material behaviour of compressible layer into calculation.

In nonlinear analyses, when compressible layer was used, bending moments decreased for about 35%. Shear forces depended strongly on thickness of EPS layer. Overall, shear forces were of low values.

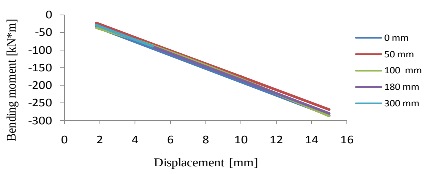

Figure 2: Bending moments - linear analysis

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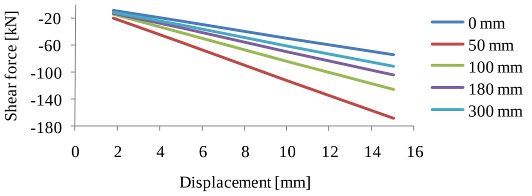

Figure 3: Shear forces - linear analysis

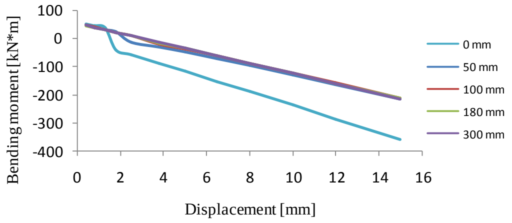

Figure 4: Bending moments - nonlinear analysis

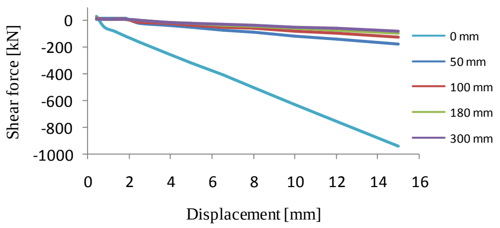

Figure 5: Shear forces - nonlinear analysis

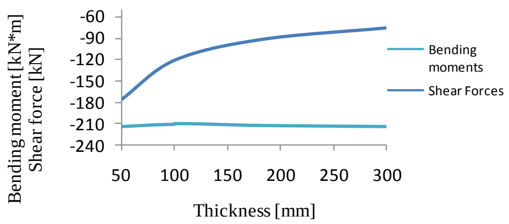

Figure 6: Influence of compressible layer thickness

Figure 6 represents influence of thickness of compressible layer on bending moments and shear forces. Even in extreme case where induced displacement on top of abutment was 40% of EPS layer, resulting bending moments were generally the same as with thicker layers.

Shear forces display considerably different behaviour in comparison to bending moments. Dependency between shear force value and compressible layer thickness appears to be exponential. Therefore, when shear force is not limiting abutment design, influence of thickness of EPS layer is of small importance.

3. Results from 3D analysis

Due to very long calculation time of load cases only model with 100 mm EPS layer was analysed. Analysis using hardening - soil model did not met energy converge criteria, therefore only results from analyses with Mohr - Coulomb and Drucker - Prager material model are presented.

Bending moments are shown in Figure 7 and shear forces on Figure 8. Difference in bending moments between 2D nonlinear analysis and 3D analysis using both Mohr - Coulomb and Drucker - Prager seem to be of approximately the same value as in comparison of 2D results, while shear forces display smaller values than in 2D analyses.

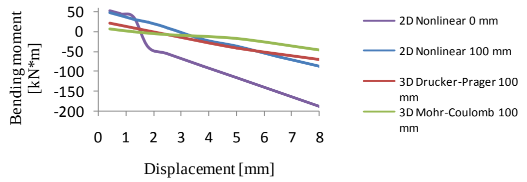

Figure 7: Bending moments - nonlinear analysis

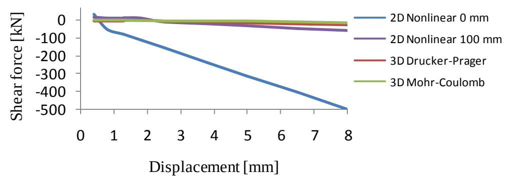

Figure 8: Shear forces - nonlinear analysis

4. Conclusions

This article presented results from integral abutments analysis where passive earth pressure is lowered by controlled yielding technique.

Linear calculation proved to be ineffective for this type of analysis, as results showed no influence of compressible layer, or in case of shear forces, even increased forces.

Comparison of bending moments between 2D model with no compressible layer and 2D/3D models with various thickness of compressible layer showed the same decrease in bending moments. There are two conclusions - 2D analysis shows reliable results and thickness of compressible layer is of small importance.

Comparison of shear forces between these models showed, when shear force is expected as limiting factor in integral abutment design, thickness of compressible layer is of significant importance and 3D analysis with nonlinear material soil model should be used.

However, it should be noted that these conclusions and results are solely based on FEM analysis. Comparison with experimental data will be conducted in the future.

References

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