Short- and long-term effects on upheaval buckling of blinding struts

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Summary

Significant economies can be achieved by using concrete blinding as struts in cut and cover excavations. It is shown that blinding struts can fail in upheaval buckling. The main parameters influencing the buckling load are identified and comparisons are made between numerical and analytical predictions of failure loads. Comparisons are also made between the measured and predicted strengths of blinding struts tested by the authors. It is shown that struts creep to failure under sustained loads greater than around 70% of the buckling load at first loading when a sinusoidal ground imperfection is assumed. The paper concludes with a brief overview of the geotechnical numerical analysis undertaken to date which gives some insights into the soil-structure interaction.

Keywords: Blinding, struts, upheaval buckling, creep, soil-structure interaction

1. Introduction

The term 'blinding' is traditionally used to refer to the thin layer of unreinforced concrete laid at the bottom of excavations to prevent the surface from being eroded by construction traffic. Powderham [1] and others have achieved significant economies by using blinding to prop retaining walls in cut and cover excavations prior to casting the base slab. This research aims to asses the levels of conservatism in current practice, and to develop a widely applicable safe and economic design method. The behaviour of blinding struts is complex since the struts are loaded within a few hours of casting by i) in-plane axial loads from the retaining walls due to consolidation of the soil and subsequent excavation, and ii) transverse loads from the upheaval of the underlying ground and construction traffic. The present research combines analytical, numerical and experimental work to obtain a better insight of the soil-structure interaction between the strut, the retaining walls and the underlying soil.

2. Analysis

Non-linear finite element analysis (NLFEA) with the structural non-linear finite element program ADAPTIC [2] shows that blinding struts can fail in upheaval buckling. Previous research in upheaval buckling is of little relevance to the design of blinding struts since it is largely concerned with the thermal buckling of pipelines, railways tracks and road pavements where the response is largely governed by friction. The present research combines analytical, numerical and experimental work to obtain a better insight into the nature of the interaction between the strut, the retaining walls and the underlying soil. A parametric study was carried out in ADAPTIC [2] to quantify the effect

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of early age loading and subsequent creep on the strength development of blinding struts. It was shown that struts can creep to failure under sustained loads greater than around 70% of the buckling load on first loading. The transition point between stable and unstable behaviour depends on the duration of the permanent load, and in the example considered varies between $0.78P_{ushort}$ for a sustained load of 2 years and $0.85P_{ushort}$ for a sustained load of 28 days. The results from the creep numerical analysis were also compared to test results, and a good correlation was obtained.

A series of 2D analyses has been made with the geotechnical finite element program ICFEP [3] to investigate the transfer of load into the strut from the retaining walls for an excavation 10m deep by 20m wide. The soil was assumed to be London Clay and the strut was represented by a spring at the base of the excavation. The analysis is currently being extended to 3D to simulate the excavation process more realistically.

3. Experimental Studies

An experimental program is being undertaken in parallel with the analytical work to validate and refine the numerical analysis. The study is being carried out on ¼ scale models of blinding struts measuring 5m long by 500mm wide and 50mm thick (Fig. 1). Good correlation has been achieved between the test data and the numerical solution, and the authors are now confident that the numerical model may be used safely beyond the experimental parameters.

Fig. 1: Photo of test specimen after test

4. Conclusions

It is demonstrated that relatively thin blinding struts have sufficient strength to work as struts in cut and cover excavations. A conservative approach should be used in the design of blinding struts since load carrying capacity is greatly dependent on the imperfection amplitude, ground imperfection wavelength and profile, thickness, and the eccentricity of the applied load from the centroid. A good correlation was obtained between the analytical, numerical and experimental data. Blinding struts may be used safely under sustained loads up to around 70% of buckling load at first loading. The geotechnical analysis is still at an early stage but gives some idea of the magnitudes of load likely to be transferred into blinding struts and the shape of the ground profile. More realistic scenarios will be investigated through the on-going 3D numerical analysis.

5. References

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