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Blinding struts, Part 2: Towards a simplified design method

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ABSTRACT

The companion paper described how concrete blinding can be used to prop retaining walls in cut and cover excavations prior to the completion of the base slab. In addition, it was demonstrated that the behaviour of blinding struts can be accurately predicted with nonlinear finite element analysis (NLFEA) if the strut properties and ground profile are known. This paper presents a simple design-oriented analytical model which can be used for blinding struts as an alternative to NLFEA. The simplified model is shown to give comparable results to NLFEA and is attractive for design since it allows the effect of variations in imperfection amplitude and length to be rapidly assessed. A case study is presented which illustrates the use of the method and demonstrates that relatively thin blinding struts can resist the maximum axial forces likely to be encountered in cut and cover excavations.

1. Introduction

The companion paper [1] shows that blinding struts fail in upheaval buckling and that the critical buckling load can be accurately predicted with NLFEA if the strut properties and ground profile are known. This paper presents a simplified design-oriented analytical method for the design of blinding struts which are cast onto geometrical imperfections arising from lack of ground flatness. The model gives useful insights into the effect of changes in the length and amplitude of the geometric imperfection. The method is an enhancement of Croll's [2,3] clamped column analogy for upheaval buckling which is discussed in the companion paper [1].

Croll's [2,3] analysis is restricted to cases where the length of the foundation imperfection L_g is greater than or equal to the empathetic length L_{po} which is given by:

$$L_{po} = \sqrt[4]{\frac{384EIw_g}{q}} \tag{1}$$

where E is the elastic modulus, I is the second moment of area, w_g is the imperfection amplitude and q is the self-weight of the strut per unit length.

In contrast to Croll's model, the model proposed in this paper is applicable to blinding struts where (i) the buckle length is limited by the excavation width (L_{exc}), (ii) end conditions can significantly affect the buckling load, (iii) the imperfection length is typically shorter than the empathetic wavelength, and (iv) failure can occur due to either elastic buckling or concrete crushing allowing for tensile cracking.

2. Research scope

The companion paper [1] shows that the strength and failure mode of blinding struts depends on factors including the amplitude of the ground imperfection, the eccentricity of the line of thrust at the ends of the strut and the degree of rotational restraint provided by the retaining wall. This paper develops a design-oriented analytical model for predicting the short-term failure load of blinding struts which are cast onto ground imperfections arising from lack of flatness. Fig. 20 in the companion paper [1] shows that sinusoidal imperfections can be critical for relatively thin struts whereas parabolic profiles with ($L_g = L_{exc}$) can be critical for thicker struts. Consequently, this paper assumes the ground profile to be either (i) parabolic with length equal to the excavation width (L_{exc}) or (ii) sinusoidal with $L_g \leq \min(L_{po}, L_{exc})$. The ICFEP ground heave profile [1] is not considered in this paper since it can be modelled with an equivalent parabolic imperfection for practical purposes. The model simplifies the design of blinding struts by conservatively assuming that the retaining walls offer no rotational restraint and that the strut is loaded at its centroid. The ends of the blinding strut are assumed to be prevented from lifting by the inwards rotation of the retaining wall, as observed in the geotechnical analysis (see Fig. 1). Importantly, failure is assumed to be governed by either elastic buckling or material failure at the centre of the buckle wavelength. The NLFEA described

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