Effect of Construction Sequences on the Behaviour of a Backfilled Retaining Wall

Rouili Ahmed

***Abstract*—Backfilled L-shaped retaining walls are considered as complex types of geotechnical structures, which are particularized by the fact that they are not only supported by the soil, as is the case with foundations, but also loaded by the soil. Actual design methodology does not take into account the construction sequences which simulate the process by which the soil and the retaining wall are brought together. However, in reality, at least during the backfilling process, the retaining wall undergoes many displacements that are not so far considered in the design. In the present investigation, the influence of the construction sequences on the behaviour of an L-shaped stiff retaining wall is investigated with a numerical model. For validating the proposed numerical model, reference was made to the results of a centrifuge experiment conducted on a reduced prototype. The numerical analysis shows that for the type of wall and soil investigated, considerable displacements of the wall (rotation and translation) occur during the backfilling process. The rotational movement of the wall is not occurring around the toe as it is usually assumed in design practices, but it follows a total displacement path of the toe. It is recommended that a better estimation of the rotation (s) of the wall is necessary to reach the state in which active earth pressure can be fully mobilized.**

***Index Terms*—Retaining walls, construction sequences, numerical modeling, design.**

I. Introduction

L-shaped walls are simple to construct and thus often used as earth retaining solution in urban area. If the usual approaches of the design for overall stability (e. g. bearing capacity, sliding) are believed to be reliable and sufficiently accurate, despite many erroneous assumptions, it is primarily because a caution and adequate safety factors has been allowed for in design. Questions remain concerning the disturbances induced to the structure and soil foundation during the construction process. In practice the analysis of retaining walls start from an initial condition related to the assumption: that, the wall is already in place (Constructed) and the supported soil already backfilled to the desired level, without considering the construction process, by which soil and retaining wall are brought together. The nature of wall movements, whether translation or rotation, has a considerable effect on the distribution of earth pressure, as, greater movement in any part of the wall away from the backfill reduces the earth pressure, and movement towards the soil increases the earth pressure [1].

The scope of the present investigation is to undertake a numerical investigation, where the behaviour of an L-shaped retaining wall is simulated. The Plaxis programme [2] was used for the numerical modelling. The effect of the construction sequence on the behaviour of the retaining wall is simulated by the mean of the multiphasic 'staged construction' procedure incorporated in the Plaxis.

II. Reference System

The numerical model proposed in the present investigation was developed with respect to the geometry, dimensions, boundary conditions and the loading conditions of the reference system presented in Fig. 1. This system was investigated by previous researchers [3] in a centrifuge experiment conducted on a reduced scale prototype. The soil used in the experiment was the Leighton buzzard sand, this dry sand may be classified on the basis of its particle size distribution as a uniform fine to medium sand with a dry density γ_{unsat} = 17 KN/ m^3. The results were compared according to the centrifuge scaling laws fully discussed by Schofield [4]. The numerical modeling concept used for the validation of the numerical model developed together with its possible limitations has been fully investigated by Rouili et al. [5]. For the stiff wall the bending deflection are negligible and the measured horizontal and vertical displacements reported concerns the rigid body movements. As illustrated in Fig. 2, δ_{ht} is the horizontal movement of the top of the wall (displacement of the point A_n); δ_{hb} is the horizontal movement of the bottom of the wall (horizontal displacements of the points B and C); δ_v is the vertical movement of the wall (vertical displacement of the points A_n and B_n).

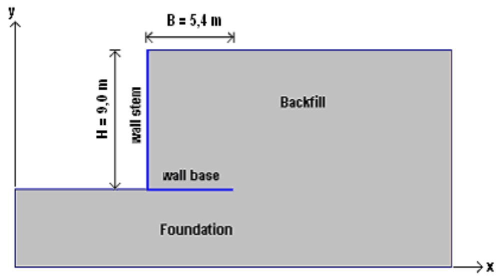

Fig. 1. Reference system.

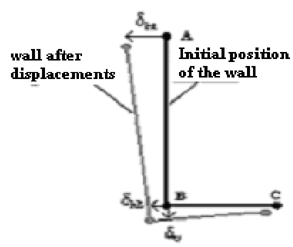

Fig. 2. Displacements of the wall

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III. Numerical Analysis

The numerical analysis was carried out in plane strain, the model extends 28m horizontally and 14m vertically, to account for the centrifuge dimensions box converted to the prototype scale. The retaining wall is defined through an L-Shaped beam (with a rigid slab footing) representing the prototype dimensions of the centrifuge model. Conditions of plane strain were assumed throughout. Fig. 3 shows a typical finite element model with the displacement boundary conditions. The retaining wall was modeled by beam elements with a Young's modulus (reinforced concrete) assumed with $E_b = 3 \cdot 10^4$ MN/m^2. The soil has been modeled using the hardening soil model, considered in drained conditions [6]. The soil modeling parameters are presented in Table I.

TABLE I: Modeling Parameters of the Soil.

$E_{oed\ ref}$	$E_{50\ ref}$	$E_{ur\ ref}$	m	Φ	c	ψ
25 [MN/m^2]	25 [MN/m^2]	100 [MN/m^2]	0.65	35 [°]	0	2,5 [°]

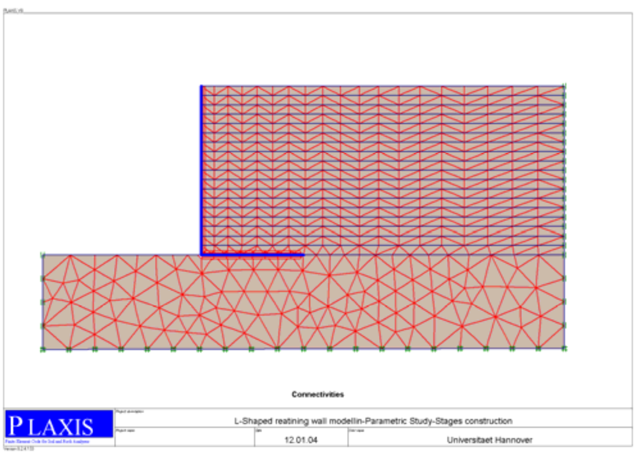
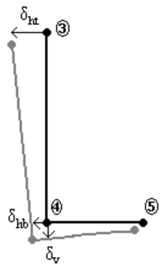


Fig. 3. Typical finite element model.

IV. Validation of the Numerical Model

For the validation of the proposed numerical model, the numerical results in terms of wall displacements and horizontal earth pressure acting on the wall (corresponding to the final loading stage), are compared to the experimental results obtained in the centrifuge experiment. Fig. 4 illustrates the correlation obtained between the centrifuge measured displacement (converted to the prototype scale) and the numerically predicted displacements. As can be seen on this figure, the numerical model proposed was found to be able to produce a very close prediction of both: the displacement pattern and the magnitude of the displacements. Fig. 5 shows the associated distribution of the horizontal earth pressures at the vertical plane: immediately adjacent to the wall. On this plot the good agreement between the output of the numerical model proposed and the experimental results obtained in the centrifuge is clearly apparent. Also for the appreciation of the obtained results, the at-rest (K_0), and the classical Rankine active earth pressures (K_a) profiles are also shown on this Figure.



	Experimental model	Numerical model
δ_{ht}	-73.8 mm	-82.1 mm
δ_{hb}	19.2 mm	27.5 mm
δ_v	-37.8 mm	-36.0 mm

Fig. 4. Computed and measured displacements.

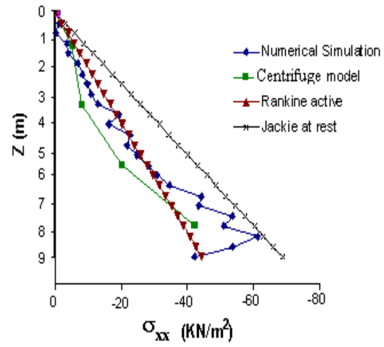


Fig. 5. Profile of the lateral Pressure

V. Simulation of the Construction Sequences

In order to investigate the effect of the construction sequences, the backfill soil was divided into 18 layers of 0,5m thick each, which yield the total initial height of 9m, the general layout of the geometry configuration of the numerical model as shown in Fig. 3. Consequently, calculation for the multi-phases numerical analysis was performed using the *stage construction* procedure, the calculation was executed in 18 phases, starting from the initial state where the wall is resting on the soil foundation, for sequences loading, each phase corresponding to a single loading of 0.5m of backfilling, yielding a total of 18 layers (phases), and ending with the state where the finite element model components are all activated. For each stage the calculation progresses until the prescribed ultimate state is fully reached.

The deformed mesh of some selected loading stages (corresponding to phases: 1,3,7,10,15 and 18) are presented in Fig. 6. From this figure it could be clearly seen that the wall undertake during the first stages of loading (1 up to 5) a slight backward tilting towards the backfill side, this could also been checked in Fig. 7 and Fig. 8, where the horizontal and vertical displacements corresponding to geometrical reference nodes (points) of the wall i.e., A_n, B_n, and C_n are plotted against the loading multiplier.

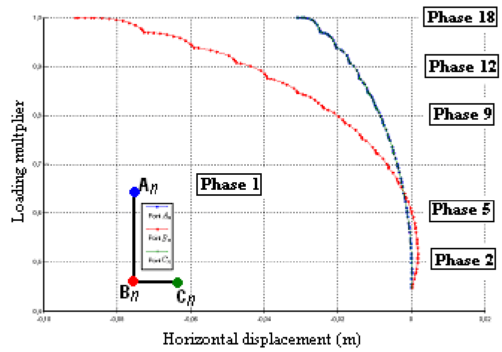


Fig. 7. Horizontal displacements of the wall

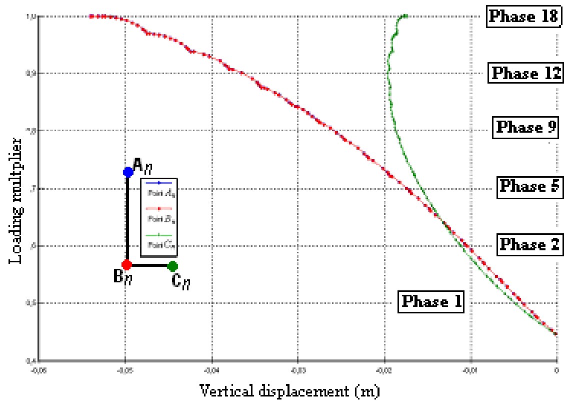


Fig. 8. *Vertical* displacements of the wall

From Fig. 7 and Fig. 8, it could be argued that on the horizontal displacements plot, the point A_n moves clockwise (on the positive side) toward the soil mass up to the 6th phase, and then return backwards (anti-clockwise) and keep progressing until the end of loading (phase18). On this plot the points B_n and C_n undertake equal displacements path, which characterizes the rigid body displacement of the wall base. On the vertical displacement plot, the downward displacement of the point C_n is continuous up to phase number 9, and then the displacement seems to be less pronounced as the loading progresses. The vertical displacement path of the Points A_n, and B_n are similar, which is due to the vertical body displacement of the rigid wall-stem, and continuously progresses through the increasing loading stages till the end of backfilling. These observations highlight further the fact that rotations and translation of the wall occur simultaneously during the staged backfilling process which simulate better the real construction process. The rotational movement of the wall is not occurring around the toe as it is usually assumed in design practices, but it follows a total displacement path of the toe (Point B_n), similar observation were observed and reported by Arnold [7].

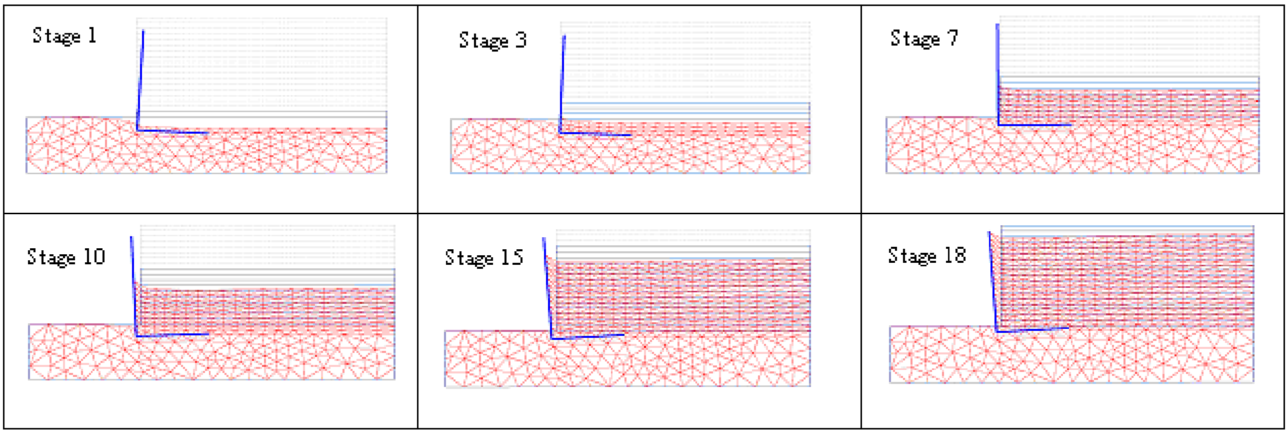


Fig. 6. Deformed meshes of selected phases

VI. Conclusion

Actual design methodology of retaining walls does not take into account the construction sequences which simulate the process by which the soil and the retaining wall are brought together. In the present investigation, the influence of the construction sequences on the behavior of an L-shaped stiff retaining wall is investigated with a numerical model. The present analysis shows that for the type of wall and soil considered, considerable rotations and translation of the wall occur simultaneously during the backfilling process. The rotational movement of the wall is not occurring around the toe as it is usually assumed in design practices, but it follows a total displacement path of the toe. The average rotation of the wall should be evaluated taking into account all the displacements induced to the structure during the backfilling process. A better estimation of the rotation (s) of the wall is necessary to reach the state in which active earth pressure can be mobilized. There is no doubt that those observations need further verification by experimental tests. But, the results of the present numerical study can form the basis for a new, and in most cases more realistic, design approach for the L-shaped retaining walls.

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