International Journal of Engineering Sciences 2021 14(1) 1-9

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES

Behavior of Soil Tunnel Digging when case of Tunnel Elharouche Skikda

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(Received 6 June 2020; Accepted 2 February 2021)

https://doi.org/10.36224/ijes.140101

Abstract

The digging of one or more tunnels is a process that destabilizes the field, maintaining the stability of the tunnel wall and control of ground movements around the gallery resulting from each excavation and the interaction between two tunnels must be controlled. This research aims to analyze and understand the physical mechanisms games during the digging of two twin tunnels throughout the spatial configurations and evaluated the ground motion induced by the interaction between these two lasts. The three-dimensional effect of widening is taken into account using the decontainment λ rate of soil adjacent to the excavation by the application of the convergence-confinement method. The modeling work is executed in two-dimensional, by using the finite difference code Flac-2D. A comparison of numerical simulation results with in-situ measurements was established in the particular case of two parallel horizontal tubes of the tunnel T4 on Elharouche Skikda and for which experimental data exist.

Keywords: Tunnel, interaction, numerical simulation, prediction.

1. Introduction

The construction of a tunnel at low depth results inevitably in change in the distribution of stresses in the soil around this underground structure and therefore generates deformations within the massif. In order to limit the impact of the excavation, it is necessary first to know the techniques used for its construction, and to identify the causes and consequences of soil motion.

Twin tunnels are often constructed for the subways, railways, highway junctions. For several reasons (geotechnical conditions, previous use of the basement), the tunnels may be located very near each other and also they can take any configuration. In fact, the tunnels centers are located either on the same horizontal line (parallel tunnels horizontally) or on a same vertical line (parallel tunnels vertically) or on an inclined line (parallel tunnels inclined). Several research works have studied the interaction between tunnels, D. K. Koungelis & C. E. Augarde[1] ,S. A. Mazek[2], Shahin H. Md & al. [3], William H. Hansmire & al. [4], F. Hage Chehade & I. Shahrour [5] . In some configurations, the interaction between the tunnels may have important effects on soil compaction. That is why more detailed studies are needed (digital modeling). These studies coupled with inspections of the field are essential [6] .This article is a numerical analysis devoted to the study of ground motions after digging the tunnel with boring machine of two parallel tunnels in all spatial configurations. It is applied to the modeling of the digging of two parallel tubes in horizontal position of the tunnel T4 OF Elharouche Skikda (Algeria) excavated by the traditional method and taking the same characteristic of coating.

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ISSN 0976 – 6693.

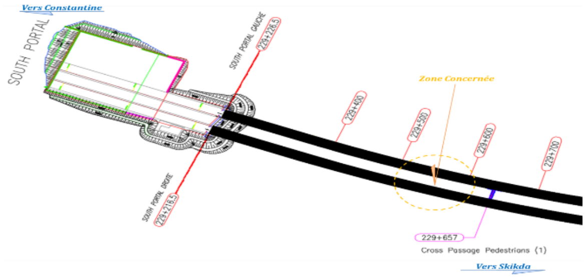

Figure 1: plan view and longitudinal section of the tunnel T4

2. Descriptions of work and field of geology

T4 tunnel comprises two parallel tubes with a horizontal spacing between the two centers 39 m provided for geological needs. The tunnel crosses Djebel El Kantour, located in the northeast of the city of Constantine; it is part of Section 4 of the Project of the East-West Highway - Lot East [20] .The medium shipyard widened according to the conventional method excavation in divided section. The dimensions of the cross section of each tube around the theoretical excavation line are 17m and 13m near width height [20] .The solid geology penetrated by the tunnel consists of marl and lime. These are covered by deposits, including clays, silts and conglomerates [20].

For the work simulation, the tunnels have a circular section with a diameter of 17m. The spacing between the centers of two tunnels is equal to 39 m, for all spatial configurations the center of the left tunnel is 17.84 m from the surface. The calculation section was selected to the PK229 + 240-229 280. This section is completely in clays and compact marl.

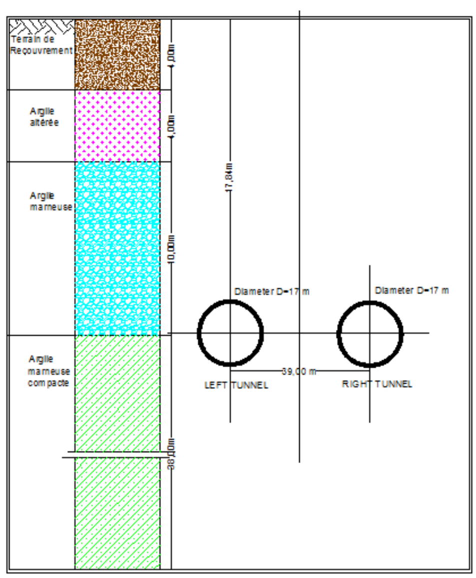

Figure 2: geological cross of the terrain and cross section of the tunnel T4

Table 1: Data of the Tunnel and *geotechnical characteristic of the coating* (7)

Construction site	H(M)	D(M)	C/D	Width segments (CM)	Thickness segments (CM)
T4	17.84	17	0.55	1	60

Table 2: Parameters of resistors of layers traversed [7]

diapers	Thickness (M)	γ(Kn/m^3)	C (KPA)	Φ (degrees)	E (MPa)
Overburden	0-4	16.5	5	27	5
altered clay	4-8	17.5	5	27	25
marl clay	8-18	20	10	20	140
Compact marl clay	18-56	22	25	22	240

3. Simulation of digging procedure

Non-associated rule requiring little flow parameters [8]. The coating will be simulated using shell elements with a linear elastic behavior. The boundary conditions are imposed in terms of travel to the base of zero area and zero displacement in the direction perpendicular to the lateral limits of the model. The extent of the mesh to the three spatial configurations in the longitudinal and transverse direction is determined by the position of the second tunnel, to which the results become independent of the boundary conditions. Massive receiving the two tunnels is considered virgin, the geostatistical constraints are established according to a coefficient of land at rest K0 = 1-sinφ [8]. The excavation is simulated by disabling soil disc elements, the application of déconfinment rate (λ) Final provided along the tunnel wall is achieved incrementally, at the end of this phase, the coating is thus activated along the tunnel wall these procedures are repeated for the excavation of the second tube.

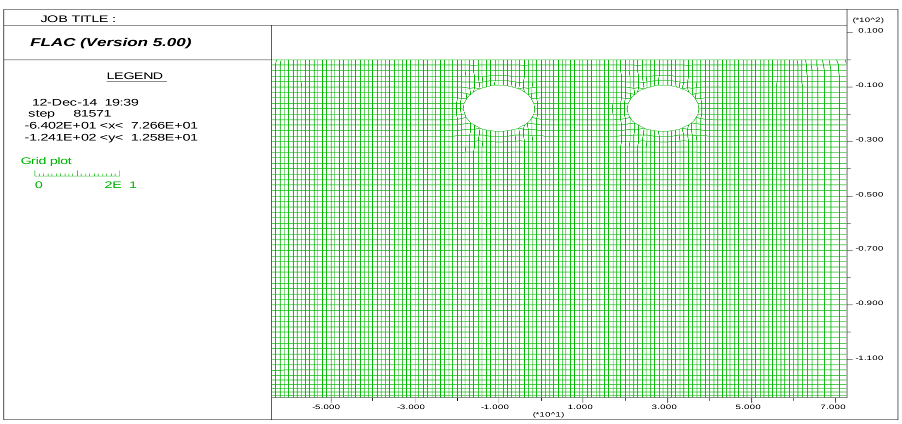

Figure 3:

Given the crossed horizons, calculations are carried out in total stresses without considering the presence of a water table. The results of the 2D simulations are confronted with the reference from an experimental approach to data based on a set of observations and field measurements [9] collected after excavation of the two tunnel tubes taken as a support site.

4. Results

The results of calculated simulations (longitudinal deformation bowls) are confronted with the results measured during the excavation of two horizontally parallel tubes excavated by the traditional method the overall tap bowl resulting from the excavation of the two tunnel was obtained by applying the superposition technique [10], [11] the representation of the global slowdown was associated with a given distance of 1500m progress that perfectly matches the rates λ decontainment chosen. The influence of the change of the speed of advance of one of the tunnels was taken into considerations .Des digital simulation processes 2D and 3D student changing forward speed heckled by distance delay of two parallel horizontal tunnels dug into soft ground have been proposed by various authors in recent decades, [12], [13]. three sequences were put into the first consideration is the widening of the second tunnel directly after completion of the construction of the first without any time delay and maintaining the same speed of advancement to the two tunnels, the second consists of the widening second tunnel directly after completion of the construction of the first tunnel by decreasing the speed of the second and the third is that the excavation of the second tunnel directly after completion of the construction of the first increasing the speed of the second spatial configurations have .Three were analyzed in order to study the influence of the change of positioning of the two tunnel on the surface settlement. First, the two tunnels are horizontally according to two parallel tubes of the support construction and the two tunnels are vertically parallel while keeping the same position for the upper tunnel and finally the tunnels are parallel inclined always maintaining the same position of the upper tunnel.

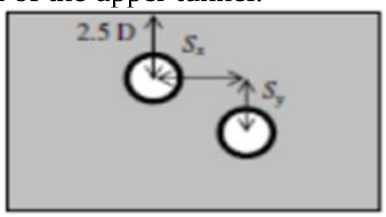

Figure 4: Spatial configurations tunnels

The profiles of surface compaction are given in Figures 3.4 and 5.L'analyse was established for a spacing between axis of 39 m corresponding to the value dx = 2.29 D for the horizontal position, dy = 2.29 for the D vertical position and d_{xy} = 2.29 D to the inclined position dx, dy and d_{xy} is the distance between axis of the two tunnels to the various configurations, D being the diameter of the tunnel.
For positron inclined this configuration has been proposed by various authors over the last decade, F.Hage Chehade et al. [5] D.Tabbal & al. [6] , with an inclination of 45 ° .To this case the second tunnel (tunnel lower) will rotate around the first tunnel (upper tunnel) the distance between the center of the d_{xy} two tunnels will be fixed at 2,29D , while the angle of inclination α will take the following values : α = 15 °, 30 °, 45 ° .In law measures section, the axis of the left tunnel (tunnel top for vertical and inclined positions) is a depth H = 17,5m under a blanket C = 9,34m . The profiles of surface compaction are given in Figures 4,5 and 6.

4.1. Results of the first sequence

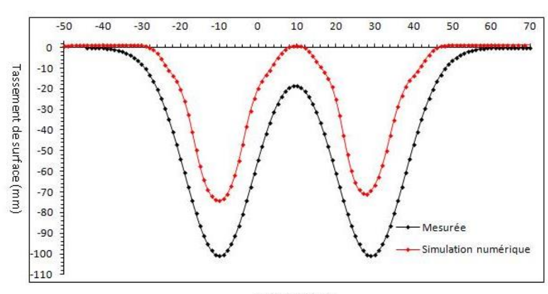

Figure 5: Settling basin to the horizontal position.

Comparing the results of the calculated deformation bowl to the horizontal position in case of digging the tunnel that measured during the excavation by the traditional method indicates that:

- The Digging TBM leads to a maximum decrease compaction and a narrowing of the lateral extension of the settlement basin of approximately 26 % compared to the traditional method.
- The Digging TBM led to a 50% decrease in the volume Vs of the surface trough compared to the traditional method

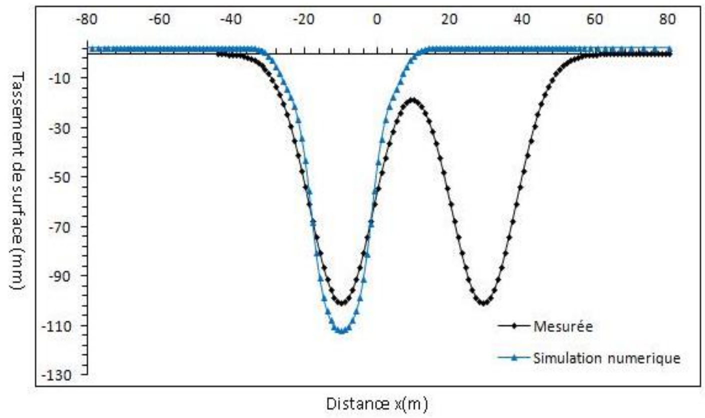

Figure 6: Settling basin for the vertical position

All the results reported in Figure 6 allows, at first, to graphically examine the influence of the excavation method. Figure 6 thus shows that the TBM excavation of two tunnels in a vertical spatial position leads to a decrease of 52% of the volume Vs of the bowl surface compared to two horizontally parallel tunnels support sites dug to the traditional method. Similarly, Figure 6 shows a certain increase in the maximum compaction of approximately 10% compared to the case of the support site and then 34% in compare with the simulation results of Figure 5 which shows a very significant impact of likely the spatial position of the two tunnels.

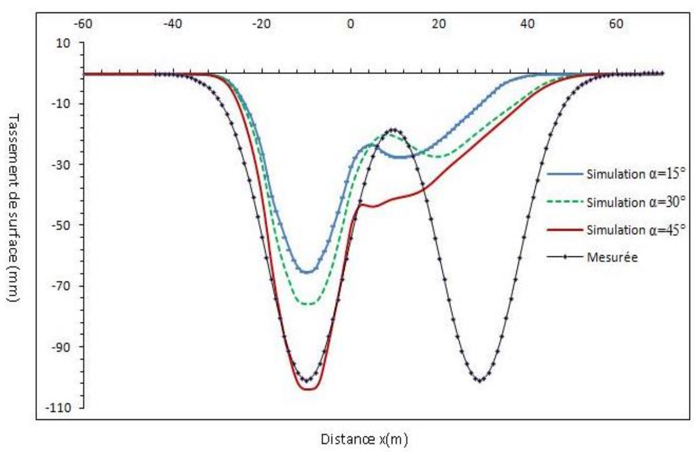

Figure 7: Cups for packing inclined positions.

Figure 7 clearly shows the influence of change of the angle of inclination of the two tunnels, the maximum settling, the volume Vs of the bowl surface and the lateral enlargement of the settlement bowl tend to increase with increasing the angle of inclination α (°) . Table 3 shows all the results obtained in our digital experience for the case of the inclined position as well as those of the support site.

Table 3: quantitative analysis of the influence of the angle of tilt and the excavation method

	shipyard Support (Traditional method)	Numerical Simulation (Digging TBM)		
		Inclination Angle		
		α=15º	α=30º	α=45º
Maximum compaction δmax (mm)	100.9	65.38	75.93	103.82
Volume Vs of the bowl surface (m2)	4.97	1.94	2.40	3.40
Side of the packing tray Enlargement (m)	98	72	81	85

4.2. Results of the Second Sequence

The use of the convergence-confinement method in numerical simulations 2D allows consideration indirectly the third dimension, that the progress of the excavation. However, the λ decontainment rate was judiciously chosen to adequately represent the state of stress in the siding [15] . The aim of this part is to quantify the influence of changing the forward speed of the second straight tube on the stability of the ground surface [13].

In the first scenario the excavation of the second straight tunnel is effected just after the excavation of the tunnel left but with a decrease in the forward speed of the right tunnel 5 and 10% with respect to the speed of the left tunnel.

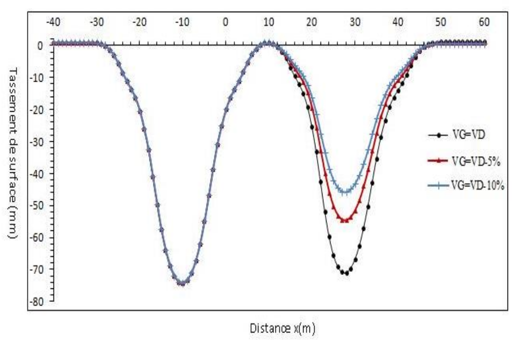

Figure 8: packing bowls.

The general shape of the settlement trough takes the form of an assembly of two adjacent pans left and right. In diminish the forward speed of the right tunnel we find the same trend for the first bowl left than predicted by the digging of the two tubes at the same speed. While the maximum compaction of the second straight bowl tends to decrease with the decrease of the forward speed of the right tunnel.

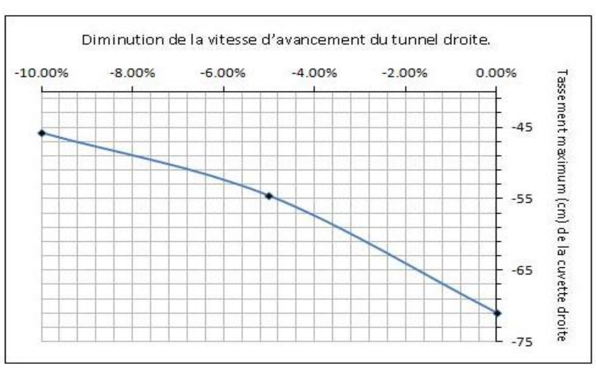

Figure 9: Influence of reduction of the forward speed of the right tunnel the maximum compaction δmax

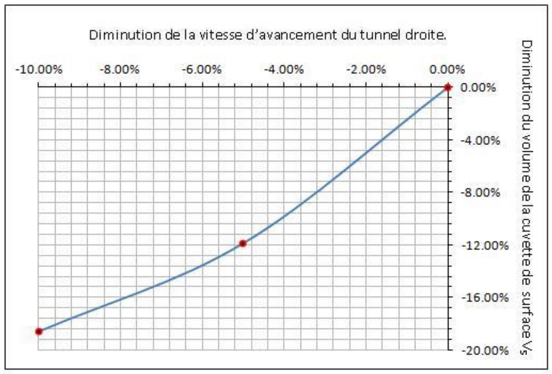

Figure 10: Influence of reduction of the forward speed of the right tunnel on the volume of the settling basin (vs)

The Figure 9 and 10 shows the change in maximum compaction (δmax) and the volume of the settling basin (vs) according to the decrease of the feeding speed of the right tunnel , the two parameters (δmax) and (vs) decreases with the decrease of the forward speed of the right tube such digital finding are framed by the results of C.Djelloul & T.Kareche [13] .

4.3. Results of the third sequence

In the second scenario the second straight tunnel excavation takes place just after the excavation of the tunnel left but with an increase in the forward speed of the right tunnel 5 and 10% with respect to the speed of the left tunnel.

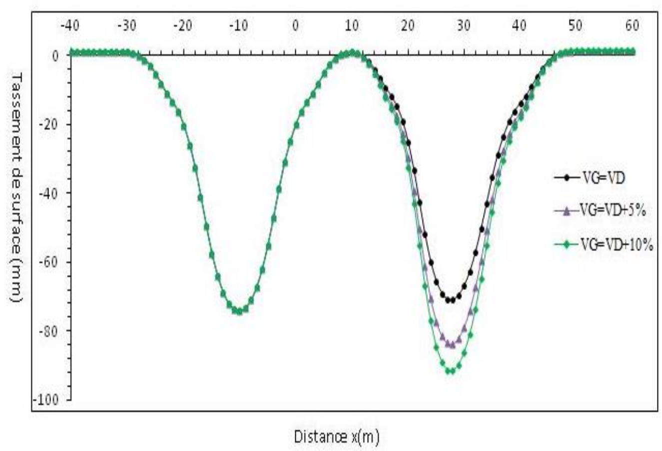

Figure 11: compaction Bowls

The general shape of the global slowdown bowl (11) takes the form of an assembly of two adjacent pans left and right. Concerning the effect of the increase in the forward speed of the right tunnel there is the same trend for the first left bowl than that predicted by the widening of the two tubes at the same speed. While the maximum compaction of the second straight bowl tends to increase with the increase in the forward speed of the right tunnel.

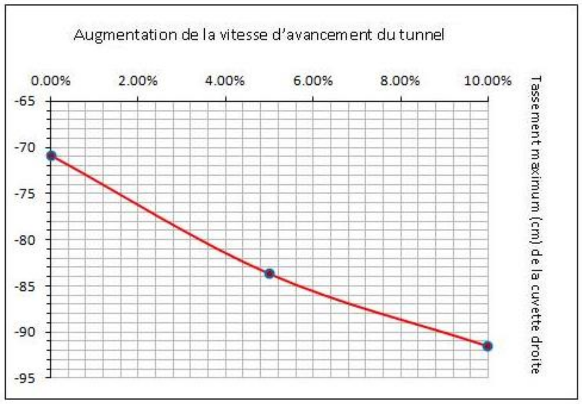

Figure 12: Effect of increasing the forward speed of the right tunnel the maximum compaction δmax

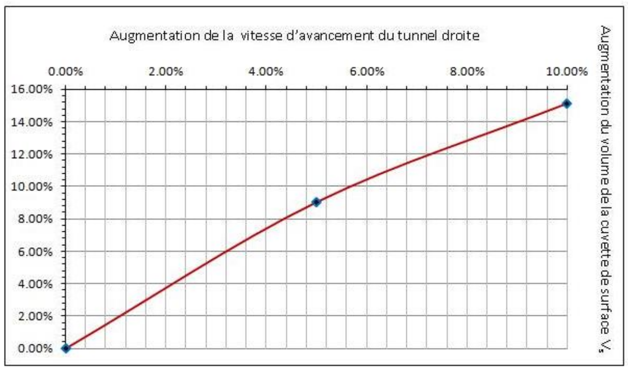

Figure 13: Effect of increasing the forward speed of the right tunnel on the volume of the settling basin (vs)

The Figure 12 and 13 shows the change in maximum compaction (δmax) and the volume of the settling basin (vs) depending on the increase in the forward speed of the right tunnel , the two parameters (δmax) and (vs) increases with increasing forward speed of the right tube such digital conclusions were also confirmed by the results of C.Djelloul & T.Kareche [13] .

5. Conclusions

Comparing the simulation results when the digging TBM (developments longitudinal settlements) for the three spatial positions (horizontal, vertical and inclined), with the records of the support site excavated by the traditional method (horizontal positions) shows that results of this comparative analysis are relevant, some or the spatial position selected digging TBM double tunnel has the advantage of less disturb the field by a significant narrowing of the transverse expansion of the packing trough and sometimes by decrease in the maximum settlement if both horizontal and inclined positions. Numerical analysis conducted in this article allows to highlight the influence of the choice of method of digging a double underground structure in soft ground, this work shows quantitatively that the correct choice of the spatial position (and the tilt nail to the inclined position) and the forward speed of the second tunnel significantly reduces the field of displacement caused by the double excavation. It is therefore appropriate to integrate the choice of excavation method, the spatial position and the forward speed at the stage of engineering design project. However, from an experimental point of view, the third criterion is difficult to implement since the range of forward speeds depends on the use and magnitude of induced phenomena in healthy ground.

However, we will emphasize the contribution of the establishment of an instrumentation adapted to implement the criterion of forward speed. Finally This analysis allowed us to identify and better understand the existing paths for good decision making between excavation method, spatial position and forward speed. Even though our results arrive too late to be used on our support site, it would provide extremely important bases for double excavations conducted in the future in the same land or similar fields.

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