

**EFFECTS OF EXCAVATION SEQUENCE AND HEADING
DISTANCE ON SETTLEMENT IN NEW AUSTRIAN
TUNNELING METHOD**

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Effects of Excavation Sequence and Heading Distance on Settlement in New
Austrian Tunneling Method

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Dedicated with much love and affection to my beloved mother and father,
and all my family who always supported me

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ABSTRACT

The shallow underground excavation may leads to ground movements and surface settlement which may cause damage to structures. Several tunnel excavation methods had been developed during the last decades to minimize the effects of the tunnel construction on the surface settlement. The Karaj Metro tunnel (KMT) had been constructed in accordance with the principles of the New Austrian Tunneling Method (NATM). This method had been used widely to construct large diameter tunnels mainly due to its flexibility to adapt different ground conditions. Tunnel designs by NATM are generally based on empirical and numerical methods and construction process may be changed according to the observed response of the ground. Induced displacements are empirically controlled by adjusting the excavation rate, distance between tunnel face and support, partial heading excavation and closure of invert. This research is aimed at determining the effects of the excavation sequence and heading distance on the surface and subsurface settlement by carrying out two and three-dimensional Finite Element Modelling (FEM). Initially, the FEM is carried out to simulate step by step excavation sequence of KMT which had been constructed in soft soils by NATM method. The settlements obtained from monitoring of KMT had been used to validate the modelling work. The results show that the settlement varies with different excavation sequence and heading distance in NATM. The Side Galleries (SG) excavation model produced the lowest transverse and longitudinal surface settlements compared to KMT excavation model and other excavation sequences. The tunnel heading distance had more effect on both the transverse and longitudinal settlements for the KMT excavation model compared to SG model. Hence, the SG excavation model with heading distance of 2 m is recommended in the construction of KMT using NATM based on the minimum settlement occurring during excavation.

ABSTRAK

Kerja-kerja pengorekan cetek bawah tanah boleh menyebabkan pergerakan tanah dan enapan permukaan, dan seterusnya boleh mengakibatkan kerosakan kepada struktur. Beberapa kaedah pengorekan terowong telah dihasilkan sepanjang beberapa dekad yang lalu untuk mengurangkan kesan kerja pembinaan terowong terhadap enapan permukaan tanah. Terowong "Karaj Metro" (KMT) telah dibina menurut prinsip "New Austrian Tunneling Method" (NATM). Kaedah pembinaan ini telah digunakan dengan meluas untuk membina terowong bergarispusat besar kerana kaedah ini sesuai digunakan untuk pelbagai keadaan tanah. Rekabentuk terowong yang dihasilkan menggunakan kaedah NATM adalah berdasarkan kepada kaedah-kaedah empirikal dan berangka, manakala proses pembinaan boleh diselaraskan menurut perubahan dan pergerakan tanah yang dipantau secara berterusan. Enapan yang teraruh oleh kerja pengorekan boleh dikawal secara empirikal dengan menyelaraskan kadar pengorekan, jarak antara permukaan terowong dan penyokongan, pengorekan separa permukaan terowong, serta pengecutan bumbung terowong. Penyelidikan ini bertujuan untuk menentukan kesan urutan pengorekan serta kesan jarak permukaan terowong terhadap enapan di permukaan dan sub-permukaan tanah dengan menghasilkan model unsur terhingga "Finite Element Modelling" (FEM) dalam dua dimensi dan tiga dimensi. Pada mulanya FEM diguna untuk mensimulasi urutan proses pengorekan secara langkah demi langkah bagi projek KMT yang telah dibina di dalam tanah lembut dengan kaedah NATM. Bacaan enapan tanah yang diperolehi daripada pengawasan proses pembinaan Terowong "Karaj Metro" telah digunakan untuk mengesahkan kerja-kerja pemodelan yang telah dilakukan. Keputusan yang diperolehi daripada kerja pemodelan tersebut menunjukkan bahawa nilai enapan tanah berubah dengan perubahan kepada urutan proses pengorekan dan jarak maju terowong di dalam kaedah NATM. Model pengorekan "Side Galleries" (SG) menghasilkan enapan-enapan melintang dan memanjang yang terendah dibandingkan dengan model pengorekan KMT dan urutan pengorekan yang lain. Jarak maju terowong memberi kesan yang lebih besar keatas enapan-enapan melintang dan memanjang bagi model pengorekan KMT dibandingkan dengan model SG. Justeru, model pengorekan SG dengan jarak pengorekan 2 m disyorkan untuk pembinaan KMT dengan menggunakan kaedah NATM berdasarkan kepada nilai enapan minimum yang berlaku semasa pengorekan.