Effect of Niche-Tunnel Face Distance and Excavation Time in Tunnel Construction

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ABSTRACT

Estimated time and costs of construction are one of the most important factors influencing the decision whether and how a tunnel is to be built. Underground excavation works carry a lot of uncertainties that effect the time and cost of tunnel construction so it is essential to make the decisions based on the past best experiences. This study has analyzed the time needed to load the muck in truck, measured in 89 tunnel faces which have different distance from tunnel face to nearest niche, measurements are done in excavation phase of 10.245,00 meters of tunnels which have different diameters varying from 4,20 to 9,40 m. Results indicate that the best distance between tunnel face and niche increase linearly the time of excavation from 0 to 200 meters and exponentially for distances longer than 200 m. It is concluded that in small and medium diameter tunnels the optimal excavation time is achieved when distance from niche and tunnel face is not longer than 200 meters.

Keywords: *tunnel, excavation time, niche –tunnel face distance*

INTRODUCTION

One of the most important factors influencing the decision whether and how a tunnel is to be built are the estimated time and costs of construction [1]. The construction time significantly influences the tunnel construction costs, because substantial part of the costs comprises of the labor and machinery costs, which are time dependent [2-3]. As the labor and machinery costs are time dependent researchers have worked to collect statistical data for the consumption of time during various different working steps within a drill-and-blast method of tunnel excavation, such as excavation, mucking out and the installation of rock bolts and steel arches support [4].

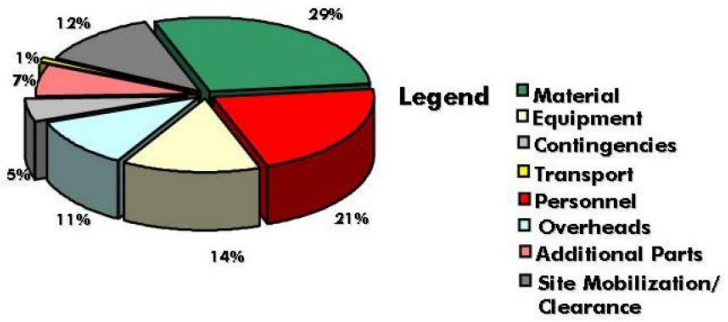

Figure 1 Typical Cost Distribution – Conventional Tunneling [3]

Drill-and-blast method of tunnel excavation typical cost distribution is shown in Figure 1, as it can be seen there the labor and machinery take 35% of tunnel construction cost.

Both labor and machinery costs are a function of time. Niche is a temporary structure build in excavation phase of the tunnel with its main function to organize and control the equipment and personnel traffic within the tunnel. The distance between niche - tunnel face and two consecutive niches is the one of the most important factor that optimizes the operational time of labor and machinery.

Tunnel excavation can be seen as a cyclic process with the main activities executed in series a schematic view of which is shown in Figure 2 [5-6]. The unit of each cycle in drill and blast method is named round and consists of successive operations, namely: drill, blast, muck and installation of primary support and their sub operational steps [7-8]. Several reports states that cost and time, estimated by the early design phases, overruns commonly in infrastructure projects that include tunnels [9]. Statistical and updated data for Albanian labor and machinery time consumption in tunnel construction projects are limited not found for some particular processes [10]. This study tend to contribute in creation of a realistic database which can be successfully implanted in existing tunnel construction time and cost models, especially for the ones planned to be built in Albania, for the time needed to load the muck in truck.

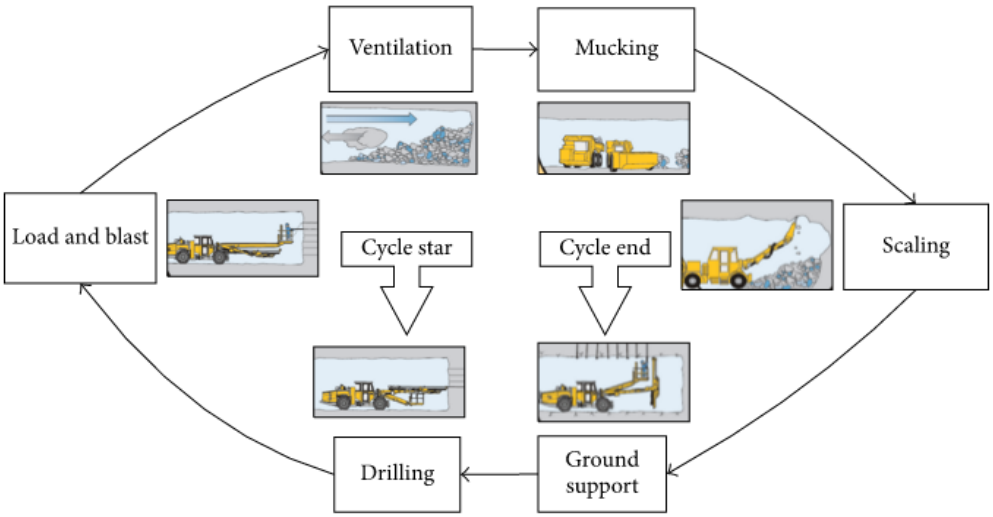

Figure 2 The drilling and blasting cycles in tunneling. [5]

TUNNEL NICHE

Niche is a temporary structure build in excavation phase of the main tunnel, commonly with the same diameter of main tunnel and length of the operating truck, with its main function to organize and control the equipment and personnel traffic within the tunnel. A typical layout of the main tunnel, niches and machinery operating within the tunnel is shown in Figure 3.

In Figure 3, A is the entrance of the tunnel, T is the tunnel face where the excavation and primary support takes place, F zone shown in red rectangular is the part of tunnel where all the equipment go and come forward, B zone shown in yellow rectangular is the part of tunnel where all the equipment go forward and come backward, N zone shown in green circle are the niches. Trucks, loaders and all other equipment used in tunnel excavation, primary and final support of the tunnel enter the tunnel in point A moves forward in F zone as shown position 1 of the truck, goes to the niche as shown position 2 due to their function the move in zone B either go directly to the tunnel face and then come backward to the niche, turn there, and take the position 3 of

the truck or turn into the niche go backward to tunnel face and then take the position 3 of the truck. There are some machines like excavator which have only forward direction of move.

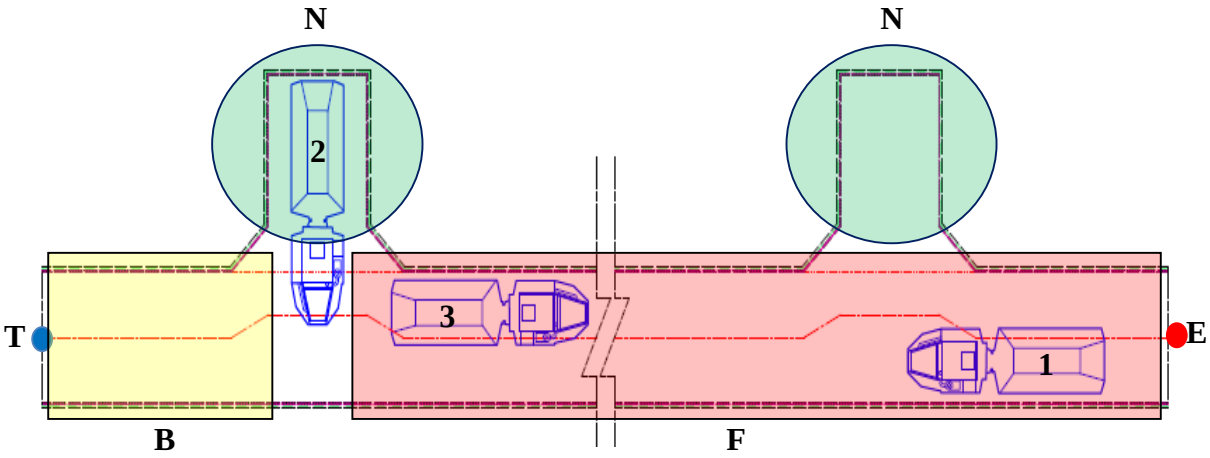

Figure 3 Typical layout of the main tunnel and niches

METHOD OF MEASUREMENTS

The vehicles used in drill-and-blast method of tunnel excavation are; jumbo and rock, which are used to drill the holes in tunnel face as well as to drill the holes for rock bolt and forepolings; excavator, which is used to remove pieces of loosened rock remaining on the tunnel roof and walls during blasting, loader, which is used to load the muck in trucks which haul it out of the tunnel face, pick-up trucks which is used for technical staff transport within the tunnel. Previous studies [7] has shown that jumbo, rock and excavator move exactly with the same velocity forward and backward, the pick-up tracks park at niches after that technical staff walks so the only equipment in which the backward and forward movement differs are loader and trucks which are used to load and haul the muck.

The truck that hauls the material out of tunnel stays on nearest niche from tunnel face and the material is transported from tunnel face to nearest tunnel niche by loader. Loader moves forward and backward in the B zone of the Figure 3, for this reason the measurement of this work are done only in this zone. The volume of material produced in a single cycle of drill-and-blast tunnel excavation method is a function of tunnel diameter and rock quality. In early stages of tunnel excavation work scheduling the calculation are done based on complete cycle. Tunnels may have different diameter and may pass through different rock qualities so the time needed to complete a cycle varies as function of this parameters. In order to enlarge the usage of the findings time in minutes needed to load 1 meter cube muck is used as unit of measurement.

To receive the results there are done three types of measurements: 1. The distance between tunnel face and nearest niche, 2. the volume of muck loaded on trucks and haul out of the tunnel face, 3. the time in minutes needed to load a specific volume of muck. The measurements of distance between tunnel face and nearest niche and the volume of muck loaded on trucks are done survey engineer using Topcon QS3M total station which has a measuring accuracy of ± (1,50 mm + 2 ppm), for our research propose this values are very small and they are neglected. Time in minutes needed to load a specific volume of muck is measured by shift engineer, responsible for any tunnel face excavation, with a chronometer having a measuring accuracy of ± 1 second, similar to distance measurement this value is very small and is neglected.

The measurement for this work are done on 89 tunnel faces which have different distance from tunnel face to nearest niche in excavation phase of 10.245,00 meters of four different tunnels which have different diameters of 4,20 m, 5,40 m, 7,60 m and 9,40 meters. According to technical specification and drawings of the project the distance between two consecutive niches is determined to be 250,00 meters so the measurements are done in the distance interval between 0,00 m and 250,00 meters. Although there are done a few measurement in a distance longer than 250,00 meters the results are not included in this paper.

RESULTS

Results of this work are presented in Figure 4, the vertical axis shows the time in minutes needed to load 1 meter cube muck and the horizontal axis shows distance from tunnel face to the nearest niche. As it can be seen from Figure 4 the results can be easy grouped in two distance interval, the first one is distance interval 0,00 to 200,00 meters and the second one is 200,00 to 250,00 meters.

In the first distance interval, 0,00 to 200,00 meters, the results shows that the time needed to load the material increases linearly with distance and it best fits with Equation 1, similar to the first interval in the second distance interval, 200,00 to 250,00 meters, the results shows that the time needed to load the material increases linearly with distance but the slope of the graph is much higher and it best fits with Equation 2, where L is the unit time in minutes needed to load one meter cube muck and D is the distance in meters of tunnel face from nearest tunnel niche.

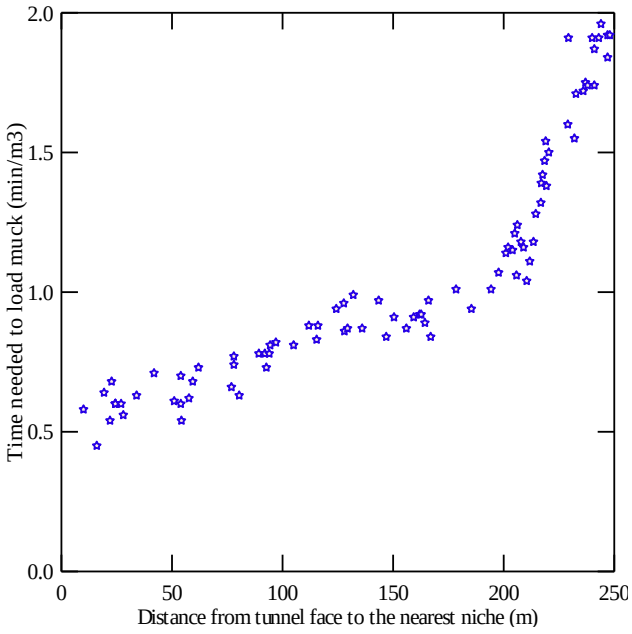

Figure 7 Time needed to load one cubic meter material in track

$$L = 2{,}50 \times 10^{-3} \times D + 0{,}53 \quad (1)$$

$$L = 1{,}89 \times 10^{-2} \times D - 2{,}73 \quad (2)$$

The time needed to load one cubic meter of material changes from 0,50 min/m^3 to 1,00 min/m^3 in the distance interval from 0,00 m to 200,00 meters in the distance interval from

200,00 to 250,00 meters the time needed to load one cubic meter of material changes from 1,00 min/m^3 to 2,00 min/m^3. In the last 50,00 meters the time needed to load the material is doubled, this is an indicator that for distances longer than 200,00 meters it is difficult to operate within the tunnel.

The length of niches, excavated for equipment movement, are commonly designed to be 5,00 meter long and same diameter with the main tunnel, so decreasing the distance of two consecutive niches from 250,00 to 200,00 meters will increase the cost of tunnel excavation at most by 0,50%.

CONCLUSIONS

Loading the muck in trucks and haul it out of the tunnel face is one the most time consuming process in tunnel excavation. This work concludes that for distances greater than 200,00 meters the time needed to load the muck is doubled, this effects both construction period and commissioning time. Cost of construction is increased due to longer equipment and labor use, commissioning time is postponed which leads to contractual penalties. Constructing the niche every 200,00 meters increases the tunnel excavation cost by 0,50% but optimize the time of equipment use. As the equipment and labor takes 35% of tunnel excavation cost, it is suggested that in small and medium diameter tunnels the optimal excavation time is achieved when distance from niche and tunnel face is not longer than 200 meters.

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