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# Tunnel lining analysis and design using staad pro

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***Abstract*— The design of tunnel lining requires a proper estimate lining forces. In engineering practice different design methods tend to be used, varying from simple empirical and analytical formulations to advanced finite element analysis. This paper begins with a review of empirical and analytical analysis for tunnel lining forces and materials, followed by the design methodology, the analytical results and the concrete design of the tunnel lining using structural software known as STAAD Pro. The scope of this research is mainly focused on the analysis and concrete design of the tunnel lining. Finally, the results obtained are carefully shown in this paper and performed by mean of two different approaches: a tunnel lining analysis and a concrete design results, showing the excellent accuracy achieved in terms of displacements, stresses, reactions, bars criteria and main reinforcement.**

***Keywords*—Tunnel lining,lining analysis, lining forces, lining design, staad pro.**

## I. Introduction

**Over the past few years,the headway of the Tunnel Boring Machines (TBM) and the advancement systems identified with these boring contraptions gave the opportunity to organize and fabricate tunnels under progressively troublesome circumstances. Nowadays, it is possible to construct tunnels under genuine conditions and at any extent of overburdens, with the probability of attaining unsuspected penetrating rates under high ground and water pressure. Nowadays, it is possible to construct tunnels under genuine conditions and at any extent of overburdens, with the probability of attaining unsuspected penetrating rates under high ground and water pressure.**

## II. Tunnel lining

### A. *Synopsis of Tunnel Lining Design Procedure*

After the planning works for the tunnel, the lining of a tunnel is designed according to the following sequence.

**1. Adherence to detail, code or standard.**

The tunnel to be constructed should be designed according to the appropriate specification standard, code or standards, which are dictated by the authorities of that particular project.

**2.Specify Geometric parameters:**

Alignment, burrowing diameter, lining diameter and lining thickness, average width of ring, segment system, joint connections.

**3.Determine Geotechnical Data**

Specific gravity, cohesion (unconfined and effective),friction angle (unconfined and effective), modulus of elasticity, modulus of deformation, Ko-value.

**4. Define Material Properties:**

Concrete class, compressive strength, modulus of elasticity, steel type, tensile strength, allowable gap.

**5. Determination of load condition.**

The loads acting on the lining include earth pressure and water pressure, dead load, reaction, surcharge and thrust force of shield jacks, etc. The designer should select the cases critical to the design lining.

**6.Kinds of Loads**

The following loads should be considered in the design of the lining.

These loads must always be considered:

(1) Ground pressure
(2) Water pressure
(3) Dead load
(4) Surcharge
(5) Subgrade reaction

**7. Design model**

Utilizing STAAD-Pro which is a capable application for investigating complex static or element structural problems. It regularly is utilized to dissect the conduct of steel, concrete, and timber structures amid configuration. Results encourage the understanding of complex connection of diverse material and parts in structures.

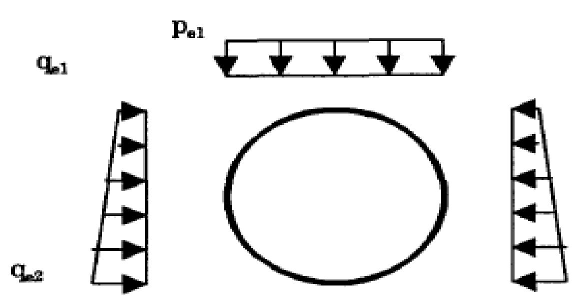


***Fig. 1 Loading on lining***

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**The aim of this research is to provide a framework for managing the engineering design process. Guidelines are provided covering most technical issues and it is intended that, combined with the engineer's judgment and experience, they give valuable assistance in the preparation of concept and detailed designs that meet project performance and safety requirements. Tunneling as an engineering discipline is unique. Traditionally it has relied heavily on experience and most lining designers came from a structural engineering background. The natural approach was to estimate, as accurately as possible, the magnitude and distribution of loads applied to a tunnel support system and then detail the lining to carry the loads.**

# III. Derivation of load acting on the lining

**General**

For the design and dimensioning of the lining the ground load and load cases such as dead load , water pressure, loads resulting from the operation of tunnel , shrinkage and creep to be considered. While most of the above mentioned load cases have been clearly defined in the literature

The ground pressure should be determined in accordance with appropriate analysis. For example, the ground pressure should act radially on the lining or be divided into the vertical ground pressure and the horizontal ground pressure. In the latter case, the vertical ground pressure at the tunnel crown should be a uniform load and, as a rule, should be equal to the overburden pressure, if the designed tunnel is a shallow tunnel. If it is a deep tunnel, the reduced earth pressure can be adopted in accordance with Terzaghi's formula (see Formula 1), Protodiaconov's formula or other formulae.

The horizontal ground pressure should be the uniformly varying load acting on the centroid of lining from the crown to the bottom. Its magnitude is defined as the vertical earth pressure multiplied by the coefficient of lateral earth pressure (see Fig. 2) the value of coefficient of lateral earth pressure to be used in the design calculation should be between the value of coefficient of the lateral earth pressure at rest and the value of coefficient of the active lateral earth pressure. The designer should decide this value considering relaxation and construction conditions. Concerning the unit weight of soil for the calculation of earth pressure, the wet unit weight should be used for soil above the groundwater

$$P_{e1} = P_0 + \sum \gamma i\ Hi + \sum \gamma i\ Hi \qquad (1)$$

### A. Lateral earth pressure at tunnel crown

As the lateral pressure various from the crown (see formula 2) to the bottom (see formula 3) of the Tunnel lining, there for a trapezoidal pressure is used for designing the horizontal pressure (Fig.1).

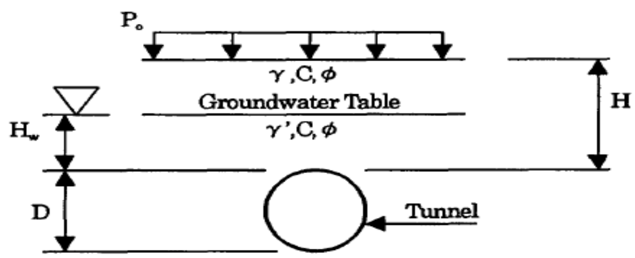


**Fig.2 Ground pressure**

$$P_e = 2\gamma' D_o \qquad (2)$$

$$P_{e2} = P_{e1} + P_{w1} - P_{w2} \qquad (3)$$

## A. *Design model*

The modeling of the tunnel lining will be model in software known as STAAD Pro which is a very powerful Structure software. The following Fig.3 describes briefly the Methodology used of modeling and designing the tunnel lining.

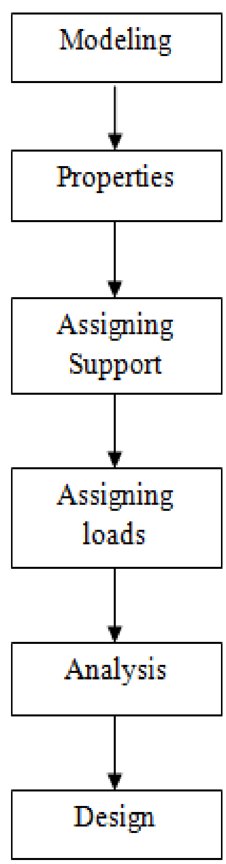


**Fig. 3 Method of modeling**

## *B. Analysis and design results*

The combination of the ground pressure, vertical pressure and the lateral pressure analyzing results is illustrated in Fig.4.This contour analysis diagram shows the maximum stresses applied on the lining due to the loading. However, all the stresses shown in the lining start from 9.58 to 15.7 N/mm2. For the concrete design and the bars criteria of the plates of the tunnel lining are shown in Table 1. This design is based on the standard code BS8110.

The design presents the advantage of providing the real structural response of a certain tunnel section by taking into account all the parameters that affect it, from the most important to the less relevant. The lining behavior obtained by the numerical model perfectly fits to the real one deduced from the test measurements. The local arch behavior and the rings displacements caused by joints and cracked sections rotations were clearly appraised.

Additionally, within this process there are a lot of secondary parameters, mainly caused by the tunnel construction process (backfill grout influence, irregular segments connections, etc.), that can affect the precision of the analytical results but should not be determinant on the behavior of the segmental tunnel lining.

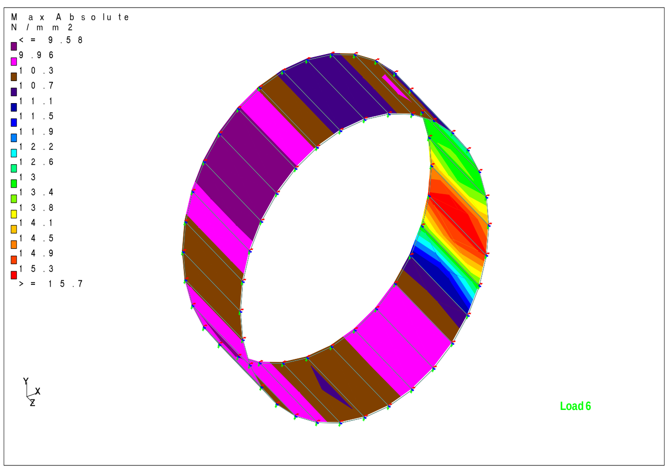


**Fig.4 Maximum Stress due to combination load case**

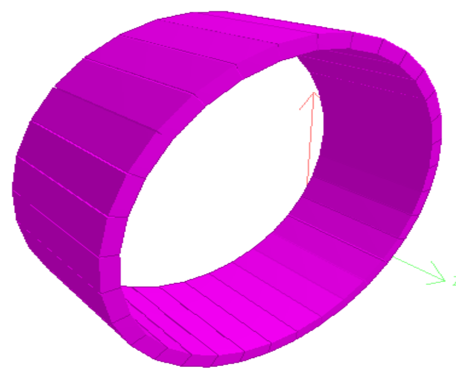

**Fig. 5 Final tunnel lining model**

**Table 1 Concrete Design Criteria of the Lining**

| | | | | |
|---|---|---|---|---|
| Top Cover | 30 | Aggregate Size | 20 | **Bar Size** |
| Bottom Cover | 30 | Concrete strength class | C28/35 | H20 |
| Envelope | Slab Design | Wood and Armer | No | H20 |
| Sampling | 0.200 m | Design Type | Fixed Bar Size | H20 |
| | | | | H20 |

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