RECENT EXPERIENCES IN THE DESIGN AND CONSTRUCTION OF TUNNELS IN THE CENTRAL AND SOUTHERN ANDES

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In this paper the design as well as the construction experiences in a series of tunnels located in the Central and Southern Andes are analyzed. The construction of all of them, except Majes – Siguas, has already been completed or is near completion, as CH Cheves, so interesting experiences that can be extrapolated to future tunnel projects have been achieved.

The following 23 tunnel cases totalizing 73 km have been included in the analysis done: - Ruta 68, 3,647 m, 82 m^2- Acceso NO Santiago, 3,305 m, form 85 to 145 m^2- San Cristóbal, 3,140 m, 75 m^2- Toquepala, 2,440 m, 35 m^2- CH La Confluencia, 23,377 m, from 26 to 36 m^2- Ch Cheves, 18,758 m, from 16 to 30 m^2- Majes-Siguas, 18,565 m, 16 $m^{2.}$

These 23 tunnels corresponds to 8 road tunnels (Lo Prado 2, Zapata 2, Manquehue 1, Manquehue 2, Chamisero, y San Cristóbal), 3 hydroelectrical projects (La Confluencia, Cheves, y Majes-Siguas) and 1 mine infrastructure project (Toquepala). Geometrically their excavation section ranges from 16 to 145 m2 and their length goes from 250 m to 11,565 m. The tunnels analyzed have been excavated in a wide range of rock masses geotechnical qualities, and the overburden ranges from 100 to 1,200 m. The following phenomena have been systematized in the analysis done:

- squeezing (high convergences)
- faces collapses
- water
- wedge failures (over excavations)
- spalling: for overburdens above 600 m topographic asymmetry problems have occurred
- rock bursts: for overburdens above 900 m rock bursts can be expected
- swelling: in clayly lithologies typical of volcano-sedimentary type formations

The experiences in the design and construction of tunnels in the Andes can draw the following conclusions:

- Support: Shotcrete thickness ranges between 5 and 15 cm. If RMR > 30 in some tunnels thicknesses up to 35 cm. Bolt length is one third of the width of the excavation. No bolts were systematically used for rock masses with an RMR lesser than 35. Steel arches placement is below RMR values of 35-45 but its installation differs by up to 10 points RMR as the overburden reaches 400 m.
- Convergences: In less than 5% of cases exceeded 2 cm, which in any case is less than a 0.5% strain. All cases of convergence exceeding 0.5% strain are associated RMR values below 40.