Indian Strategic Petroleum Reserve Limited (ISPRL) is presently constructing an underground unlined rock cavern complex for storage of imported crude oil at Visakhapatnam (India) for 1.3 MMT (million metric tons) of crude oil.

Engineers India Limited (EIL) is acting for ISPRL as the project management consultant (PMC) on the project. EIL, in turn, have employed SWECO of Sweden as foreign back-up consultant (FBC) advising EIL and ISPRL on geotechnical and operational issues specific for this kind of underground storage project.

Hindustan Construction Company (HCC) is the contractor which has been awarded by ISPRL with the construction of this scheme. HCC have appointed Geoconsult Asia Singapore (GCAS) as their design consultant to produce detail designs for all underground works and shafts. Further, Geoconsult is providing on-site engineering geologist services over the entire construction period.

The site is located under a hill to the SW of Visakhapatnam city in the Vishakhapatnam district in the Indian state of Andhra Pradesh.

The principle of storage of oil in underground rock caverns essentially employs ground water pressure for containing the oil within an unlined rock cavern complex (water curtain system). The water curtain system used on this project consists of two water curtain tunnels running parallel above each storage unit and a systematic series of horizontal boreholes, which will be used to ensure constant saturation and pressurization of the joints within the rock mass surrounding the caverns.

Geology

The district Andhra Pradesh is part of the Eastern Ghat Mobile Belt and is comprised of typical rock types of Eastern Ghat Supergroup, the Khondalite Group and the Charnockite Group. The local geological conditions of the project site are characterized by three geotechnically relevant rock mass layers of varying thicknesses. These layers can be generally described as follows:

- The top layer is varying in thicknesses of up to approx. 10m and consists of residual soil (laterite), occasionally embedded with boulders.
- The intermediate layer is weathered, jointed and fractured rock (Khondalite) with thicknesses varying from 5m to 29m.
- The bottom layer is hard, fresh and massive to jointed rock (Khondalite) Khondalites are quartz-feldspar-sillimanite gneisses, with graphite, garnet and biotite, ± cordierite. Representative is the dominant gneissic banding developed by segregated minerals allowing schistosity to develop along this segregated banding itself. The mean hydraulic conductivity of the massive to jointed rock is 1 x 10⁻⁷ m/s.

Key Design Aspects

Typical rock mass classes are derived from geotechnical assessments carried out by engineering geologists. Analysis models derived from such rock mass classes are checked with numerical methods in order to verify that excavation related rock mass deformations are adequate. Rock support classes are defined accordingly. The rock support application during construction is carried out using the Q-system. If the rock support proposals derived and justified by the design deviate from the support suggested by the Q-system, deviations are allowed and the Q-system rock support is adjusted accordingly.

In addition, the proposed rock support is analyzed using block/wedge analyses considering the effects from the various joint sets present in the rock mass and their orientation with respect to the specific tunnel/cavern/shaft structure. The results of these block/wedge analyses too, may also result in adjustments to the rock support system.

On this project, a rigorous risk management approach was implemented. This started with assessment of risks at the design stage, and was seamlessly carried over into the construction stage. A on-site risk review team integrated the risk management between the design and the construction team.

Key Project Data

The storage facility consists of two separate storage units (VUA and VUB) in the proportion of 70:30 with a total storage capacity of 1.3 MMT.

Banded Khondalite
The caverns within each storage unit are connected to forming legs in a U-shaped arrangement in plan. The three cavern legs of the larger storage unit are 820m long. The smaller unit comprises of 2 cavern legs which are 320m long, respectively. The cavern cross section is generally about 30m high and 20m wide.

The product intake is located at the end of one leg and the pump installation is located at the end of the other leg. Therefore, one pump shaft and one inlet shaft will be provided for each leg of a particular storage unit. This is resulting in two product inlet shafts and one pump shaft for Storage Unit A and one inlet shaft and one pump shaft for Storage Unit B. While the crude storage caverns are built underground by rock excavation using conventional drill & blast method, all its associated operation facilities will be located above ground.

For construction purposes, access tunnels with a total length of 1400m will be constructed. The access tunnel was designed to allow the use of heavy excavation equipment. The access tunnel is excavated from the inner part of the valley within the project area, separated from the shafts and the surface installation area. This layout minimizes the transport distance to the rock disposal area and eliminates disturbances to shaft construction and the installation of the above ground facilities. The access tunnels are generally made at a 1:8 slope and horizontal in curves. The main access tunnel is designed to allow for two way traffic of heavy plant during construction.

Geoconsult’s Services
For the project Geoconsult provides the following:
- Complete engineering design of the storage underground works of the scheme including tunnels, caverns, slope works, shafts, plugs, etc.
- Instrumentation and monitoring plan and on site interpretation of geotechnical monitoring results
- Geotechnical design manager
- Engineering geologists for on-site geological/geotechnical documentation and rock support recommendations during construction
- On-site design engineer and co-ordinator
- Risk management facilitation
- General consultancy services during construction

PROJECT:
STRATEGIC CRUDE OIL STORAGE PROJECT IN UNDERGROUND CAVERNS
TYPE OF PROJECT:
Design engineering, consultancy and geological and geotechnical documentation and interpretation
LOCATION:
Visakhapatnam, Andhra Pradesh, India
OWNER:
Indian Strategic Petroleum Reserve Limited (ISPRL)
CLIENT & CONSTRUCTOR:
Hindustan Construction Company (HCC)
PERIOD OF SERVICES:
2008-2011
CONSTRUCTION TIME:
3 years
PROJECT COSTS:
Approximately US$ 100 million
PROJECT DATA:
Capacity of oil storage caverns: 1.3 million metric tons
Total cavern lengths: 3 x 820m and 2 x 320m = 3100m
Cavern heights and widths: 30m and 20m
Total length of access tunnels: 1400m
Total lengths of water curtain tunnels: 1140m