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Geo-engineered slope failure at the power house pit of a power project in the Himalayas, Himachal Pradesh, India – causes and remedies

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A geo-engineered slope, called southern wall, of a depressed and E-W aligned power house at 412 MW Rampur Hydroelectric Project in the state of Himachal Pradesh, India completely failed for its entire length of 111m on 2nd February 2010 (Figure 1) along with a 6m high cantilever retaining wall founded on rock at the top of the cut slope. The height of the cut slope in rock varied from about 13m in the middle to 20m at its eastern and western ends at the time of failure. About 20m deep power house pit, on the right bank of westerly flowing Satluj river, has been constructed within the thinly foliated carbonaceous phyllite (Kullu Group of Proterozoic age) trending parallel to sub-parallel to the power house alignment and dipping steeply towards north. There is a narrow rock ledge (20-30m wide) between the power house pit and the river, where a 10.5m diameter collection gallery tunnel has been accommodated. Southern cut slope of the power house pit was considered vulnerable to planer failure along prominent foliation joints. Accordingly, the designers incorporated this aspect in the design for protection of the wall, taking into account the orientation of the anticipated plane of failure. During the excavation of the pit, deformation/ movement of the rock mass was initially observed in August 2009, which increased with the passage of time. Keeping this in view, design was modified by incorporating enhancement of protection measures and strengthening of the rock mass. While measures to strengthen the rock mass and to contain its movement were at the execution stage, the whole length of the southern wall failed including the retaining wall at the top of the cut slope.

On analysis of the available pre- and post-failure data, reasons worked out for the failure were found to be the gentler dip (observed after failure) of the plane of failure than anticipated, i.e. adversely oriented foliation joints along southern wall of the pit, poor nature of rock mass, day lighting of the foliation joints on the cut slope, non-crossing of the installed rock bolts beyond the actual failure plane and possibly the blast vibrations due to excavation of collection gallery. Suggested remedial measures for the restoration of the structure include completion of all excavations (requiring blasting in and around the pit) without disturbing the slide debris, protection of the rock slope above the slide material by shotcrete and rock bolts, toe support at the base and excavation of collection gallery without blasting, etc.

Figure 1: View of failed slope and retaining wall