# Slope Failure on Taiwan Highway No. 3

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## Overview

Freeway No. 3 in Taiwan is a North-South freeway beginning in Keelung City in the North and ending in Pingtung. Near a town called Xizhi, close to the northernmost part of the freeway, two overpasses needed to be built. A hill between the two overpasses was excavated to allow the highway to pass through. The cut ended up being 35 meters deep at the deepest point. The width of highway needed to accommodate eight lanes for the length of 155 meters in which the highway is on the hill. During the construction an analysis of the slope was performed and it was determined that 572 rock anchors (or bolts) needed to be installed to support the slope with each bolt prestressed to 590 kN (60 metric tons). The slope behind the retaining wall was split into three tiers, the bottom two slope tiers had a gradient of 1:1 and the top slope had a steepness of 1:1.5.

On April 25, 2010, the slope failed and this stretch of highway was covered in almost 200,000 cubic meters of debris, causing five deaths and four cars to be covered with debris. Investigation of the failure concluded that the slide was caused by a combination of weakening of the thinly laminated sandstone and shale and corrosion of the anchors. The slope mass slid down along a four to five meter thick soft shale layer underlying the slope.

At least three possible failure mechanisms were considered for this particular case: construction in 1998 involving toe excavation, which caused strength reduction in the sliding layer and greater loads on the anchors; groundwater infiltration and other weathering causing strength reduction of the overlying rock mass; and corrosion and the aging of ground anchors causing the anchors to corrode and fail. Field investigations after the slope failure showed that only 58 anchors remained in place after the slope failure. Forty-eight percent of those remaining anchors showed a fracture of steel strands, meaning that the anchors provided less than 10 percent of the original reinforcement.

Using the data from the 1995 slope design and not considering spatial variability in $\tan(\Phi)$ of the soft shale layer, the slope had a probability of failure of approximately 1 percent, which is acceptable given the risks associated with the slope. However, if spatial variability is considered and the data collected after the slope failure is used, then the slope has approximately a 20 percent probability of failure when including all of the anchors and over a 50 percent probability of failure if the anchors are neglected. Both of these probabilities are in the hazardous range. Not accounting for variability in the materials on site in the original design is the most likely cause of this slope failure.

### References

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