**Case Study: Oso, Washington Landslide**

CEEN 544: Seepage and Slope Stability

## Introduction

A significantly large landslide wiped out the Steelhead Haven Community near Oso, Washington, along the North Fork of the Stillaguamish River on March 22, 2014 snatching the lives of 43 people and causing a damage of around $12 million as reported by the state authority. This is the deadliest landslide ever occurred at the slope near Oso located at the elevation of 270 m on the north side of West-trending valley of the Stillaguamish River.

## Geology and Subsurface Profile

The height of the slope was approximately 200 m and the width of Stillaguamish River Valley floor was from 2 km to more than 6 km. The slope was developed from continental glacial terrace deposit. The subsurface profile from the top of the slope consists of few distinct layers e.g. Recessional outwash (40 m thick unsaturated cohesion-less fluvial deposit of medium dense fine sands), Glacial till (21 m thick unsaturated stiff consolidated soil stratum), Advanced outwash (30 m thick medium dense coarse sand and sandy gravel), Advanced gacioclaustrine (approximately 82 m thick medium stiff low to high plasticity clays and silts) followed by a fine to medium grained and gravel layer. In the downstream side there was loose saturated colluvium deposit.

## Failure Analysis

This landslide occurred primarily due to intense rainfall for 21 days prior to March 22, 2014. During this high precipitation groundwater and runoff increased and resulted in the initiation of two phase failure mechanism. As per the 2D limit equilibrium analysis and field observation it is concluded that in the first phase there was a slide mass which impacted the saturated softened colluvium strata along the downstream side of the slope. The failure surface was obtained to be a compound slip surface passing through all the soil profile along the face of the slope. Rapid downward movement of the slide mass caused the colluvium strata to undergo a massive loss of undrained shear strength and get liquefied. This initial slide mass in first phase removed the support to the upper side of the slope leading to another mode of failure in phase II. Based on a limit equilibrium analysis a compound failure surface was obtained passing through the outwash sand, glacial till and upper portion of glaciolacustrine clay deposit. This failure exhibited a frictional behavior forming large landslide blocks instead of a flowsilde as observed in first phase.

Two different analysis was performed in UTEXASED as well to analyze the two stage of failures separately. In both the cases factor of safety has been obtained less than unity with compound failure surface which is quite consistent with the failure surface obtained earlier.

## Conclusion

This 2014 landslide was historically different in nature than the preceding landslides which took place in earlier history as they were primarily due to the river erosion. But in 2014 incident, massive rainfall was an important factor instead to cause the disaster. Large slide mobility causing liquefaction of colluvium deposit and further leading to a second stage failure makes the incident extremely significant and interesting for the researchers in the field of geotechnical engineering.

## References

Stark, T. D., Baghdady, A. K., Hungr, O., & Aaron, J. (2017). Case Study: Oso, Washington, Landslide of March 22, 2014—Material Properties and Failure Mechanism. *Journal of Geotechnical and Geoenvironmental Engineering*, *143*(5), 05017001.