HOW TO PLAN ROUTE TO REDUCE THREAT FROM SUBMARINE MASS WASTING?

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Abstract: Submarine mass wasting, defined as the large movement of rock, sand, regolith and debris downward, occurs as mainly submerged landslides, mass flows and creep. Causes of submarine mass wasting includes earthquakes, volcano, storm surge, sedimentary input, over-steepening of the slope and tectonic activity.

Submarine mass wasting is one of the main natural hazards to subsea telecommunication. In general, optimize cable route and upgrade cable armour are common methods to reduce threat from mass wasting. However, systematic analysis for cable breaks caused by submarine mass wasting will be helpful for planning a new route.

The goal of this paper is to raise the awareness of cable fault caused by mass wasting. This paper will discuss cable fault mechanism by mass wasting. Then this paper provides suggestions for route planning facing mass wasting.

1. SUBMARINE MASS WASTING

Submarine mass wasting (also known as mass movement), defined as the large movement of rock, sand, regolith and debris downward, occurs as mainly submerged landslides, mass flows and creep. Submarine mass wasting events often have a trigger, something that causes sediment movement to occur at a specific time, such as earthquake shaking, volcanic eruption, storm waves or rapid stream erosion.

Mass movement is mainly distributed in open continental slope, river deltas on the continental shelf, submarine canyon-fan system where there are slope, sediment input and triggers (Figure 1). Besides, subduction zones are among the most frequently affected by these catastrophic events especially earthquake and volcanic eruption. Booth et al. research for USA Atlantic margin shows that landslides in open slope and canyons account for 47% and 37%, respectively (Figure 2) [1].

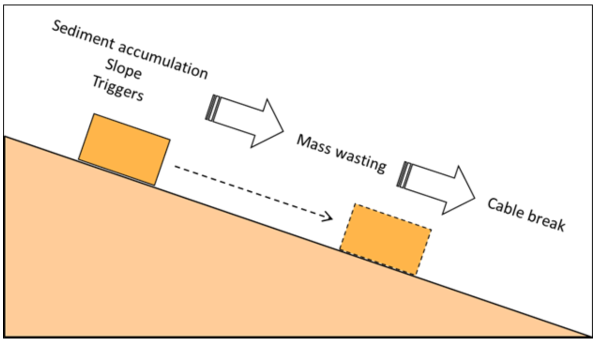

Figure 1: Sketch Map of Mass Wasting

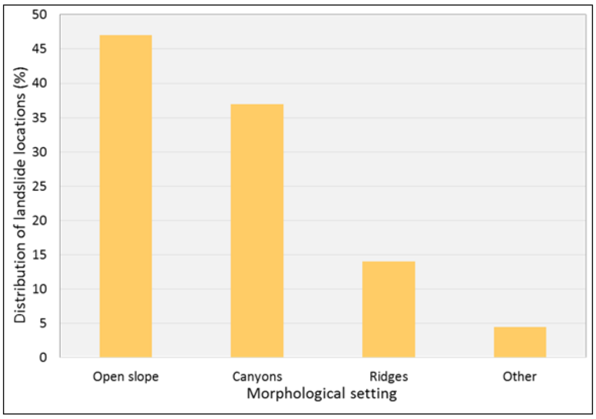

Figure 2: Distribution of landslide locations for the same sites [1][2]

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Submarine mass wasting may occur in areas where there exists sediment or rock accumulation, slope and triggers. Sediment can be provided by adjacent rivers and former mass movements. Triggers can mobilize sediment or rock in a scarp area. For example, as one of the most important factors, earthquake can cause seismic shaking of the earth where the shake not only causes density flow but also conditions the seabed for failure in the future. The trajectories of mass movement is controlled by complex seafloor morphology. Large slope scarps of tectonic origin may increase instability of local sediment. The scarps are preferential sites for submarine landslides. Some continental slopes are incised by several canyons and gullies. Numerous canyons and valleys provide mass flow with ideal paths. Sometimes, seabed slope with small gradient even less than 1 degree also can trigger mass movement.

2. CABLE BREAKS CAUSED BY MASS WASTING

Submarine mass wasting can not only induce tsunami causing property damage and casualties onshore but also cause damage to offshore infrastructure like platform and submarine cable (Figure 1). It has been reported that submarine mass movement especially landslides and turbidity currents results in cable breaks since 20th century. For instance, during 1929 Grand Banks earthquake, twelve cables broke same time as earthquake shock, one hour later another eleven cables broke as a result of landslides triggered by earthquake [3]. 2006 Pingtung earthquake of southwest of Taiwan Island triggered landslides resulting in 22 cable breaking [4]. By the way, analysis of breaks in transoceanic communications cables promotes the research of active underwater geo-hazards (e.g. landslides and turbidity currents).

2.1 CABLE BREAKS STATISTICS

Around 150~200 cable breaks are recorded each year [5]. Main sources of hazard to cables can be classified as either human or natural. Fishing or anchoring are the primary human hazards, while sediment mobility and submarine slides are the primary natural hazards. As figure 3 shows, geological faults accounts for about 10% which are mainly attributed to earthquakes and turbidly slides in which at least one-third of breaks occurred in the seaward of the busy continental shelf and upper continental slope (Figure 3)[4][6].

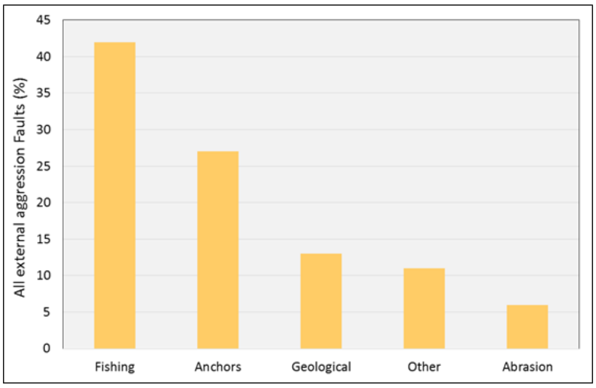

Figure 3: External aggression faults for all water depths (GMSL) [6].

2.2 CABLE BREAK BEHAVIOURS CAUSED BY MASS WASTING

Some submarine cables can't avoid mass wasting areas. They have to run across or along these areas. Sometimes, it is possible that a submarine landslide, which probably originated along one of the seafloor scarps, is at the origin of cable breaks either directly or indirectly by transforming into a turbidity current. There may be more than one turbidity flows causing cable breaks with different time periods and wide geographic span. Mass movement path and location of cable break depends on morphology, roughness and irregularities of the seafloor. It is not easy to analyse the threatening to submarine cable from mass movement with complex triggers, frequency, and behaviour of sediment density flows.

Earthquake and volcano eruption can shake the earth and trigger landslide. Submarine landsides can produce tsunamis that inundated coastal area and cause large deaths. It is plausible that the main shock can not only trigger a sediment density flow but also condition the seabed for failure under the weaker aftershocks. This will cause sediment re-deposition and in the future this kind of sediment will be a risk.

Submarine mass wasting has a large impact extent on submarine cable. Main flow in 2006 Pingtung earthquake travels at least 246km along the canyon and the deepest water depth is more than 4000m [4]. 2003 Boumerd`es earthquake triggered large turbidity currents responsible for 29 submarine cable breaks at the foot of the continental slope over 150 km from west to east. Its impact range extends from the continental slope to the abyssal plain [7]. In some cases, mass movements have multi-source and multi-path character with larger impact scale.

Various types of threats which may affect submarine cables to varying degrees, depending on their depths as they traverse the ocean floors to worldwide landing stations. Fishing, anchor dragging and dredging mainly happens in less than 40m water depth. However, landslide can occur in a wider depth range from inner continental slope (100m water depth) down to the abyssal plain (several kilometres water depth) [8]. After slope failure happens, its power will slow down and stop in flat abyssal plain. But during sediment movement, sediment re-deposition in some relatively gentle slope will be a potential risk in the future. If another driving force happens and its stresses exceed the shearing resistance of the sediment or rock mass, another mass wasting will possibly happen.

One serious mass movement will result in many cable breaks over a period of time which causes great losses to international communication. One earthquake may induce several mass movements as aftershocks will occur following the main shock. Sediment re-deposition and seabed feature reshaping are potential trigger in the future. It is not easy to identify and distinguish the traces of recent earthquake from other previous events.

Due to the erosion of turbidity currents and landslides, cable locations where the cables will be recovered may be shifted some kilometres offshore which increases difficulty of cable recovery.

3. REDUCE THREAT FROM SUBMARINE MASS WASTING

Given the current economic climate, new cables must be installed in the most cost efficient way whilst maintaining a sufficient level of protection against damage. Mass movement activities are complex and discrepant in the subaqueous domain. Although it is difficult to predict accurate time and collapsing force of mass movement along the cable route, it is necessary to try to optimize cable route to decrease the risk.

3.1 AVOID WHERE IT IS POSSIBLE

Avoid the areas where there is recorded or potential geo-hazards. These areas includes steep continental slope, river estuary, earthquake and volcano zone, canyon, erosion area, outlets of submarine valleys and in areas of turbiditic levee overspilling. With the increasing construction of submarine infrastructures, subsea space is becoming more and more congested. Whether or not it is feasible to avoid the geo-hazard area without obvious increase in cost.

In some cases, a new cable route can't avoid areas listed above or it will increase cost if we try to avoid. How to balance the feasibility and cost between a new planned route ? Reducing slope gradient, increasing distance from source or run-out, and widening of the flow path will slow down the

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density flow. Thus, the route crossing far border of canyon may be selected where the flow speed will be slow and it can increase the survival rate of a new cable system. The 2003 Boumerd`es earthquake gives us this lesson that after earthquake occurs, only the most distal cable, COLOMBUS3, located in the abyssal plain, 80km away from Algerian coast, remains operational (Figure 4) [7]. COLOMBUS3 route extends from east to west and doesn't land in Algeria. Keep enough distance away Algerian cost doesn’t increase the route length.

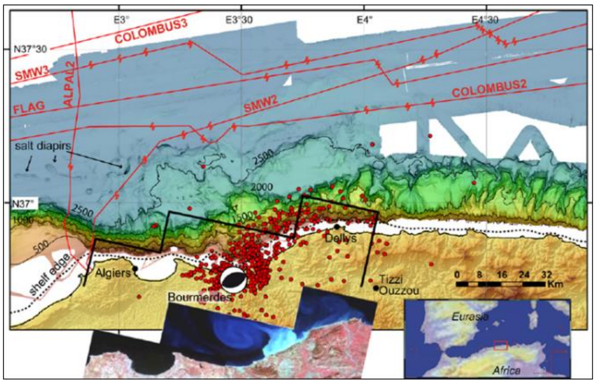

Figure 4: Cable break distribution (red symbols) after the 2003 Boumerd`es earthquake in the central Algerian margin. Red circles represent the location of the associated aftershocks. Only the most distal cable, COLOMBUS3, located in the abyssal plain, 80km away from Algerian coast, remains operational [7].

3.2 ROUTING PERPENDICULARLY TO SLOPE AND ARMOURING

In general, if a new planned cable route can’t avoid region where mass wasting has occurred before, a route perpendicularly to slope with shorter distance will be acceptable to decrease the risk from a potential mass movement in the future. The other common method to protect a cable is armouring. Although we can’t stop cable failure by using armour, armouring can prolong the life before failure. However, if water depth exceeds depth limit for armour cable, we have to use weaker cable instead like lightweight protected cable.

3.3 HISTORICAL RECORDS

When planning a new route in a specific area, the following historical records of mass wasting and cable breaks are useful for our consideration.

(1) Submarine mass wasting: Time, frequency, impact extent, result in cable breaks or not.

(2) Cable breaks: Time, location, frequency, quantity of cable breaks.

(3) Causes: sediment source, triggers (earthquake, volcano, landslide, tsunami, typhoon, river flood, turbulence associated with internal and surface wave activity), topographic features (slope gradient, scarps and canyon distributions, border position of continental shelf, abyssal plain, water depth variation, behaviour of mass flows). These information helps to plan a route more reasonably.

In the initial phase of route planning, detailed archival material or data should be collected before starting the marine survey. Accumulation knowledge of submarine mass wasting is required to interpret survey data during the survey period. It helps to allow a detailed study of seafloor morphology and the identification of submarine canyons and steep scarps. Collect more accurate bathymetry data may be used to give an estimate of the driving stress field, because the gravity-induced shear stresses vary with steepness.

Besides, frequency of mass wasting and cable breaks is also a consideration. Crossing a canyon/channel system where the probability of a density flow is one per century may be an acceptable risk for a fibre-optic cable with a design life of around 25 years [4].

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3.4 DATABASE CONSTRUCTION

With the increase of communication demand, more subsea telecommunication systems will be installed. In areas with active tectonics, earthquake and volcanic belt, steep slopes, submarine canyons and river estuaries, there is risk of mass wasting to submarine cables. Submarine mass wasting and cable break behaviour are different around the world. Records including mass movement and cable breaks in these regions should be collected. Besides, if possible, high resolution bathymetric data, seismic reflection profiling, seafloor visual observations and stratigraphic analysis of sediment cores by researcher or other institutions are also useful for our consideration when planning a new system. Such data analysis can be found in some academic papers. However, there may be commercial and security considerations for owners of database. Database construction for mass wasting and corresponding cable failure will be helpful in future route planning.

3.5 MONITORING

Mechanism of submarine mass wasting is very complex. Thus, it is difficult to monitor the mass movement in real time. Currently, seabed topographic feature is investigated by bathymetry or sonar data collected in a specific region after mass movement occurred. However, monitoring of earthquake or volcano activities, river discharge, tsunami, typhoon and human activities is significant for the safety of not only human life and property but also submarine infrastructure including fibre-optic cable.

4. CONCLUSION

Submarine mass wasting is one of the main natural hazards to subsea telecommunication cables. A severe mass failure can result in dozens of cable breaks. It's better to balance the feasibility and cost of the new system to assess how to avoid mass wasting areas. Routing perpendicularly to slope and armouring when crossing mass wasting regions are acceptable in some cases. Historical records of mass wasting and cable breaks will be helpful for our consideration. Monitoring of earthquake or volcano activities, river discharge, tsunami, typhoon and human activities is required for safety of not only human life and property but also fibre-optic cable. Database construction for mass wasting and corresponding cable failure will be helpful in future route planning. With the increasing communications traffic, the subsea space is much more congested than before and a new cable system has to face challenge of mass movement. Awareness of cable fault caused by submarine mass wasting should be raised.

5. REFERENCES

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