SHORELINE EROSION AND IMPACT TO CABLE PROTECTION

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Abstract: Shoreline erosion has long been an important consideration for infrastructure development along coasts and shorelines around the world, and the significance has only increased. Property and structures along coastal area are subject to the forces of increased sea levels, high wind and waves, current, and sediment transport. In this paper, we discuss the issue of beach erosion with respect to telecommunication cable landing sites and cable protection over the life of the system. Recent experience in South America and other regions are used to illustrate the problem, influences, and mitigation measures that are being considered to address the problem at specific beaches and landings.

1. INTRODUCTION

The shallow water approach and beach landing portions has historically been one of the most commonly ignored, yet one of the most important aspects of any submarine cable system since the first ocean cable made landfall. These shallow water cables are among the most difficult to repair. Traditional deep-sea jointing techniques are cumbersome to perform on small vessels used for shallow water repair while terrestrial joints are not suitable in an area that might spend equal time being wet or dry. Repairs typically require a merging of marine and terrestrial tools & technology to repair or replace the shallow water portion of the existing system. This has proven to be a risky and expensive process with multiple variables. Minimizing or eliminating the risk to shallow water cables is of primary concern.

Shore-end cables are subject to unique external aggression not found in any other area of the submarine system. These range from typical commercial vessel activities such as anchoring, to sport and commercial fishing all the way to tourist beach activities. Initially, most systems are engineered and installed to robustly meet these challenges without impact to the system reliability. For example, a vehicle driven on the beach poses little or no threat to a submarine cable system buried 2 meters below. However, should this protective barrier be removed by coastal erosion, the system reliability is now in jeopardy.

2. ENVIRONMENTAL INFLUENCES

Beaches and shorelines impacted by waves, currents, and seawater levels will adjust to these forces by redistributing sand along the coast. Changes to the outflow of rivers crucial to the supply of sediment to beaches affect the shoreline position and elevation. Other structures such as jetties, groins, port development, river dams, and seawalls all affect the natural transport of sediment and movement of the shoreline. Changes to the coastline to improve a situation for one land owner may have negative impacts further down the beach. Periodic events such as La Niña and El Niño in the Pacific Ocean alter sea levels, increase winter storm strength and increase wave energy impacting shorelines. Changes in rainfall in turn impact the sediment supply from rivers that replenish beaches. Erosion experienced at specific cable landings is part of a global problem of changing sea level and weather patterns. [1].

This is demonstrated by the current trend to fortify the beach-front in an attempt to control the loss of beach and property. This trend results in "low tide only" beaches like those seen in Jeddah, KSA. In this location, the severe erosion issue was addressed by installing vertical seawalls with large riprap to break the wave action, reduce wave reflection and reduce sand loss. While seawalls protect property behind the lines, they do nothing to protect the beach; even with riprap some wave energy is still reflected and carries sediment offshore.

However, leaving a beach to its own natural erosion is not the answer either. The cable landings along the coast of Lagos, Nigeria experienced severe erosion in 2011 with the destruction of Alpha Beach. Everything on the seaward side of the access road was washed away during heavy storms. This included homes, businesses, infrastructure and large parts of the road. [2] [3].

While deeper burial and reburial of subsea cables may serve as short-term protection in many cases, it may not always address the root cause of the problem or prevent future exposures.

3. SEDIMENT TRANSPORT

Before we can propose solutions, we must first attempt to understand the specific process behind the movement of the sediment that creates, defines, and maintains the beach at a specific cable landing. The primary influence is waves. Scott Douglas stated in "Saving America's Beaches" [4] that as a wave moves into shallower water the circular movement transitions into an elliptical shape with a back and forth surge along the bottom as each wave passes. As a wave reaches a water depth that is approximately half its wavelength, it begins to "feel" the bottom. The size, shape, speed and even the direction can be altered. The waves eventually break, transferring their momentum into turbulence causing sediment to become suspended and carried offshore or alongshore by the wave induced currents. This transport of sand can be all in one direction or the direction can change over time depending on location, wave heights and wave direction. The result can be either accretion, where the beach is restored with new sand or else increased erosion. Typically sand is carried offshore in winter and back on shore during summer when waves are smaller. Waiting for summer waves to transport sand inshore to cover exposed cable may work at some landings and in some seasons, but it does not work all sites and is not a reliable means of cable protection.

4. PROTECTION REQUIREMENTS

Fortunately there are several cable protection options available to the cable owner during the planning and installation phase. Cable armoring, articulated cable armoring (split pipe), burial, deep burial, conduits, concrete encasement, horizontal directional drilling, mattressing, rock dumping and others are methods of increased cable protection which improves upon network reliability. However, each has an inherent upfront cost during the installation phase. Each option and cost is reviewed and evaluated to determine if the measure is required and will provide adequate long-term benefit to the system.

One may be tempted to simply recommend Horizontal Directional Drilling for all Submarine Cable landings. While this technique does provide unparalleled protection through the encasement of the cable in a steel pipe well below the level that would normally be impacted by erosion or most surface aggressors, it is also often a more expensive option and the operation simply does not fit all budgets and locations.

5. CASE STUDY

Changes in weather, changes in the amount of sediment available to the shore line, and new construction can all have future impact to a landing site. In addition, neighboring properties may exacerbate the problem through good intentioned efforts to slow the erosion.

This appeared to be the situation in a case study location in South America. The location has been a very popular surfing destination for many years. (Figure 1). During storm conditions plunging breakers are constant and dramatic, greatly changing the beach profile.

Figure 1: Plunging Breakers

The Beach Manhole (BMH) was located 79 meters landward of mean low water in an area of low vegetation and adjacent to a local hotel. (Figure 2)

Figure 2: Landing Site 2007 prior to development

There were existing conduits from the BMH to a small anchor block located 36m seaward of the BMH. After the cable was landed, split pipe was applied to the cable to a position well offshore. The cable was then buried to 3m below grade, transitioning to 1m below grade at mean low water. (Figure 3)

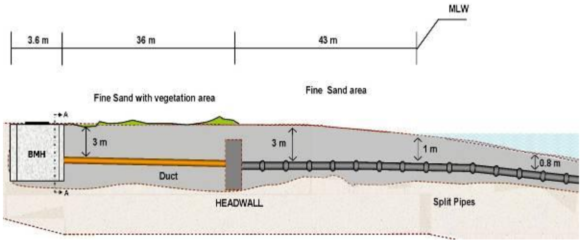

Figure 3: Initial conduit and split pipe installation

The beach began showing signs of severe erosion in late 2008 with loss of much of the surface sand. The loss of sand and the development of a small wave cut cliff did little to slow the development near the beach. Houses were built and over time properties were expanded seaward. (Figure 4)

Figure 4: Wave Cut Cliff Face Forming Near Landing Site

As the beach continued to recede, property owners constructed cement walls and filled sandbags in an effort to protect their property from the continued erosion due to wave action and transport of covering sediment. (Figure 5)

While some of these efforts seemed to provide temporary relief, the majority did not and some accelerated the erosion process. Sand bags were washed out to sea and vertical seawalls reflected the waves accelerating the erosion of the foreshore and at the ends of the seawall.

Figure 5: Vertical seawall reflects wave energy but does not dissipate, exacerbating erosion

After numerous cable exposures, the cable owner contracted an investigative erosion study. The cable owner and contractor collaborated with an expert in beach erosion to study and provide a comprehensive report on the specific site history, potential and means of mitigation. The study investigated the exposures which occurred between late 2008 and 2012. The study reported that the primary supply of sediment was most likely from the rivers that run high during rainy seasons but may not flood without El Niño events. There is typically little rainfall in this region; however El Niño conditions can lead to significant precipitation, frequently resulting in flash flooding. The area has a semitropical and dry climate, with an average of 60% relative humidity and more than 300 sunny days on average per year. The rainy season typically extends from December to May, with very little precipitation occurring over the remaining six months.

The effects of El Niño on the region are well documented. Rainfall follows the warm water eastward and creates flooding along Peruvian, Colombian and Ecuadorian coasts. This flooding fills the dry runoff riverbeds washing the build up of sediment down from the highlands and out to sea and replenishing the sediment that had been displaced by the long shore current. Without this supply, beaches all along the coast are starved of sediment.

To understand the local coastal processes, several analysis methods were employed using historical wave data that could be correlated with cable exposure events.

It appears as though the erosion experienced at this landing site is predominantly a natural phenomenon. The lack of any manmade structures rules out anthropogenic causes. The rate of sea level rise is very low at the site and also doesn’t appear to have much of an impact. The site does seem to be affected heavily by El Niño events. El Niño events typically bring increased water levels and storm activity; however they also increase rainfall potentially increasing the amount of sediment brought to the coast by the four surrounding rivers. Once in the system, the sediment is spread along the beaches by local wave action. The heavy dependence of the sediment supply on El Niño events is problematic because the El Niño cycle is notoriously erratic.

Due to this dependence on El Niño events, the significant erosion of the site, and the fact that relocating and/or HDD were not commercially viable alternatives for this location, the following measures were recommended:

- Deep burial while beach profile is low and pinning split pipe to rock where possible.
- Split pipe protection on the cable.
- Relocating the BMH further inshore.
- Measures to rebuild and stabilize the dune at the head of the beach in order to protect the road and BMH (rock, Tensar mats, textile tubes, rip rap).
- Measures to stabilize the dunes on the vacant lot to south such as sand fencing and planting.
- Construction of a sloping rock wall along the toe of the hotel's existing vertical seawall to reduce wave energy reflection and sand from being carried off the beach.

These measures are intended to stabilize the current situation and allow the natural sand mitigation to replenish the beach when the environmental cycles reverse.

6. MITIGATION MEASURES

For beach protection or replenishment measures to be effective, they typically need to be implemented over a wider area than the land involved with any one cable landing area. For this reason, these measures may fall under the jurisdiction of the government or municipality. This does not mean that cable owners are powerless to protect their infrastructure, but it does suggest that they need to plan ahead and seek required permits and involvement from the appropriate agencies.

The basic cable protection "toolbox" has not changed much in recent years. The same basic terminology and equipment that were used in years past are still in use today. However, there is a significant difference in the design of those protective assets, the materials used and the expertise which is employed during the engineering and deployment of the solution. A simple change in material or a modification of design may decrease the upfront cost or may impact the long term protective qualities of the solution.

In addition, our experience has taught us that one solution cannot be universally applied. Each type of protection has different installation requirements and will provide different levels of protection in different environments. This paper highlights a few of these options.

Landing sites which are identified to have a migrating sand layer may require ductile iron split pipe and consistently deep burial. Split Pipe is by far the most common form of external protection applied to the cable in the near-shore area. Split pipe is used to protect the cable from many external aggressors. In order to be effective, split pipe should be made of a good quality ductile iron and offer an interlocking design. Split pipe can then be pinned to the seabed for additional security in areas that will support that operation.

Burial and deep burial can be achieved in the foreshore during low tide utilizing traditional methods such as excavators and shoring. As the trench nears mean low water, other tools may be required. There are multiple approaches to burial in this critical area. In addition to the typical approach utilizing excavators at low tide, there are several offshore tools that have been effectively used to bury through these shallow water locations. These options vary from diver burial to jet sleds to shallow water plows, all offering burial from the beach seaward. Each option has its own benefits and must be evaluated on a case by case basis.

Any construction area is in fact a dynamic living microcosm. This is especially true of construction areas near the ocean. Heavy construction removes the natural vegetation which acts as a first defense against erosion. Respecting near shore vegetation by first trying to avoid disturbing it is an important first step. If avoidance is not an option, then replenishing the vegetation post-construction is advised and is often a condition of permit. To facilitate a faster recovery of the area, the preference is to use plants native to the area that are known to flourish near the sea. As these plants take root and cover the area, the soil is stabilized.

Horizontal Directional Drilling (HDD) is a method of cable protection that allows for minimal environmental impact while providing what is arguably one of the highest levels of cable security and protection. An HDD machine is positioned at a predetermined position a safe distance inland. The HDD machine drills a pathway to a designated depth beneath the seafloor to the engineered “punch out” point. The cable can then be installed in the existing drill casing or a specific type of bore pipe can be pulled into position. In this way, the cable is encased in a pipe and protected; buried well below where soil migration and seasonal fluctuations will affect it (actual “depth of cover” is site specific).

In some cases it may be required to remove existing underground cable facilities that are now “at risk” due to erosion. These are often concrete encased duct banks and headwalls that have become exposed, broken off, or are simply a risk to the cable system. One approach is using a non-explosive, non toxic demolition agent which permits the demolition of headwalls, concrete encased duct banks, and other beach based underground facilities without unnecessary risk to the cable system, personnel or the environment.

In the event that larger scale intervention is required, solutions from third party erosion experts can be evaluated to compliment the current cable protection and not unnecessarily inhibit future cable landings. These solutions may include the utilization of groins, sea walls, erosion mats, textiles, breakwaters, artificial dunes, and artificial nourishment.

Ultimately, the cable system owner has several options available to them to ensure proper protection of their investment.

7. CONCLUSIONS

Changes in global weather patterns are impacting coasts and shorelines and impact the sediment flow from rivers that supply sand. Beach landings that were stable can quickly change and put networks at risk. Once erosion begins, shore end protection and site remediation must address the wider impact of environmental change combined with the impact of coastal development.

Cable system owners need to remain vigilant in maintaining a current knowledge of the coastline and the projects that are being undertaken or planned locally. The installation of a groin, a jetty, the expansion of a local marina and other development can have a notable impact on the undersea cable landing location.

Once the complete picture is understood, a successful mitigation plan can be implemented using a number of methods tailored to the landing site.

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