THE SELECTION OF APPROPRIATE BURIAL TOOLS AND BURIAL DEPTHS

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Displayed at SubOptic 2001, Kyoto, May 2001

ABSTRACT

The routine burial of submarine cables on the continental shelf began in the 1970's in response to an increasing number of faults as a result of fishing activity. For many years this burial was done with a very limited range of burial tools and work was done on a 'best endeavours' basis. However, the changing nature of the telecoms industry and the increased financial risks associated with loss of service has significantly changed the demands being placed on cable installers. Most significantly, on occasions installers are being asked to guarantee a depth with significant financial penalties if this depth is not achieved, irrespective of how the required depth of burial was selected.

This paper briefly describes how appropriate burial depths and burial tools can be selected for different seabed conditions. The basis on which an appropriate burial depth may be selected is explained. Some of the various different burial tools, including both ploughs and post lay burial trenching machines, are described and their performance in different seabeds is given.

1. INTRODUCTION

The financial consequences of damage to a cable system in terms of both lost revenue and cost of repair are significant. The best means of protecting a cable is by burying it in the seabed. This is intended to place the cable below the depth to which the threat is likely to penetrate. Clearly the deeper the depth of burial that can be achieved, the greater the level of protection. However, it is also vitally important that the earliest possible ready for service date is achieved. A deep burial can be a slow and expensive operation. It is, therefore, necessary to identify an economic burial depth. Most commonly, this is expressed as a single burial depth for a project.

Over recent years typical specification burial depths have increased from around 0.6m to 1.0m, with depths sometimes in excess of 1.5m being required. How these burial depths are selected is often not clearly defined. What may not be appreciated is the significant cost associated with such depths and how the cost of burial can increase with depth.

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This paper seeks to identify a consistent approach to burial of cables on the basis of the degree of protection provided by the seabed soils. Clearly a seabed comprising stiff clay, or dense sand, provides a higher level of protection to the cable than a soft clay or loose sand.

Having identified the appropriate burial depths, it is necessary to select suitable equipment which will achieve the required burial depths efficiently. The primary burial technique currently in use is a cable plough. As this is, essentially, a passive tool, there are minimal moving parts and high reliability is possible together with rapid trenching speeds. In certain circumstances, such as in deep water it is necessary to use alternative burial techniques. The use of such techniques is discussed together with the soil conditions in which they are capable of operating.

2. THREATS TO CABLES

The main sources of threat to cables can be classified into the two groups of human and natural. The primary human threats are fishing and anchoring, while sediment mobility and submarine slides are the primary natural threats. These threats have been discussed in some detail by other workers (eg Shapiro et al, 1997, Evans, 1999) and it is not proposed to discuss them fully here, however some notes are provided which expand on the published work.

The different types of fishing operations have particular characteristics which affect the threat they pose to a cable. With the notable exception of shell fish dredging, fishing techniques are generally intended not to penetrate the seabed to any great depth. Trawling is one of the most common forms of fishing and the one most often associated with damage to cables. The net is held open by trawl doors (otter boards) that are typically of 2 to 4 tonnes in weight, but greater than 10 tonnes is possible. However, trawl doors are designed to skim over the surface, and inspection of wear marks suggests that in most seabed, penetration would be limited to 200 or 300mm. An alternative method is by a beam.

Shell fish dredging using toothed dredges which scrape the seabed can penetrate the seabed to a depth of 200mm in a single pass. However, multiple passes are probable and this potentially extends the depth of penetration. Note may be made of the fact that shell fish generally prefer sandy seabeds which have a reasonable degree of stability. As fishermen generally have a very good knowledge of the seabed conditions within their particular area, it would be unusual to find a high degree of such fishing in, for example, an area of sandwaves.

Bottom set fishing, placing nets or pots on the seabed to catch fish over a period of time, generally uses relatively small equipment and only poses a low degree of threat to a correctly buried cable. However, the technique does pose some particular problems, for example lobster fishing is performed in rocky areas where cable burial is particularly difficult.

The other significant human threat is anchoring. While anchors of many types are available for different applications, the most significant in the context of submarine cables are ship anchors. Ship anchors are designed to penetrate into the seabed to generate the maximum holding power for the weight of anchor. However deep penetration is not desirable in practice as this increases the difficulty in recovering an anchor. Therefore anchors are generally designed to skim over the surface of the seabed, supported by the shank, with only the flukes penetrating in firm seabeds. It is therefore possible to accurately predict the maximum penetration of a ships anchor in most seabed soils.

The sizing of a ship anchor is dependant on a number of factors, with guidance on appropriate sizes being provided by Lloyds classification rules. These rules assign a number to a ship based on weight, physical dimensions and proposed use. The recommended anchor size is given purely on weight, with no consideration given to use of high holding power anchors which are specifically designed for deeper penetration. However, most ships use the standard Admiralty pattern stockless anchors and therefore, using the Lloyds rules, and dimensions for standard anchors, it is possible to make a rapid assessment of the likely size and penetration of an anchor in most seabed soils. It should be noted that a more detailed analysis should be performed in clays of less than 20kPa undrained shear strength and sands with an angle of friction less than 30°. Typical anchor sizes and theoretical penetration depths in firm clay / medium dense sand, where deep penetration will not occur, is given as Figure 1.

Figure 1: Anchor size verses theoretical penetration

Statistical reviews of fault histories due to fishing and anchoring (Frantz et al, 1996 and Evans, 1999) indicate that anchoring and fishing collectively account for two thirds of all faults that occur to submarine cable systems. Of these, anchoring accounts for approximately one third. The databases indicate that most faults occur in water depths of less than 200m, however as this accounts for most of the continental shelf, this is not surprising. The most interesting factor is that 70% of anchor related faults are associated with depths less than 50m, and that 20% occurred in depths less than 10m. This implies that anchoring threats are limited to relatively shallow waters and therefore smaller ships and anchors. While more detailed data is not available, it would also be reasonable to anticipate that frequent anchoring is limited to specific areas of high shipping activity. Therefore, it should be possible to identify the level and extent of risk from anchoring and to select an appropriate burial depth.

Although fishing and anchoring may account for two thirds of all cable faults, natural hazards must also be assessed. These hazards take many potential forms and the normal preference is to route round a particular threat such as a sand wave field or an area with an unstable slope. However, as the seabeds become increasingly congested this is not always possible and cables have to be routed through such areas.

The variability of natural hazards makes a review on an individual basis an essential requirement. However it is possible to assess the conditions under which, for example, sands will become mobile and the rate of mobility.

3. SELECTION OF APPROPRIATE BURIAL DEPTHS

The selection of an appropriate burial depth must be based on an understanding of the threats to which the cable may be subjected. Once the threats have been identified, some assessment should be made of the likely depth of interaction. This will be a function of the geological and metocean conditions along the route. The cable route survey should be designed to provide sufficient information to carry out this assessment. Problem areas should be investigated by techniques such as cone penetration testing (CPT) and sampling. Lateral correlation by other techniques such as resistivity or seismic refraction is possible, however these techniques do not, in themselves provide the required engineering parameters. Additional work that may be required, particularly as part of a sediment mobility study, are some simple laboratory tests on soil samples.

There is very little documented data on the depth to which normal fishing gear penetrates in different soil types. However it is known that burial to between 0.6m and 1.0m depth has resulted in a significant reduction in the number of faults on a cable system (Shapiro et al, 1997). Unfortunately no detailed soil strength data is available to assess how this factor affects cable protection. However, there is some evidence to suggest that reasonable protection would be provided at between 0.6m and 1.0m depth in a firm clay with a strength greater than 40kPa.

It is possible to extend this soil strength / penetration depth to different soil strengths assuming an unchanged weight of fishing gear. The deepest point of penetration of most fishing gear will be when it is dropped to the seabed. As such it may be likened to a dropped object which will penetrate the seabed to a depth dependant on its weight and the bearing capacity of the soil, effectively acting as a retarding force. This force varies as a function of the undrained shear strength and increases with depth due to embedment

The concept of a burial protection index (BPI) was first proposed by Mole et al (1997) and further discussed by Allan (1999). This was intended to quantify the protection provided by seabed soils. A tentative correlation was proposed for a range of soil types. This assessed a BPI = 1 as providing good protection from fishing gear. Based on a burial depth of 1m in 40kPa clay, with extrapolation to a range of strengths, a recommended depth to achieve a BPI of 1 is presented. This estimation allows for increasing depth of burial with reducing strength of a clay seabed. Applying the same methodology to an increasing clay strength is not fully valid. A certain depth of burial is required as the lay tension will tend to reduce the apparent buried depth in any undulating seabed. A nominal minimum depth of 0.6m has been selected at a cut off undrained shear strength of 60kPa. The resulting optimum burial depth is presented as Figure 2.

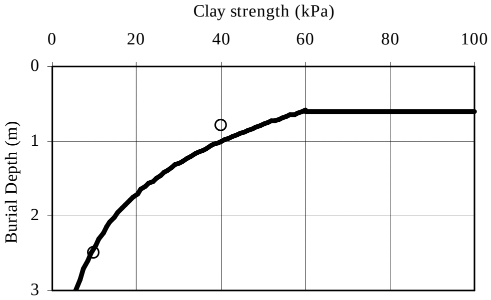

Figure 2 : Recommended depth for BPI = 1 for clays

(o - Mole et al, 1997 recommendations)

Unfortunately little data exists for sands and a direct transfer of the assessment possible in clays is not valid. This is due to the different geotechnical strength parameters associated with a sand. However it is possible to apply the analogy of the depth of penetration of an object using a correlation with bearing capacity. The strength of a sand is normally expressed as a relative density (Dr%). This is most reliably measured by in situ tests, such as cone penetration tests which are routinely performed as part of most cable route surveys.

The results of this exercise are presented as Figure 3. It is stressed that at this stage, this assessment is tentative only and makes no allowance for the mobility of sands under the action of waves and currents. The frictional nature of sands means that strength is derived from the weight of overlying soil.

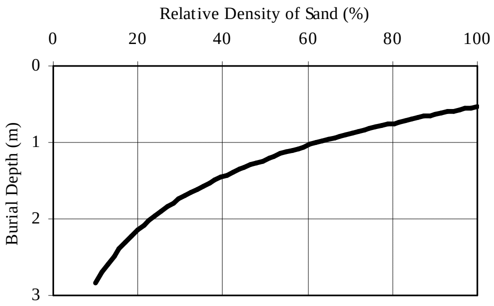

Figure 3 : Tentative recommended depth for BPI = 1 in sands (no allowance for mobility).

Near the seabed, the weight of the overlying sand is relatively low, and a densely packed sand (D_r = 100%) is required to provide the same level of protection as a stiff clay. However, a progressive increase in burial depth with reducing relative density is recommended to allow for the lower level of protection provided by loose sands.

The above recommendations should result in reasonable protection against normal fishing activities. However, a more rigorous assessment is necessary where anchoring has been identified as a greater risk. Based on an understanding of the soils, a reliable assessment may be made of the depth to which an anchor is likely to penetrate. As noted above, in many cases this simply requires that the soils are greater than the minimum strength at which the anchor begins to penetrate. Should softer soils be encountered along the cable route, a more detailed assessment of the likely burial depth should be performed. This is best done on a site specific basis and it is not considered practical to provide universal guidelines.

4. SELECTION OF BURIAL EQUIPMENT

Having selected an appropriate burial depth, it is important to use equipment which can reliably achieve such depths. As a general rule, ploughs are preferred wherever possible, as they permit lay and burial in a single operation and are relatively fast. Post lay burial tools such as jet tools mounted on a remotely operated vehicle (ROV) are preferred for more difficult areas such as crossings of pipelines and existing cables and in very deep water.

At the time of the last Suboptic conference there was, essentially, one industry standard cable plough which was capable of achieving approximately 1m in most soils, increasing to 1.5m in very soft clays. However, in the last four years, a wide variety of cable ploughs have been introduced, capable of depths of 3m and more in appropriate seabed conditions.

A brief explanation of some of the factors influencing plough performance is given here for general guidance. The basic configuration of the forces acting on a plough is shown as Figure 4. The main force that keeps the share engaged in the seabed is the self weight of the plough. This may be complemented by the reaction of the soil on the share. In Figure 4, the leading edge of the share has a negative rake angle (ie the leading edge of the share is inclined backwards from vertical) and the reaction of the soil pulls the plough into the seabed. Clearly, as the negative rake angle increases, the magnitude of the downward force increases. Conversely, with a positive rake angle (ie the share is inclined forwards), the reaction of the soil on the plough will lift the plough out of the ground. In practice the reaction of the soil is slightly below the plane of the share and a vertical share will experience an upwards force as it is dragged through the soil.

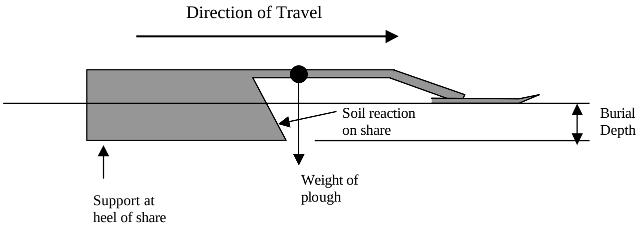

Figure 4 : Forces acting on a plough

Ploughs are supported by skids at the front and the underside of the share at the rear. The pressure applied by the share is greater than the pressure applied by the front skids. In very soft soils, which have insufficient strength to support the plough weight, the plough will pitch aft as the share sinks. Most soils gain strength with depth and a plough will tend to sink until an equilibrium point is reached. The net effect of this sinkage is to bury the cable to greater depths than the plough is theoretically capable of achieving with a neutral pitch angle.

In hard soil the plough is normally kept pitched forwards. This keeps the weight of the plough on the share tip and helps to initiate penetration. It is advantageous to regularly change share tips, to ensure optimum penetration is achieved.

Consideration should therefore be given to the plough weight, skid size and share configuration/aspect when selecting a suitable plough for the soil conditions and required burial depth.

Jet tools used for cable burial operations are generally mounted on a ROV. The current generation of cable burial ROV’s all have around 250kW power and are capable of operation in tracked or free swimming modes. This provides for a versatile machine capable of providing a high level of jetting power in trackbase mode, while maintaining the flexibility offered by free swimming for use on sloping seabeds. Good burial depths (approx 1m) should be achievable in soft clays and sands. However difficulties are likely to be experienced in gravelly soils which are difficult to fluidise and in stiff clays for which pressures of 10bar are more are desirable.

Wheel cutters are available but not generally used for cable routes. They are best suited to rocky areas. However as a track base is required, they are very prone to surface undulations, a common feature of such areas. Other problems associated with their use include the need to get slack levels just right, too much and the cable can be damaged by the machine chasing a bight, too tight and the cable cannot be pushed into the trench.

5. CONCLUSIONS

With the wide range of seabed soils and potential threats to cables, the selection of appropriate burial depths and burial tools is essential for successful and cost effective cable protection.

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