

HYDROGRAPHIC INFORMATION AND THE SUBMARINE CABLE INDUSTRY

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1. INTRODUCTION

Accurate mapping of the seabed is an essential requirement for the successful installation of a submarine cable. This paper aims to provide an overview of the cable industry and how survey data is used by the cable industry in selecting an appropriate route and the laying of a cable.

The various phases in the planning and installation of a cable commence with an outline route, which is developed by a cable route study. As the route is finalised, cable armouring and slack levels are chosen and the burial operations on the continental shelf are planned.

2. THE SUBMARINE CABLE NETWORK

Many people assume that telephone calls are transmitted by satellite between continents such as North America and Europe. In reality, submarine cables are the primary carrier of voice and data traffic. This is because fibre optic cables transmit voice and data traffic with higher reliability and security at a cheaper rate than satellite. Although the first trans Atlantic cable was laid in 1858 (it broke within one month of installation), the demand for data transmission, driven largely by the growth of the internet, has led to an explosion in the demand for submarine cable systems over the last few years. On trans Atlantic routes, the data traffic exceeded voice traffic for the first time in 1997. It is estimated that, by 2003, voice traffic will make up less than 3% of all trans Atlantic communication. There are approximately 15 cables either in service, or expected to enter service shortly, across the Atlantic with a total capacity in excess of 1gigabit/second.

A similar number of cables are also installed across the North Sea and English Channel connecting the United Kingdom to the continent. Further afield, many cables are being installed in the Asia / Pacific region, and at least three new cables are proposed along the African coasts.

Submarine cable contracts are generally let as turn key contracts that are lead by the cable manufacturer, as this forms the major capital item of the work. There are only a limited number of cable manufacturers with Tycom and Alcatel being the two most significant, each with about 30% of the world market. The remainder of the cable manufacture market is lead by KDD-SCS, NEC, Pirelli and Eriksson.

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3. ROUTE PLANNING

The selection of a submarine cable route usually commences with a feasibility study. The first consideration is to choose an area which permits relatively easy interface to the onshore fibre optic network, or from which a new cable can be laid.

If the system is a short system, for example between the UK and Ireland, or the European mainland, it is desirable to keep the length between landfalls to less than about 350km. The main advantage is that it is possible to lay a simple fibre optic cable over this length. This has significant cost advantages as no repeaters (required to amplify the signal) are required. Associated cost advantages arise from the absence of a requirement to power the repeater, thus making the cable cheaper. The capacity of the system can also be increased as the number of fibre pairs with the repeater is limited, but with an unrepeated system an almost unlimited number of fibre pairs can be used.

The outline route is developed into a survey route by means of a cable route (desk) study. This study considers all the relevant factors which may influence the routing of a cable. A major aspect of the route selection is to ensure that the cable will be secure. To achieve this the cable must avoid, as far as practical, any identifiable hazards. These include human factors such as fishing activity, dredging, anchoring and existing cables and pipelines and natural hazards such as sandwave fields, submarine landslides and rock outcrops.

Recommendations on route selection are made by the ICPC (International Cable Protection Committee, 1999). These include criteria for cable crossings, parallels and separation between repeaters.

4. CABLE PROTECTION

It is clearly not possible to avoid all hazards. The most significant hazard is fishing activity, which by its nature covers a wide area of the seabed, and accounts for about 40% of all cable faults (Evans 1999). The next most significant hazard is anchoring which accounts for about 18% of faults in all water depths, but is most significant in water depths of less than 50m.

To achieve a secure cable system, some form of protection must be provided. This essentially falls into the categories of burial and / or armouring. On the continental shelf sections, protection can be most reliably achieved by burial, which places the cable below the depth of penetration of the threat.

The effectiveness of burial is demonstrated by Figure 1.

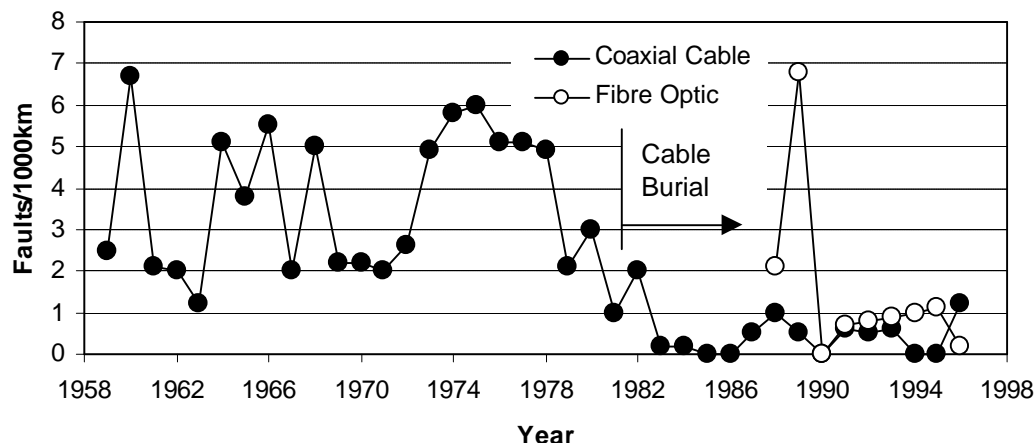


Figure 1: Cable Fault Rates by Year (after Shapiro et al, 1996)

This shows how fault rates in cable systems fell dramatically when widespread burial of cables was adopted in the 1980's. Prior to burial of cables, fault rates were around 5 per 1000km per annum. However, as cable systems were increasingly buried, fault rates fell to an average of less than 1 per year (the peak in faults with the fibre optic systems in 1989 was due to a particular problem with one cable system through a sandwave field).

Armouring of a cable is routinely performed in areas of high risk. All fibre optic cables are based around the core cable which changes little between different armouring types. The cable is armoured by placing layers of galvanised steel wires around this central core. While manufacturers offer a wide range of different cable constructions, the basic types of armouring available, and their typical characteristics, are summarised in Table 1.

Cable Type	Characteristics	Water Depth
Light weight (LW)	Deep water cable for areas where no significant hazards exist.	<8000m
Light weight protected (LWP)	Light weight cable with an abrasion resistant covering. Suitable for areas where rugged topography is crossed, such as the mid Atlantic ridge.	<3500m
Single armour light (SAL)	A relatively light weight cable for use in areas where good burial is possible, and external threat risk is relatively low.	<1500m
Single armour (SA)	Usually used in areas where only limited burial is possible.	<1500m
Double armour (DA)	A well protected cable for use in areas where little or no burial is anticipated and for shore ends	<500m
Rock Armour (RA)	Similar to double armour but with improved impact resistance and more flexible, hence better able to conform to an undulating rock seabed.	<200m

Table 1 : Typical cable armour characteristics for guidance only (refer to manufacture for specific properties).



Figure 2 : Cable Armouring (DA, SA, LWP, LW)

Wherever possible, it is desirable to engineer a route that requires the minimum length of armouring and burial due to cost. There are also time implications, as each layer of armouring requires a pass through the factory. This increases the manufacturing time and can affect the all important ready for service (RFS) date.

5. SURVEY REQUIREMENTS

The cable route survey should identify the seabed topography and give an indication of the seabed soils. Some ground truthing of the geophysical survey data should be provided by sampling and in situ testing of the seabed sediments. Survey specifications have been developed over a number of years based on significant experience and can generally be considered fit for purpose. However there are instances where gaps can, and do, occur and some examples of the potential pitfalls are given later.

The survey is undertaken to determine the final route for the cable and assess the potential for burial of the cable along the route. It will comprise a geophysical element (bathymetry, side scan sonar and sub-bottom profiling) and a geotechnical or BAS (burial assessment survey) element. The latter will comprise sampling (grabs or cores) and testing (cone penetration tests, CPTs). More recently, electronic BAS (eBAS) systems such as resistivity or refraction have been incorporated in the geotechnical / BAS survey. These are useful tools that allow interpolation of soil types between the sampled / tested point locations. However, they are not an end in themselves, since they do not provide the fundamental geotechnical parameters required to make the predictions of burial performance that are required as the output from the BAS.

6. CABLE PLANNING AND INSTALLATION

6.1 The Route Position List

The route position list is the document that provides almost all of the data required for the manufacture and installation of the cable. It should include any changes in armouring

required to suit the changing seabed conditions and topography. Hydrographic data is an essential part of this process, identifying seabed topography.

The major use of hydrographic data is in the determination of desirable slack levels. Slack is not a true description, as it is an added length of cable to the calculated geographic distance to allow for minor undulations in the seabed and slight deviations from the actual cable route. On a relatively flat seabed, it is normal to assign slack levels of about 0.35% for ploughed sections, increasing to 0.8% in areas where the cable is to be surface laid. These values are acceptable for most of the continental shelf, but once the continental slope or mid oceanic ridge or trench is reached, additional cable length needs to account for the seabed gradient. On particularly steep sections, this can result in slack levels being planned at 10% or more.

For inshore sections, water depths are required to identify the point to which the main lay vessel can come to the shore to commence the main lay operations. This water depth is typically 15m, but may be 20m depending on the vessel used and local conditions.

6.2 Cable Laying

It is important that the cable is paid out such that the planned locations of any changes in armouring are in accordance with requirements. Also, with many areas of the seabed becoming congested with several cables, it is important that the cable is laid in the correct position.

The cable engine controls the rate at which the cable is paid out. This is normally a linear cable engine (LCE) which comprises a series of pairs of rubber tyred wheels that grip the cable and pay it out at a controlled rate. In shallow water the cable engine needs to physically pay out the cable, while in deep water, the cable needs to be held back. There clearly needs to be close connection between the ship positioning and the LCE if the cable is to be paid out at an appropriate rate.



Figure 3 : A 7 Wheel Pair Linear Cable Engine

Currents can also be significant. Not only can they seriously affect the station keeping characteristics of the ship, they also affect the position at which the cable touches down on

the seabed. In the deep waters of the abyssal plain, the cable can be paid out at up to 8 knots, and may be touching down on the seabed several kilometres behind the lay vessel. Any currents can potentially carry the cable some distance to one side and it is necessary to allow for this. Specialist programmes have been written by cable installers and survey companies to improve the accuracy with which the cable is paid out and to compensate by adjusting the position of the ship.

6.3 Burial Operations

The most economical way to install the cable is to surface lay it. However, as discussed above, external threats exist which can damage the cable. The optimum method of protecting the cable is to bury it. This can be simultaneous to the cable lay or post lay. Equipment used falls into three categories: cable ploughs, post-lay burial (PLB) jet-tools and tractors (chain or wheel cutters). If burial is not possible, other protection measures such as mattressing or rock-dump may have to be considered.

Selection of the correct burial tool is a complex process affected by many factors. An overview is given by Allan and Comrie (2001). Over the last twenty years, ploughing has become the preferred method for burial of cables. The typical burial depth used was between 0.6m and 1.0m and a plough developed by BT (Marine) and Soil Machine Dynamics in the early 1980's, became the industry standard plough.

Ploughing is the most efficient burial method, operating at speeds of around 1000m per hour (with faster and slower speeds possible) in most soil conditions and achieving good burial. PLB by water jet trencher is used where ploughing cannot be used for operational reasons (e.g. cable crossings, shallow water, steep slopes). This is generally slower (typically 200 to 1000m per hour), is limited to sands and soft to firm clays (with a few exceptions), may need more than one pass to achieve the required depth and relies on natural backfill (i.e. sediment settling out of suspension) to the trench. Tractors are the slowest of the three types. They are used for burial in hard materials, particularly rock, and generally only in special circumstances.



Figure 4 : A cable plough, trenching ROV and seabed tractor

As noted above, burial has traditionally been specified to 0.6m to 1.0m depth. Locally, deeper burial is required (very soft clays, anchoring grounds). However, the required burial should be reviewed within the context of the seabed. Stiffer clays and denser sands provide more protection to a buried cable than softer clays and looser sands, hence require less

burial to provide the same level of protection. This concept is further developed in Allan (1999).

7. WHEN THINGS DON'T WORK OUT

On occasions operations do not go as planned. It is important that the lessons learnt from such mistakes are disseminated to reduce the risk of this happening again. Some examples of the significance of survey data are given below.

Bathymetry

A cable system was being buried by ploughing in water depths between 500m and 1000m. Swathe bathymetry had been used to produce bathymetric contours of the seabed and the area was noted as containing sandwaves with isolated sandwave crests noted. The development of the contours was based on interpolation of a grid of spot heights. This was computed and maximum slope angles of 5° were indicated on the alignment chart. However, as the section was ploughed, it became apparent that the slopes had been underestimated with the plough experiencing pitch and roll angles of greater than 10°. Ultimately the plough rolled over on a sidelong slope of 17° and the sandwave collapsed on top of it. This resulted in the loss of the plough.

As a result of this incident, the project was delayed and financial implications of this delay were increased by the loss of the plough, and the requirement to source some replacement cable. On inspection of the original side scan sonar records, it became apparent that not all the sandwave crests had been reported. The bathymetric data was also replotted on a finer grid and this showed up steeper slopes than those originally anticipated, including the 17° slope at the point at which the plough had been lost.

Side Scan Interpretation

At a cable landing site, the geophysical survey had identified sands and gravels overlying chalk bedrock. A number of large boulders were reported to be lying on the seabed along the proposed route of the cable. It was proposed to bury the cable with a seabed tractor and wheel cutter. This has the theoretical advantage of being able to cut a trench through the sand and gravel and into the underlying chalk. The route was carefully revised to avoid any boulders that might obstruct the progress of the seabed tractor.

In practice two problems were experienced. The first was that the tractor had difficulty trenching due to the large number of cobbles and small boulders present. This caused a significant loss of picks and excessive wear. The major problem that was encountered was that the tractor became stuck on a large boulder, not identified on the route.

The problems arose from two sources. Firstly, while an experienced geologist looking at a chart identifying boulders would have anticipated cobbles to be present in the seabed sands and gravels, charts are often looked at by non geologists and it is important that the information presented can be easily understood. The second factor is that the positioning of

any features identified can be critical. If the boulder on which the tractor became stuck had been identified, significant disruption would have been avoided. Where a lot of sonar contacts are identified, it is important that each one is clearly identified together with its physical dimensions.

Sub-Bottom Interpretation

Sub bottom data can give an indication of the underlying structure of seabed soils. While it is generally recognised that some form of ground truthing is required, it is important to ensure that this ground truthing is adequate for the task in hand. In this instance, a cable was being buried by ploughing through an area interpreted as sands and gravels, greater than 2m in thickness. This was based on sub bottom profiling and drop cores every few kilometres. It was anticipated that the specification burial depth of 0.6m could be achieved by ploughing and the cable therefore had single armour protection.

During cable lay and burial operations, it was found that the plough could not penetrate typically more than 200mm. On closer inspection of the survey data, no reflectors could be identified in the underlying rock and it was noted that the drop cores had only penetrated a few centimetres. To demonstrate that only limited burial was possible, a cable plough was pulled along adjacent to the as laid cable. Based on this work, and material recovered from the plough, it was found that rock was at shallow depth and the maximum practical burial had been achieved. As a result of the failure of the survey to adequately identify the underlying strata, it was necessary to recover the cable and replace it with double armoured cable.

8. CONCLUSIONS

This paper has described the process of planning a cable route and how accurate survey data is vital at all stages of the planning, manufacture and installation of a submarine cable. Some examples of how inadequate survey data are given to illustrate what might go wrong when a sufficiently detailed survey is not performed.

9. REFERENCES

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