LW and LWP cables Abrasion

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Abstract: Comparing the Abrasion Resistance & Properties of lightweight protected (LWP) cables manufactured with Flat Metal Tapes (FMT) and Corrugated Metal Tapes (CMT).
When clients and suppliers of cable systems work on the route selection and cable engineering of systems, it is often a difficult to decide and agree on which areas of the route LW cable should be upgraded to LWP cable for enhanced abrasion resistance. Clients want to understand the additional abrasion protection offered by the LWP cable design.
This paper describes a series of abrasion tests performed on three deep water cable types, LW, LWP (with a flat metallic tape) and LWP (with a corrugated metallic tape). The relative abrasion resistance results are presented and discussed in terms of cable costs and the trade off in mechanical cable properties.

1. INTRODUCTION

LW and LWP are two types of submarine optical fibre cable which are most commonly used in deep water. Transoceanic cable systems utilise LW & LWP cables which are the smallest diameter, lightest and most cost-effective cable designs available for route engineers to select for use in deep water sections of the selected cable route, where the risks of cable damage are generally considered the lowest.

The unarmoured LW cable structure is generally used in those areas of the ocean which have a soft sea bottom and very low or no sea bottom currents.

In sea bed areas with a bottom current combined with hard bottom, steep slopes or areas with rugged irregular terrain the LWP cable type can be selected to offer additional abrasion protection and to mitigate the risk of LW cable abrasion. The additional protection is an important factor affecting the service life of submarine optical fibre cable. Due to the additional materials and manufacturing resources required to produce LWP cable, there is a higher cable unit cost / km, compared to LW cable. Customers and route engineers need to understand the cost - benefit relationship in selecting the correct cable for the correct seabed to normalise the risk of cable damage. This paper aims to provide some additional understanding on the relative benefits of LWP compared to LW cables when considering seabed abrasion and the cost – benefit relationship.

A study of three different types of deep water submarine optical fibre cable are presented here based on industry standard designs. A LW cable produced using high density polyethylene insulation and 2 types of LWP cable one with a flat metallic tape (LWP-FMT) and another with a corrugated metallic tape (LWP-CMT) are characterised for abrasion protection and bending stiffness.

It should be noted that LW cable abrasion should never occur in deployed systems as this cable type is restricted for use in areas of soft bottom with very low bottom currents.

The LW cables tested here are only to provide a reference datum for the LWP cables.

2. CABLE ON-BOTTOM (SEABED) STABILITY

Why is cable on-bottom (seabed) stability important? Well firstly, the cable should remain on the as laid cable route for ease of location & recovery during future maintenance operations. Secondly for the convenience of other seabed users, to avoid damaging any adjacent equipment, sensitive or protected marine organisms and to avoid cable damage due to Abrasion, kinking, or fatigue failure of cable elements due to repeated flexing and bending.

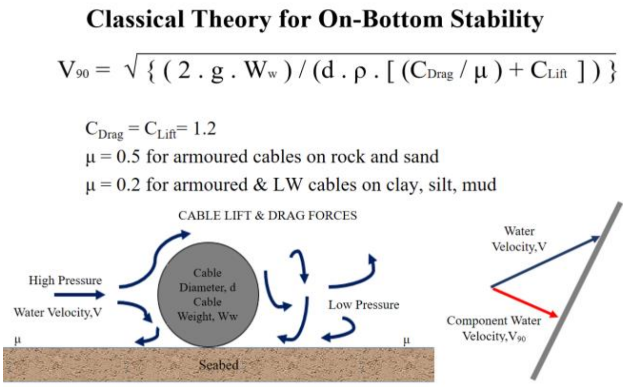

Figure 1: Classical Theory for On-Bottom Stability

From the classical theory for on-bottom stability shown in Figure 1 it is possible to calculate the bottom current required to initiate on-bottom instability and cable movement shown in Figure 2.

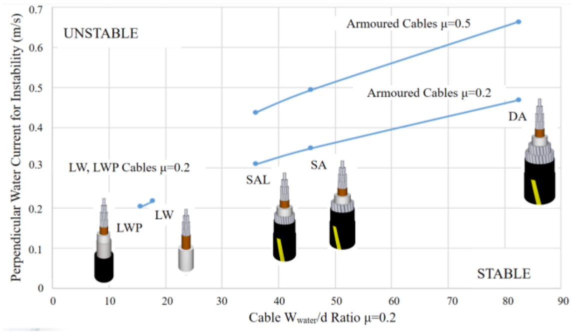

Figure 2: Initiate On-Bottom Instability and Cable Movement

The results from Figure 2 show the relative bottom current required to initiate cable movement / instability in a range of cable types (LW, LWP and armoured cables SAL, SA & DA). As you would intuitively expect LW and LWP cables are displaced by lower bottom currents than armoured cables. The bottom current to displace LW & LWP cables are very similar at approximately 0.2 m/s.

3. ABRASION TEST METHOD

A summary of the key cable specification parameters for the 3 types of deep sea cable used in the abrasion tests are shown in table 1.

Cable Element / Property	LW	LWP (FMT)	LWP (CMT)
Insulation radial thickness(mm)	4.8	4.8	4.8
Metallic Tape thickness(mm)	n/a	0.25	0.25
Jacket radial thickness(mm)	n/a	2	2
Weight in water(kg/m)	0.3	0.4	0.41
Cable OD(mm)	18	23	23

Table 1: Cable Dimensions & Properties

An in-house design of abrasion test apparatus has been manufactured to mimic the relative movement of cables and hard seabed materials. This involves moving a simulated hard seabed material over the same section of cable in a reciprocating motion, to wear the cable materials in such a way as to create a flat wear scar, simulating the observed cable abrasion defects on recovered cables. The choice of material to replicate the hard seabed was carefully considered as the abrasion testing will continue to characterise the performance of steel wire outer armoured cables and other abrasion resistant materials in the near future. The general LWP cable structure is shown below, with a LW cable forming the core element:

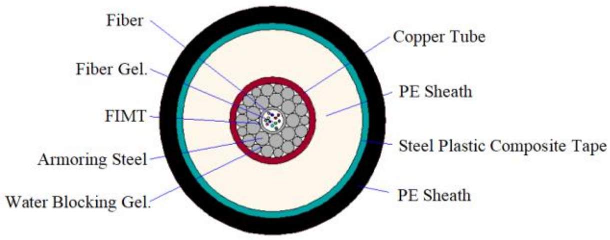

Figure 3: View of LWP General Structure

Abrasion resistance is mainly provided by metallic tape layer which is maintained in the design position by the outer cable sheath and underlying LW cable insulation layer. LWP is superior to LW cable characteristics in terms of impact, crush & abrasion resistance, due to the added metallic tape layer and outer sheath. In terms of the cost, LWP is about 4.5% more expensive than LW(12 fibers), because of the additional raw material costs and additional manufacturing processes.

The Abrasion testing apparatus (Figure 4) used to evaluate the wear rates of different types of submarine optical fibre cables utilised a simulated hard seabed material, moving back and forth over the same section of cable. A green grindstone block was selected to simulate the hard seabed material Grade 320#. The number of motion cycles was recorded together with the wear on the cable.

Figure 4: Equipment of Cable Abrasion Test

The test parameters controlled included the cable / hard seabed contact force, the stroke length and the speed of relative motion. In practice the stroke length was selected to provide an abrasion speed of 32 cycles per minute to reflect the cable motion due to water flow speed, and the contact force used was about 150N (equivalent to the weight of 30-50m cable length in seawater). on the bottom.

Test schematic diagram as follows:

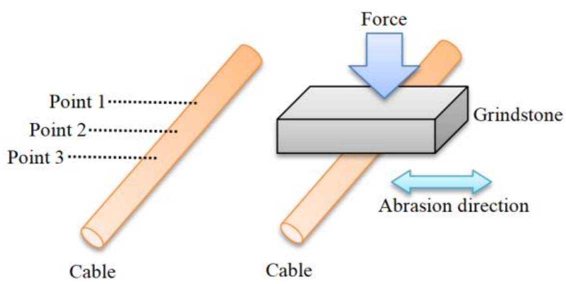

Figure 5: View of Cable Abrasion Test

The number of cycles was recorded and at regular intervals the abraded cable was examined and measured to monitor the cable materials removed. This was accomplished by measuring the cable dimension at three points on the abrasion surface and taking an average value.

4. CABLE ABRASION RESULTS

LW CABLE

LW cable should never be deployed on a hard sea bottom in the presence of bottom currents which could cause relative motion between the cable and seabed, leading to abrasion. However, in order to understand the abrasion resistance of LW cable on a hard sea bottom, a LW cable sample was tested in laboratory conditions, to simulate movement over a hard sea bottom. The sample tested in the abrasion test apparatus was manufactured with a High-Density Polyethylene (HDPE) insulating material. A typical abrasion wear scar is shown in Figure 6 and the recorded cable dimension versus number of abrasion motion cycles is shown in Figure 7.

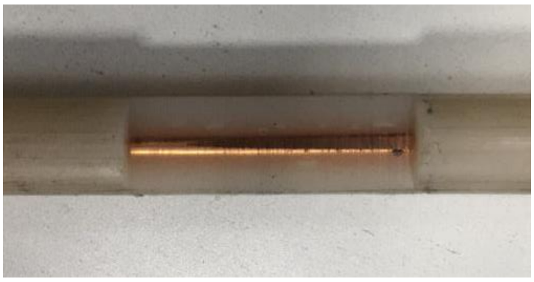

Figure 6: LW Abrasion Sample

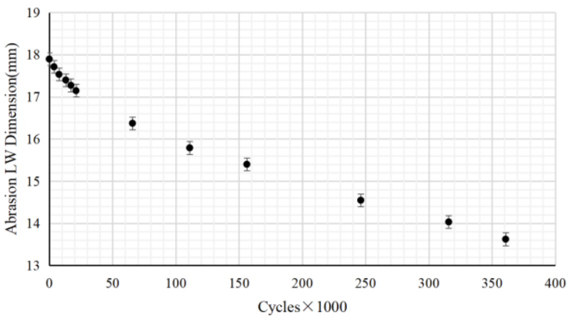

Figure 7: Abrasion LW Dimension vs Cycles

Figure 7 characterises the abrasion resistance of LW cable provided by the HDPE insulation. The graph reveals that the LW cable abrasion characteristic is close to linear and is not greatly altered as the size of the abraded cable contact area increases.

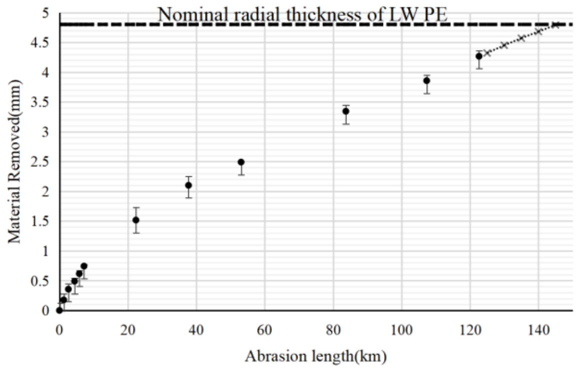

Figure 8: Material Removed vs Abrasion Length

Abrasion length is calculated by the stroke length and number of cycles the grindstone passes over the cable.

LWP (WITH A FLAT METALLIC TAPE) CABLE

LWP(FMT) sample test shows as below:

Figure 9: LWP Abrasion Sample (with a flat metallic tape, FMT)

Plastic coated Steel tape is used as an additional cable element to provide enhanced mechanical protection offering improved 'fish bite' resistance and enhanced abrasion resistance. The FMT is wrapped around the LW cable core with a longitudinal overlap and maintained in the design position by the application of an outer PE sheath. The design of metallic tape is related to the manufacturer's production process. Currently within the submarine cable industry LWP (with a flat metallic tape) and LWP (with a corrugated metallic tape) are available to customers. These two types of LWP were selected for the abrasion test.

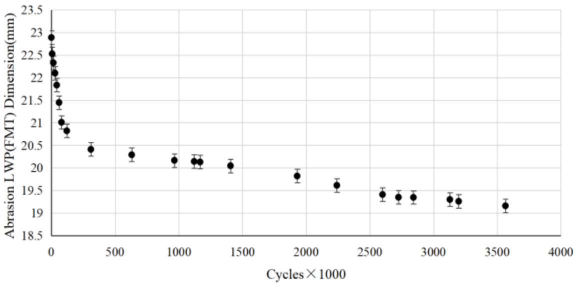

Figure 10: Abrasion LWP(FMT) Dimension vs Cycles

In the initial stage, during the abrasion of the outer PE cable jacket, the abrasion resistance is close to linear during this stage similar to the LW cable. The abrasion resistance of the cable jacket is approximately similar to the LW insulation material but increases rapidly when the grindstone reaches the metallic tape layer.

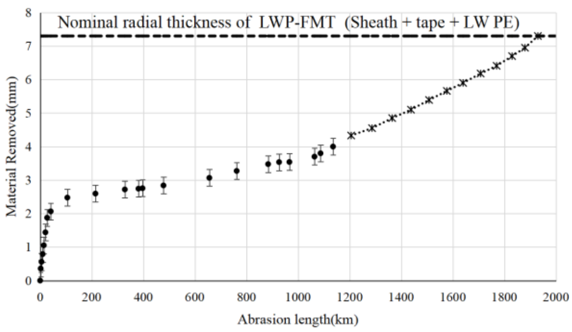

Figure 11: Material Removed vs Abrasion Length

Once the FMT meets the Grindstone, the abrasion resistance increases dramatically as can be seen from Figure 11. As the testing time was now much longer the material removed from the cable, tended to clog and polish the surface of the Grindstone, with a corresponding dramatic improvement of abrasion resistance. At some times when the Grindstone was clogged and polished the cable abrasion thickness dimension barely changed for example between 920 and 960km.

LWP(WITH A CORRUGATED METALLIC TAPE) CABLE

LWP with a corrugated metallic tape CMT was chosen as the third cable sample for comparison (see Figure 12).

Figure 12: LWP Abrasion Sample (with a corrugated metallic tape)

Although this design of LWP(CMT) cable uses approximately 16% more steel tape than the FMT design, it can provide a more flexible cable with a lower bending stiffness (EI), allowing better conformity to seabed undulations.

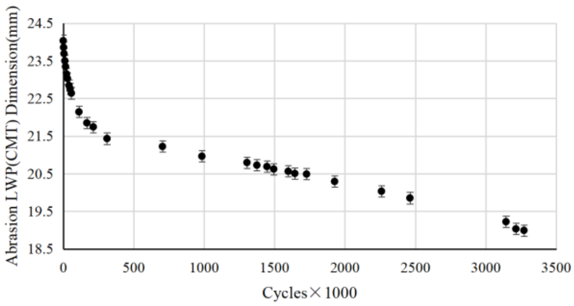

Figure 13: Abrasion LWP(CMT) Dimension vs Cycles

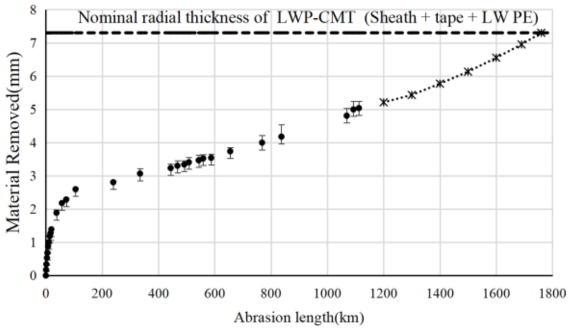

Figure 14: Material Removed vs Abrasion Length

As observed previously, the polyethylene jacket abrasion resistance is approximately linear, but increases dramatically when the CMT is exposed. Once the FMT meets the Grindstone, the abrasion resistance increases dramatically as can be seen from Figure 14. As the testing time was now much longer the material removed from the cable, tended to clog and polish the surface of the Grindstone, with a corresponding dramatic improvement of abrasion resistance.

ABRASION COMPARISON BETWEEN LW AND LWP

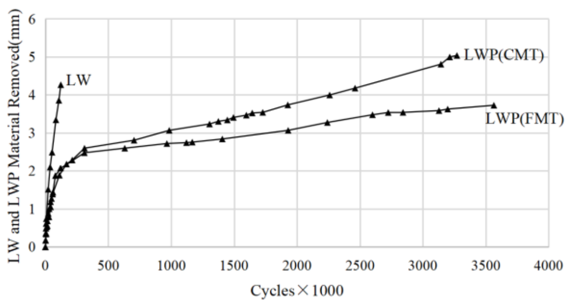

Figure15: LW and LWP Material Removed vs Cycles

Figure15 shows that the abrasion on the outer sheath of the two types of LWP cable is almost identical, with the initial removal rate of polyethylene abrasion being very similar to that of LW cable.

As the abrasion test progresses the abrasion resistance of LWP(FMT) appears to be slightly better than that of LWP(CMT).

Figure 16: View of Grindstone for LWP(CMT)

Figure 17: View of Grindstone for LWP(FMT)

The same commercial grade of Grindstone from the same supplier, were used to complete all testing.

During testing, the rough surface of grindstone became contaminated with the debris of the cable material resulting in the grindstone becoming clogged and polished.

Debris on the grindstone surface will reduce the efficiency of the abrasion test. When the test was paused to take cable dimensional measurements, the grindstone surface was cleaned as best possible, before re-starting the test.

5. MEASUREMENT OF CABLE BENDING STIFFNESS

The bending stiffness of the LW, LWP(FMT) and LWP(CMT) were determined using the technique shown in Figure 18.

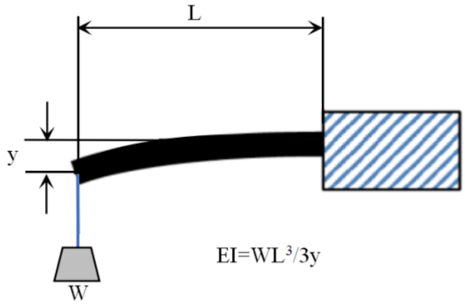

Figure 18: Method used to measure Bending Stiffness (EI)

The results obtained are presented in table 2

Cable Type	Bending Stiffness (E.I)(N·m2)	Remark
LW	4.021	LWP(FMT) (E.I) is 63.7% higher than LW;
LWP(FMT)	6.586	
LWP(CMT)	5.378	LWP(CMT) (E.I) is 33.7% higher than LW.

Table 2: Bending Stiffness Data

The results confirm that the LWP(FMT) has a much higher bending stiffness than LWP(CMT), being about 22.5% higher. This means that the LWP(CMT) can conform more closely to undulating seabed contours than the LWP(FMT) structure, with a corresponding reduction in length of cable left in suspension. Cable in suspension is at a higher risk of being disturbed by currents and of being moved at the contact points with the seabed at the ends of the suspended cable. Cable laid in good conformity / contact with the seabed is at less risk of being disturbed by currents and hence at less risk of cable abrasion against hard seabed materials.

6. CONCLUSIONS

1) The complete LW cable abrasion characteristic is close to linear and confirms cable engineering rules which restrict the selection of LW cable to those areas of the seabed which are benign in nature (i.e. flat abysmal plains) and areas with low or no bottom currents.

2) Assuming LW cable was deployed over a hard seabed with bottom currents present then approximately 140km of relative cable to sea bottom movement is required to cause cable failure. Note LW cable should not be deployed in this type of sea bottom, which is where LWP is required.

3) The LWP abrasion performance has been quantified and is mainly due to the presence of the metallic tape.

4) Two designs of LWP cable using the same LW cable core, were tested to compare abrasion resistance. Results show that the FMT LWP abrasion resistant is slightly better than the CMT LWP design, being able to withstand 1900km of relative movement compared to 1800km. The FMT design is also more cost-effective to manufacture compared to the CMT variant due to material savings and faster processing speeds.

5) The abrasion resistance of the HDPE jacket material is slightly better than that of the HDPE insulating material. The HDPE insulation abrasion resistance is between 30,000 and 50,000 cycles per mm, the abrasion resistant of the HDPE cable jacket is between 40,000 and 60,000 cycles per mm. Presumably the carbon black used in the cable jacket has some beneficial effect.

6) The LWP variants tested show that the abrasion resistance measured in terms of cable relative movement over a hard seabed is 1800 - 1900 kms.

7) The benefits of choosing a FMT over a CMT are not as clear cut as the abrasion test results might imply. The higher bending stiffness of LWP (FMT) compared to LWP (CMT) is approximately 22.5% higher and will result in longer and more frequent cable

suspensions than the LWP (CMT) when laid under the same conditions and over the same undulating seabed. Cable in suspension will be moved by currents more easily than cable laid in direct contact & in good conformity to seabed materials. Suspended cable has a greater potential for abrasion at the cable / sea bottom contact points at each end of the suspension.

8) While the cable abrasion performance may vary over different hard seabed materials, the simulated seabed material used here is considered a good rapid wearing material which allows the relative comparison of submarine cables.

7. REFERENCES

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[2] C.J.Sandwith, R.L.Ruedisueli, and M.L.Welch, A Standardized Abrasion Resistance Test For Undersea Cable Jackets, 10.1109/OCEANS.1991.613946, pp. 296-300

[3] Jerry Brown, On-Bottom (Sea Bed) Stability Design of Cables, ICPC Plenary Meeting 12 April 2016.