Appendix B
Resin Socketing of Steel Wire Rope

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The concept is not new. The first published data on this topic were produced in the early sixties. In essence, these two papers by Doherty and Campbell, stated that a resin filled socket under either static tension (tensile) or fluctuating tension (fatigue) could offer strengths that were comparable with those of the rope itself.

There is a dearth of information on socketing and the mechanisms by which it works, so it was necessary to establish some basic knowledge before a resin socketing system could be designed.

In theory, the requirements for a successful system are:-

1) High bond strength between resin and wire
2) High modulus of elasticity

To ascertain the bond strength and the magnitude of the predicted frictional grip, tests were done on a single, straight wire cast into a cylindrical block of resin. The embedded length being such, that the wire when loaded would slip rather than break. The cylindrical resin termination was chosen so that there would be no distortion of the figures, due to the mechanical lock, inherent in a conical termination. The results are shown in Figure 1.

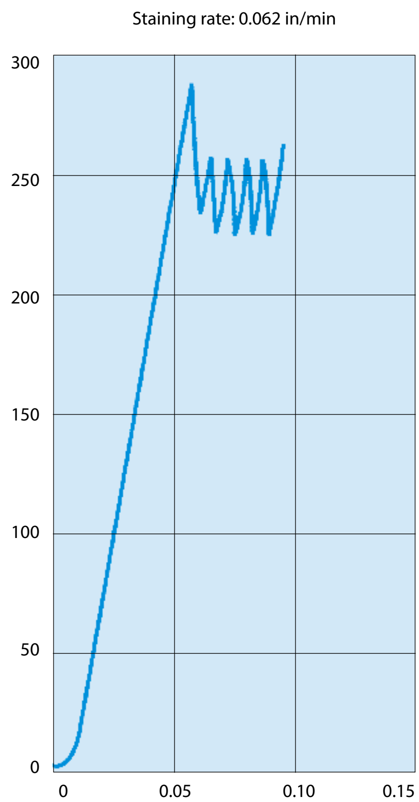


Fig 1

Pull out characteristic for single wire embedded in polyester resin/silica

The graph shows that high bond strengths are achievable between the resin and the wire and that shrinkage of the resin and the inclusion of hard silica in the resin gave a very high frictional grip on the wire. The classic slip/grip peaks and troughs on the right hand side of the loading curve show that the frictional grip is very nearly of the same magnitude as the bond strength.

In practice, it has been found that the wires in the rope broom, which is about to be socketed, are rarely clean enough to achieve anything approaching a good bond strength. Indeed, it will be shown later, when dealing with uncleaned wires, that the frictional grip alone is enough to seat the cone. Either the bond strength of the resin to the wire or the frictional grip of the resin on the wire, is sufficient on their own to seat the cone. Between them they offer a comforting reassurance that the wire will hold and the cone will seat even if the wire has not been cleaned properly.

The modulus of elasticity was measured and found to be 6085 Mpa (BS63 19 Part 6, 1984).

It very soon became apparent, that the bonding action between the socketing medium and the wire was not in itself sufficient to break the rope. Therefore the focus was moved to the shape of the socket, the wedging action it would produce and the mechanism by which this occurred.

The usual total included angle in sockets is between 14/15 degrees and experiments were carried out over the range 9/25 degrees total included angle. It was predicted that the narrower the angle, the lower the load at which movement occurred and the greater that movement would be. In general, this prediction was confirmed, although in the case of the lower angles, the straight line relationship experienced on the wider angles was not found. See Figure II In all cases, the rope ultimately broke, this confirms that the system will cope with a fairly wide deviation from standard socket dimensions.

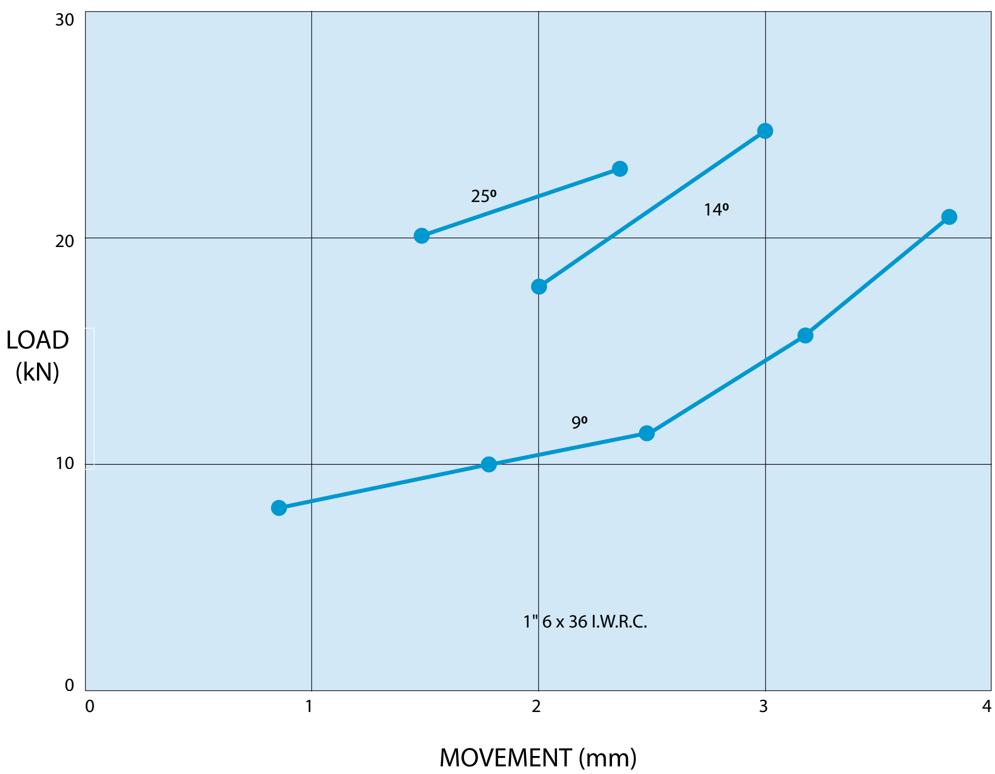
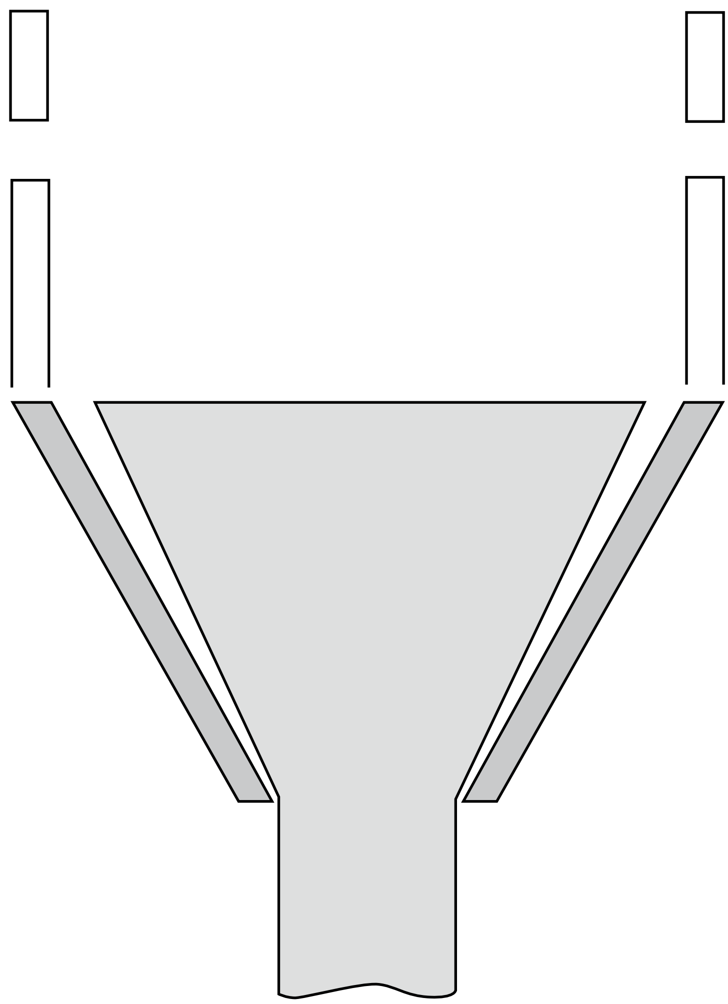


Fig II
Movement within the socket under load for the two extreme angles and the standard 14º taper

The mechanism of this movement and wedging action were investigated by looking at the distribution of pressure through the socket. This showed that approximately two thirds of the total pressure within the socket was concentrated in the bottom third of the socket. Whilst pressure at the top of the socket was very low indeed.

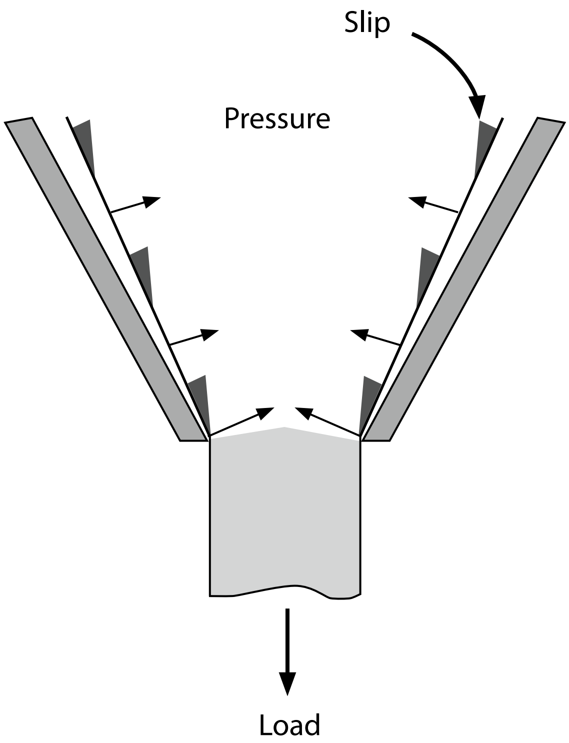
It is necessary to explain why any movement is possible within the socket and to link it with the pressure distribution findings above.

When the resin is first poured into the socket there is a perfect match between the shape of the socket and the resin cone. Once the resin has cured, however, shrinkage occurs and in an exaggerated form the effect is as below. (Fig III)

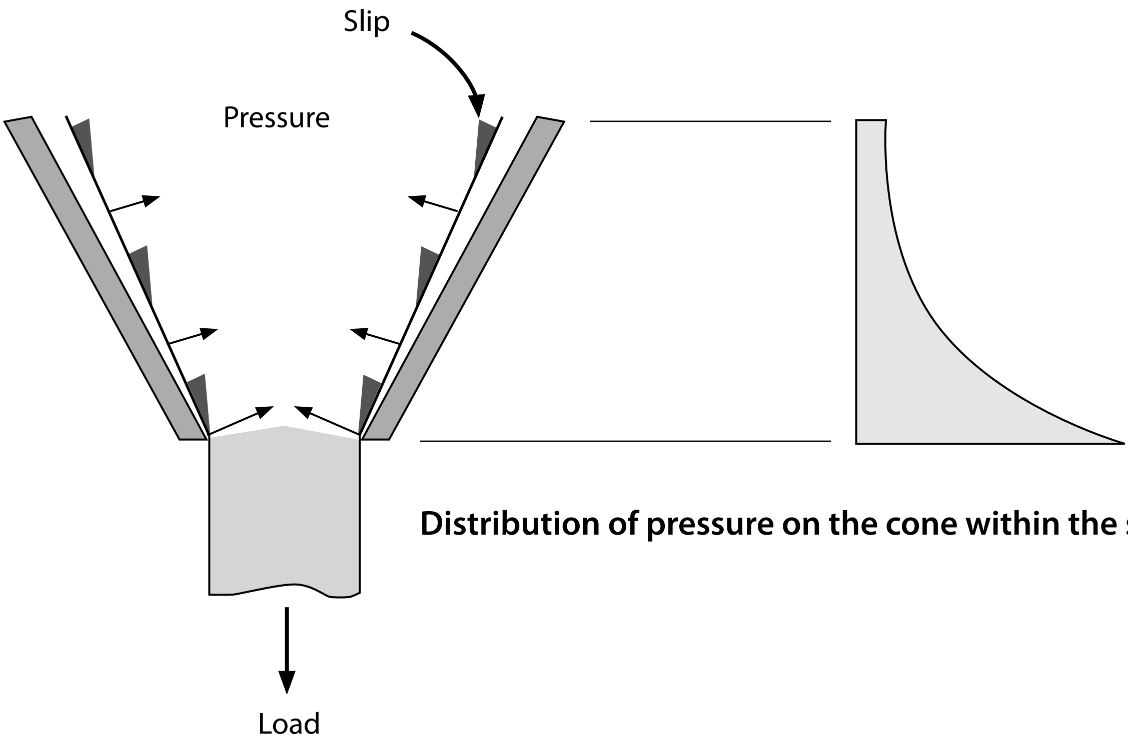


Exaggerated Relationship between Cone and Socket after the Resin has cured
Figure III

When the load is applied to the rope, any adhesion of the resin to the socket will shear and the cone, which is now slightly smaller, will begin to engage the socket wall at the neck of the socket, thereby generating pressure. Although it still retains a high modulus, the resin in contact with the socket is subject to plastic deformation and some flow is possible, allowing more of the cone to share in the loading process. This participation in load bearing diminishes as we proceed up the cone.
See figures IV & V.



Load causes the cone to slip at the socket interface and the pressure generated locks the cone within the socket
Fig IV



Distribution of pressure on the cone within the socket

Fig V

If we examine the forces present in Fig IV, we can see that when load is applied, the cone will seat progressively generating forces normal to the socket face. These forces are transmitted through the resin to the wire surface. We are, in effect, creating a wire reinforced composite wedge on the end of the rope, which is capable of withstanding the ultimate strength of the rope.

We now have to consider two different scenarios to establish the key to this mechanism. In the first case, when the load is applied, the wire slips at the resin/wire interface before the cone slips at the cone/socket interface. In the second case upon application of the load the cone slips in the socket/resin interface before the wire slips within the resin.

In the first case, we have a disaster, as the rope will pull out. In the second case we have success, as the rope will break. What is it that determines which will occur?

Assuming that the coefficent of friction between the wire and the resin and the resin and the socket are of the same order, (an over simplification, but it does produce a simple model), the factor that determines which of the above scenarios will occur is the relationship between the surface area of the wire (S1) and the surface area of the inside of the cone (S2). If S1 is greater than S2 then the cone will seat and the rope will break. If S2 is greater than S1 the assembly will fail.

If, for example, we take a 13mm diameter 6 x 19 IWRC rope the relationship between S1 and S2 is of the order of 6:1, for a 36mm diameter 6 x 36 IWRC 9/:1 and for a 52mm diameter 6 x 41 IWRC 10:1. These figures give an indication of the margins of safety involved when resin socketing is employed. It also shows that the degreasing would have to be disastrously bad to reduce the coefficient of friction at the wire/resin interface to a critical level. One factor that has been ignored in this simple model, is that the unstraightened wires in the broom produce deformation forces when any attempt is made to induce slip thus increasing the grip of the resin on the wire and giving a further factor of safety. This wire in the cast cone, also tends to prevent any significant degree of axial extension of the cone during loading and the cone remains almost a constant length.

It would be useful at this point to examine the Federal Specification socket which has grooves or rings internally. It is obvious, that these rings must shear before the "locking" mechanism can operate and as such, are a hindrance to that process. Incidentally, in the case of zinc and white metal, this rupturing of the rings is also required before the rope will break. The only justification for these rings is to stop the cone "backing out" of the socket. In fact, once "seating" of the cone within the socket has occurred, it is not reversible and the cone is then locked into position.

This irreversibility offers the bonus that the stresses created within the socket are fixed and because there is no fluctuation, it follows that the opportunities for fatigue within the socket are reduced.

Let us return to the question of clean and uncleaned wire. A series of tests were carried out by A.I.F. in France, in which two samples of each of a series of rope sizes and constructions were broomed. One sample was degreased with trichlorethane and the other sample was left uncleaned.

Both samples went on to achieve the full breaking strength of the rope and almost identical breaking loads were achieved.

This highlights the fact that the frictional grip on the wires is highly efficient. If we take an overview of the whole situation it becomes apparent that the key operation in the resin socketing process is the brooming of the rope. Indeed this operation is vital for zinc and white metal as well.

Surface area of wire is vital, especially in the highly loaded section at the neck of the socket. From a quality point of view the broom should be opened right down to the seizing. Very often we see brooms which look very pretty and are nicely opened at the top but the strands remain substantially closed near the seizing. This state of affairs does not produce a quality assembly, even though it may break the rope.

One further point on the production of a quality assembly, is that care should should be taken to ensure that the neck of the socket has been sealed with clay or putty. Any leaks could cause voids in the neck area of the socket. These voids are able to form because the resin starts to gel - harden - in the centre of the mass and if resin leaks out at the neck of the socket, the resin above it during gel is no longer liquid and is, therefore, unable to flow down to fill the void.

It is not necessary to hook wires when resin socketing except in the case of coarse construction wire rope such as 6 x 7.

In use, the resin socketed assembly offers a higher achievable tensile strength and a better fatigue performance of the assembly. In general, this can be attributed to two factors; the excellent penetration of resin, ensuring a complete cone and, secondly, the fact that there is no annealing of the wires due to heat from molten metal. A further benefit that is derived from the lack of heat, is that the lubricant in the rope remains intact and is not burned off. It is an easy matter to replace the lubricant on the outside of the rope but very difficult to replace the lubricant in the centre of the rope. It is, as it does not require any heat, acid etching or neutralising, an inherently safe method, for the rigger to use both in the shop and on site. Finally, the quality and reliability of this method is, without question, superior to other methods of socketing. It also avoids the damage caused to ropes by other mechanical methods of attachment of end fittings, which may affect both the tensile and fatigue potential.

Bibliography.

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Cordon Dr C.R.R.	The Use Of Resin For Man Riding In Mine Shafts	IMEMME	- March 1987

Appendix C

An ISO 9001 Certified Company

the Crosby group, inc.

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April 4, 1989

TECHNICAL BULLETIN NO. 1

Guidelines for re-use of Spelter Sockets (416 and 417)

The use and inspection of Spelter Sockets is the responsibilty of the user.

1 PROCEDURE FOR REMOVING SPELTER CONE

A. Cut the rope close to the nose end of the socket and press the cone out of the socket.

B. We do not recommend the use of heat to remove the spelter cone for metallurgical medical and environmental reasons. (If socket preheat is used in subsequent speltering operations, the socket should not be heated above 200°F)

II SELECTION or SOCKETS FOR RE-USE

A. Use only sockets that:

1. Do not show discolouration from excessive heating.
2. Do not show any signs of welding

B. Select only sockets that have been cleaned and passed a Magnetic Particle Inspection by a qualified technician and performed in accordance prescribed by ASTM E709.

C. Select only sockets that do not show any signs of overloading or wear on the socket or pin. i.e., elongated pin holes, undersize pins. etc.

D. Select sockets that are free from nicks, gouges and abrasions. Indentations may be repaired by lightly grinding until surfaces are smooth provided thay do not reduce the dimension by more than 10% of the nominal catalog dimension.

E. Select sockets that are not distorted, bent or deformed. Sockets having these indications shall not be re-used.

III. PROCEDURES FOR SPELTERING SOCKETS

A. The proper procedure for speltering sockets can be found on Pages 112 - 116 of the Wire Rope Users Manual, Second Edition, and in American Petroleum Institute (API) Recommended Practice 9B (RP 9B), Ninth Edition, May 30, 1986, Pages 10 - 13.

IV. PROOF TESTING

A. We recommend the socketed assembly be proof tested at (2) two times the Working Load Limit (WLL) assigned to the socketed assembly.