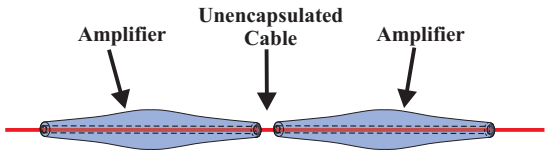
TDR systems have, and are, being utilized at present to successfully monitor displacement in many geotechnical situations. Information regarding location of displacement, type of displacement (shear, tension, etc.), and approximate magnitude of displacement have all been obtained from such systems.

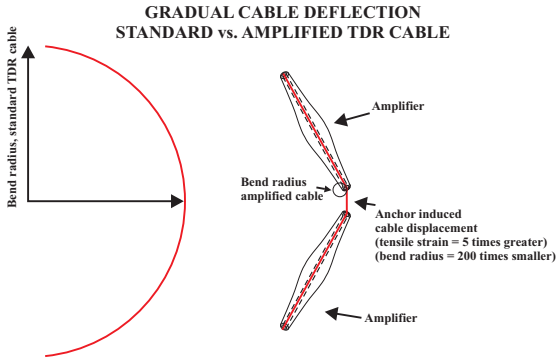
One problem that has been noted with TDR is its relative insensitivity to distributed displacement within a soft soil.

The problems of deformation sensitivity are addressed by a patented system of a displacement magnifier, compliant grout materials, and proper cable selection.

The first portion of this system is the displacement amplifier. The monitoring cable is segmentally encapsulated in a material chosen such that no cable deformation will be allowed within this encapsulated segment. As such, ALL deformation of the geologic material is transferred to the unencapsulated cable between the amplifiers.

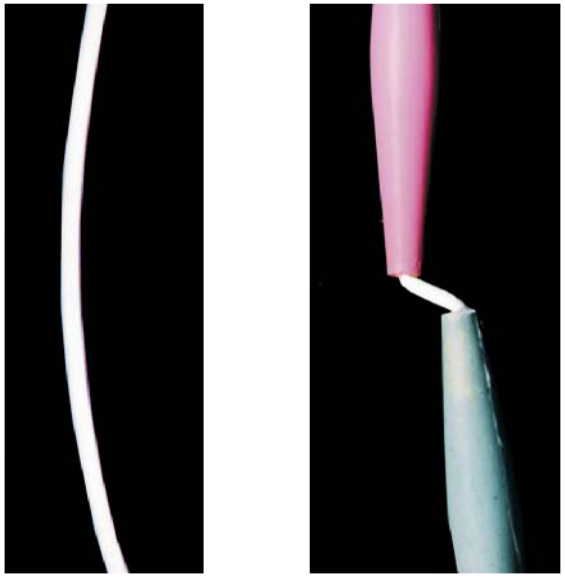


As can be seen below, gradual deformation of a TDR cable without the anchor system will be very difficult to detect. However, the localized strain and displacement in the displacement magnified system is easily seen.



The length and spacing of the amplifiers are chosen such that specific tolerance for displacement is determined, limited only by the constraints imposed by hole dimension and material modulus of the amplifier.

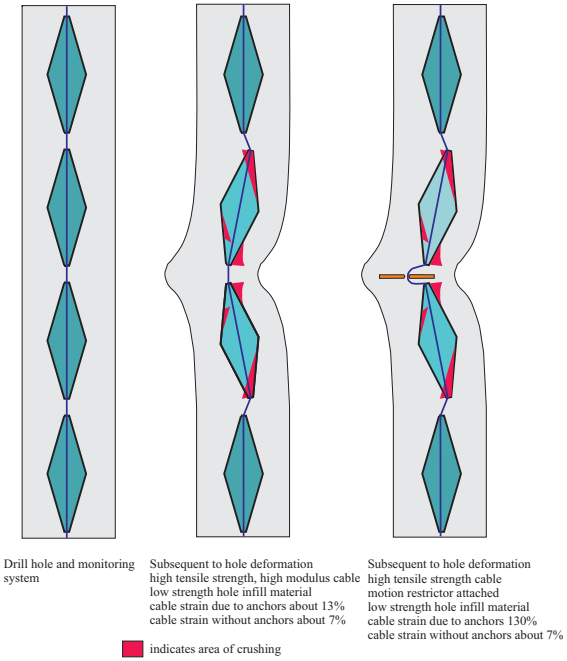
The second portion of the instrument consists of a grout chosen for the material being examined. It should be relatively compliant with the surrounding material but with a compressive strength that allows failure adjacent to the amplifier upon displacement of the host material. Note the crushing adjacent to the amplifiers in the diagram below as the geologic host displaces. This is a function of the rotation of the displacement amplifiers about their centroid. It is a highly desirable characteristic as it increases the tensile strain and decreases the bend radius on the encapsulated TDR cable, increasing the probability of inducing a detectable inflection in the cable.



Unencapsulated **Encapsulated**

Comparison of coaxial cable with similar total deformation. Note the amplification of displacement in the encapsulated version

Soil shear test



In extremely soft materials, a displacement restrictor may be placed between the amplifiers along the TDR cable (right, above). This displacement restrictor forces the TDR cable to travel with the grout as the geologic material is displaced, but only within the immediate vicinity of the restrictor. Thus, as the amplifiers rotate within the grout relative to hole displacement, the restrictors and cable, travel with grout displacement. This dramatically increases the local bending of the TDR cable (right, above).

The TDR cable is then chosen as to performance criteria. Low strength, high sensitivity cables can be chosen if cable breakage (greatest accuracy) is required for a specific locale. High strength, reinforced cable can be utilized for multipoint monitoring.

It must be realized that the exact magnitudes of displacement cannot be determined with this system. It will indicate that displacement is occurring within a geologic mass with high sensitivity. It will allow an estimate of total relative displacement until cable shear. It cannot, due to the rotation of the anchors, indicate exact type or magnitude of displacement.

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