Recent developments in the use of FRP anchors and masonry wall strengthening techniques

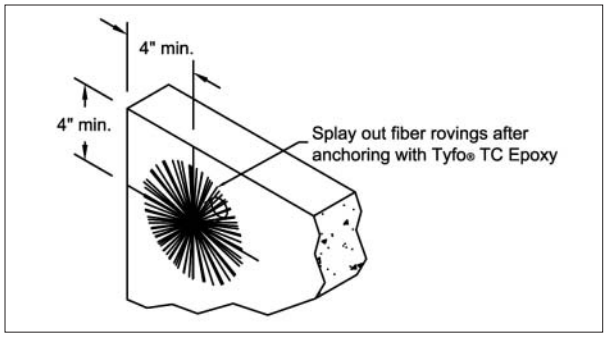
Alan C. Burr, corresponding member of the Research Panel, writes about research in California and Texas into the use of fibre-reinforced polymers (FRP) as embedded anchors and the use of frp to strengthen masonry walls against blast loading

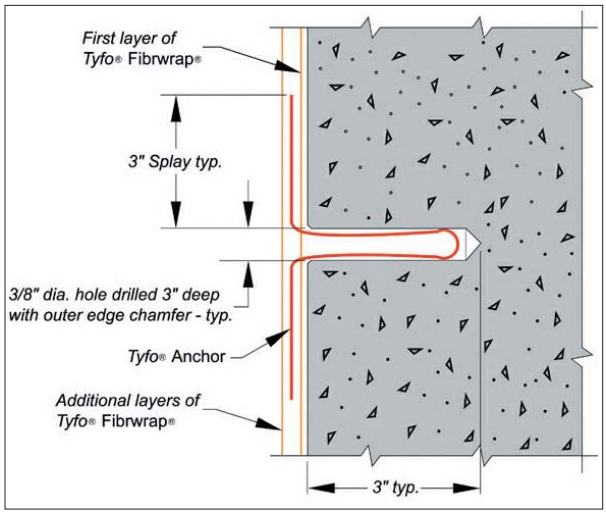
FRP anchors

Testing is currently in progress at the University of California at San Diego to investigate the use of glass and carbon fibre-reinforced polymers as embedded anchors. The anchors would be used to provide a connection for an externally applied FRP laminate on the surface of a concrete or masonry section to the body of the member. The FRP anchor connection provides shear and tensile capacity by embedding the FRP into the substrate and bonding with epoxy, in the same way as a standard steel adhesive anchor. At the surface of the member the FRP rovings are splayed out and then bonded to the externally applied FRP laminate layers with epoxy adhesive. The number of surface fibre layers can be increased locally around the anchors for reinforcement. Figs 1 and 2 show typical anchor details for an embedded anchor.

Anchors can be either partially embedded or pass completely through the member. Partial embedding anchors can be used to connect to the surface of a thick member or when the bonding of the FRP to the surface of the member is not sufficient.

Anchors passing through the member can be used where the member is being wrapped on all sides or where continuity through the member for tensile capacity is required. An example of this would be a reinforced concrete or masonry shear wall which is being strengthened at its ends because of inadequate boundary closed steel reinforcement ties. The FRP would be used on the end face of the wall and for the required length of the boundary element on the sides. To complete the reinforcement for closed ties, FRP anchors would be installed through the wall at regular spacing and bonded to the surface FRP laminate on the sides of the wall.





Another example would be where an existing beam in either concrete or wood is being retrofitted to increase its moment and shear capacity and where it is impractical to fibre wrap the top of the beam. This could be a concrete 'T' beam or wood beam supporting existing joists. FRP is added to the bottom and sides of the beam to increase its strength. At the sides of the beam FRP anchors can be added to provide a positive connection. Fig 3 shows a shear test of an anchor passing through a concrete section.

The advantages of using FRP anchors is that they are fully compatible with the FRP laminate cladding and that they can be securely bonded to the FRP in a way that steel bolts cannot without additional steel side plates or other hardware.

Early testing of the FRP anchors in a testing program sponsored by Fyfe Co. indicates that they have been shown to outperform conventional steel anchors in some applications.

Fig 1. (Top) Arrangement for an embedded FRP anchor
Fig 2. (Above) Section through typical anchor detail

Fig 3. (Left) Shear test of an FRP anchor passing through a concrete section

FRP strengthened masonry walls

A testing programme on masonry walls strengthened with FRP has recently been completed by Baker Engineering and Risk Consultants, Inc. in San Antonio, Texas. The testing investigated strengthening of concrete masonry unit (CMU) walls using FRP for use in blast resistant construction. The testing programme was commissioned by Fyfe Co and Delta Structural Technology, Inc.

The programme consisted of a series of seven tests on three different wall designs strengthened with different configurations of FRP reinforcement. The tests were conducted in a large

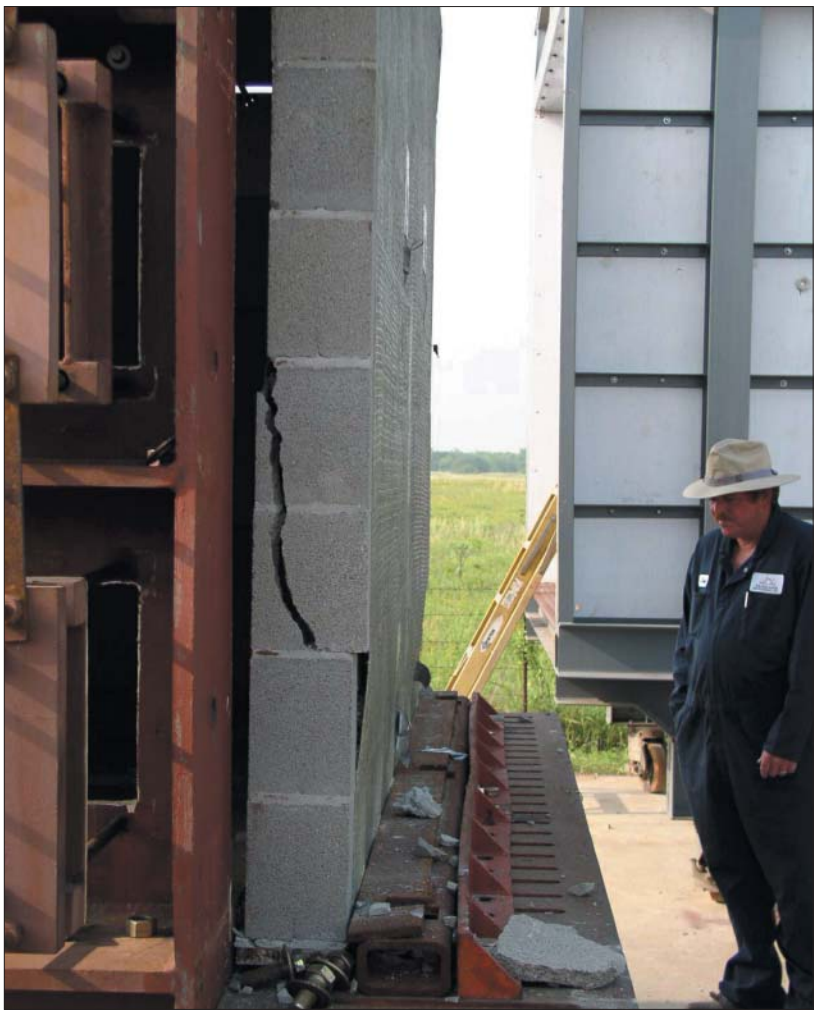


Fig 4. (Above) Test apparatus for blast loading
Fig 5. (Right) Un-grouted masonry wall with high level of FRP reinforcement after blast loading to 6.9psi

shock tube, which was able to subject the test specimens to controlled blasts of air to simulate actual explosive blasts. The test specimens were all 8ft 0in square panels of 6in thick CMU with simply supported boundary conditions. FRP anchors were used along the top and bottom edges of the panels to bond the reinforcement to the walls. The size of the test panels was chosen to represent an equivalent wall of 11ft 0in tall and 8in thick. The FRP used for the tests was Tyfo BG System from Fyfe Co.

The three wall designs included grouted and un-grouted walls with different configurations of the FRP reinforcement. Each wall had vertical strips of reinforcement with 37.5% coverage on the loaded face and either 92% or 69% coverage on the unloaded face. The applied loads varied from between 3.2psi with associated impulse of 100 psi-msec and 7.4psi with associated impulse of 191psi-msec.

The shock tube delivering the blast is a test apparatus that consists of a driver section and expansion section (Fig 4). Blast pressures are generated when a set of diaphragms placed between the two sections is ruptured at a predetermined driver pressure in the driver section. A shock wave then travels down the expansion section and loads the test specimen at the end of the expansion section.

During the tests measurements were taken including strain, deflection and support reaction data, together with high speed film to show the response of the walls and ultimately the mode of failure.

A wide range of wall responses were observed during the test program. The fully grouted wall was tested to the highest load of 7.4psi and incurred only a minor amount of cracking and little permanent deflection.

The un-grouted wall with higher level of reinforcement was tested to a load of 6.9psi and incurred significant damage at the supports due to shear failure (Fig 5) and the second un-grouted wall with lower level of reinforcement collapsed under a load of 4.7psi (Fig 6).

The tests showed that FRP can effectively be used to strengthen existing unreinforced masonry wall panels against long duration blast loads with a peak pressure in excess of 4psi. The tests also showed that the shear mode of failure of the un-grouted walls is less brittle with the added FRP. The FRP strengthening system also can be used to strengthen unreinforced masonry walls against out of plane loads such as from seismic forces and to improve the shear strength of the wall near the support. se

Fig 6. (Below) Un-grouted masonry wall with low level of FRP reinforcement after blast loading to 4.7psi

BIBLIOGRAPHY

- Tyfo Systems product literature by Fyfe Co. LLC
- Shock tube testing of frp strengthened masonry walls by Baker Engineering and Risk Consultants, Inc. for Fyfe Company and Delta Structural Technology, Inc.