CHAPTER 8

STRENGTHENING OF MASONRY WITH COMPOSITES

8.1 General

Strengthening of masonry with composites may be accomplished by employing the same principles as in the case of concrete structures, but with special attention paid to the following subjects: (a) the lack of existing reinforcement (unless the masonry is reinforced) and (b) the proper identification of action effects on various masonry elements within a structure. The latter is explained in Fig. 8.1, which illustrates how different elements of the same masonry building are loaded and damaged during seismic excitation.

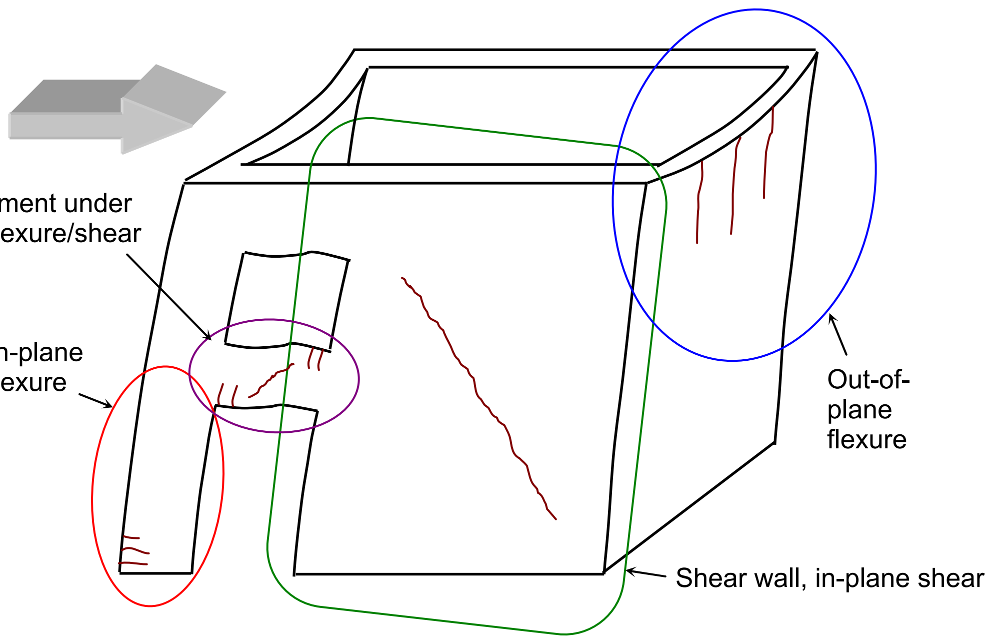


Fig. 8.1 Seismic action effects on unreinforced masonry.

As shown in Fig. 8.1, the primary action effects on unreinforced masonry elements may be summarized as follows:

(a) Out-of-plane flexure, e.g. due to inertial forces perpendicular to vertical walls.
(b) In-plane flexure, e.g. in pillars or lintels.
(c) In-plane shear in shear walls.
(d) In-plane shear in beam-type elements (e.g. lintels).

For each one of the above cases the composite materials may be used with the fibers as parallel as practically possible to the principal tensile stress trajectories (Triantafillou 1998), as described briefly in the next section.

8.2 Configuration of composites for masonry strengthening

Here we present schematically the configuration of FRP reinforcement for the basic actions (a) – (d) described above as well as for the case of confinement.

8.2.1 Out-of-plane or in-plane flexure

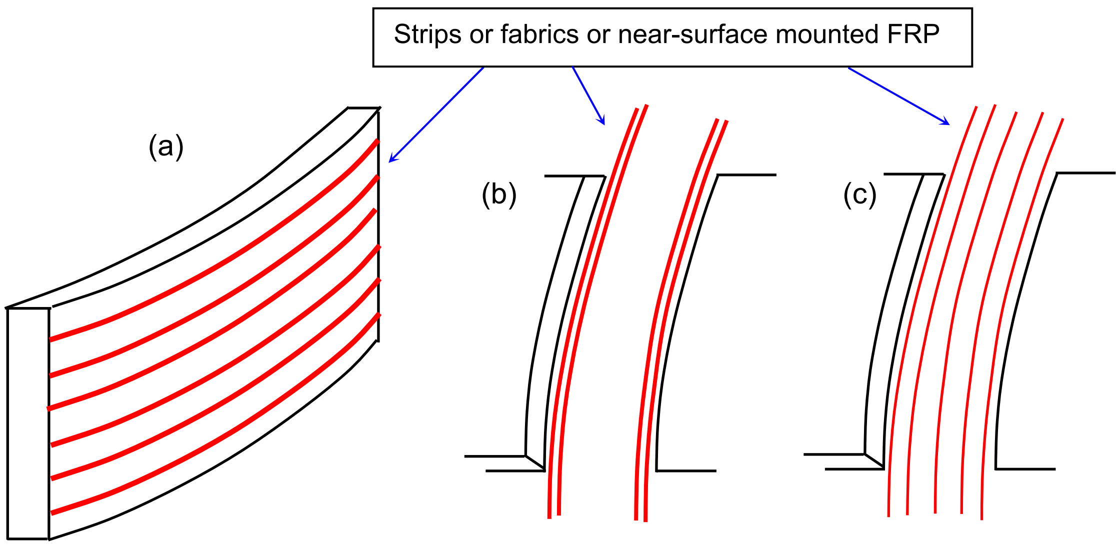


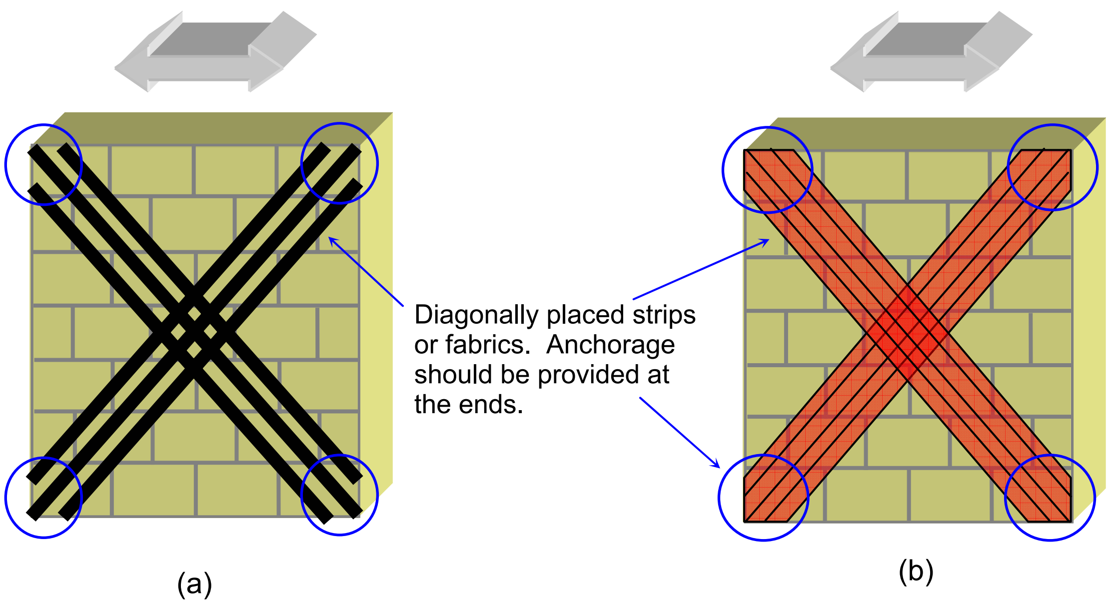
Fig. 8.2 Configuration of composites for flexural strengthening: (a) out-of-plane, (b) in-plane with reinforcement near the extreme tension zones and (c) in-plane with uniformly distributed reinforcement.

In the case of out-of-plane flexure, the composite materials are bonded externally or placed inside grooves, with the fibers parallel to the principal tension trajectories (Fig. 8.2a). However, in the case of in-plane flexure (e.g. pillars, lintels), the placement of reinforcement in the tension sides is not always easy to achieve; hence, the reinforcement is typically bonded on the sides (as in the case of out-of-plane flexure), either as close as possible to the tension zones (Fig. 8.2b) or uniformly distributed (Fig. 8.2c).

8.2.2 In-plane shear

Possible configurations of composites for in-plane shear action are shown schematically in Fig. 8.3. Key advantage of the diagonal placement of strips (Fig. 8.3a) or fabrics (Fig. 8.3b) is the relaxation of the requirement for full removal of plastering. But in order for the diagonally-placed reinforcement to be highly effective, the FRP ends should be anchored either on concrete elements, if any, or onto the masonry, e.g. inside specially prepared cavities, so that the tensile stresses will be transferred from the FRP to masonry not only through shearing but also through compression.

Instead of the diagonal configuration, strips or fabrics may be bonded also with the fibers placed horizontally, that is parallel to the loading direction (Fig. 8.3c, 8.4d – top). Another interesting possibility, in the common case of masonry with horizontal bed joints, is the placement of FRP bars inside the joints, after removal of the mortar near the surface (near-surface mounted FRP); this is illustrated in Fig. 8.3d-e.



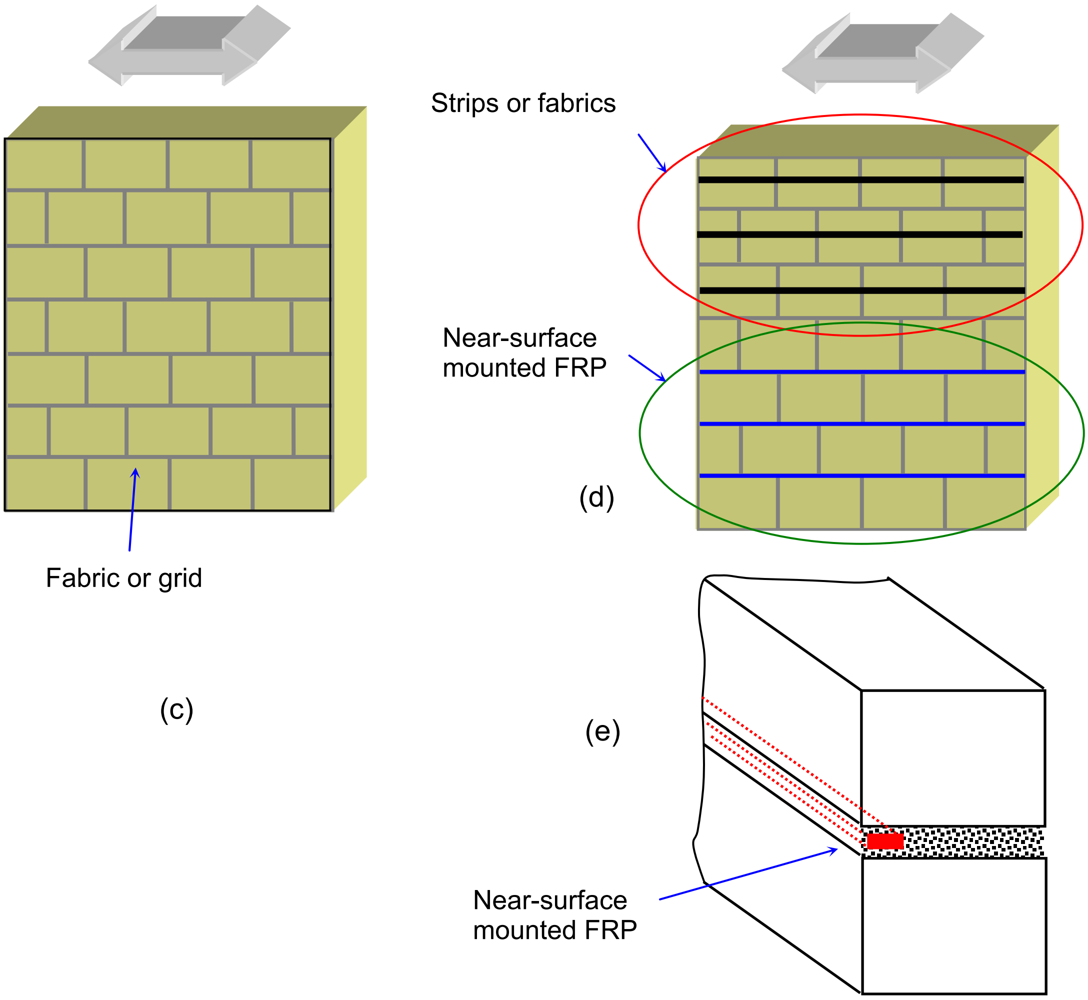


Fig. 8.3 Composite materials strengthening configurations for in-plane shear.

Fig. 8.4 Diagonally placed strips.

8.2.3 Confinement

Confinement in masonry structures may be employed to increase the strength (compressive, tensile, shear) and/or the ductility, by suppressing cracking perpendicular to the principal compressive stress trajectories. This is achievable using externally applied prestressing tendons (e.g. Triantafillou and Fardis 1997) or even jackets, as in the case of concrete. Schematical configurations of composites used for confinement are given in Fig. 8.5 and photographs are shown in Fig. 8.6.

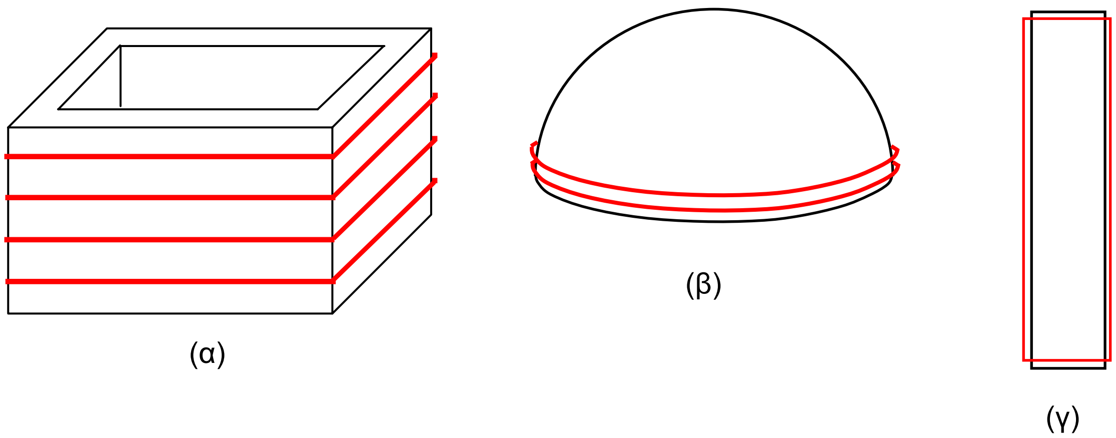


Fig. 8.5 Confinement of masonry to increase: (a) the shear strength, through prestressing; (b) the tensile resistance at the base of domes, through prestressing; and (c) the ductility or shear resistance or axial resistance of columns.

(a) (b)

Fig. 8.6 Confinement (a) of masonry columns and (b) using horizontal ties.

8.2.4 Consolidation of vaults and arches

The consolidation of vaults and arches using composites (e.g. strips or fabrics) aims to increase the out-of-plane flexural resistance. The objective in this case is basically to activate the fibers in the locations of potential hinges during collapse (Fig. 8.7) and hence to prevent severe damage during earthquakes.

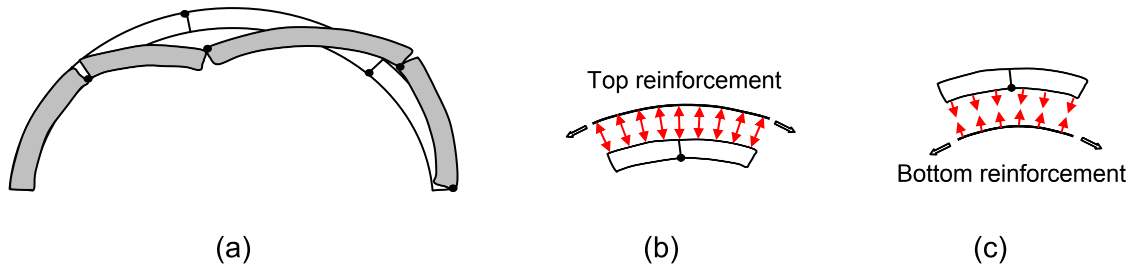


Fig. 8.7 Consolidation of vaults and arches with composites on top and bottom.