Geogrids for reinforcing masonry buildings and structures

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ABSTRACT: The paper presents the mathematical model for reinforcing masonry in seismic areas. The model is based on Prandtl's Theory of Plasticity and approaches the ultimate limit state reached by mortar under the combined action of vertical and lateral loads. It is assumed that when on some interfaces the shearing stresses reach their limit values of yielding the bed joint mortar behaves like a plastic material and is laterally expelled. The so-called *sandwich effect* occurs. Beside the loading conditions the phenomenon depends on the mechanical properties of mortar by its shearing strength and by the geometry of masonry by its aspect ratio. With the aid of polymer grids inserted in bed joints the expulsion phenomenon is put under control and can be reduced or definitely prevented. The synthetic reinforcement was already successfully used in other engineering applications. In the case of masonry by lab tests the techniques of reinforcing, either by inserting in bed joints or by confining, were statically and dynamically validated. They are cost effective and easily applied either to existing damaged buildings for repair and retrofitting or to new ones for strengthening and preventing damages. Neither additional qualification of labor nor extra devices is required

1 INTRODUCTION

Masonry is one of the oldest construction materials still used for a large number of buildings and structures. Originally, it was consisting of elastic clay brick and plastic lime mortar. During centuries by its ductility masonry self-defended against any stress concentrations caused by unequal settlements, natural hazards or technological aggression. After the industrial revolution the bearing capacity of masonry buildings has had to be increased. The porous solid bricks were replaced with ceramic caved bricks, while in mortars cement replaced the lime. Therefore brittle bricks are now bound with brittle mortar. The resulted masonry became indeed more resistant and stronger but it almost completely lost its ductility. Under seismic actions for example the brittle caved bricks are easily crushing. The principle of *fail-safe* does not any longer apply to the modern masonry. Since to the occurring dramatic situation there is no returning way to the old masonry the advanced technology answered with alternative solutions beginning with chemical additives for mortars and ending with a large sort of fibbers. The basic idea promoted by this paper is to restore the ductility of masonry with the aid of synthetic reinforcement.

2 POLYMER GRIDS

The proposed synthetic reinforcement consists in polymer grids. When placed in a continuous medium such as mortar, the ribs that are transverse to the direction of primary loading act as a series of bearing surfaces or anchors. This is a highly efficient mechanism for transferring stress that mobilizes the maximum benefit from the grid reinforcement and minimizes anchorage lengths. The ribs of the integral biaxial grids are manufactured with near vertical faces, which provide an excellent bearing surface for interlocking with aggregate particles of the mortar. The interlocking mechanism between grid reinforcement and different matrices has been demonstrated in both laboratory and on site pull out testing. Polarized light has been used to view the rupture patterns during pull out testing of a grid in a bath containing sintered glass and glycerin. This effective interlock mechanism combined with high junction strength, sufficient constraining hoop bursting stress and high tensile stiffness at low strains, accounts for the efficiency of the biaxial grids in strengthening mortar and confining masonry.

The reinforcing approach with synthetic grids essentially differs from that used for steel bars. Polymer grids are firmly fixed in mortar by interlocking of their joints. The mechanism of stress transfer from mortar to grids is discontinuous and produces only around the solid joints through normal stresses, without any contribution of the tangential ones. Only tensile forces are transferred from mortar to grids. Inserting such grids in bed joints prevents lateral expansion of the mortar through tensile forces in the grid. In addition, the tensile forces in grids together with shearing stresses at the two interfaces prevent the development of lateral strains in the horizontal plane. In this way the mortar is subjected to a three axial state of compression, which substantially increases its bearing capacity. Since the strengths of grids are much higher than the loads transmitted by bricks, it is practically unnecessary to reinforce each bed joint. In most cases, reinforcing each fifth layer, or 2-3 layers per meter run, would be sufficient.

3 REINFORCING TECHNIQUES

For seismic protection of buildings and structures, reinforcing the masonry structural members with polymer grids shows great potential. This work involves three specific techniques for reinforcing masonry with polymer grids: 1) inserting them in the horizontal layers of mortar between bricks; 2) coating the outer surfaces of masonry with reinforced plaster; and 3) confining the structural members with the same reinforced plaster. In all cases, synthetic reinforcement compensates for masonry's lack of ductility and enhances its natural strength capacity.

The first technique improves load transfer capacity between the masonry units, since the reinforcement prevents horizontal expansion of mortar. As already mentioned, it is not necessary to lay the grids in all mortar beds, but only in some of them at vertical distances between 20 cm and 40 cm. The joints are obtained by superposition without any joining devices. Coating the masonry with reinforced plaster improves the shear resistance of the masonry wall, whether or not the horizontal reinforcement is present. This technique is efficient only when the reinforced plaster adheres well to the masonry surface. The effect of this type of reinforcement is bi-directional, in the plane of the wall. Finally, confinement with reinforced plaster improves both compression and shears resistance and is most efficient when combined with the reinforcement in horizontal layers. This type of reinforcement acts in a three-dimensional sense and can be used to increase the bearing capacity of structural members several times.

The polymer grids can be used as reinforcement for both engineered and non-engineered masonry within either new or old buildings. Each case should be analysed separately according to the characteristics of the masonry units and the mortar, as well as the type of construction. The importance of workmanship in this context cannot be overstated. Typical masonry configurations are commonly laid in *running* bond, with the units overlapped on half their length. Single-wythe, or barrier walls are most common. Multiple-wythe walls are also constructed and can consist of composite brick-block walls. However, cavity walls are not allowed in seismic areas.

All the available masonry units, such as bricks and blocks, can be associated with polymer grids. Clay units, dense or lightweight aggregate concrete units, autoclaved aerated concrete units, calcium silicate units and natural stones can be used in reinforced structural members. Solid clay bricks are the most efficient for use with reinforcing, since they produce a rather uniform pressure on the polymer grids. Vertically perforated bricks are also useful in reinforced masonry. In seismic areas vertically hollowed bricks are not recommended, while horizontally hollowed ones are prohibited.

Three types of mortar are commonly used for masonry: cement, cement–lime and lime mortar. When masonry is reinforced with steel bars, lime is not allowed for corrosion reasons and only cement mortar should be used. On the contrary, for synthetic reinforcement there are no restrictions on mortar composition. Of course, the most common cement-lime mortar, in all code-specified proportions, can be freely used. In some cases, lime mortar may be preferred for special convenience. There is also no limitation on characteristic compressive strength of the mortar. The additives like plasticizer, air-entraining, water-retention and set-retarding agents can be freely associated with the polymer grids (Sofronie 1999 a,b).

4 MATHEMATICAL MODEL

In order to explain the behaviour of masonry under the simultaneous action of vertical force of compression *P* and a horizontal shear force *Q* the Prandtl's type of mathematical model was adopted. The bricks are considered as parallel, rigid and rough plates while the mortar as a thin, plastic layer with the ratio *a/b* always larger than 10 (Fig.1).

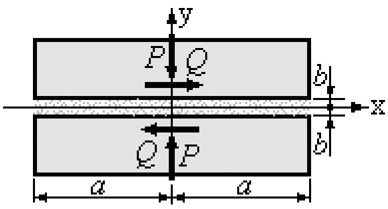
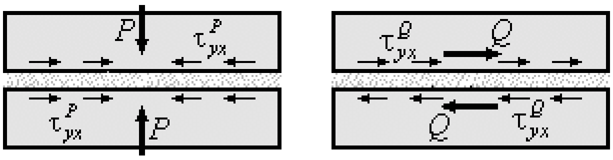


Figure 1: Prandtl's mathematical model

When only compressed up to the limit state of plastic equilibrium the layer of mortar flows sideways from the centre to the edges. Large tangential stress arise at the contact surface (Fig. 2a).



a. Vertical force *P* b. Horizontal force Q

Fig 2: Tangential stresses τ_{yx}^{P} and τ_{yx}^{Q}

When submitted only to shear up to the same limit state of plastic equilibrium in the bed joint of mortar tangential stresses occur (Fig. 2b). For the sake of simplicity they will be assmed uniformly distributed.

Usually, the forces *P* and *Q* are simultaneously acting. Then the two components of tangential stresses are superposing. On the interfaces, where the maximums value *k* is reached, i.e.

$$\tau_{yx}^{Q} + \tau_{yx}^{P} = k \tag{1}$$

plastic deformations are developing. In the other interfaces where

$$\tau_{yx}^{Q} - \tau_{yx}^{P} = k_1 < k \tag{2}$$

the yield limit for shear *k* is not reached (Fig. 3).

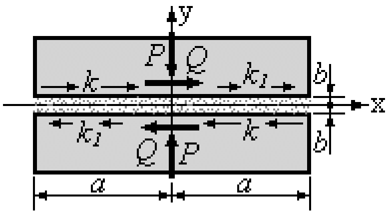


Figure 3: Limit state of tangential stresses

Generally, when $\tau_{yx}^{Q} > \tau_{yx}^{P}$ k_1 is positive. The cases when $\tau_{yx}^{Q} = \tau_{yx}^{P}$ and $k_1 = 0$, or $\tau_{yx}^{Q} < \tau_{yx}^{P}$ and k_1 is negative are also further considered.

With the notation

$$\frac{k_1}{k} = \kappa \tag{3}$$

where always

$$|\kappa| \le 1 \tag{4}$$

one assumes for the state of stresses in plane strain the solution

$$\sigma_x = \sigma_y + 2k\sqrt{1 - \left(\frac{\tau_{xy}}{k}\right)^2} \tag{5}$$

$$\sigma_y = k\left(C + \frac{1-\kappa}{2}\frac{x}{b}\right) \tag{6}$$

$$\tau_{xy} = k\left(\frac{1+\kappa}{2} - \frac{1-\kappa}{2}\frac{y}{b}\right) \tag{7}$$

where C is an arbitrary constant.

This solution should satisfy both the differential equations of equilibrium

$$\left.\begin{aligned} \frac{\partial\sigma_x}{\partial x} + \frac{\tau_{yx}}{\partial y} &= 0 \\ \frac{\partial\tau_{xy}}{\partial x} + \frac{\partial\sigma_y}{\partial y} &= 0 \end{aligned}\right\} \tag{8}$$

and the yield criterion

$$(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2 = 4k^2 \,. \tag{9}$$

In addition the expression of tangential stresses τ_{xy} (7) should satisfy the boundary conditions along the lines $y = \pm b$. Indeed, for $x > 0$ and $y = +b$, $\tau_{xy} = k_1$, and for $y = -b$, $\tau_{xy} = k$.

In particular for $\kappa = -1$ from (5-7) one finds

$$\left.\begin{aligned} \sigma_x &= k\left(C + \frac{x}{b} + 2\sqrt{1-\left(\frac{y}{b}\right)^2}\right) \\ \sigma_y &= k\left(C + \frac{x}{b}\right) \\ \tau_{xy} &= -k\frac{y}{b} \end{aligned}\right\},$$

(10)

which corresponds to the state of compression without shear, while for $\kappa = +1$

$$\sigma_x = \sigma_y = 0; \;\; \tau_{xy} = k, \tag{11}$$

i.e. the pure shear of the plastic layer of mortar occurs.

The above equations must be supplemented by relations which link the stress components with the increments in the strain components. Such relations are those of the Saint Venant-von Mises Theory of Plasticity. For the case of plane strain there is the equation

$$\frac{\sigma_x - \sigma_y}{2\tau_{xy}} = \frac{\dfrac{\partial v_x}{\partial x} - \dfrac{\partial v_y}{\partial y}}{\dfrac{\partial v_x}{\partial y} + \dfrac{\partial v_y}{\partial x}} \;, \tag{12}$$

where v_x and v_y are velocity components.

This equation states that the direction of the surface of maximum tangential stresses coincides with the direction of the surface which experiences the maximum rate of shear strain. In addition the incompressibility condition

$$\frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} = 0 \tag{13}$$

should be satisfied.

The components of the velocity vector

$$v_x = V + c\left(\frac{x}{b} + 2\sqrt{1 - \frac{y^2}{b^2}}\right) \tag{14}$$

and

$$v_y = -c\frac{y}{b} \tag{15}$$

satisfy the incompressibility condition (13) and equation (12) for the arbitrary values of the constants c and V. It follows from (14) and (15) that each of the bricks moves on the mortar layer with a speed c.

The parameters c and V are related through the incompressibility condition; the flux of material through the section $x = a$ must be equal to the amount of material which extrudes in unit time and length a as the bricks move together

$$-\int_0^b v_x dy = ac \;. \tag{16}$$

Replacing here v_x from (14) and with $x = a$ one obtains

$$V = -2c\left(\frac{a}{b} + \frac{\pi}{4}\right). \tag{17}$$

The constants C and κ are further determined form the condition of static equivalence. First from the condition that there are no normal stresses on the edge of the layer, in the Saint Venant sense, i.e.

$$\int_{-b}^{+b} (\sigma_x)_{x=a}\, dy = 0\,, \tag{18}$$

one finds

$$C = \frac{1}{1-\kappa}\left(\kappa\sqrt{1-\kappa^2} + arcsin\,\kappa - \frac{\pi}{2}\right) - \frac{1-\kappa}{2}\frac{a}{b}\ . \tag{19}$$

In particular, for $\kappa = -1$

$$C = -\left(\frac{a}{b} + \frac{\pi}{2}\right). \tag{20}$$

Next, the condition that the normal stresses σ_y are equivalent with a compression force P, i.e.

$$\int_0^a \sigma_y\, dx = -\frac{P}{2}\ , \tag{21}$$

gives

$$C = -\frac{P}{2ka} - \frac{1-\kappa}{4}\frac{a}{b}\ , \tag{22}$$

and for $\kappa = -1$

$$C = -\frac{1}{2}\left(\frac{P}{ka} + \frac{a}{b}\right).$$

With the notation

$$\frac{P}{2ka} = p \tag{23}$$

the above expression of arbitrary constant C becomes

$$C = -p - \frac{1-\kappa}{4}\frac{a}{b}\ . \tag{24}$$

By comparing expressions (19) and (24) one obtains

$$p = \frac{1-\kappa}{4}\frac{a}{b} + \frac{1}{1-\kappa}\left(\frac{\pi}{2} - \kappa\sqrt{1-\kappa^2} - arcsin\,\kappa\right), \tag{25}$$

where

$$p = f(\kappa), \quad \kappa \in [-1\ \ +1]\ .$$

In particular, for $\kappa = -1$

$$p = \frac{1}{2}\left(\frac{a}{b} + \pi\right). \tag{26}$$

Finally, the condition that the contact tangential stresses are equivalent to a shearing force Q yields to

$$k + k_1 = \frac{Q}{2a}\ . \tag{27}$$

With the notation

$$\frac{Q}{2ka} = 2q \tag{28}$$

from (27) results

$$1+\kappa=2q \ . \tag{29}$$

Replacing κ in expression (25) one finds

$$p=\frac{(1-q)}{2}\frac{a}{b}+\frac{1}{2(1-q)}\left[\frac{\pi}{2}-2(2q-1)\sqrt{q(1-q)}-arcsin(2q-1)\right] . \tag{30}$$

In particular, for $q = 0$ one finds

$$p=\frac{1}{2}\left(\frac{a}{b}+\pi\right) ,$$

which is identical with (26), and from (23), for the bearing capacity under compression without shearing, results

$$P=ka\left(\frac{a}{b}+\pi\right) . \tag{31}$$

Shearing force *Q* reduces this bearing capacity as it is shown in figure 4 where expression (30) is represented for five values of the aspect ratio *a/b*.

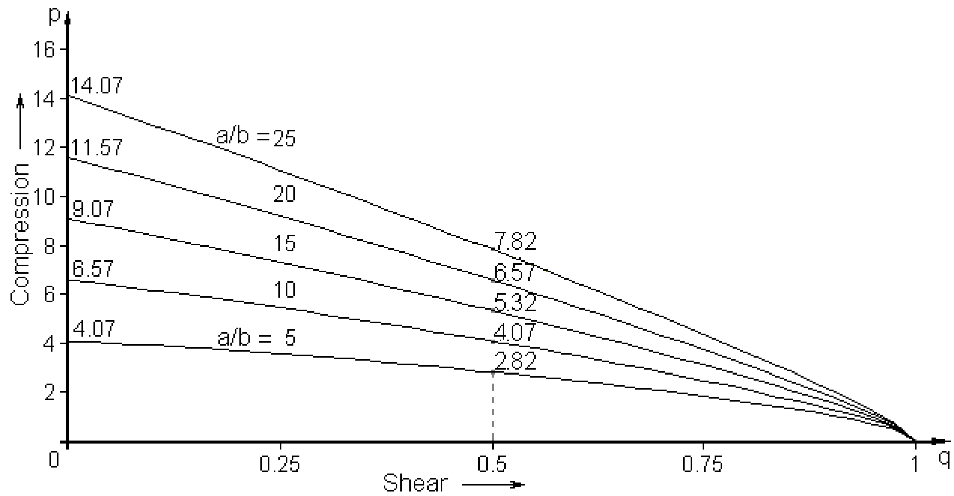


Figure 4: Shear – Compression diagram

For the particular cases when κ = 0 and $q = 1/2$

$$p=\frac{1}{4}\left(\frac{a}{b}+2\pi\right) , \tag{32}$$

while when κ = +1 and $q = 1$, $p = 0$, i.e. the pure shear occurs.

Now, by considering expression (19) for the arbitrary constant *C* the solution of the state of stresses (5÷7) becomes

$$\sigma_x=k\left[\frac{1}{1-\kappa}\left(\kappa\sqrt{1-\kappa^2}+arcsin\,\kappa-\frac{\pi}{2}\right)\frac{1-\kappa}{2}\frac{a-x}{b}+2\sqrt{1-\left(\frac{1+\kappa}{2}-\frac{1-\kappa}{2}\frac{y}{b}\right)^2}\right] , \tag{33}$$

$$\sigma_y = k\left[\frac{1}{1-\kappa}\left(\kappa\sqrt{1-\kappa^2} + arcsin\,\kappa - \frac{\pi}{2}\right) - \frac{1-\kappa}{2}\frac{a-x}{b}\right], \tag{34}$$

$$\tau_{xy} = k\left(\frac{1+\kappa}{2} - \frac{1-\kappa}{2}\frac{y}{b}\right), \tag{35}$$

where κ is as defined by expression (3). Note that expression (19) satisfies only the condition (18) for σ_x not also the condition (21) for σ_y.

Particularly, for κ = -1 one finds

$$\left.\begin{aligned} \sigma_x &= -k\left(\frac{\pi}{2} + \frac{a-x}{b} - 2\sqrt{1-\frac{y^2}{b^2}}\right) \\ \sigma_y &= -k\left(\frac{\pi}{2} + \frac{a-x}{b}\right) \\ \tau_{xy} &= -k\frac{y}{b} \end{aligned}\right\}, \tag{36}$$

what means compression without shear. For κ = 0

$$\left.\begin{aligned} \sigma_x &= -k\left(\frac{\pi}{2} + \frac{a-x}{2b} - 2\sqrt{1-\frac{1}{4}\left(1-\frac{y}{b}\right)^2}\right) \\ \sigma_y &= -k\left(\frac{\pi}{2} + \frac{a-\kappa}{2b}\right) \\ \tau_{xy} &= -\frac{1}{2}k\left(1-\frac{y}{b}\right) \end{aligned}\right\}, \tag{37}$$

and for κ = +1

$$\sigma_x = \sigma_y \quad ; \quad \tau_{xy} = k \ , \tag{38}$$

what means pure shear.

It is to notice in expressions (33÷35) that

$\sigma_x = \sigma_x(x/a\ ,y/b;\ a/b)$; $\sigma_y = \sigma_y(x/a;\ a/b)$; $\tau_{xy} = \tau_{xy}\ (y/b)$.

For x = 0 , y = 0 from (33÷35) one finds

$$\left.\begin{aligned} \sigma_x &= \sigma_y + 2k\sqrt{1-\left(\frac{1+\kappa}{2}\right)^2} \\ \sigma_y &= k\left[\frac{1}{1-\kappa}\left(\kappa\sqrt{1-\kappa^2} + arcsin\,\kappa - \frac{\pi}{2}\right) - \frac{1-\kappa}{2}\frac{a}{b}\right] \\ \tau_{xy} &= k\left(\frac{1+\kappa}{2}\right) \end{aligned}\right\},$$

(39)

and for x = *a*, y = 0 from the same expressions (33÷35)

$$\left.\begin{aligned}\sigma_x &= \sigma_y + 2k\sqrt{1-\left(\frac{1+\kappa}{2}\right)^2}\\ \sigma_y &= k\left[\frac{1}{1-\kappa}\left(\kappa\sqrt{1-\kappa^2}+\arcsin\kappa-\frac{\pi}{2}\right)\right]\\ \tau_{xy} &= k\left(\frac{1+\kappa}{2}\right)\end{aligned}\right\}. \tag{40}$$

The distance $\bar{x}$ at which the normal stress σ_x vanishes, i.e. $\sigma_x \rightarrow 0$, results from (33)

$$\bar{x} = \frac{2b}{1-\kappa}\left[\frac{1-\kappa}{2}\frac{a}{b}-\frac{1}{1-\kappa}\left(\kappa\sqrt{1-\kappa^2}+\arcsin\kappa-\frac{\pi}{2}\right)-2\sqrt{1-\left(\frac{1+\kappa}{2}-\frac{1-\kappa}{2}\frac{y}{b}\right)^2}\right]. \tag{41}$$

For κ = -1 expression (41) takes the values

$$\left.\begin{aligned}(\bar{x})_{y=+b} &= a+\frac{\pi}{2}b > a\\ (\bar{x})_{y=0} &= a-\left(2-\frac{\pi}{2}b\right) = a - 0.43b < a\\ (\bar{x})_{y=-b} &= a+\frac{\pi}{2}b > a\end{aligned}\right\}. \tag{42}$$

The variation of function σ_x, as defined by (33), in *x* direction is shown in figures 5 and 6.

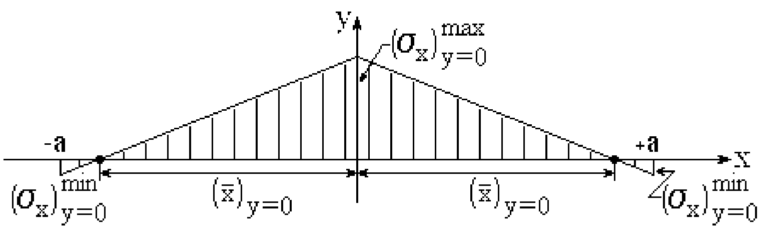


Figure 5: Normal stress σ_x in x direction for *y* = 0

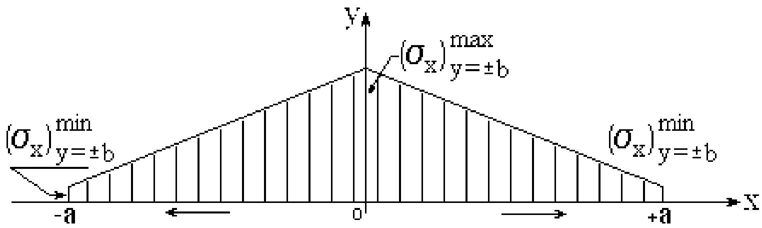


Figure 6: Normal stress σ_x in x direction for $y = \pm$b

The function of normal stress σ_y, as defined by (34), is constant in *y* direction. Its extreme values in *x* direction are

$$(\sigma_y)^{max}_{x=0} = k\left[\frac{1}{1-\kappa}\left(\kappa\sqrt{1-\kappa^2} + arcsin\,\kappa - \frac{\pi}{2}\right) - \frac{1-\kappa}{2}\frac{a}{b}\right] \quad (43)$$

and

$$(\sigma_y)^{min}_{x=a} = k\left[\frac{1}{1-\kappa}\left(\kappa\sqrt{1-\kappa^2} + arcsin\,\kappa - \frac{\pi}{2}\right)\right]. \quad (44)$$

For κ = -1 one obtains

$$(\sigma_y)^{max}_{x=0} = -k\left(\frac{a}{b} + \frac{\pi}{2}\right) \quad (45)$$

and

$$(\sigma_y)^{min}_{x=a} = -k\frac{\pi}{2}\,. \quad (46)$$

The last value is small but non-zero because for integration constant *C* expression (19) not (22) was considered.

The variation of function σ_y, as defined by (34), in *x* direction is shown below in figure 7.

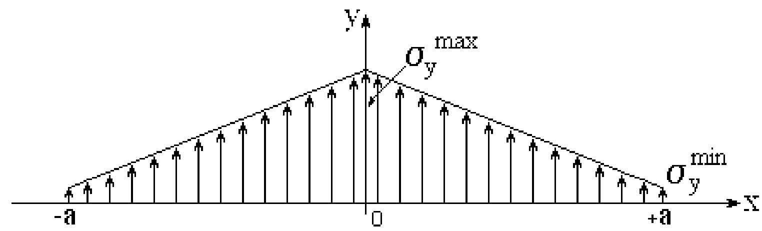


Figure 7: Normal stress σ_y in x direction

The difference between the two normal stresses σ_x and σ_y is rather small, namely

$$\Delta\sigma = \sigma_x - \sigma_y = 2k\sqrt{1-\left(\frac{1-\kappa}{2} - \frac{1-\kappa}{2}\frac{y}{b}\right)^2} \quad (47)$$

and varies on *y* direction as follows

$$\left.\begin{aligned}(\Delta\sigma)_{y=b} &= 2k\sqrt{1-\kappa^2}\\ (\Delta\sigma)_{y=0} &= 2k\sqrt{1-\left(\frac{1+\kappa}{2}\right)^2}\\ (\Delta\sigma)_{y=-b} &= 0\end{aligned}\right\}.$$

(48)

The variation of the three stresses σ_x, σ_y, τ_{yx} on *y* direction is represented in figure 8.

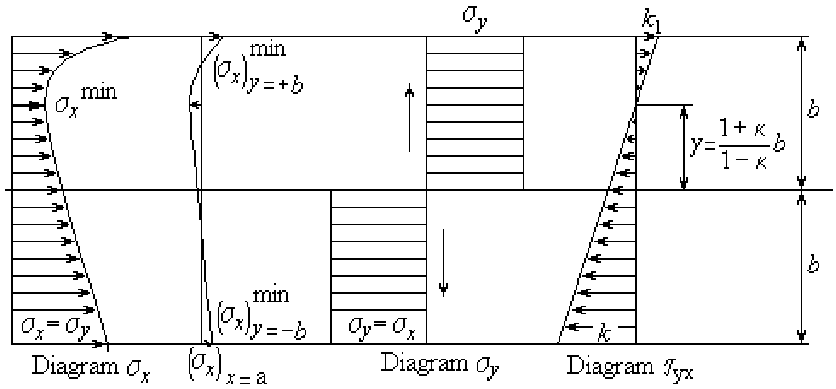


Figure 8: Variation of stresses on mortar layer thickness

The expulsion force developing in bed joint layer it is composed by the influence of normal stresses σ_x and tangential stresses τ_{xy}. The first one gives

$$N_x = \int_{-b}^{+b} \sigma_x dy = k(1-\kappa)(x-a) \ , \tag{49}$$

while from the second one finds

$$S_x = \frac{1}{2} k_1 \frac{2b\kappa}{1+\kappa} - \frac{1}{2} k \frac{2b}{1+\kappa} = (k_1 - k)b \ . \tag{50}$$

By superposing the two expressions results

$$F = N_x \ + \ S_x \ = \ k(1\text{-}\kappa)(x\text{-}a\text{-}b) \ . \tag{51}$$

This takes the maximum value for $x = 0$

$$F_{max} = -k(1\text{-}\kappa)(a+b) \ , \tag{52}$$

and becomes minimum for $x = a$,

$$F_{min} = -k(1\text{-}\kappa)b \ . \tag{53}$$

As concerns the ratio κ at compression without shear, for κ = -1, from (51) results

$$F = 2k(x-a-b) \ , \tag{54}$$

for $\kappa = 0$

$$F = k(x-a-b) \ , \tag{55}$$

and finally for pure shear when $\kappa = 1$,

$$F = 0 \ , \tag{56}$$

when no expulsion occurs.

By inserting a reinforcement in the bed joint the phenomenon of expulsion can be reduced or prevented (Fig. 9).

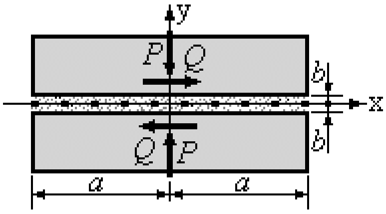


Figure 9: Bed joint reinforced with polymer grid

The strength condition is

$$F \leq R \ , \tag{57}$$

where R is the design strength of the synthetic reinforcement in kN/m. Since the maximum expulsion occurs in the central zone of the model condition (57) should be checked for $x = 0$.

Practically, there is not necessary to reinforce every bed joint of masonry columns and walls. For the usual values of forces P and Q the analysis has shown and the lab test confirmed that is good enough if only each fourth, fifth or sixth bed joint were reinforced with polymer, grids (Fig. 10).

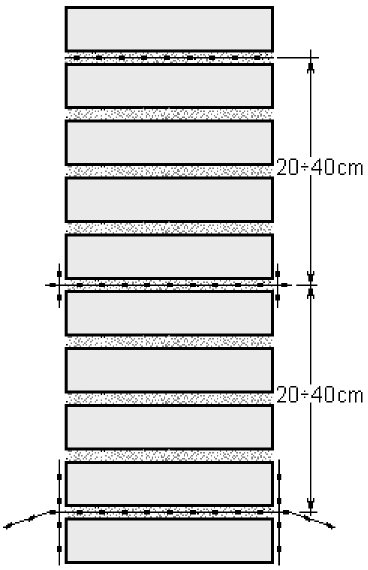


Figure 10: Reinforcement layout

When the vertical forces of masonry member are foreseen to be plastered, with plain or reinforced mortar, the length of horizontal grids will be accordingly provided. No special devices for joining the grids are necessary, since they are simply overlapping.

5 TESTING VALIDATION

The method of reinforcing masonry with polymer grids was patented in 1995 (Sofronie, Feodorov 1995). The first static tests have been comparatively carried out on 12 short columns subjected to axial compression and on 18 wall panels subjected to both axial compression and diagonal tension (Sofronie 1997). Then two three-dimensional models, one for masonry buildings and another for RC frames with masonry infills, have been successively tested on ISMES' shaking table in Bergamo (Juhasova, et al., Sofronie 1998). Further, some masonry infills reinforced with polymer grids have been included among other infill models comparatively tested to lateral actions at LNEC in Lisbon (Pires et al.1998, Sofronie, Popa 1998 a,b).

The behaviour of masonry infills reinforced with polymer grids under lateral loads has been recently tested at the European Laboratory for Structural Assessment of the EC in Ispra. Two typical infills were chosen for testing at full scale: one full panel without openings for doors or windows and another one with two non-symmetric openings. The scope of the testing programme was to obtain basic data on the response of such infills when the surrounding frame is subjected to prescribed alternating lateral displacements of increasing amplitudes, in a manner that simulates earthquakes (Colombo et al., Juhasova et al. 2000).

6 CONCLUSION

Polymer grids have proven to be one of the most appropriate reinforcements for repair and strengthening of masonry buildings. They are cost effective, easily applied and long lasting construction materials. Neither additional qualification of labour nor extra devices is required. By using polymer grids, it became possible to eliminate massive RC members or expensive steel reinforcement and create more homogeneous masonry structures accordingly shaped. The existing theoretical background and validated testing data allow developing any conceptual design. The required degrees of safety are achieved on the basis of a *fail-safe* principle. Reinforcing techniques are applied either to existing damaged buildings for repair and retrofitting or to new buildings for strengthening and preventing damages. Polymer grids also solve the problem of compatibility between the old, possibly ancient, and new construction materials for preserving or restoring historical buildings and monuments. Indeed, one of the most important advantages of polymer grids as reinforcement consists in the fact that cement can be eliminated from the mortar composition and, if necessary, only lime mortar or other binding materials compatible with the polymer can be used. Romanian authorities e.g. already delivered the technical agreement for the use of polymer grids for repairing masonry buildings in seismic areas (Sofronie, Bolander 1999, 2000)

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