Determination of Willam-Warnke criteria needs to be defined by following parameters: the uniaxial compressive strength f (fig. 2b); the uniaxial tensile strength f_t (fig. 2b); the biaxial compressive strength f_{cc} (fig. 2b); the high-compressive-stress point on the tensile meridian $f_{1,max}$ (fig. 2b); the high-compressive-stress point on the compressive meridian $f_{2,max}$ (fig. 2b).

To estimate the aforementioned parameters the mortar and brick uniaxial and triaxial tests were conducted.

Distribution of Masonry lateral stress

There is no possibility to set masonry spatial stress distribution using actual experimental methods. Many authors performed a numerical analysis of the results shows, that acting the longitudinal stress σz occurring ratio of lateral stress σ_x/σ_y, which varies in the range from 0,73 to 0,83 (from 1,7/2,34 to 1,99/2,4 when $\sigma_z = 10{,}0$) [8]. According to the research results of other authors, carried out by using fixed parameters, the ratio of lateral stress distribution is obtained $\sigma_x/\sigma_y = 0{,}90$ (2,58/2,88 when $\sigma_z = 11{,}73$) [1, 8]. The numerical model analysis noted, that the lateral stress distribution ratio crucial to the sample characteristics of the materials and the contact layer between the masonry and mortar stiffness. Changing the characteristics of the lateral stress ratio σ_x/σ_y varies in the range of 0,8 to 1,0 when the geometry of masonry unit is unchanged. According to the research results in most cases the ratio of lateral stress σ_x/σ_y close to the one. Therefore, the mortar three-dimensional state of stress research (carried out on the assumption that the distribution ratio of lateral stress $\sigma_x/\sigma_y = 1{,}0$.

The mortar and brick tests

Three types of mortars and two types of bricks were tested. The tests of mortar and brick tensile strength were made on the cylindrical samples 120 mm high and diameter equals 60 mm (fig. 3). The compressive strength tests of mortar were made on the cylindrical samples 60 mm high and diameter equals 60 mm (fig. 3). The brick compressive strength tests were made on the whole elements (fig. 3). Each test consists of at least 6 samples. The average results are displayed in table 1. To define other parameters of failure surface the triaxial tests were made. In the tests the triaxial compression equipment was used (fig. 4). It allowed to load the side surface of cylindrical samples with uniform pressure. The samples were tested to failure in two ways: due to vertical stress σ_{ver} at different levels of constant horizontal compression σ_{rad} and due to radial compression σ_{rad} at constant vertical compression σ_{ver}.

Each test consists of 3 samples. The values of constant horizontal and vertical compression were different for each sample. Mortar M1 and brick B1 they were equal 2, 4, 6 N/mm² and 0, 2, 4 N/mm², for mortar M2 they were equal 1, 2, 3 N/mm² and 1, 2, 3 N/mm². Loading paths in triaxial tests of mortars and brick samples were presented on fig. 5 and fig. 6, table 2.

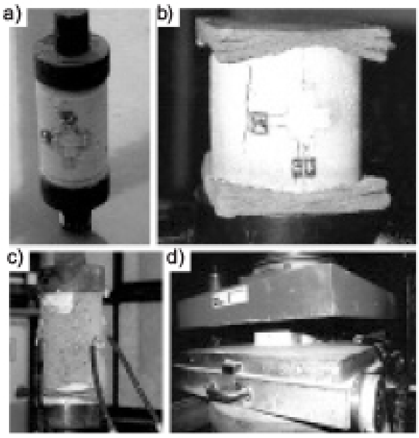

Fig. 3. Uniaxial tests of mortar and brick: a) mortar tensile strength test; b) mortar sample after compressive strength test; c) brick tensile strength test; d) brick compressive strength test

Rys. 3. Jednoosiowe badania zaprawy i cegły: a) badanie na rozciąganie zaprawy; b) badanie na ściskanie zaprawy; c) badanie na rozciąganie cegły; d) badanie na ściskanie cegły

Table 1. Average results of uniaxial tests of mortar and brick

Tabela 1. Uśrednione wyniki badań zaprawy i cegły na osiowe rozciąganie i ściskanie

Material	Tensile strength [N/mm²]	Compressive strength [N/mm²]
Mortar M1	0,5	-11,4
Mortar M2	0,5	-3,5
Brick B1	1,2	-28,4

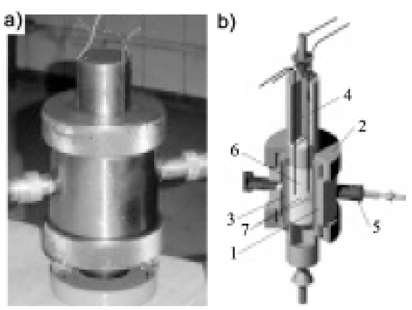

Fig. 4. The triaxial compression equipment: a) general view; b) lateral section; 1 – steel body, 2 – upper cap; 3 – plastic shield of samples; 4 – piston with spherical bearing; 5 – connector pipe; 6 – sample; 7 – electric resistance wire strain gauge

Rys. 4. Aparat trójosiowego ściskania: a) widok; b) przekrój; 1 – stalowy korpus komory aparatu; 2 – pokrywa górna; 3 – osłona próbki z poliuretanu; 4 – tłoki z łożyskiem sferycznym z utwardzonej stali; 5 – zawór ciśnieniowy; 6 – badana próbka; 7 – tensometry elektrooporowe

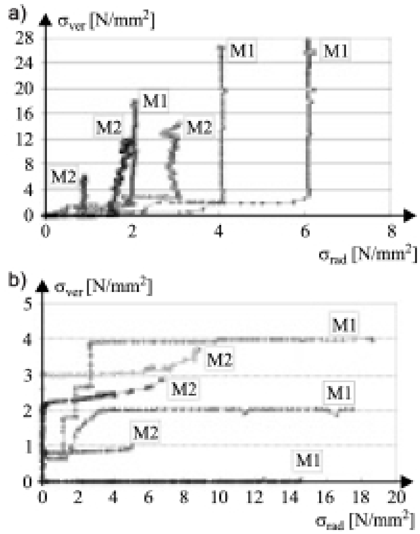

Fig. 5. Loading paths for mortar M1 and M2 samples: a) at different levels of constant radial stress; b) at different levels of constant vertical stress

Rys. 5. Ścieżki obciążenia w badaniach zapraw M1 i M2: a) przy zróżnicowanym poziomie naprężeń promieniowych; b) przy zróżnicowanym poziomie naprężeń pionowych

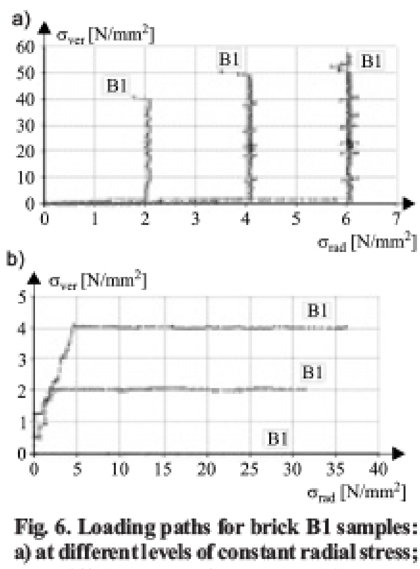

Fig. 6. Loading paths for brick B1 samples: a) at different levels of constant radial stress; b) at different levels of constant vertical stress

Rys. 6. Ścieżki obciążenia w badaniach cegły: a) przy zróżnicowanym poziomie naprężeń promieniowych; b) przy zróżnicowanym poziomie naprężeń pionowych