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Toshkent shahri, Yakkasaroy tumani, Kichik Beshyogʻoch koʻchasi, 70/10-uy.
Elektron manzil:
scienceproblems.uz@gmail.com

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METHODS OF STRENGTHENING BRICK WALLS WITH MODERN COMPOSITE MATERIALS

Shukurova Karomat
dotsent, Republic of Uzbekistan
E-mail: kshukurova035@gmail.com

Tolipova Munira
magistr, Tashkent University of Architecture and Civil Engineering,
Republic of Uzbekistan
E-mail: t.munira24@gmail.com

Annotation. This research is aimed at studying the effectiveness of reinforcing brick walls using ECC, steel mesh, steel tapes, and zinc sheets to increase their seismic resistance. As a result of experimental and numerical analyses, it was established that these methods significantly increase the strength, deformation properties, and energy absorption of walls.

Keywords: brick walls, wall reinforcement, engineering-cement composites, steel mesh reinforcement, galvanized steel sheets, sustainable construction, finite element analysis, composite materials, structural analysis.

G'ISHT DEVORLARINI ZAMONAVIY KOMPOZIT MATERIALLAR BILAN MUSTAHKAMLASH USULLARI

Shukurova Karomat
dotsent, O'zbekiston Respublikasi

Tolipova Munira
magistr, Toshkent arxitektura va qurilish universiteti,
O'zbekiston Respublikasi

Annotatsiya. Ushbu tadqiqot g'isht devorlarini seysmik chidamliligini oshirish uchun ECC, po'lat to'r, po'lat lentalar va rux plitalari yordamida mustahkamlash samaradorligini o'rganishga qaratilgan. Eksperimental va sonli tahlillar natijasida bu usullar devorlarning mustahkamligini, deformatsiya xususiyatlarini va energiya yutishini sezilarli darajada oshirishi aniqlandi.

Kalit so'zlar: g'isht devorlari, devor mustahkamlash, muhandislik-tsement kompozitlari, po'lat to'rli mustahkamlash, galvanizli po'lat plitalar, barqaror qurilish, chekli elementlar tahlili, kompozit materiallar, strukturaviy tahlil.

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Introduction. Brickwork structures are widespread throughout the world, especially in developing countries and historic urban areas, and constitute a major part of the building stock. Although such structures can effectively withstand vertical loads, they are significantly vulnerable to horizontal loads, especially seismic effects. Earthquakes in recent years have clearly demonstrated the brittle behavior of unreinforced brick (URM) structures, leading to serious structural damage, large economic losses, and human casualties [3,4]. The main disadvantages of brick walls are their low tensile strength, brittle failure properties, low plasticity, and insufficient bonding between structural elements. In particular, such walls are prone to in-plane cracking and often collapse out of plane under seismic loading [1]. Therefore, strengthening existing brick structures with effective, economical, and technologically feasible methods is a pressing problem. In recent decades, various modern technologies have been developed for strengthening brick structures. In particular, fiber-reinforced polymer (FRP) systems are characterized by high strength and lightness [2,10]. Studies show that FRP reinforcement can increase the shear strength of walls by up to 160%. However, the high cost of these systems, sensitivity to high temperatures, low vapor permeability, and the problem of debonding limit their widespread use. As an alternative to FRP systems, textile-reinforced mortar (TRM) technology has been proposed, which consists of a combination of fiber mesh and cementitious mortar [5,9]. This system is characterized by good adhesion to the brick base, fire resistance, and environmental friendliness. In particular, the basalt fiber TRM (BTRM) system significantly increases the shear resistance of walls: when applied on one side, an increase in strength of approximately 30% is observed, and when applied on both sides, up to 60%. In addition, textile-reinforced concrete (TRC) systems are characterized by high performance indicators. According to the results of the study, the shear strength of walls reinforced with TRC increases by 1.4–3.6 times, the degree of plasticity by 2.6–11.5 times, and the energy dissipation by 10–54 times. This makes TRC systems a particularly effective solution for seismic areas. In recent years, innovative materials, in particular, engineered cement composites (ECC), have also been widely used. ECC materials, unlike ordinary concrete, have a high deformation capacity and convert brittle failures into plastic failures. This material creates microcracks on the wall surface, limiting their expansion and increasing overall seismic resistance. Studies show that ECC coatings, when applied over the entire surface, give more effective results than local (linear) strengthening methods. In addition, hybrid systems used in combination with stainless steel elements further improve the load-bearing capacity and plasticity properties of structures. This approach combines the deformability of ECC with the strength of steel to create a highly effective reinforcement system. At the same time, economically viable and practical solutions are also important for developing countries. For example, reinforcement methods based on wire mesh and cement-sand mixture can increase the bending strength of walls by 87% and the energy absorption G1 (base group) — walls that are not reinforced and are covered only with ECC. This group allowed us to assess the independent effect of ECC material. capacity by 46%. Numerical modeling methods such as finite element modeling (FEM) are widely used to study the behavior of reinforced brick structures in depth and predict their performance. These approaches are an important tool for validating experimental results and optimizing structural solutions. The main objective of this study is to evaluate the effectiveness of a hybrid system consisting of ECC coatings and stainless steel strips embedded in them in strengthening brick walls. Within the framework of the study, the effect of this system on the cracking load, maximum shear strength, deformation capacity and energy dissipation is analyzed using experimental tests and finite element modeling. At the same time, the accuracy of the developed numerical model in reproducing real structural behavior is also evaluated. The scientific novelty of this work is the comprehensive study of a hybrid reinforcement system based on ECC and stainless steel elements and the justification of its effectiveness based on experience and numerical modeling. Experimental program and research methodology. This study aims to evaluate the structural efficiency of brick walls reinforced with various strengthening methods, especially hybrid systems that combine several strategies. The study was organized taking into account the requirements of construction technologies, materials and regulatory documents practically used in the Republic of Uzbekistan. Experimental work was carried out on a total of 14 brick wall samples. All samples were prepared with the same geometric dimensions to ensure the comparison of results: length — 560 mm, thickness — 90 mm, height - 550 mm; The walls were laid out of baked bricks measuring 180 × 90 × 50 mm, and the thickness of the joints between the rows of bricks was set at 10 mm [5,7]. These parameters correspond to traditional bricklaying practices widely used in Uzbekistan.

The test program was divided into six main groups (G1–G6), with each group focusing on a specific reinforcement strategy:

G1 (base group) — walls that are not reinforced and are covered only with ECC. This group allowed us to assess the independent effect of ECC material.

G2 — The effectiveness of internal horizontal steel reinforcement placed between brick rows was studied. These reinforcements were placed in every third row.

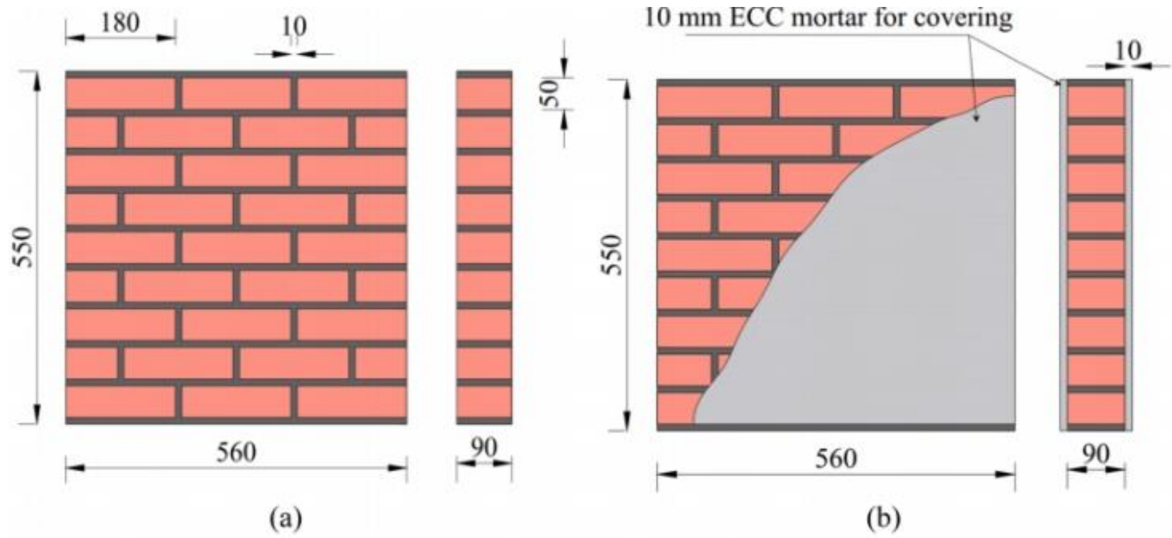
G3 — The vertical reinforcement and its interaction with the horizontal reinforcement were studied.

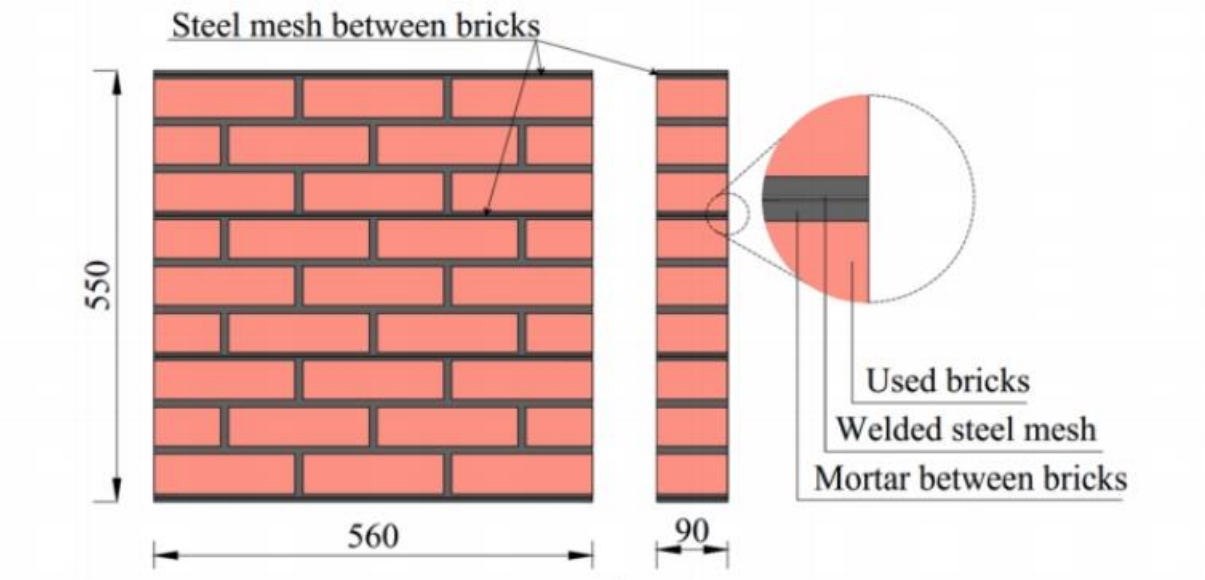
G4 — Diagonal and orthogonal (vertical + horizontal) reinforcement configurations were compared.

G5 — full-coverage (maximum density) steel mesh systems were studied.

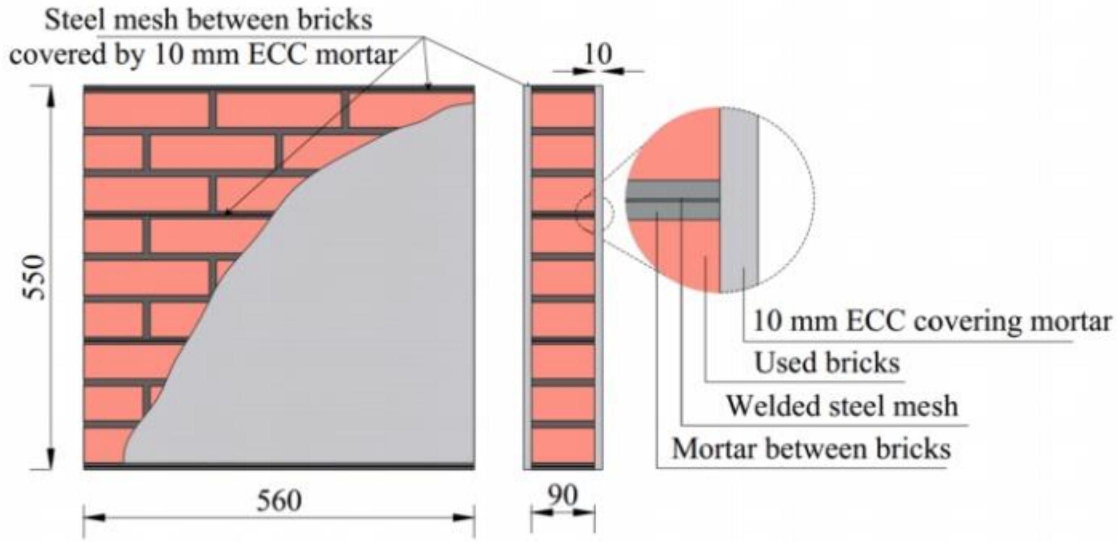
G6 - galvanized steel sheet reinforcement systems (vertical, horizontal and orthogonal) were tested instead of traditional mesh [9,10].

This grouping allowed for an in-depth analysis of the influence of various types of reinforcement (vertical, horizontal, diagonal), their combinations, and fully covering systems on the structural behavior.




Steel mesh between bricks
550
560
90
Used bricks
Welded steel mesh
Mortar between bricks

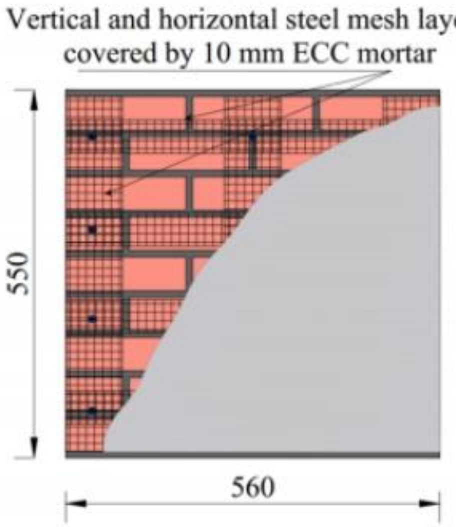
(c)


Steel mesh between bricks
covered by 10 mm ECC mortar
10
550
560
90
10 mm ECC covering mortar
Used bricks
Welded steel mesh
Mortar between bricks

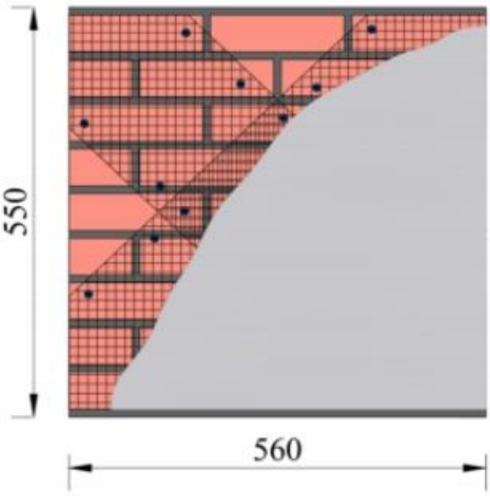
(d)

(e)

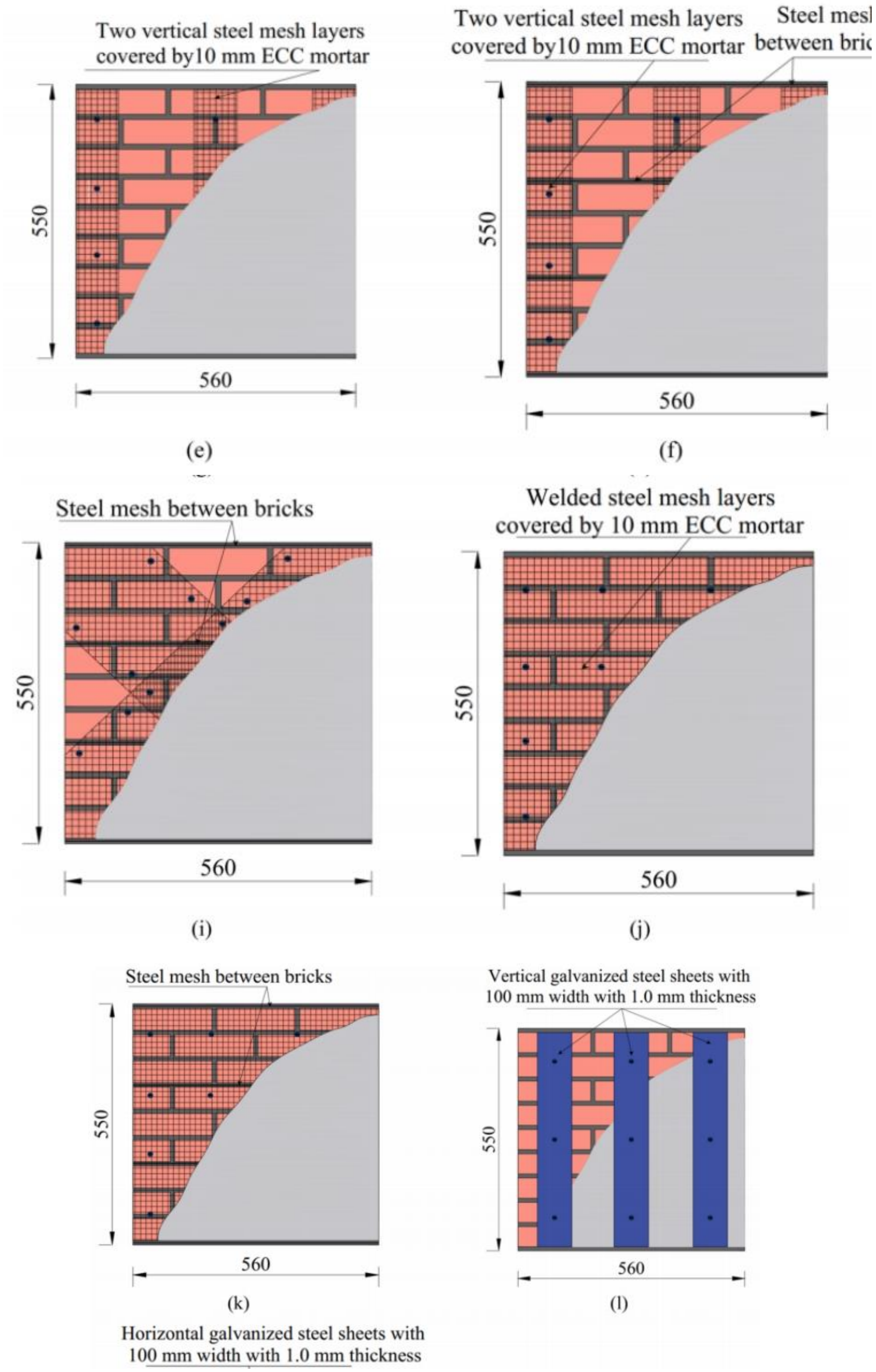
(f)

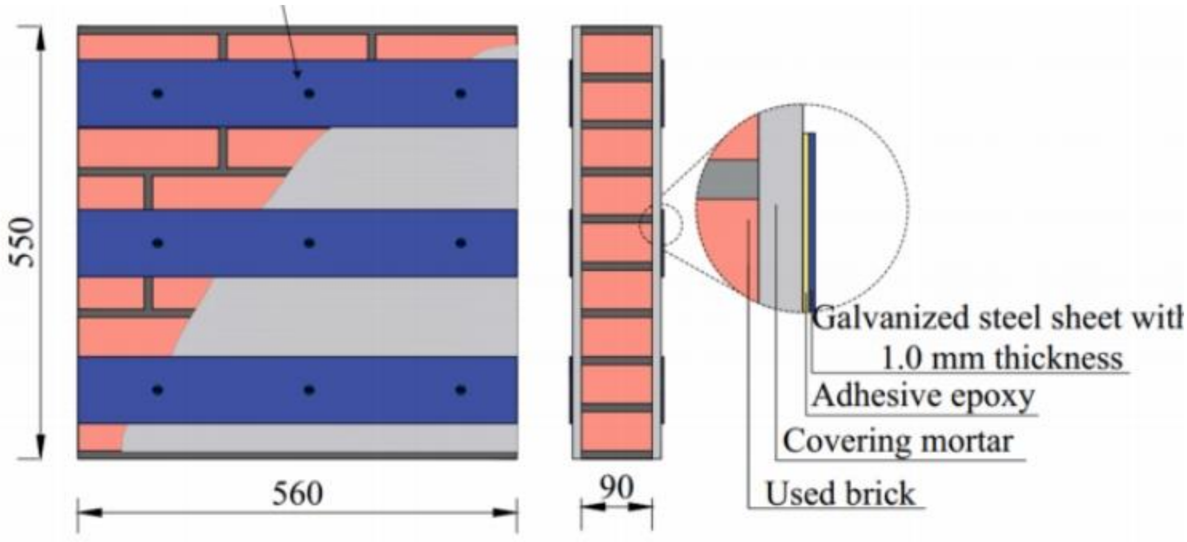

Vertical and horizontal steel mesh layers
covered by 10 mm ECC mortar
550
560

(g)

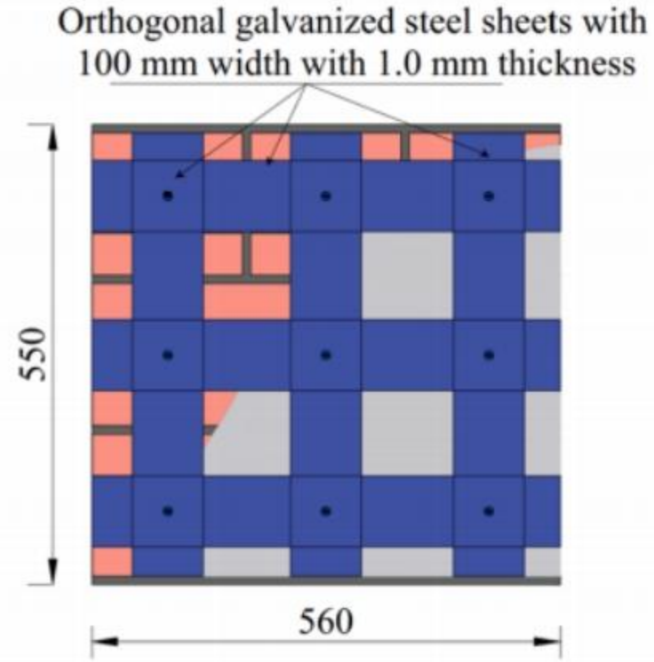

550
560

(h)


Two vertical steel mesh layers covered by10 mm ECC mortar
550
560
(e)
Two vertical steel mesh layers covered by10 mm ECC mortar
Steel mesl between bric
550
560
(f)
Steel mesh between bricks
550
560
(i)
Welded steel mesh layers covered by 10 mm ECC mortar
550
560
(j)
Steel mesh between bricks
550
560
(k)
Horizontal galvanized steel sheets with 100 mm width with 1.0 mm thickness
Vertical galvanized steel sheets with 100 mm width with 1.0 mm thickness
550
560
(l)



(m)



(n)

The reinforcement systems used in the study included the following main areas:

Internal horizontal reinforcement placed between rows of bricks, steel meshes mounted on the wall surface (vertical, horizontal, diagonal, orthogonal),full-coverage mesh systems, continuous reinforcement based on galvanized steel sheets, in all cases, ECC mortar as a reinforcing and additional reinforcing layer.

The ECC mixture played two different roles in this study: as an independent reinforcing layer; as a matrix connecting steel reinforcement elements and transmitting load [1,3].

The effect of reinforcement density was also studied across a range from minimal reinforcement (partial reinforcement) to fully covering systems. The study applied bricks with three round holes (each hole is 40 mm in diameter). The mechanical properties of bricks were determined by laboratory tests based on the building standards of Uzbekistan:·compressive strength — 11.8 MPa ,direct shear strength — 1.40 MPa.[6]

The tests were carried out in accordance with the requirements of the current standard for testing building materials. applied as a reinforcing material, ECC (engineering cement

Composite) was prepared on the basis of a special composition. [4,9] It included the following: cement, minuscule sand, silica Phumi, PVA (polyvinyl alcohol) fibers high efficiency plasticizers.

The ECC mixture is designed to provide a compressive strength of 45 MPa. The high plasticity of the material is explained by the following factors: ·the absence of large aggregates ·low water-binding ratio ·reinforcement with fibers ·As a result of tensile tests, ECC showed the following indicators: tensile strength — 6.16 MPa ·high strain hardening ability (strain-hardening effect). These properties confirm the ability of ECC material to effectively control cracks and prevent brittle failure. Experimental studies were mainly conducted under unidirectional (monotonic) loading. However, the risk of corrosion was taken into account when using steel reinforcement, especially in brick structures prone to moisture. Considering the climatic conditions of Uzbekistan, the following is recommended when using such reinforcement systems: ·application of protective plaster layers ·restriction of moisture penetration for use in indoor or protected environments The experimental program conducted allowed for a comprehensive assessment of the effectiveness of various reinforcement configurations and hybrid reinforcement systems based on ECC. It is expected that the selected parameters — reinforcement direction, density, type, and combination with ECC — will have a significant impact on the structural behavior of the walls, fracture mechanisms, and overall strength performance. [5,8]

Conclusion. As part of this study, the structural effectiveness of reinforcing brick walls using modern composite materials, in particular ECC mortar, steel meshes, internal reinforcement elements, and galvanized steel sheets, was experimentally evaluated. The results showed that the proposed reinforcement methods significantly improve the strength, deformation capacity, and energy absorption properties of brick walls. According to the study, the use of ECC coating alone also improves the mechanical performance of the walls, but the use of ECC in combination with steel reinforcement elements provides much higher efficiency. Hybrid systems, especially those combined with internal horizontal reinforcement and external steel mesh or sheets, significantly improve the ductility of the structure while increasing its load-bearing capacity. The results of comparing different reinforcement configurations showed that full-coverage and orthogonal systems are most effective in controlling cracks and distributing loads evenly. Diagonal and combined (hybrid) reinforcement schemes showed high results in complex stress states. At the same time, continuous reinforcement systems based on galvanized steel sheets have been shown to perform more stably than traditional mesh systems. The use of ECC material has been confirmed to reduce the brittle failure characteristics of walls, making them more plastic in behavior. As a result, microcracks are formed in the structures, through which energy is efficiently dissipated and overall seismic resistance is increased. The study also found that the density and placement of reinforcement have a significant impact on structural behavior. The transition from minimally reinforced systems to systems with maximum coverage leads to a gradual improvement in the strength and deformation characteristics of the walls. From the perspective of Uzbekistan's construction practice, the proposed reinforcement methods can serve as an effective and practical solution to increase the seismic resistance of existing brick buildings and structures. However, when using steel elements, it is important to apply protective layers and choose the right operating conditions to reduce the risk of corrosion. In general, the results of the study showed that hybrid reinforcement systems based on ECC and steel elements significantly increase the structural reliability of brick walls and provided a scientific basis for their use in practical construction.

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