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# Restoration and Reinforcement of Stone Buildings and Brick Walls: Review paper

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**Abstract**

The art of maintaining our cultural legacy through architecture is known as restoration. It is the process of restoring historic structures that have lost a large amount of their aesthetic value due to deterioration and cracking caused by time, natural disasters, and other factors.

Finding engineering solutions to fix cracks and damage in brick walls is necessary to reduce material loss rather than demolishing buildings or preserving historical or archaeological significance because stone buildings and brick walls sustain significant material damage from weather, time, seismic movements, and other factors.

In general, restoration seeks to sustain the buildings through engineering and documentation while maintaining the structural integrity of the structures to be repaired. More than just a building or institution, preserving architectural history and emphasizing its worth has become crucial to urban growth. It maintains the character of the location and the structure and forges enduring ties between succeeding generations. Heritage and historically significant structures that represent the nation's age and civilization are being protected more and more these days.

There are numerous engineering and scientific ways to address these damages, enhance the walls, and increase the longevity of brick-built structures and walls.

**Key words**: Stone structures, Brick walls, Polymer-cement, Repair cracks.

## Introduction

Before inspecting stone structures, it is necessary to identify their structure, highlighting the supporting elements. It is especially important to take into account the actual dimensions of the load-bearing elements, the design scheme, estimate the magnitudes of deformations and damage, identify the conditions of bearing on the stone structure of beams, plates and other bent

elements, the state of the reinforcement (in reinforced stone structures) and embedded parts. The size and nature of defects and presence of typical damage (chips and cracks) directly depend on the above conditions.

To determine the strength of masonry tools and instruments of mechanical action, as well as ultrasonic devices were employed. Hammers and chisels through a series of blows can approximately assess the qualitative state of the material of stone and concrete structures. More accurate data is obtained with the help of special hammers, i.e., mechanical action devices based on the evaluation of traces or the results of impact on the surface of the test structure. The simplest, though less accurate tool of this type is the Fizdel hammer. A ball of a certain size is pressed into the hammer face of the hammer. By elbow impact, creating approximately the same force in different people. On the surface under study remains a trace — a hole. According to its diameter Utilize a calibration table to assess the strength of the material.

**1- Field of application**

1.1. This standard is used to stone and reinforced stone structures and their elements used or temporarily mothballed buildings and structures for various functional purposes.

1.2. In order to evaluate the physic-mechanical properties of materials and masonry as a whole in buildings and construction, as well as the development of defects and damages in the laying and the estimation of its bearing capacity based on the revealed defects and damages, the standard establishes fundamental standards and rules. It also outlines the basic methods for restoring or increasing the bearing capacity of masonry walls and their elements, the production of works, quality control, and safety engineering during performance.

1.3. Standard does not apply to the design of restoration and strengthening of the rock constructions of buildings and construction in seismic regions or operable under the conditions of systematic action increased (from 50°C to 200°C) and high (above 200°C) technological temperatures.

1.4. The provisions of this Standard do not limit the development and application of new methods for estimating the bearing capacity, determining the physic-mechanical characteristics of masonry materials, methods for restoring and strengthening masonry structures or improving existing ones, as well as clarifying design patterns and dependencies

1.5. Standard is developed in accordance with the requirements of the acting technical-normative documents.

**2. General considerations**

**2.1. Tasks and purpose**

2.1.1.The need for restoration and strengthening of rock constructions in the process of their operation appears both with reconstruction and technical reequipping of buildings and construction and as a result of their physical wear and accumulation in them of different damages, caused by the corrosion of materials, by different, including mechanical, by actions, by poor quality structural design, by the violation of the requirements of the technology of production and erection as well as through operational instructions.

2.1.2. To determine the degree of low endurance and operational performance of building structures in constructions and building stheir actual technical condition should be determined based on the results of the surveys, calibration calculations or comprehensive testing in accordance with GOST R 53778.

2.1.3. Inspection, repair, restoration and strengthening of stone structures and their elements require consideration of the requirements of special regulatory guidance documents, the development of specific technical solutions and close monitoring of the implementation

2.1.4. The restoration or reinforcement of structures is preceded by their examination with the identification of defects and damage, the causes of them, the assessment of the technical condition, the development of proposals (of the project) to carry out repair and restoration work or reinforcement of structures.

2.1.5. Work on the establishment of the nature of defects and damages in the rock walls and their elements, evaluation of their influence on the bearing capacity and operational indices, the positive confirmation of the solution of their strengthening, organizing of works and direct performance, and also quality control and observance of the safety regulations with the carrying out of works adopted should be carried out in accordance with the requirements of the current norm.

2.1.6. Methods of restoration and strengthening of stone structures and their elements must meet the requirements of adaptability and efficiency. When developing a project for their restoration or strengthening, one should proceed from the need to perform work without or with a short-term operation shutdown, taking into account the aggressiveness of the operating environment, the degree of fire resistance of the premises, and the functional purpose of buildings and structures.

2.1.7. All works on restoration and strengthening of construction should be carried out when the project of the organization of building (POS) and They are present and completely in agreement with the project of the carrying out of works (PPR).

2.2. Defects and damage in the rock walls and their elements

Defects and damages rock construction of walls and their elements are categorized according to the following signs:

**2.2.1. For origin-related reasons:**

a) design errors: incorrect accounting of the actual loads (technological overloads, as a result of accumulation of snow, ice, industrial dust, etc.); the discrepancy between the design scheme and the actual operation of the structure; unsuccessful constructive solution of interfaces; loss of stability due to insufficient links; unaccounted load eccentricity; incomplete information on the engineering-geological assessment of foundation soils;

b) low quality materials: the curvature of the faces of the brick; its non-qualitative firing deviations in size; fractured bricks low frost resistance of bricks and mortar; reduction of brick and mortar brands against design requirements;

c) the low quality of the execution of the works: the disturbance of horizontality, weld throat, and the rules of their bandaging; the deviation of load-bearing walls and posts with respect to the vertical line the disregard of temperature and humidity of the environment with the carrying out of works

g) unsatisfactory operating conditions: mechanical damages, moistening, alternating freezing and thawing during the moistening, aggressive environmental effect temperature actions.

d) uneven sediments of bases under the foundations of walls and posts, caused by the insufficient study of geological engineering and hydrogeological conditions by the disturbance of the technology of the carrying out of earthen and construction work by errors at the stage of the design of objects by the violation of standards and technical operation instructions of building

**2.2.2. On the exposure time:**

a) in the period of building;

b) with the prolonged interruption in the building without conducting the proper conservation of constructions and object as a whole;

c) in the period of planned operation;

g) after the production of the periods of the operation

2.2.3. Using the detecting techniques

a) the explicit defect, detected with the visual observation of constructions;

b) the concealed, assumed defect, revealed with the application of known methods, means and a rules provided in the normative and reference literature and approved under other similar conditions;

c) aconcealed defect, for a development of which are not provided the corresponding rules, methods and the means

**2.2.4. According to the degree of the damage**

a) the insignificant degree of damage – the bearing capacity of laying is reduced from 0 to 5%;

b) the weak degree of damage – the bearing capacity is reduced to 15%;

C) the average degree of damage with the reduction in the bearing capacity to 25%;

d the strong degree of damage – the bearing capacity is reduced to 50%;

e) the weak degree of damage – the bearing capacity is reduced to 15%;

h) the average degree of damage with the reduction in the bearing capacity to 25%;

i) the strong degree of damage – the bearing capacity is reduced to 50%;

g) the emergency degree of damage – the bearing capacity is reduced more than 50%.

**2.2.5. On the opportunity of the elimination.**

a) The damages and disposable flaws, whose removal is both technically feasible and financially advantageous. It is believed that the following techniques will be used to remove masonry damage and defects.

b) Inevitable flaws and damages, whose eradication is either fiscally impractical or technically impossible.

**2.2.6. Damages and flaws.**

a) damage caused by deformations of the walls;

b) damage caused by spalling, shells, potholes and other discontinuities;

c) damage associated with moisture and possible freezing of masonry walls;

d) damage to the protective and finishing layers of masonry;

d) damage caused by the violation of the basic material of the walls in the form of cracks in the stone and the solution.

Detailed characteristics of the defects and damage to the masonry for each of their species with an assessment of the possible consequences are given in 15, 16, &17.

2.3.1. Polymer cement and polymer solutions are made by the introduction of fillers into epoxy adhesive. Epoxy adhesive is an epoxy resin or compound. In addition, it may include: plasticizer to eliminate the brittleness of epoxy glue (dibutyl phthalate, poly ether); solvent to reduce viscosity (acetone); hardener (polyethylene-diamine, triethanol-amine, etc.); modifier to reduce viscosity and ensure curing at low temperatures. Increasing the viscosity and reducing the fluidity of the adhesive an achieved by the introduction of polyvinyl acetate glue.

As the filler adapts the quartz sand, river sand, cement and other

Hardening epoxy glues and polymer solutions in the winter time of prit≤1°C (in t. h. and at minus temperatures) is accomplished with the aid of the aminophenol hardener AF-2 or polyethylene polyamine with the introduction into the composition of glue of modifier

Regulating the amount of hardeners of polyethylene polyamine (PEPA) and triethanol-amine (TEA), respectively, in parts (10 ... 0) and (0 ... 15), in parts by weight of epoxy resin, the viability of the glue is regulated from 2 hours to 7 days.

**2.3.2. Polymer solutions are used in one of two compositions.**

Injection or hermetic. In order to restore the firmness of the structures that have been damaged by cracks, the sealing compound is utilized to create a closed chamber for the cracks during injection. Sealing compounds should have sufficient viscosity and provide a short curing time injectionshould have good penetration and sufficiently high technological viability. If it is necessary to regulate viability in the interval from 1.5-2 hours to 7-8 days. Polyethylene_ polyamines and triethanol-amines are added.

2.3.3. Polymer-cement solutions are made on the basis composition binding, which comprises the organic polymer (glue PVA), inorganic binding (portland cement), sand and water. To accelerate the hardening gypsum or calcium chloride are introduced.

**3. Methods and the restoring circuit or strengthening of constructions:**

3.1. Restoration and strengthening of rock constructions can be executed without the shift and with a change in the design diagram.

The overall diagram of the methods of restoration and strengthening the rock construction is represented in Fig. 1.

3.2. The most loaded elements of buildings with stone structures are foundations, load-bearing walls, pillars, piers, and above-wall lintels. In these elements, force injuries from overvoltage under load, which manifest themselves in the form of vertical cracks, are most often observed.

3.3. Besides power, in the laying appear shrinkage, temperature, sedimentary and other cracks, which also to a considerable degree lower a bearing capacity and three-dimensional hardness of buildings.

3.4.In stone buildings, inclined or vertical cracks often appear due to their different compressibility and shrinkage rate at the junction of internal and external walls, in addition tolongitudinal and transversely loaded walls. If the connection between the walls is strong, then oblique cracks appear, and if weak, then exfoliation of the external walls from the internal ones is observed. In this case, the incorporation of cracks with a mortar until the end of the period for completing the process of basic creep of the masonry (46 years when building from a ceramic brick on solutions of grade 50 and higher) does not eliminate the cracks. For buildings erected in areas with difficult ground conditions, sedimentary cracks arising from uneven sediments infoundations are most characteristic.

3.5. Rock construction components that have power cracks that are discovered during the examination may need to be strengthened or restored. Additionally, when the bearing capacity of the existing rock constructions (posts, partitions, and walls) is found to be inadequate for building reconstruction, as well as when there are flaws in the laying due to the uneven settling of the base beneath the foundations, prolonged moistening, multi-cycle alternating freezing and thawing of the laying, and other factors, strengthening the existing rock constructions is produced.

**3.6.** Restoration and strengthening of the separate elements of buildings from the masonry (partitions, the individual sections of walls and the units of their joining's) depending on the technical state of laying established with the inspection is reduced to three basic cases:

1. The bearing capacity of laying, taking into account the existing weakening's, is sufficient. The damages of laying insignificant, the general state of laying operational, and the bearing capacity decrease is no more than 15% of the original.

In this case taking special design measures for restoration is not required. The existing cracks are sealed by solutions.

2. The bearing capacity of the masonry by calculation is sufficient and reinforcement is not required, but the weakening of the masonry exceeds 1/3 of the original strength there is a significant separation of the masonry and a large number of cracks. The technical condition of the masonry is assessed as partially operable.

In this instance, the local transfer of material captured by the deep wall fissures is used to accomplish the restoration, while solution is applied to the smaller cracks. The transfer is carried out in accordance with the turn from two sides to the thickness of half of the brick from each side using the through cracks. On the design grid, posts and partitions are plastered. The strengthening made them 4 mm in diameter and 6 mm in diameter, with 15 x 15 mm cells.

3. The bearing capacity of stone elements is insufficient, their technical condition is assessed as unacceptable (inoperable), restoration or reinforcement is required.

3.7. Strengthening and restoring elements of masonry structures can be performed by injection, arranging various clips, increasing the cross section of pillars or walls, replacing brick supermodel bridges with reinforced concrete or metal, installing systems of metal cords and linings, etc. and the strengthening of frameworks and the guiding ideas behind their application are shown in Fig. 1.

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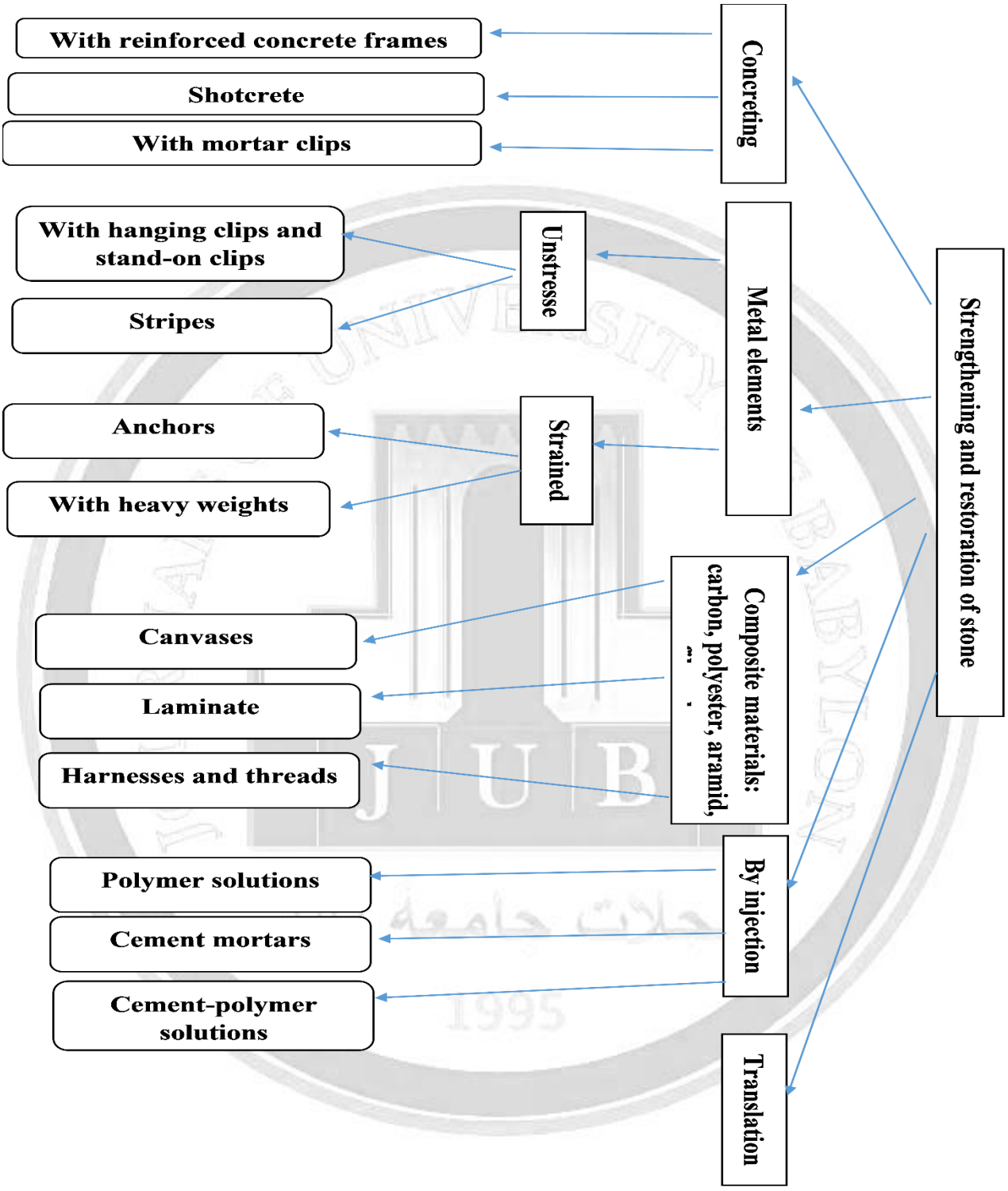



**Figure 1. classification of the methods of strengthening and restoring constructions**

3.8. Strengthening of the squeezed elements of clips and cores. One of the most effective methods of increasing the bearing capacity of existing masonry is the arrangement of the yoke in the damage zone.

The device of the clips increases the bearing capacity of the masonry 1.25 ÷ 2.5 times with little effort. The clips are reinforced as separate structural elements (posts, piers) (Fig. 2), as well as wall sections, working for central and eccentric compression (Fig. 3).

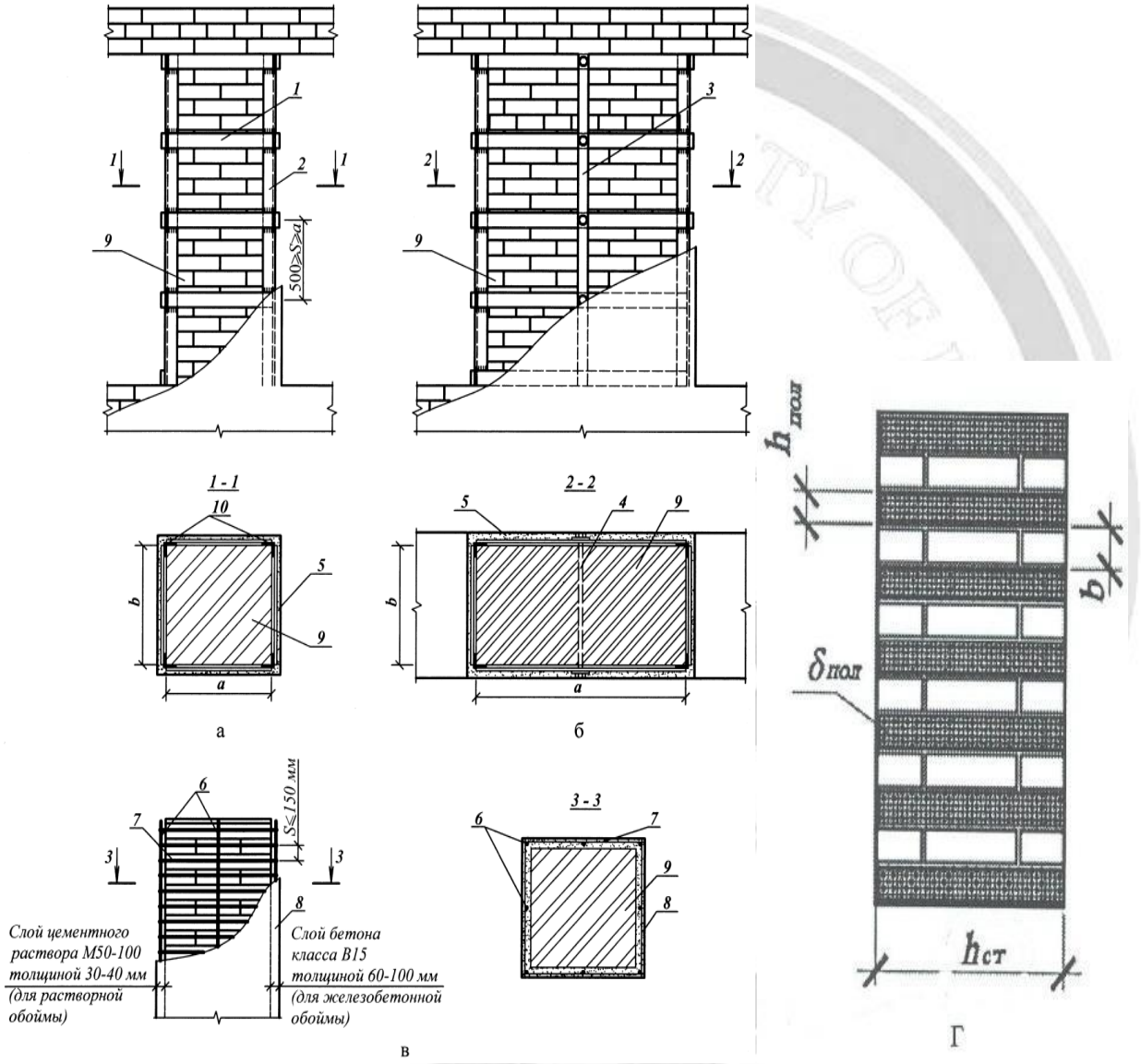



**Figure. (2) Reinforcement of Stone Constructions by the Device of the Clip**

**a - steel, with the aspect ratio of less than 1: 2; b - the same, with the ratio of the sides of the section greater than 1: 2; c - reinforced concrete and mortar; g - carbon fibre cloth; 1 - clamps (strips) made of round or flat steel; 2 - corners; 3 - intermediate vertical strips of strip steel; 4 - coupling bolts; 5 - a layer of cement-sand solution**

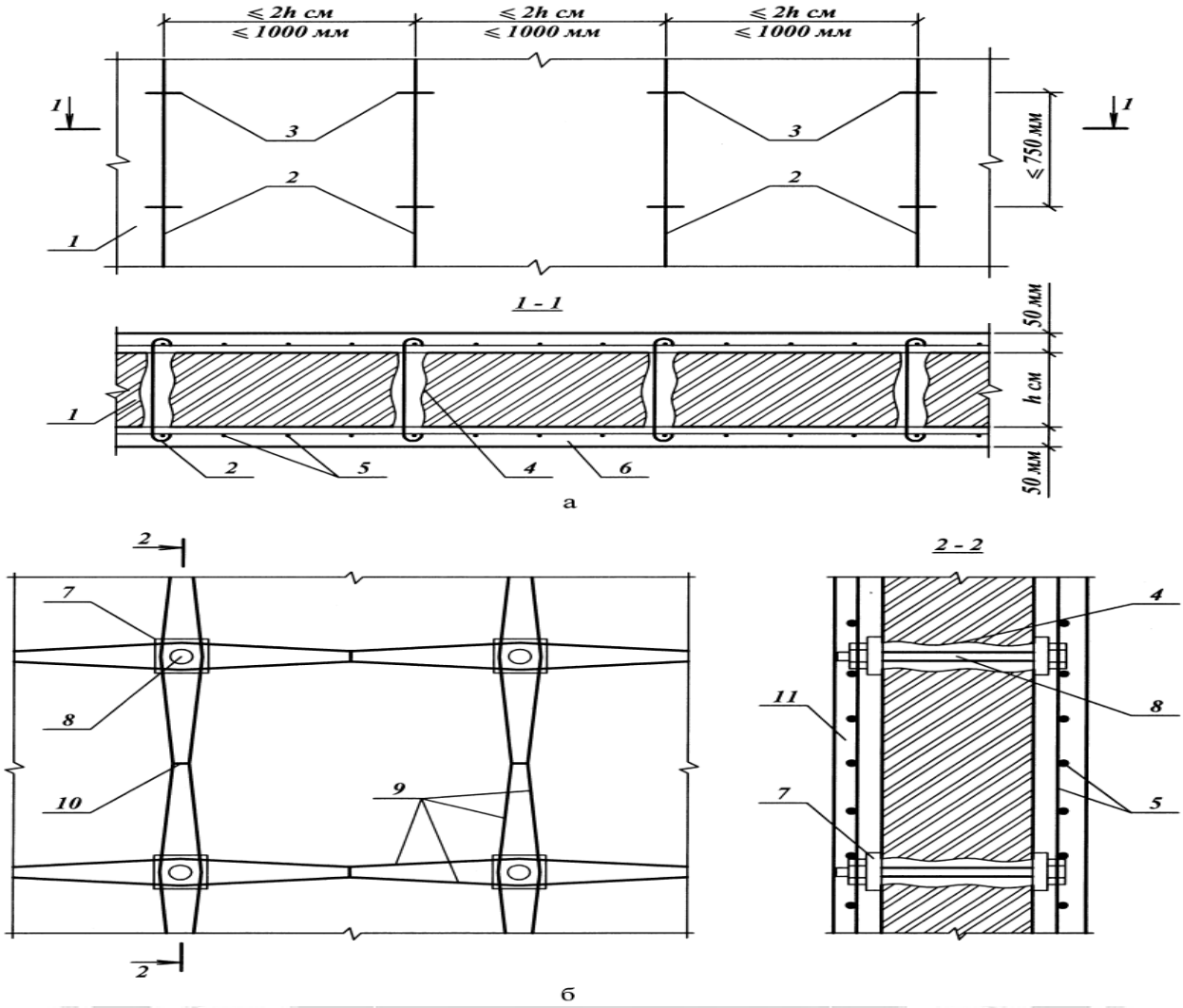



**Figure 3. Strengthening Walls by the Cartridge Clips:**

**a - reinforced concrete; b - plaster pre-stressed; 1 - strengthened wall; 2 - reinforcing bars Ø10 ÷ 14 mm; 3 - hose clamps Ø10 mm; 4 - holes in the wall; 5 - reinforcing mesh attached to the reinforcing bars; 6 - concrete sleeves; 7 - steel plates with holes for strands; 8 - connectors 9 - reinforcing rods welded to the plates and tightened in pairs; 10 - clamps; 11 - cement-sand mortar plaster.**

3.9. The following types of clips are used: steel, reinforced concrete, mortar-reinforced, as well as ballast fiber, glass fiber, and coal fiber.

3.10. The steel ferrule is arranged from vertical angles, mounted on the solution at the corners of the reinforced element cleared of the plaster layer, and clamps made of flat steel or round rods were welded to the corners. The distance between the clamps should be no more than a smaller section and not more than 50 cm (Fig. 2 a, b). To enable the cage to work, the gaps between the masonry and the corners are caulked or injected with a cement-sand mortar. Steel ferrule must be.

3.11. The reinforced concrete cage is made of concrete classes B12.5 ÷ B15 with reinforcement with vertical rods and clamps welded to them. The distance between the clamps should be no more than (15cm). The thickness of the clip is assigned by calculation and is taken from 6 to 10 cm (Fig. 2, c; Fig. 3, a). Anchors on non-shrinking cement or chemical anchors are used to ensure a joint work with masonry.

3.12. The cage is reinforced from the solution in the same way as reinforced concrete, but instead of concrete, the reinforcement is covered with a layer of cement-sand mortar M50 ÷ M100 fig.2. c

3.13. The holder is made of composite materials based on special glass aramid and carbon fibres, glued to the reinforcing element with special adhesives walls fig. 2, d. A distance between the bonds should be no more than 75 cm (Fig. 3, a). Connections should be securely connected to the steel elements of the clip.

3.15. It is recommended to reinforce the damaged elements with clips, followed by an injection of damaged masonry with cement mortar.

3.16. If, due to architectural or other reasons, it is prohibited to break the walls from the outside or if their cross-sections are small in size and the load needs to be significantly increased, the wall reinforcement can be made with a metal or reinforced concrete core placed in a vertical niche cut into the wall (Fig. 4). The device of reinforced concrete cores can be carried out from one or two sides of the wall.

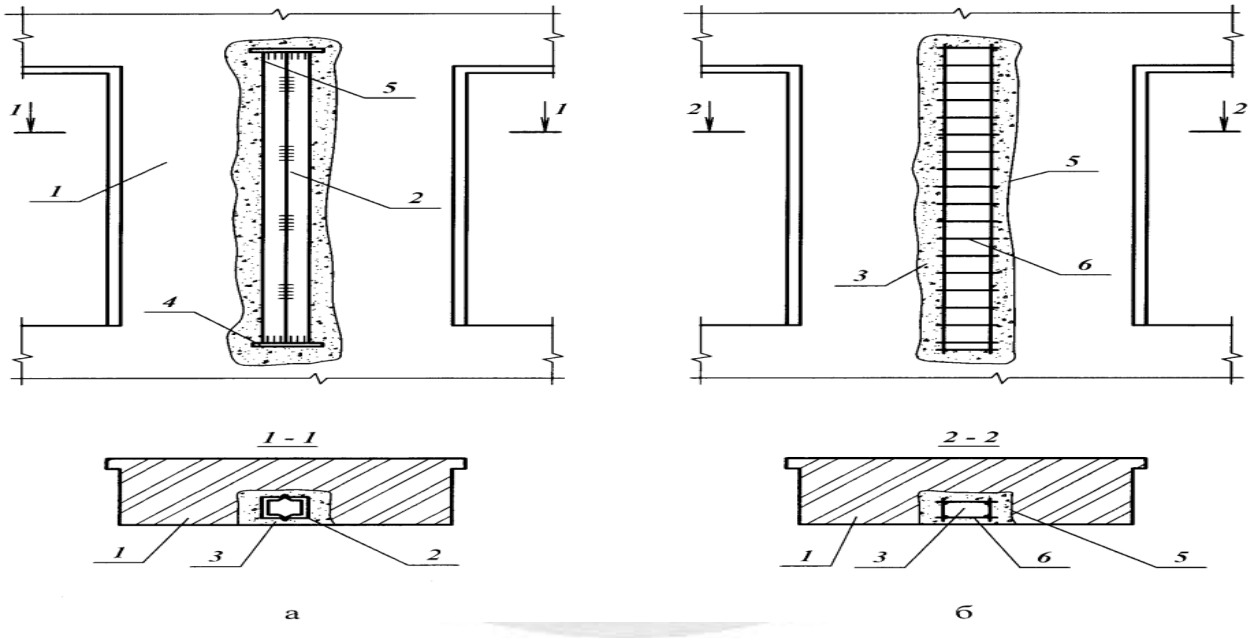



**Figure 4. strengthening rock partitions by the device of the carrying core: a- welded of two channel bars; b- of ferro concrete ; 1- strengthened partition; 2- steel core; 3- concrete of the class of w10… of w15; 4- supporting plates of steel core; 5- vertical niche, pierced in the partition; 6 reinforcing cage.**

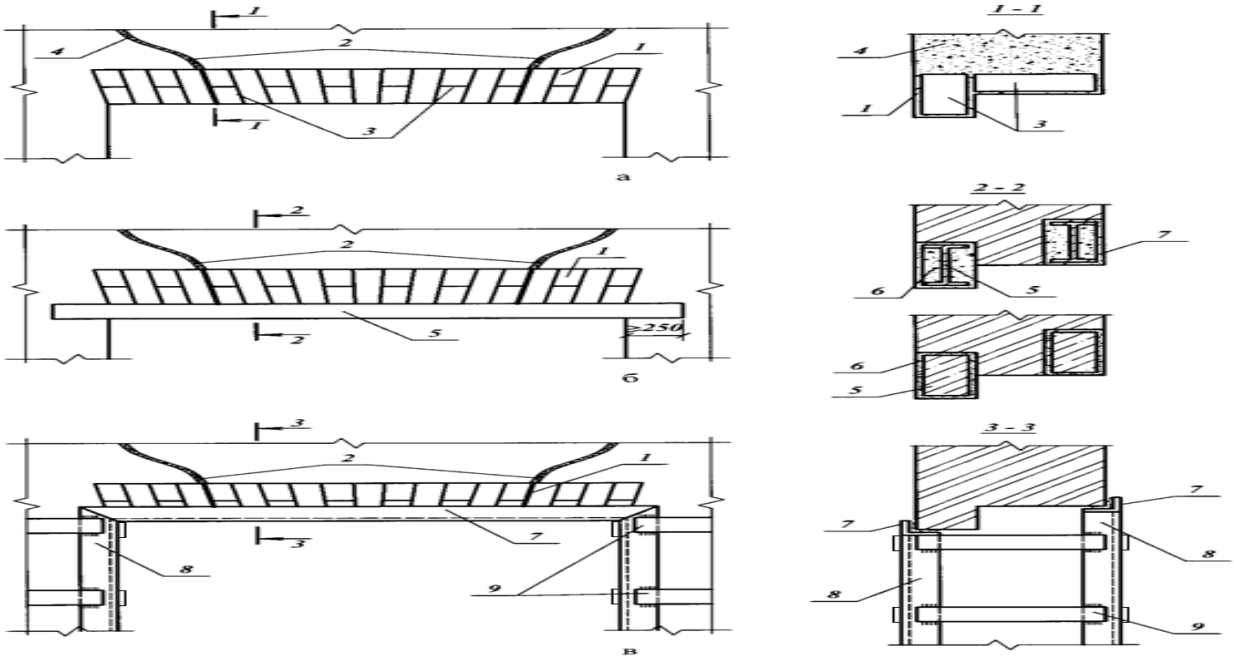
3.17. Moreover, relining and injection are employed. When using clips, injections, or other forms of reinforcement is not economically or technically feasible (due to severe damage, section weakness, or an emergency situation involving the masonry), or when other strengthening techniques are not adequate, or when maintaining the building's aesthetics is imperative, the pillars and walls are moved.

3.18. enhancing the masonry's cross connections. The strengthening the brick cross connections above the window and door apertures can be achieved by the closing of cracks (fig. 5, by a), partial or complete transfer band furthermore by substituting ferro concrete or metallic for brick cross connections (fig. 5, by b).

3.19. Series and wedge-shaped cross connections strengthen thinner than Ferro concrete beams by allowing steel to be admitted less often. With the light loads preferably the application of angle sections connected by laths and melted into the solution seams in the limits of partition (Fig. .5, in, d, f). With the large efforts the beams from the channel bars, installed into the cut from two sides walls of too thing and bolted or yokes are arranged (Fig. 5, g).

With the flight of series and wedge-shaped cross connections more than 1, 5m additionally to the steel corners are established steel suspensions made of the strip steel, which below weld on to the corners, and in the upper part they attach to the laying with the tightening bolts, openings under which carry out by drilling (fig. 5, g).

**3.20.** The counters are made from the steel corners in the supports, to which weld on the steel strips are fastened by another end on the wall with the help of the tightening bolts. This strengthens the arched cross connections in the aperture. Weld a 6x8 mm thick arched steel sheet to the counters that surround the aperture (Fig. 5, i).



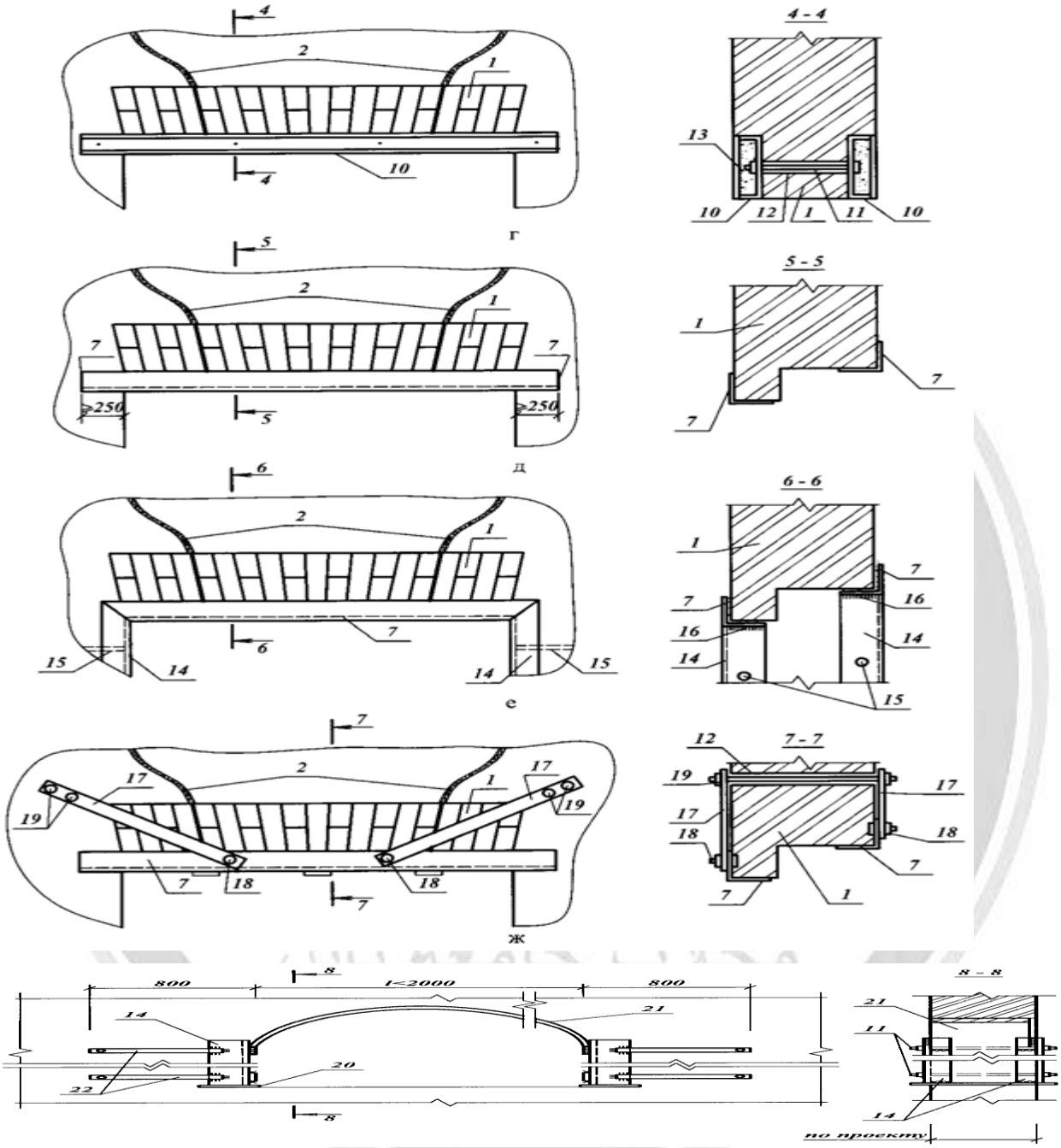



**Figure 5: Reinforcing the brick cross connections above the openings for windows and doors a) patching cracks; b) substituting ferro concrete or metallic**

when angle sections are applied to c, d, and e; z,h - using a steel pendant; g - beams from the channel bars; and by arched steel sheet; 1. reinforced rock; 2. fissures, sealed with cement mortar following strengthening; 3. plates of steel; 4. cement-sand mixture; 5. cross-connection of

steel or ferroconcrete; 6. plastering, either with or without a grid, using a cement-sand solution; 7. Steel corners that are positioned on the cement-sand mixture; 8. The cartridge clip's vertical corners. 9The tenth cover plate from the channel bar is the ninth connecting strip. 11. Bolt tightening; 12. Wall opening (bolts are called by solution after installation); 13. Applying plaster to the grid; 14-from the corners, counter; 15: strut attachment anchors; 16: welding 17-strip steel belts; 18-bolts for fixing; 19. anchor bolts 20th is the supporting steel sheet. 22-metal strips; 21-arched steel sheet.

**3.21.** The first step in restoring the series cross connections is to move away from the old layout by flying to a distance of 1.5 meters. The reinforcement, which is constructed of round bar steel measuring 5–6 mm, is plotted beneath a smaller number of bricks into the layer of solution on the initial established planking at a rate of one rod per half-brick of the wall's thickness (if not required, estimated reinforcement). Rods with hooks at the ends are started for the face of supports that are at least 0 and 25 meters long. The cross-laying connection is then completed.

**3.22.** The restoration of the wedge-shaped cross connections by transfer is produced from two sides from the heels to the sand willow with the tapered seams possessing the same thickness as than 5mm below and not more than 25mm above the cross connection. If required, along with the cross-connection's restoration, it can be intensified by the installation of two steel corners, fastened by the laths, placed with the step of 400mm.

**3.23.** Strengthening rock walls in the zone of crumpling (local contraction). Short cracks and breaking up of separate stones in the zone of the transfer of load are the characteristic features of destruction with the crumpling. Strengthening laying in the zones of crumpling is accomplished by one of the following methods: by the device of ferroconcrete or steel cartridge clips in pilaster or the posts, which receive loads from the floor beams or rafter constructions of coatings (Fig. 6);

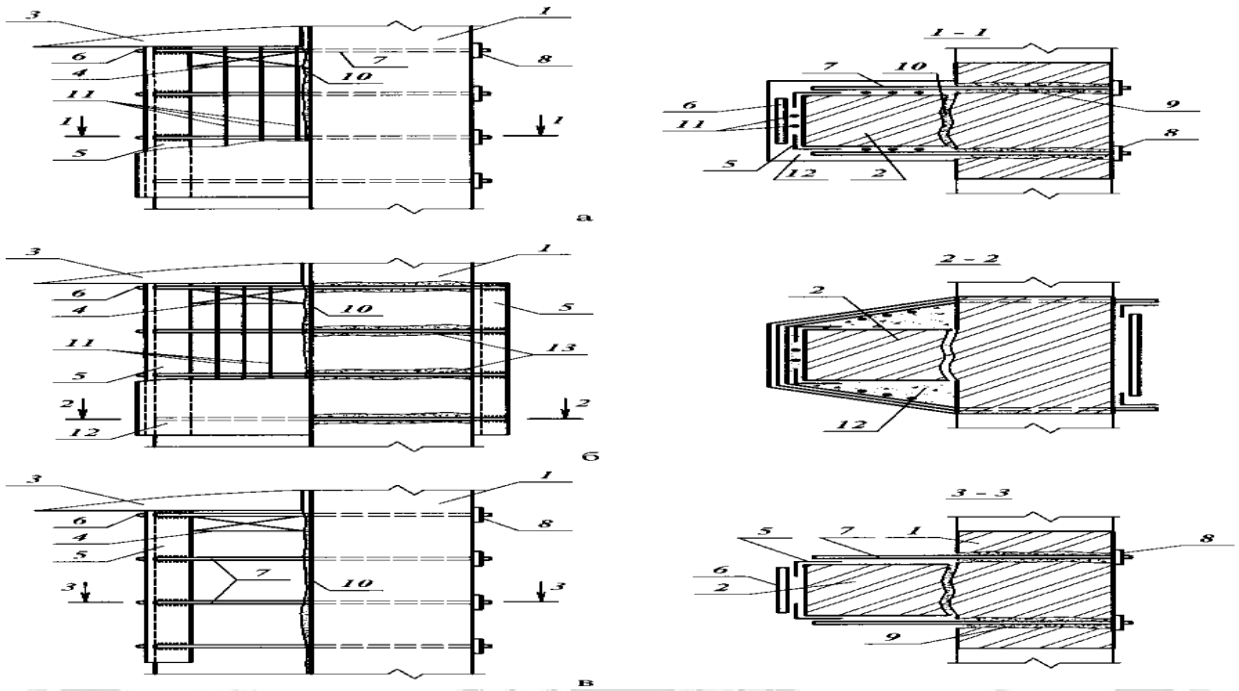


**Figure 6: Using device clips to reinforce the bearing beam nodes on stone building elements**

**a, b - reinforced concrete; c - steel; 1 - a pier; 2 _pilaster; 3 –carrier beam; 4 –support cushion; 5 - steel corners of the holder; 6 - transverse yoke clips of armature rods; 7 - transverse clamps strands with nuts 8 - washers; 9 - holes in the wall (after installation, the strands are filled with cement-sand mortar); 10 - crack on contact pilasters with the wall (filled with mortar); 11 - 11 - additional armoured tour; 12 - concrete cage; 13 - grooves on the lateral surfaces of the pier (after installing the transverse collars the slats are staked with a cement-sand mortar).**

An increase in the area of supporting the elements of floors and coatings by means of steel support tables (belts) fixed to the wall under them or steel posts, the force from which is transmitted to the wall outside the damage zone (Fig. 7, a; 8, a, b ); an increase in the area of supporting plates or beams by placing beams on racks under the wall near them (Fig. 7, b);

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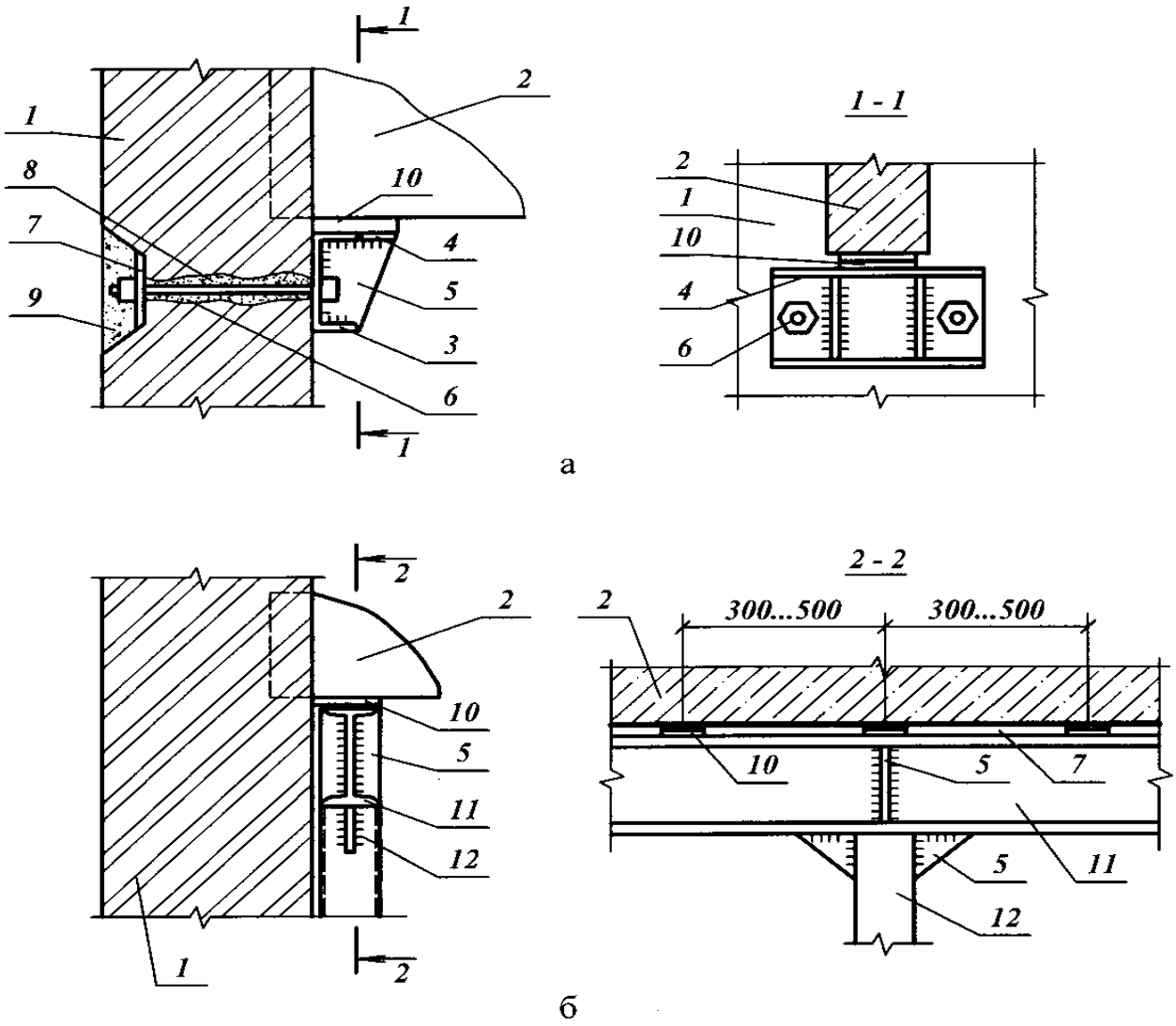


**Figure 7. Strengthening the units of the support of beams and plates to the elements of the rock construction.**
**a-by the installation of steel tables; b-by bringing beams on the counters;**
**1- wall; 2- carrier beam or the plates, which do not have a sufficient length of support to Well, steel ; 3- supporting table from the channel bar; 4 _additional plates, welded to the shelf of the channel bar; 5 stiffening rib; 6_ anchor bolts; 7 _plate-washers; 8_ openings in the wall (they are filled up with cement-sand solution after the installation of bolts); 9 _niche in the wall (it is filled with solution up); it is 10th steel plate-wedges for including the tables.**

The body ferroconcrete pillow is distributed by a mechanism beneath the reference plane of beams, farms, and the like. The load is transferred from the element of overlap, either coating on the counter, cutting into the wall, or to pilaster and resting on the foundation (Fig. 8, b).

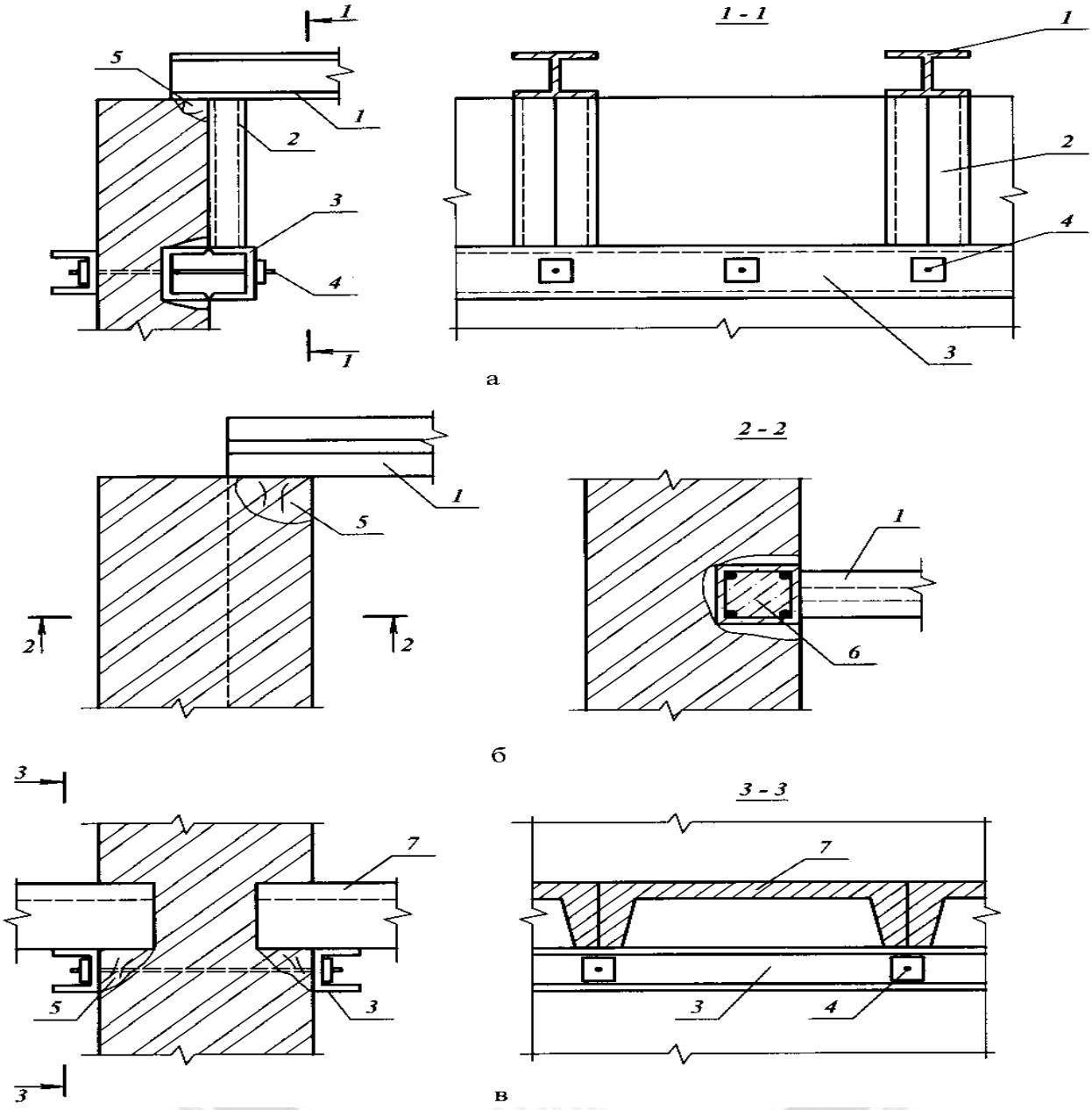


**Figure 8. strengthening (unloading) the wall in the zone of the local contraction:**
**a- by short counters; b- of fitted steadfast; in by steel belt;**
**1 -beam of coating; 2 -counters of strengthening; 3- steel belts - channel bars 18… 20**
**4- tightening bolts of Ø12… 16; 5 -zones of crumpling; 6 cut into the wall**
**ferroconcrete counter; 7 -plate of overlap.**

3.24. When installed on a distribution cushion support, the wall is unloaded, bringing temporary support under the beam (truss, etc.). Then damage

The bottom of the masonry zone with a height of 3-4 rows is removed and in its place a reinforced concrete pad, reinforced with a spatial frame or nets, is installed.

Temporary supports are dismantled when concrete is of the required strength.

3.25. To avoid the sudden caving of the elements of overlap as a result of the significant progressive deformations of building and also the insufficient connection of the elements of overlap with the walls, which decreases as a whole the three-dimensional hardness of building, it is expedient to forego strengthening the zones of crumpling and to use the insurance anchoring of the elements of overlap in the load-bearing walls. This is effective when there are no signs of the crumpling of laying, but the opportunity of their fast appearance is not excluded. The possible versions of anchoring the construction of overlaps and coatings in the zone of crumpling (local contraction) are represented in Fig. 9. The anchoring was accomplished with the aid of the anchor belts which go through the wall and welded to the revealed longitudinal rods of the reinforcing cage of the anchored construction or steel distributive plate (see Fig. 9 and b). Works on anchoring of beams are produced in the following sequence: drilling in the wall of openings and the opening of the reinforcing rods of beam; the installation of the anchoring devices and their start-up; the monolithization of the revealed reinforcing rods and the calking of openings in the wall by the rigid solution. Unloading beams in this case is not carried out.

The process of anchoring vacuum plates is more labour-intensive and is carried out in the following sequence (see Fig. 9 and b)

openings in the wall drill; they unload plate; they divide the upper shelf above the voids and put the anchoring devices; voids are filled with concrete; the remaining elements of strengthening are mounted, stretching them with the aid of the nuts after collection by concrete of design strength; openings in the wall are sealed by the rigid solution. The sequence of works on an anchoring of ribbed slab in bases Nome consists of similar operations with the exception of those that are connected with the strengthening of voids (Fig. 9, c).

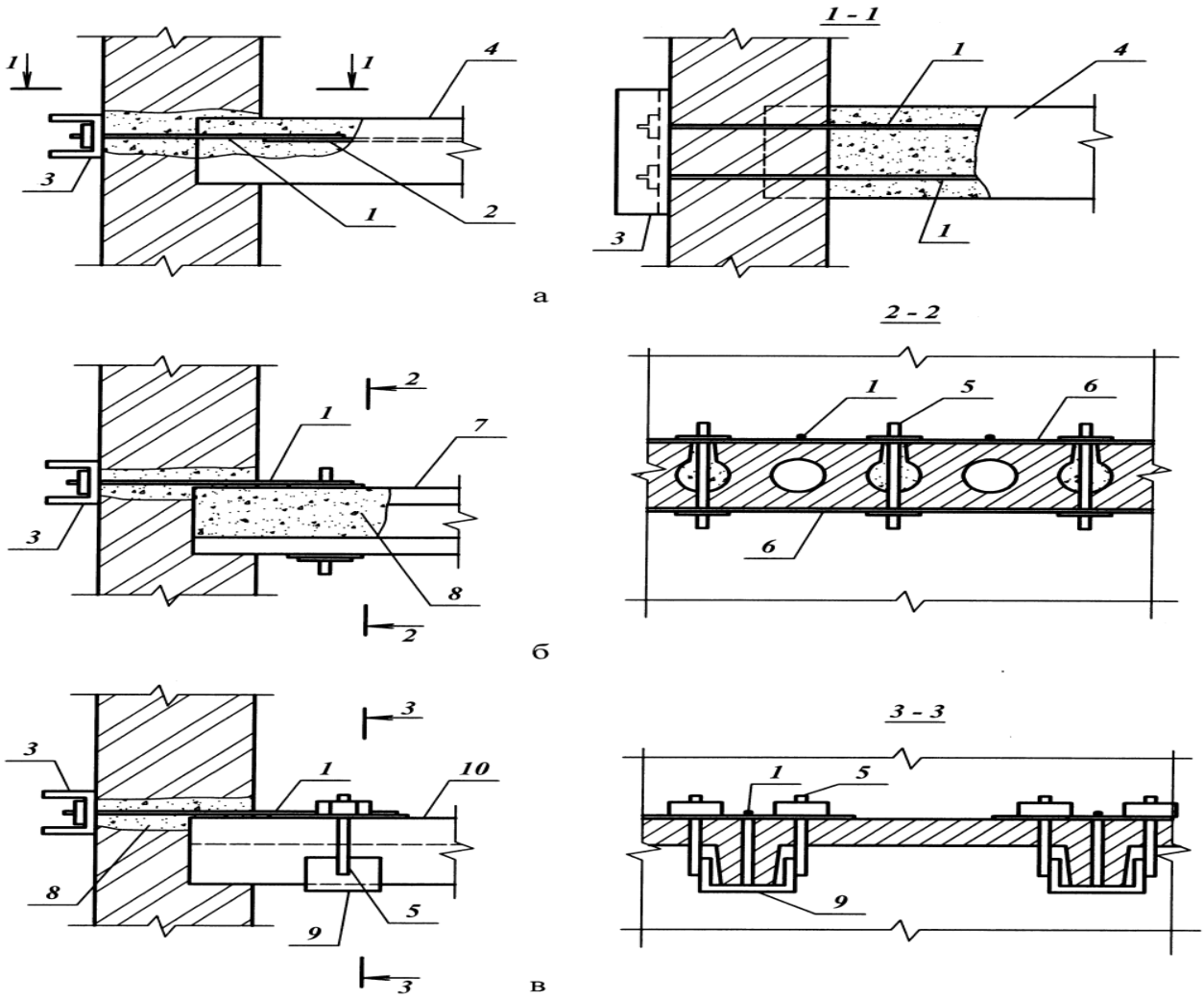


**Figure 9. anchoring constructions in the zone of the local contraction:**

**a- beams; b - vacuum plates; in ribbed slabs; 1- anchor rod of Ø20… 25; 2- reinforcing rods of beam; 3- the section of channel bar 12… 14; 4- floor beam; 5- bolt of Ø20; 6- steel plate of 120x8; 7- vacuum plate; 8- concrete of the class of V25; 9- severing's of channel bar 20; it is 10th- ribbed slab.**

**3.26.** Strengthening and restoration of the damaged revetment of walls from the masonry. Facing materials for the rock walls can be facial or profile brick or stones, plate and component from natural stone, ceramics, decorative concrete. In Fig. 4.10 certain forms of revetments and bandaging's with the basic laying of walls are given. To increase or decrease the distances between the facial castellated stones is not recommended since at large distances crack formation in the headers and scaling of revetment, and an improvement in the joint operation of facial layer with the laying is not reached across shorter distances. Facing brick strength shouldn't be less than that of the wall's foundational material. The mortgage plates' retraction (Fig. 10, c) is created concurrently with wall construction to their regiment they seal in the

laying at depth not less than 75 mm. the revetment by the leaning plates (Fig. 10, g) is produced on the finished walls after their erection and sagging, strengthening them in the solution of the stamp not lower than M50. With the revetment of their unique buildings, furthermore, they anchor.

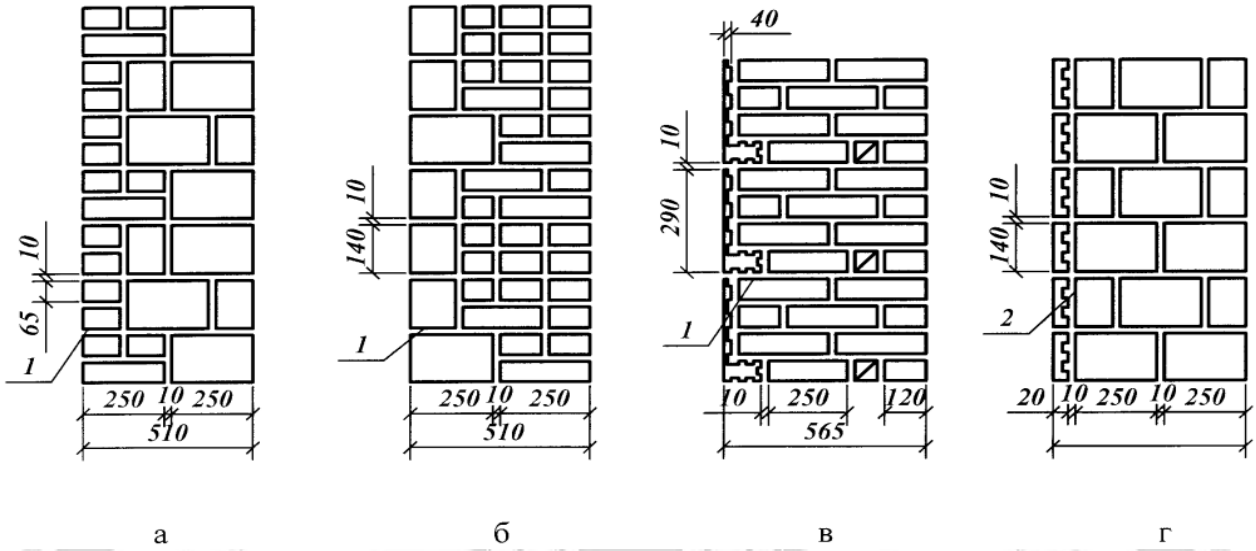


**Figure 10. examples of the types of revetment of the walls:**

**and by the facing brick of wall from the ceramic stones; b by the facial ceramic stones of wall from the brick; in by the mortgage ceramic plates of wall from the brick; g by the leaning ceramic plates of wall from the ceramic stones; 1 _ The stamp is not lowered by the solution of M25; 2_it was the same, not below M50.**

Stones or bricks with a ceramic face that are used to revetment walls made of light-concrete. It is not permitted to use leaning plates or mortgages in these situations. Weld throat in the facial laying and in the revetment by plates is taken as the equal of 10mm in this case the thorough pointing of seams on one of the forms, given in Fig. 11, is produced.

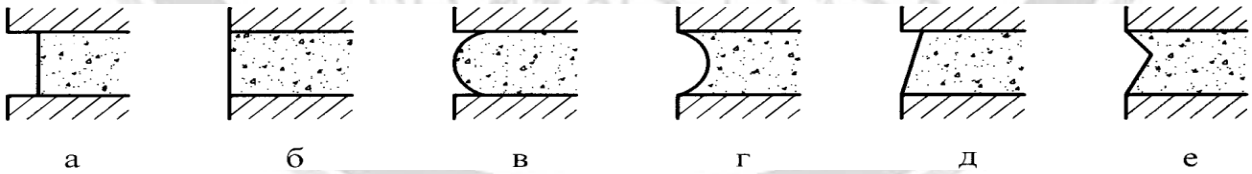


**Figure 11. Varieties of the pointing of seams.**

**3.27.** Concrete measures to ensure the durability of the lining include: lining without identical vertical strands; top surface device for all types of gratings to prevent moisture leakage to the wall; proper splitting of window sills with wide panels and a drip-stone device in exposed parts of the walls; mortar composition and time of year which brick construction is carried out; reducing the height of hard cladding not cut by eaves, belts and horizontal projections of walls in order to avoid differences in the cladding and construction project, etc.

**3.28.** During the shallow damages of revetment its restoration can be realized by plastering on the grid, fixed to the wall with the aid of the anchors (Fig. 12, a). With the deeper defeat of the revetment (to fourth and more than brick) and also with the scaling of facing layer from the basic laying, its substitute is created. with the guarantee of bandaging with laying of wall (Fig. 12, b).

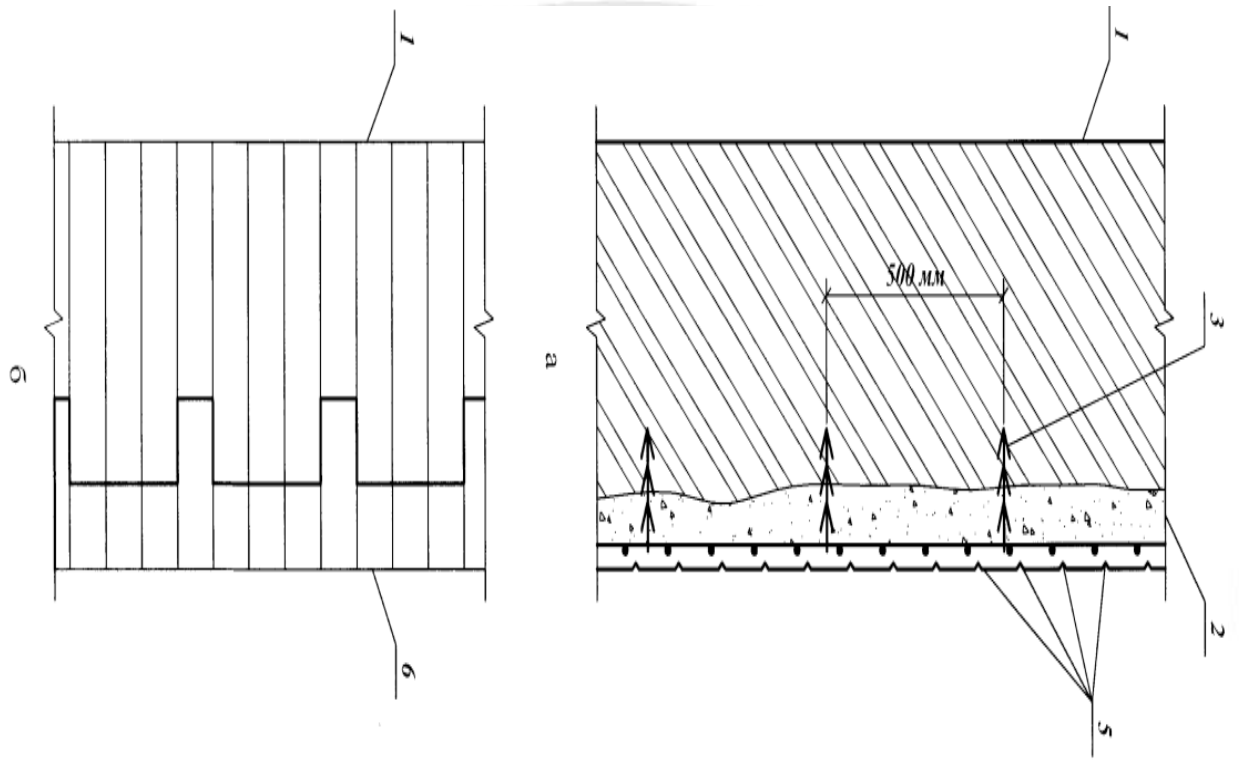


**Figure 12. Restoration of the damaged revetment of the brick walls:**
**a- by plastering; b- by the replacement of the damaged revetment via bandaging with the existing laying; 1- laying wall; 2- cement-sand plastering; 3- Anchors were inserted 500 mm up and down the horizontals of the laying walls.; 4- reinforcing grids, attached to the steel connections; 5- rustics, which imitate the seams of masonry; 6- new revetment tied up with the existing laying of the wall (It was removed after being scaled from the construction of more than 20 mm revetment.**

**3.29.** Strengthening and restoration of the facing layer can be done by installing anchors or replacing the facing with fixing an-ceramics with the existing masonry. In the first case, when the cladding is peeled off from the main wall masonry up to 20 mm, in the wall cladding and masonry, holes are drilled with a slope to the horizon of 30˚ with a diameter of 20-30 mm to a depth of 350-400 mm with an interval of 600-800 mm vertically and horizontally, in which on the cement-sand (or polymer-cement) paste an anchor is installed - reinforcing bars of a periodic profile with a diameter of 10-14 mm. After the solution hardens

in the wells (after 7 days), the gap between the lining and masonry of the wall is injected with a cement-sand mortar (Fig. 13, a).

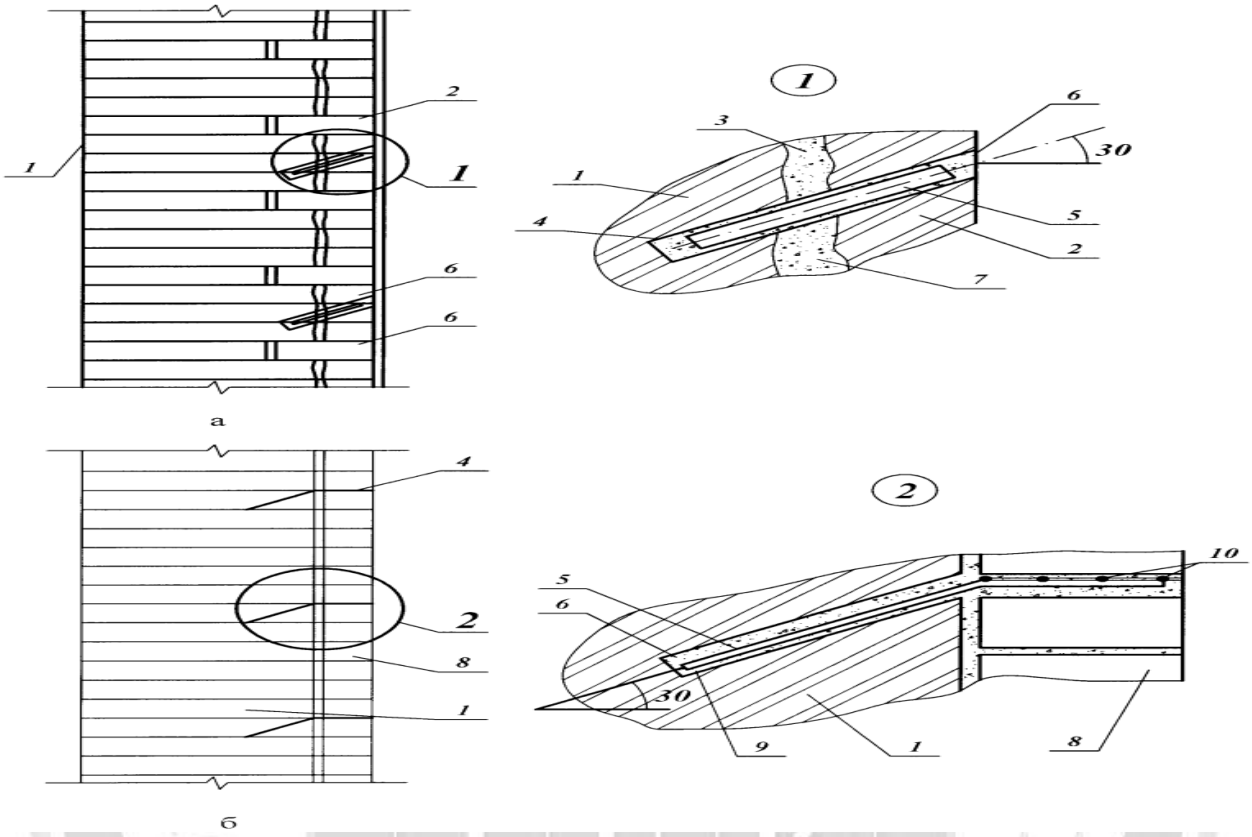


**Figure 13. Strengthening and the restoration of the damaged revetment of the walls: a- with the installation of steel connections; b – with replacement of the facing by fixing anchors with existing masonry; 1 - wall laying; 2 - damaged (peeled off from the laying of up to 20 mm) lining thickness ½ brick; 3 - the gap between the masonry and lining; 4 - Drill masonry holes with a diameter of 20 to 30 mm to a depth of 350 to 400 mm through 600 to 800 mm horizontally and vertically; 5 - bond-rod of the periodic profile anchor Ø10 ... 14 mm, length 300 to 350 mm; 6 - cement-sand paste;**

**3.30.** Injection of masonry [6, 7, 12, 13, 14, 15].

Depending on the type of reinforced structure, the following types of solutions are recommended for their restoration and strengthening by the injection method:

a) cement (sandless) and cement-sand;

b) cement-polymer using as a polymer addition PVA or latex SKS 65 GP-B in the amount of 15-20% by weight of cement, polymer-cement ratio 0.15-0.2;

c) polymer based on epoxy resins ED-16, ED-20 or GLOBALPOX 1-10 / 138 / W and others.

**3.31.** Replacing the masonry elements of masonry buildings is carried out during the superstructure and reconstruction when the bearing capacity is insufficient, in case of an emergency condition of the walls and lowering the bearing capacity of the masonry as a result of moistening.

The most frequently encountered task of replacing masonry is associated with moistening the masonry of the lower girdle of the first floors to the level of window openings. First of all, the masonry section is replaced under the openings, and then under the pro-walls. To improve the connection between the masonry sites, reinforcement meshes are successively installed in the seams (Fig. 16, a).

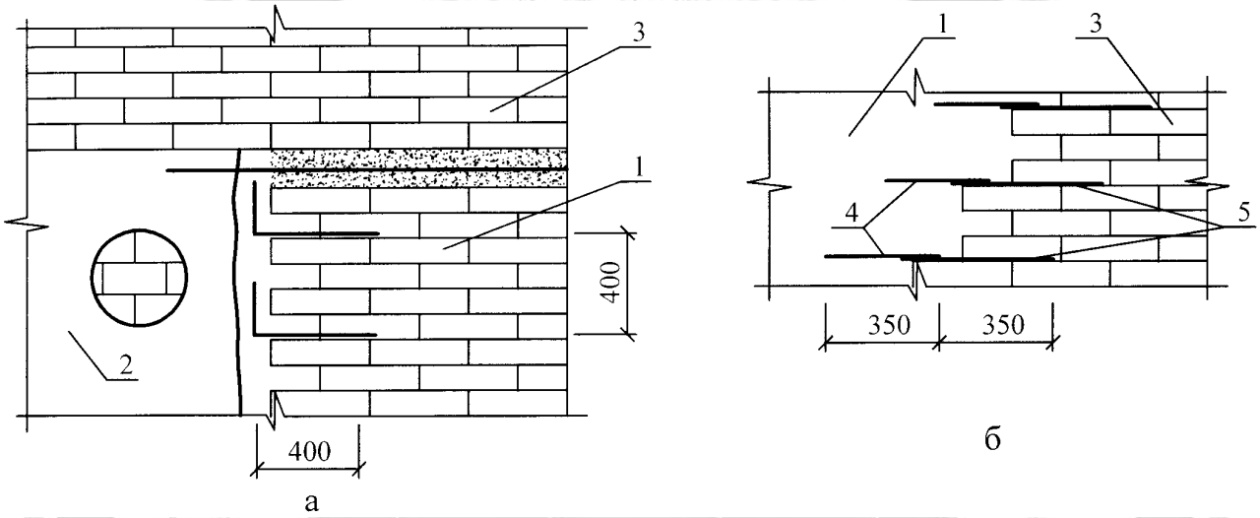


**Figure 16. connection of new laying on the reinforcing releases: a- while the step-by-step laying; b- in connecting with the old laying; 1- new laying; 2- laying, plotted in the second turn; 3- old laying; 4- reinforcing grid of Ø4 V500, Vr500 with the cell of 100x100 mm; 5- reinforcing rods of Ø6 A240**

More rarely, more complex work includes the replacement of masonry to the height of the floor or the entire height of the building. Structurally, in this case, it is important to ensure the joint work of the old and the new masonry by bandaging the seams along the entire height of the area being replaced. To improve the operation of the joint, the connection is additionally reinforced by the device of the anchor rods Ø6 A240, driven into holes of 4 mm diameter and welding of rebar grids made of Ø4 B500, Bp500 wire with cells of 100x100 mm to them, laid in the expansion joints of the new laying (Fig. 16, b).

Strengthening the junction of the longitudinal and transverse walls with the separation of the latter was carried out with bolts and plates. The bolts Ø18 ... 22 mm are located at the height of the wall with an interval of 0.8 ... 1.5 m. corners, laid in the punishment, punched in the wall and sealed with fine-grained concrete. To increase the rigidity of the pairing longitudinal plates are connected to the welding of transverse elements - channels or angles. The pitch of the transverse elements is the same as that of the tie bolts (Fig. 17, b).

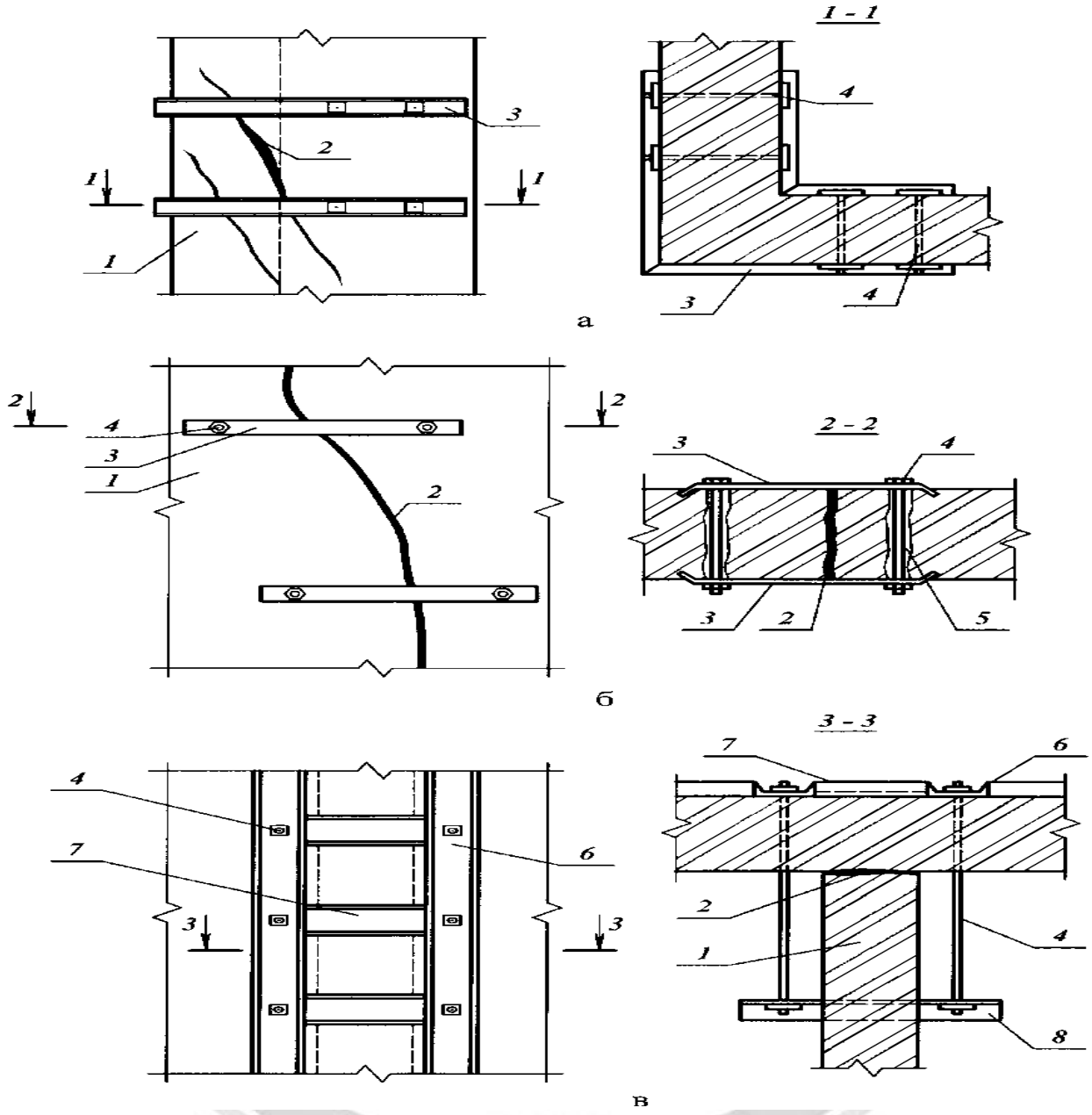


**Figure 17. Strengthening walls from the masonry in the zone of the local cracks: a, b- by steel cover plates; in by tightening bolts; 1- strengthened wall; 2- crack in the laying; 3- steel cover plates; 4- tightening bolts; 5- opening in the wall for the bolts; 6- longitudinal cover plates; 7- transverse cover plates; 8- anchor arms.**

**3.32.** Strengthening walls with crack formation in the angles of buildings or in the places of the contiguity of transverse walls to the longitudinal can be executed by internal anchors. It is possible to use them even during the incomplete damping process of the uneven sagging of foundations. The construction of the internal preliminary: strained anchor is shown in Fig. 18.

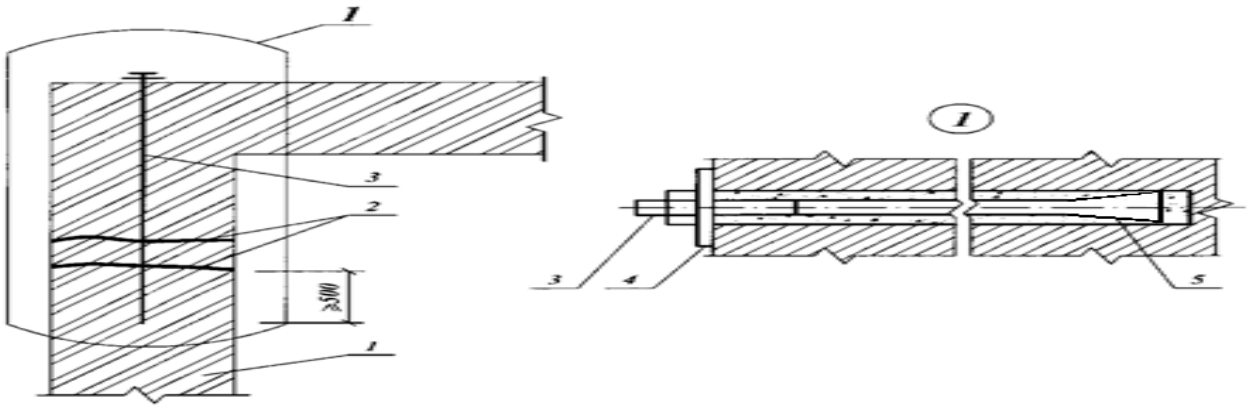


**Figure 18. Strengthening walls with the cracks in the angles of buildings or in the contiguity of transverse walls to the longitudinal:**
**1 -strengthened wall; 2- cracks in the wall's construction; 3- internal wedge anchor; 4- quadrangular washers whose sizes don't exceed 150x150 mm; 5 openings, filled with cement-sand or polymer-cement solution.**

**3.33.** The restoration of the masonry of walls in the zones of local cracks is carried out with the aid of keys made from the segments of steel rental or reinforcing rods (Fig. 19). Keys work the tension and shear; therefore effectively they are set in operation with the possible deformations of laying walls in the zone of cracks with a width of disclosure of up to 10 mm.

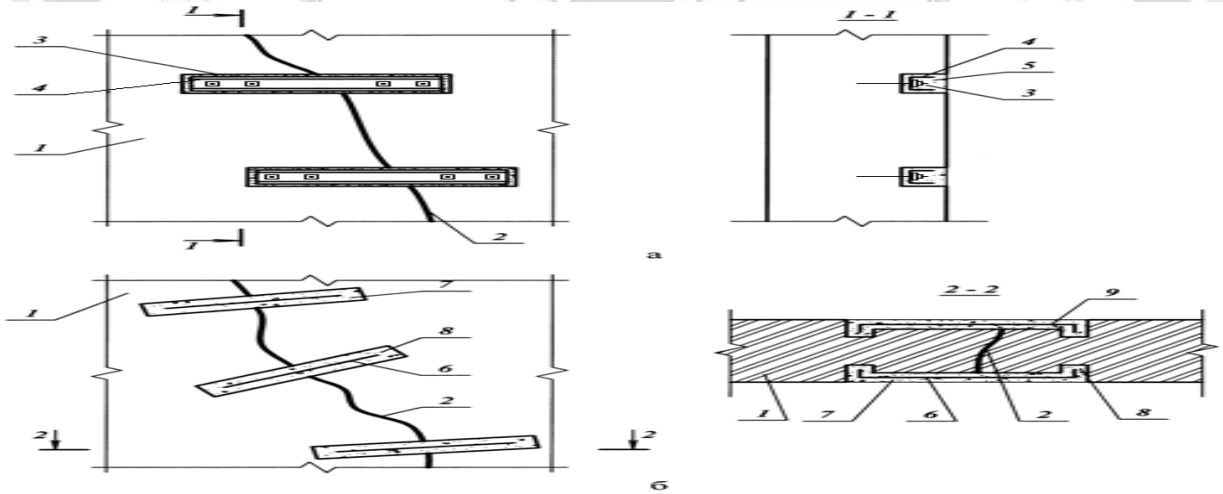


**Figure 19. elimination of local cracks in the walls:**
**a- by the installation of keys from the rolling metal; b- the same clamps from the reinforcing rods; 1 strengthened wall; 2- crack in the laying with width 10 mm, injected by cement-sand mortar after the installation of keys; 3- Additionally, objects in the wall; 4 - key from the rolling metal (channel bar, corner); 5 - cavities that are filled with solution or concrete; 6- clamp from the reinforcing rods; 7- groove in the laying, selected with cutter; 8 deepening on the ends of the groove, performed by drill; 9 filling with the solution of grooves and deepening**

**3.34.** With the width of the disclosure of local cracks in laying of walls it is more than 10 mm and has a negligible extent by the restorer of simple brick locks (Fig. 20, a) or brick locks with the anchor (Fig.20, b).

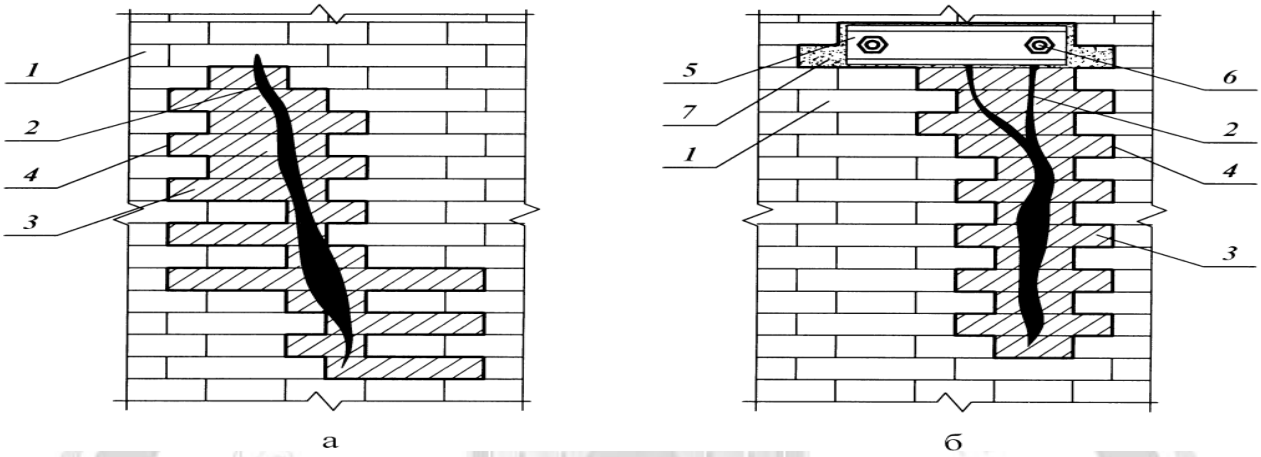


**Figure 20. Restoration of masonry walls in areas of local cracks:**

**a - with wide cracks by the insertion of simple brick locks; b - the same, inserting a brick-like lock with an anchor; 1 - reinforced wall; 2 - crack in masonry more than 10 mm wide; 3 - brick castle ½ brick; 4 - boundary of disassembly of damaged masonry; 5 - rolled metal anchor; 6 - anchor ties (bolts); 7 - cavities filled with solution.**

## Conclusion

Important and historic structures serve as both a bridge for the transmission of social conventions and experiences from one generation to the next and as monuments to human history. In order to maintain them, the past must be brought back to life and buildings must be renewed through restoration and rehabilitation in order to retain its beauty. Buildings need to be maintained and restored in order to be sustainable.

These days, buildings are restored and rehabilitated using current, contemporary techniques, which greatly aid in the preservation and revitalization of heritage and noteworthy structures as well as the restoration of damage brought on by time, the elements, and other factors.

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# ترميم وتدعيم المباني الحجرية والجدران المبنية من الطوب (الطابوق)

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**الخلاصة:**

يُعرف فن الحفاظ على إرثنا الثقافي من خلال العمارة بالترميم. وهو عملية ترميم المباني التاريخية التي فقدت جزءًا كبيرًا من قيمتها الجمالية بسبب التدهور والتشققات بفعل الزمن والكوارث الطبيعية وعوامل أخرى.

يُعد إيجاد حلول هندسية لإصلاح الشقوق والأضرار في جدران الطوب أمرًا ضروريًا لتقليل الخسائر المادية بدلًا من هدم المباني أو الحفاظ على أهميتها التاريخية أو الأثرية، لأن المباني الحجرية وجدران الطوب تتعرض لأضرار مادية جسيمة بفعل عوامل الطقس والزمن والزلازل وعوامل أخرى.

بشكل عام، يهدف الترميم إلى استدامة المباني من خلال الهندسة والتوثيق مع الحفاظ على السلامة الهيكلية للهياكل المراد ترميمها. ليس مجرد مبنى أو مؤسسة، بل أصبح الحفاظ على التاريخ المعماري والتأكيد على قيمته أمرًا بالغ الأهمية للنمو الحضري. فهو يحافظ على طابع الموقع والهيكل، ويبني روابط دائمة بين الأجيال المتعاقبة. وتحظى التراث والمباني ذات الأهمية التاريخية التي تمثل عصر الأمة وحضارتها بحماية متزايدة هذه الأيام. هناك العديد من الطرق الهندسية والعلمية لمعالجة هذه الأضرار، وتحسين الجدران، وزيادة عمر المباني والجدران المبنية من الطوب.

تهدف هذه الدراسة البحثية إلى تغطية عدة محاور علمية تُسهم في الحفاظ على التراث المعماري للعراق، ومدينة بابل تحديدًا. وتتمثل هذه المحاور أو الأهداف فيما يلي:

- تحديد مواد البناء المستخدمة في المباني التراثية في بابل، سواءً كانت حجرًا أو طابوقًا أو ملاطًا أو خشبًا، وذلك باستخدام الأساليب والمعدات العلمية الحديثة.
- تحديد تقنيات البناء المستخدمة قديمًا في تشييد المباني التراثية.
- وصف العناصر الإنشائية والمعمارية والزخرفية لهذه المباني.
- دراسة وتشخيص عوامل ومظاهر تدهور مواد البناء المستخدمة في المباني التراثية في بابل.

• اقتراح الأساليب العلمية والمواد المناسبة لمعالجة المشاكل التي تواجه هذه المباني.

• تقليل معدل هدم المباني والحفاظ على البيئة.

**الكلمات الدالة:** هياكل حجرية، جدران من الطوب، بوليمر، أسمنت، إصلاح الشقوق، استدامة المباني، التراث المعماري.