Comparative analysis of the materials’ choice for the brick restoration technologies in the cultural heritage sites’ facades

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Abstract. The restoration of the “brick facades” of historical objects is a fairly studied task. A large number of materials and technologies are used in its solution today, however, their application does not always lead to the excellent results. The purpose of this study is a comparative analysis of the effectiveness of the materials used and the methods of repair and restoration work with brick materials, depending on the monument’s initial condition, its utilitarian use and the architectural stylization of its facades. This article compares and discusses three methods of repair and restoration of the historical objects’ “brick facades”: the “traditional” method of brickwork restoration, used mainly in the monuments’ restoration experience in Russia; materials and technologies of Caparol company (Germany), as well as the materials and methods of repair and restoration of the brick facades in the Remmers company (Germany). The analysis objects are the history and architecture monuments of a number of South Russian cities; the period of repair and restoration of these facilities from 2013 to 2020. The effectiveness of the indicated methods and materials’ application at the stage is compared: preparatory work, repair and restoration of lost masonry, restoration of masonry with reprofiling; and at the stage of the facades’ finishing. The results of the combined use of various methods are presented. The presented observations and conclusions on the practical conduct of repair and restoration work using various materials and technologies on a number of architectural monuments made in the “brick style” are “equipped” with the data for effective planning and development of “optimal” technological maps for the future restoration objects.

Introduction
Currently, the repair and restoration of the historic city center objects is an urgent task. A special place in this list is occupied by the buildings made in “brick style”, the facade solutions of which positively contrast with modern decoration materials, support the local authenticity of the environment, and the regional specifics of the urban context. At the same time, despite the abundance of materials and techniques for the repair and restoration of such objects, the quality of the work performed often does not correspond to the costs incurred, and does not bring the monument to the appropriate level of its historical significance. There are the reasons for both the economic plan (low quality of products, the lack of professionalism of performers) and the technological nature: the choice of the effective methods and materials for repair and restoration in accordance with the stylistic features of the monument, the nature of its operation and its specific role in the urban context.
The purpose of this study is to conduct a comparative analysis of the various technologies and materials’ effective use for the historical facades’ repair and restoration using a number of objects made in “brick style” with various stylistic features and the initial state as an example.

The experimental setup included the following initial data. The objects of the experiment were the iconic buildings of the historical city center from a number of South Russian cities related to the cultural heritage objects: “Bath by A.M. Vinogradsky”, Krasnodar; “The complex of the tobacco factory by V.A. Asmolov”, Block JA, Rostov-on-Don; the building of the former “Apartment building, beginning of the XX century” Soborny lane, 58 in the city of Rostov-on-Don; “The newspaper “Priazovsky Krai” building”, Rostov-on-Don Bolshaya Sadovaya street, 18. The following technologies and materials were used in the experiment: 1) the traditional, classical technology of brickwork restoration used mainly in the Russian experience in compiling the technological maps and design recommendations [1], [2], [3]; 2) the technology of repair and restoration of masonry using materials from the company Remmers (Germany) [5], [6]; 3) the technology of repair and restoration of masonry using the materials from the company Caparol (Germany).

The experiment tasks included:
- the choice for the restoration and restoration work of several restoration objects made in the “brick style”, and differing in plastic features of the front facades, the initial state of the masonry, and the operation nature;
- practical selective application at these facilities of the most common methods and technologies for the repair and restoration work based on the use of exclusive materials for the brickwork repair and restoration;
- fixing the results of repair and restoration work at various methodological stages, including: a) preparatory work, cleaning masonry; b) restoration, reprofiling of bricks and masonry joints; c) repair with the bricks replacement (laying masonry); d) finishing work, hydrophobization.
- a comparative analysis of the applied methods’ effectiveness and the materials for the brickwork restoration according to a number of specified criteria.

The following indicators acted as the criteria for optimality and effectiveness in the use of various materials and technologies: a) the return of a “reliable” historical appearance and significance of an architectural monument, taking into account its stylistic features; b) the brickwork color uniformity; c) texture uniformity of the front facades’ masonry; c) the quality of the texture and profile of the masonry joints, corresponding to the facade’s stylistic features and the color scheme of the main material - brick, including: the junction’s thickness uniformity, the junctions’ straightness (evenness).

Materials and methods
The experiment has been carried out for a long time: from 2013 to the present, which allowed a comparative analysis of the methods and materials used at different times and at different facilities and to draw the general conclusions on their effectiveness.

The building “Baths of the merchant A.M. Vinogradsky”, located at the intersection of Gimnazicheskaya and Kommunarov streets in the city of Krasnodar, is characterized by the decision of its front facades in the modern style. Repair and restoration of the facility was carried out in the period 2013-2014. The landmark angular location of the building in an urban context determined the abundance of “visual accents” in its brick facades, including: decorated pediments and attics. Visual inspection made it possible to establish: the brick is porous, has traces of erosion, low strength, chips, crevices, weathering of masonry joints. On the walls of the facades there are numerous old colorful coatings with weak bearing capacity.

The operation nature of the building with internal wet processes and the external locking of the facades’ masonry led to the presence of the mold areas on the surface, numerous shoots of moss, plants. The first “preparatory” phase of the facade repair made it possible to evaluate the effectiveness of the materials used. The use of traditional biocidal treatment and cleaning of building facades in these areas in the form of alkaline solutions, household detergents has shown their low efficiency, due to low penetrating ability. Instead, Caparol technology was used: after mechanical cleaning of the
areas from mold, removal of moss and plants, the Histolith® Algenentferner material was applied: the application was carried out undiluted with a brush; after the surface has completely dried, the subsequent application was carried out after 12 hours.

At the second stage, the bulk of the restoration work was associated with repurposing the surface of the elements of the numerous “brick decoration” of the building “Baths of the merchant A.M. Vinogradsky”, characteristic of the Art Nouveau style, including: a) rusticated pilasters in the form of “towels”; b) parapet cabinets with a rounded finish; c) eaves metric belt of step “widths”; c) attics of complex curved shape with round openings - “lucarnes”; numerous “niches” and contour “cuts” with deepening in masonry up to 70-90mm; radial projections of the masonry, giving the facade plastic a centrifugal “movement” up. The nature of such plastic elements’ “reprofiling” in the places of chips, erosion and masonry defects is shown in Figure 1.

Figure 1. The nature of the re-profiling of brick decor in individual fragments of the front facades of the building of the former “Baths of the merchant A.M. Vinogradsky” in the Krasnodar city

Figure 1 shows that the complexity of arcuate movement and contours, the abundance of niches and protrusions reduced the rate of re-arrangement and re-profiling of brick decor. Initially adopted by the “classical method” [1] of the home casting work production on the brickwork restoration included the use of the following materials: Portland cement M-400; brick fractions: 0.01-0.25 mm and 0.5-1.5 mm; additives: superplasticizer C-3, 40% solution. However, the technology for preparing modified additive solutions with a dosage of the starting components turned out to be prolonged in time and practically impossible due to the complexity and busyness of the brick decor restoration. Therefore, Caparol dry mixes were used as an alternative, having a clearly fixed composition and properties for the entire scope of work. After wetting the surface, the bricks were re-profiled using the quick-hardening Histolith® Restauriermörtel mineral solution. The repair composition was tinted in brick color by adding a maximum of 10% Histolith® Sylitol-Volltonfarbe. To grout the weathered masonry joints, it was recommended to use the lime-cement mortar PIc or a stronger PII mortar of a strength group M75-M100.

At the third stage, in the places of “breakdown” and necessary restoration of the lost brickwork sections, “old-style” brick from the courtyard facades of the building, having a different nature of operation, was used as a replacement. This led to heterogeneity of color and texture of the front facades’ masonry. Therefore, at the final stage, the proposal by Caparol technologists to use the topcoat of the brickwork with Histolith® Außenquarz silicate paint tinted using the brick chips in the required color with a dilution of a maximum of 5% Histolith® Silikat-Fixativ solution, became effective.

Specific from the point of view of the initial state was the building located at the address: Rostov-on-Don, Soborny lane, 58/7, block A, identified the cultural heritage site “Apartment building, beginning of the XX century”. Brick decor, typical of the Romanesque period structures and the “pseudo-Russian style” was used in its facades”. The building had significant settling of foundations,
through the cracks and deformations of lintels, profiled rods and rusts. Repair of the building was carried out in the period 2015-2016.

Taking the nature of the losses into consideration, the first question was not about the building facades’ brickwork restoration, but about the walls’ bearing capacity restoration. And here the “classical method” of crack injection in brick masonry perfectly proved itself [1]. To level the geometric deformations of a linear brick decor (rods, rusts), a method for focusing on the mixing of color shades during the front bricks’ repurposing was emphasized. This was achieved using a special restoration modeling composition on a mineral basis Remmers Restauriermortel (art. 0752, 0760, 0769) mixed with the clutch activator Remmers Haftfest.

A slightly different approach was applied in the repair of the building located at the address: Rostov-on-Don, Krasnoarmeyskaya street, 170/84, block JA, as a part of the cultural heritage object “Complex of industrial buildings of the tobacco factory of V.I. Asmolov”. Repair and restoration of the facades were carried out in the period 2016-2017 and included the reconstruction of the lost building’s historical appearance with the characteristic “French” rustic of the lower tier walls. At the initial preparatory stage, the use of traditional washing compounds for cleaning masonry from the outside and paint stains did not give any results due to the multilayer and old coatings. The classical method of JVAC (jet-vortex abrasive cleaning) [1] with a fraction of 0.3 - 0.5 mm was found to be effective. The key factors that determined the further choice of the materials and restoration technology were the following circumstances: a) the presence of heterogeneous plastic components from the local sandstone and limestone-shell rock in the facade’s front masonry; c) in view of the frequent adaptations of the monument, loss of slopes in the openings and their replacement with foreign materials were revealed.

Based on these circumstances, Caparol materials and technology were selected for conducting the mastication re-profiling and re-installation of masonry, which allows selective control of the modeling composition color and texture using the Histolith® Restauriermörtel quick-hardening mineral solution. The repair composition was tinted in brick color by adding a maximum of 10% Histolith® Sylitol-Volltonfarbe (see Figure 2). In the process of searching for the necessary texture and color of the masonry, test “colors” were made (see Figure 2).

**Figure 2.** The texture and color selection of the modeling composition during the repair of the masonry of the block JA in the complex of the former “Tobacco factory of V.I. Asmolov” building in Rostov-on-Don

However, when comparing several ready-made “maps” on the facade with the same composition of the repair mortar, the nuanced differences in color tone were found, due to the fact that the initial components for mixing were taken from different procurement lots of the material, the work crews changed. The last contractor, as a second method for the masonry repair and restoration, used the
ready-made Remmers molding materials. To fill the chipped cavity and re-establish the brickwork, a special mineral-based modeling composition was used, prepared in the consistency of Remmers Restauriermortel sludge (art. 0763) mixed with a clutch activator — liquid polymer dispersion Remmers Haftfest (art. 0220) (see Figure 3).

Figure 3. The selection of the modeling composition’s colors and textures of Remmers during the brickwork restoration in the complex of buildings of the former tobacco factory of V.I. Asmolov

The second method’s advantage of conducting work was the presence of molding materials in Remmers technology for the stone replacement, casting and broaching of stucco elements, which made it possible to carry out a set of repair work in places where “foreign” materials were included in the masonry. The joint restoration was performed on the basis of a mineral dry mortar for filling the joints and restoring the Remmers Fugenmortel suture solution, followed by priming the Remmers Impregniergrund siloxane-based, colorless solvent-based primer. At the final stage, the final glazing coating of the facade masonry was used - azure based on silicone resins with mineral fillers Remmers Historic Lasur. As a result, the painted surface acquired the final color and texture of the brick, originally set in the project by the architects and restorers.

The most difficult decisions when choosing the effective methods of repair and restoration work had to be taken for the object of the regional significance cultural heritage “The building of the newspaper Priazovsky Kraj”, in which from 1893 to 1895 writer A.I. Svirs ky worked, and from 1886 to 1898 as a writer A.S. Serafimovich worked’, located at the address: Rostov-on-Don, Bolshaya Sadovaya street, 18. The work started in 2018 and is still ongoing. The building was built at different periods, has three ceremonial facades, significant precipitation of shallow foundations. In view of this building, the buildings are cut through the cracks into incompatible fragments and need a set of urgent emergency measures. The following installations adopted in the project were decisive for the restoration process: 1) preservation of the facade wall on the Bolshaya Sadovaya street with angular ripping on the Bratsky lane; 2) disassembly of the building’s remaining emergency parts with subsequent recreation. The project provides for the temporary safety structures of the retained front facade wall and phased disassembly of the remaining facades’ masonry with the preservation and storage of “old-style” bricks.

Further solutions for the repair and restoration of the building’s front facades provide for the combined use of the advantages of each brick repair methods presented. So, at the stage of cleaning the preserved facade on the B. Sadovaya street from the numerous paint layers the classic method of sandblasting JVAC was applied [1]. For other less painted facades, the disassembled brick is cleaned of contaminants with a washing solution: Remmers Fassadenreiniger-Paste jelly-like weak cleaner (art. 0666). Also, the materials on Remmers technology are used according to the project at the stage of strengthening and waterproofing the masonry of the building’s preserved part and at the stage of repair and re-profiling of the front brick using the mineral-based modeling compound Remmers Restauriermortel mixed with the Remmers Haftfest clutch activator.
Since the building’s facades incorporated a combination of facing ceramic bricks with the plastered surfaces of columns, rods and belts, a combined restoration method with the additional use of Caparol materials was provided, which proved to be effective for repairing the plastered surfaces: Dupagrund deep penetration primer; facade putty Capalith Fassaden-Feinspachtel; Elastic-Rissspachtel elastic putty for crack repair; materials for finishing painting of the restored surfaces: Capagrund-Universal primer and PermaSilan highly elastic weather-resistant facade paint. The advantages of each indicated methods of repair and restoration work will help to achieve the planned restoration of the cultural heritage lost appearance.

Discussions and Results
Thus, the observation of the repair and restoration work progress at a number of historical sites in South Russian cities makes it possible to record the following results:
- the application of the brick walls repairing and restoration classical traditional methods is a well-tested and effective technology [1], [2], especially at the stage of preparatory work, including: a) mechanical cleaning of brick facades from strong pollution - the JVAC method; b) strengthening and repair of emergency walls having significant precipitation (crack injection method); which is also confirmed by a number of studies on the local experience example in the city of Samara and others [3], [5], [6];
- however, at the stage of restoration and re-profiling of brickwork of facades, the use of traditional materials with molding mixtures’ dosing and preparation at the site reduces the effectiveness of this technique;
- the use of ready-made molding materials and modeling compounds for the restoration and recreation of the colors, textures and textures of masonry brick facades is the most acceptable at this stage. This is confirmed by the effective use of similar materials at other restoration sites in St. Petersburg [4];
- at the stage of the masonry large masses final tinting, in the areas of “mashing” and replacing bricks, Remmers materials showed greater efficiency, allowing to achieve a more uniform masonry surface texture;
- for the restoration of facades with different types of stone (brick, limestone, sandstone, etc.), the Remmers technologies turned out to be the most effective, allowing to re-arrange such elements and materials with a wide palette of modeling compositions of “stone substitutes”. This is also confirmed by the example of the “complex” brick facade restoration in the “Moorish style” in St. Petersburg [4];
- for the buildings with styling features in the form of inclusions the plastered surfaces in “brick facades”, the combined method becomes effective: for the brick surfaces’ restoration - using the materials and Remmers technologies, and for the additional inserts from plastered elements - the Caparol materials palette.

The results presented in this article indicate the importance of a selective and flexible approach to the restoration materials and technologies’ selection. This is confirmed by a number of similar foreign studies, including: a) on the design decisions’ variability in the monument buildings’ repair and adaptation [7]; b) a comparative analysis of various historical brick walls’ strengthening methods [8]; c) by the methods of strengthening complex historical facades in the form of curved brick structures [9]. These studies qualitatively and substantively complement the traditional method of restoration and repair of brick facades. An effective addition to the restoration methods described in this study can also be the advanced technologies’ use for determining the age and composition of the masonry, including the stimulated luminescence methods’ use [10].

Summary
The analysis of the various technologies’ effectiveness in the study significantly complements and concretizes the existing traditional methods and recommendations for repair and restoration of the masonry, as it reveals an expanded palette of new materials and approaches to their use at various methodological stages.
The presented observations and the results of the selective conducting of restoration and restoration work using various materials and technologies using a number of architectural monuments made in the “brick style” as an example can serve as the basis for future effective planning and development of optimal technological maps for the restoration objects.

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