TECHNICAL TRANSACTIONS | CZASOPISMO TECHNICZNE
ARCHITECTURE | ARCHITEKTURA
8-A/2014

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A MOISTURE TRANSFER IN EXTERNAL WALLS WITH NATURAL STONE CLADDING GLUED DIRECTLY TO THERMAL INSULATION LAYER

TRANSPORT WILGOCI PRZEZ ŚCIANY ZEWNĘTRZNE Z OKŁADZINĄ KAMIENNĄ KLEJONĄ BEZPOŚREDNIO DO WARSTW IZOLACJI TERMICZNEJ

A b s t r a c t

Currently the most common stone cladding facades are made of 3 to 4 cm thick panels fixed with steel anchors. A new approach of gluing 2 cm thick stone boards directly to the thermal insulation layer made of EPS polystyrene or mineral wool insulation is currently investigated. The aim of the article is to present natural stone cladding hygrothermal properties obtained from laboratory research. Also analysis results of moisture transfer through wall thickness are provided for the walls finished with a natural stone cladding glued directly to the thermal insulation layer.

Keywords: natural stone claddings, moisture transfer

S t r e s z c z e n i e

Współcześnie najbardziej popularną technologią wykonywania elewacyjnych okładzin kamiennych są okładziny wentylowane z płyt o grubości od 3 do 4 cm, mocowane na kotwiach stalowych. Nowym, obecnie wprowadzanym do stosowania rozwiązaniem jest klejenie dwucentymetrowej grubości płyt kamiennych bezpośrednio do warstwy izolacji termicznej ze styropianu EPS lub z wełny mineralnej. Celem artykułu jest przedstawienie parametrów cieplno-wilgotnościowych okładzin z kamienia naturalnego uzyskanych z badań laboratoryjnych, a także analiza przepływu wilgoci przez ścianę z zewnętrzną okładziną kamienną klejoną bezpośrednio do warstwy izolacji termicznej.

Słowa kluczowe: okładziny z kamienia naturalnego, transport wilgoci

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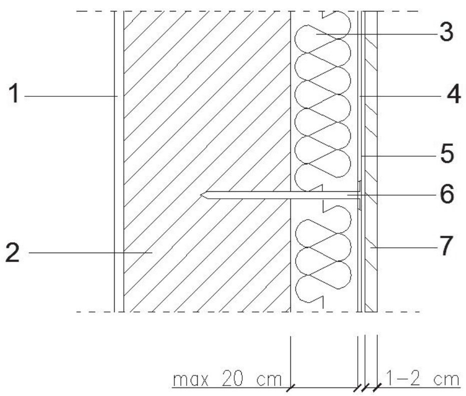
1. Introduction

The function of stone, applied in historical buildings, has been currently and significantly altered in modern civil engineering. Solid and structural (beam and trusts) elements have been replaced by thin-layer stone claddings laid on reinforced concrete walls, brick walls and other structural elements made of various building materials. The changes of stone function are caused mostly by: economic, structural strength and workmanship factors. Modern stone claddings are commonly used at representative building facades. These buildings are often designed as tall structures located in large urban agglomerations. Typical stone facings are connected to the structure with both stainless steel and aluminum anchoring systems.

A new solution of gluing thin-layer stone claddings directly to the structure thermal insulation layer is being introduced. In the first stage, the installation method is similar to making thermal insulation together with thin-layer plasters in the ETICS system. Arrangement of layers in the component with stone cladding glued directly to the thermal insulation of the wall is shown in Ill. 1.



Ill. 1. Section of external walls with a natural stone cladding glued directly to the thermal insulation layer: 1 – internal plaster, 2 – bearing wall, 3 – thermal insulation layer, 4 – adhesive mortar, 5 – reinforcing fabric, 6 – PVC fastener, 7 – stone cladding

The stone facing is glued directly to the thermal insulation in several steps. In the first step, the thermal insulation layer made of polystyrene, XPS or mineral wool up to 20 cm thick is attached on the gluing mortar to the structural base. In the second step the thermal insulation layer is covered with a reinforcing fiberglass mesh glued with white cement mortar. Next, to improve thermal insulation adherence to the structural base, mechanical (PVC) fasteners are installed. On such a prepared substrate, thin-layer stone boards of a surface density of up to 40 kg/m^2 are laid [2]. At the final stage, once the gluing mortar dries, the point board joints are made. The technology of fixing the claddings directly to thermal insulation is much cheaper than traditional technology, but due to the lack of the layer of ventilated air, there can be problems with water vapour diffusion through the building component.

2. Stone cladding water vapor diffusion resistance

2.1. Natural stones vapor diffusion resistance

Thermally insulated external wall layers should be characterized by low water vapor diffusion resistance. Depending on the quality of the stone type, the stone claddings applied as an external layer exhibit different diffusion resistance coefficients. Vapor diffusion resistance coefficient values for various stone type qualities are summarized in Table 1.

Table 1

Water vapour diffusion factors for different stone types according to [3]

Stone sort quality	Vapor diffusion resistance factor μ	
	Dry	Wet
Natural stone-crystalline rock	10 000	10 000
Natural stone-sedimentary rock	250	200
Natural stone-light sedimentary rock	30	20
Natural porous stone (e.g. lava)	20	15
Basalt	10 000	10 000
Bastrad granite-genesis	10 000	10 000
Granite	10 000	10 000
Marble	10 000	10 000
Limestone extremely soft	30	20
Limestone soft	40	25
Limestone semi-hard	50	40
Limestone hard	200	150
Limestone extremely hard	250	200
Sandstone	40	300
Natural pumice stone	8	6

Natural stone physical parameters strongly depend on: chemical constitution and composition, structure and density. The vapor diffusion resistance factor value for the particular stone type qualities should be evaluated as based on research made on samples taken from particulars beds. Vapor diffusion resistance factor values for two of the most popular polish sandstones evaluated from laboratory research are shown in Table 2.

2.2. Moisture transfer throughout the walls with natural stone cladding

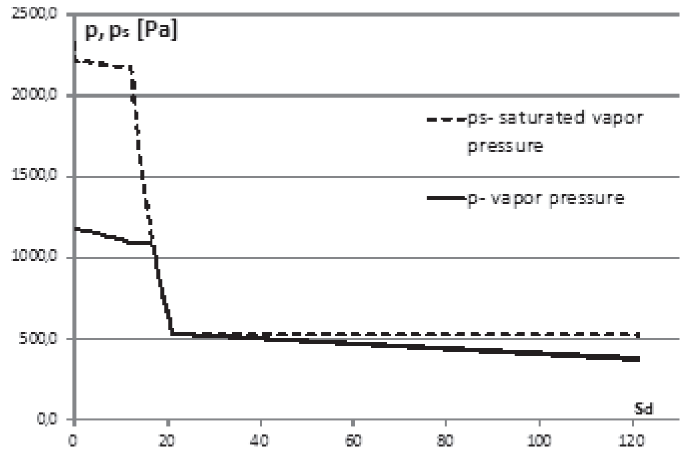
Granite, hard limestone, semi-hard limestone and sandstone reveal the best aesthetic and functional qualities. However, granite stone claddings show a high water vapor diffusion resistance coefficient value. Better water vapor diffusion resistance factor values are displayed by limestone and sandstone. Although sandstone cladding displays a relatively low vapor diffusion resistance value due to low strength parameters, sandstone claddings should be designed at least 2 cm thick.

Table 2

Sandstone vapor diffusion resistance factor values evaluated from laboratory research

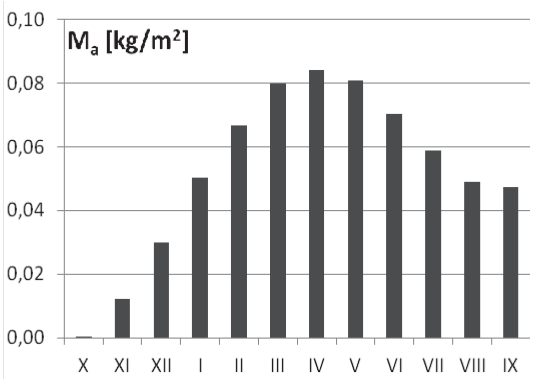
Stone type quality	Vapor diffusion resistance factor μ	
	Dry	Wet
Sandstone "Skała"	20,3	18,5
Sandstone "Czaple"	22,7	19,5

In polish climatic conditions, moisture interstitial condensation in the walls designed with stone claddings glued directly to the thermal insulation layers is observed only during the winter season. An example of moisture pressure distribution based on the "Fick" law and worked out for the wall made of an inner concrete bearing layer and externally insulated with polystyrene is depicted on Ill. 2. The seasonal water vapor condensation balance at a wall for the typical climatic conditions in Cracow Poland (an average value for a 30 year period) for a concrete reinforced wall insulated with polystyrene is depicted in Ill. 3.



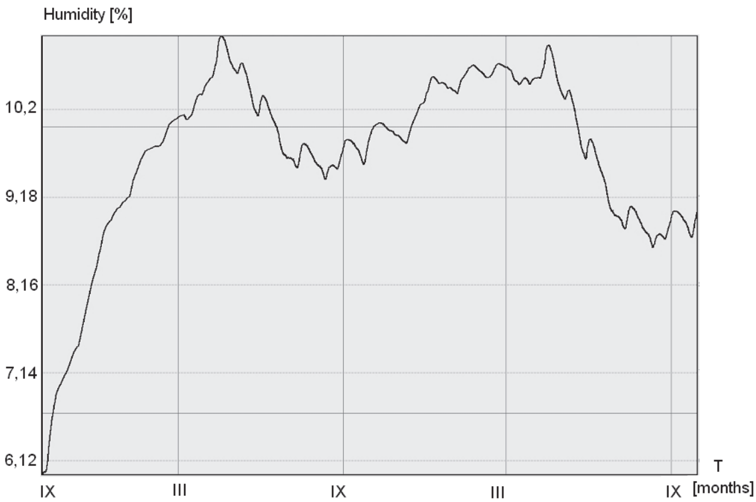
Ill. 2. Moisture pressure distribution scaled in terms of vapor diffusion thickness for the wall made of reinforced concrete insulated with polystyrene and granite stone claddings glued directly to the insulation layer (see also Table 3)

Water vapor transfer throughout the bulkhead is significantly impacted by stone cladding humidity. Wet stone, depending on its kind, may indicate a different vapor diffusion resistance than dry stone. Stone cladding humidity may be caused not only by interstitial moisture condensation but also by rainfall. Stone cladding is highly prone to soak and once it becomes humid, it may impact on the humidity of the wall insulation layers. In order to analyze the above described phenomena, calculations of moisture transfer through the wall with stone cladding glued directly to the thermo-insulation layer have been made utilizing



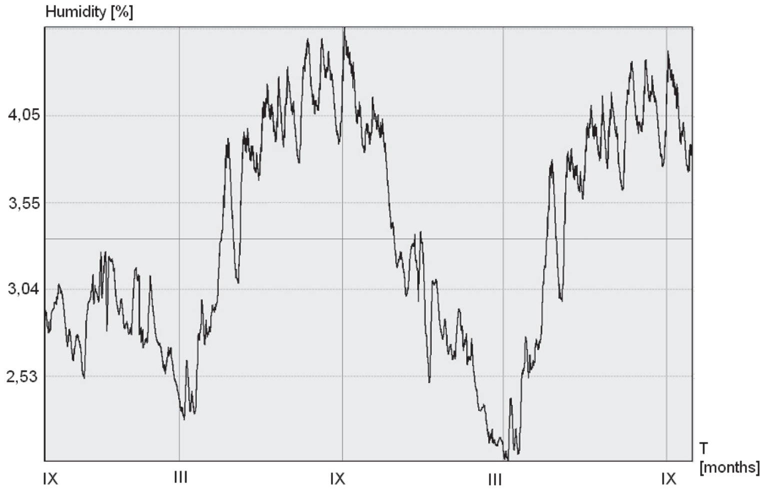
Ill. 3. Moisture condensation annual balance for the wall made of reinforced concrete insulated with polystyrene and granite stone claddings glued directly to the insulation layer

WUFI software. For the purpose of analysis, the multi-layer walls insulated by polystyrene foam EPS and mineral wool combined with stone cladding made of granite, limestone and sandstone have been used. The northern wall of a residential building (located in Cracow Poland) subjected to the climatic changes for a period of two years, beginning from September to September two years later, has been analyzed. The results demonstrated by the analysis of the humidity changes of insulation layers, also taking into account the process of technological dry up, are shown on the pictures 4, 5 and 6.

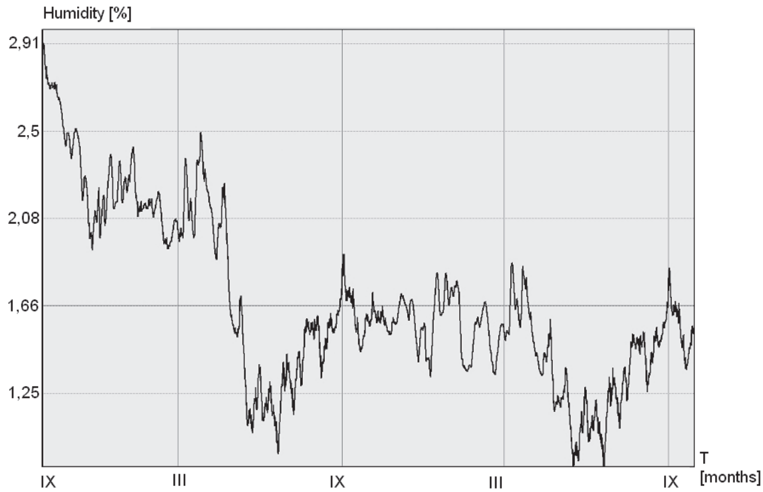


Ill. 4. Chart of the polystyrene EPS humidity changes in the wall of a reinforced concrete structure and granite cladding

The scope of the research covers the seasonal moisture balance analysis for the walls insulated with polystyrene EPS or mineral wool and stone cladding and for the wall heat



Ill. 5. Mineral wool humidity changes in the wall made of reinforced concrete structure with sandstone cladding



Ill. 6. Mineral wool humidity changes in the wall made of reinforced concrete structure and limestone cladding

transfer coefficient assumed as U ≈ 0,25 [W/(m^{2}K)]. As a result of the computational analysis, the use of granite stone cladding for the climatic conditions of Cracow Poland x is not recommended. Granite stone cladding, due to high water vapour diffusion resistance, causes condensation of moisture defused from the structure's interior at the wall and obstructs condensed moisture released from wall in the summer season. Particular stone type quality claddings usage capabilities to be glued directly to insulation layer are summarized in Table 3.

Table 3

Analyzed wall configurations with assumed wall heat-transfer coefficient of U ≈ 0,25 [W/(m²K)]

Structural bearing layer/ thermal insulation	Cladding sort		
	Genesis, granite 1cm	Sandstone 2 cm	Hard limestone 1 cm
Structural bearing layer/ thermal insulation	–	+	+
Porotherm” ceramic brick 25 cm /polystyrene 9 cm	–	+	+
Reinforced concrete 14 cm/ polystyrene 15 cm	–	+	+
“Porotherm” ceramic brick 25 cm /polystyrene 9 cm	–	+	+
“Ytong” aerated concrete 24 cm /polystyrene 9 cm	–	–	+
Reinforced concrete 15 cm/mineral wool 15 cm	–	–	+

Remarks: + sign denotes recommended usage
– sign denotes not recommended usage

2.3. Influence of thermal insulation moisture on the facade operating service

Thermal insulation moisture should not influence the aesthetic aspect of a natural stone façade and in particular should not adversely impact its look. Stone cladding should be made of materials resistant to atmospheric factors. A stone cladding layer should be glued on cement mortar chemically neutral to natural stone. The main problem which should be taken into consideration is the change of the material’s mechanical properties. The long-term presence of water in the material according to [5], may affect the resins used to hold the fibres together. In that case, stone wool’s compressive and tensile strength values may be significantly weakened, leading to structural failures of part of the façade.

3. Conclusions

Directly glued to the thermal insulation layer, natural stone cladding technology implementation significantly reduced workmanship and overall cost of an architectonically attractive stone façade. Computational analysis has indicated some usage limitation of cladding made of granite due to multi-seasonal moisture accumulation in the building components. For practical applications the diffusion resistance coefficient value has to be checked for any particular stone type quality.

Analysis of water vapour diffusion resistance factors, conducted for the most popular sandstone in Poland, have indicated significant differences compared to data provided by [3]. The use of diffusion resistant value data provided by [3] may lead to high calculation inaccuracy.

For the purpose of analysis of the seasonal moisture condensation balance in the building component, the external air temperature is assumed as being based on meteorological statistical data. Walls made with stone facing are warmed up as a result of sun radiation and indicate capabilities to accumulate a considerable amount of heat. Cladding stone surface temperature during the summer seasons reaches up to 70°C which improves the capability to dry condensed moisture [1].

Thermal insulation layer moistness impacts both its thermal insulation parameters and its strength parameters. Described moisture adversely affects particularly the mineral wool parameters. According to the researchx described in [5], mineral wool moistness causes high thermal conductivity coefficient reduction of even up to 38%.

In order to verify the conducted calculation and analysis of moisture transfer through the wall with stone cladding glued directly to the thermal insulation layer, a validation test in a climatic chamber should be made accordingly to the procedures provided in [4] or verified based on sophisticated numerical models.

The work reported in this paper was partially funded by the project L-1/116/DS/2013 "Revitalization of existing buildings". This financial support is gratefully acknowledged.

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