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RESEARCH METHODOLOGY PROPOSED FOR RESILIENCE OF CONTEMPORARY FACING WALLS

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Abstracts: The article refers to proposition of research methodology for durability prognosis for facial walls. In present fast technology development there are new materials introduced to construction, and although their properties are known there is not necessary experience regarding their durability and resistance to influences of environmental impact for many years. In authors research there is possibility of migration of soluble compounds originating from the same ceramic material as well as from mortars in laboratory and field tests. After the analysis of European construction regulations the authors stated that they have not been prepared in such state to be a sufficient base for evaluation of durability of a facial wall. This element was left for designers decision, which results often in accidental choice of compound materials.

Key words: efflorescence, facing wall, mortar, methodology.

1. Introduction

The skill of construction of ceramic walls of building has been known from ancient times. On the territories of Poland beginning of erecting of brick buildings started in 10th century. In historic objects the basic component of mortars for facial walls was lime, and after inventing the Portland cement in the second half of 19th century also this kind of joint. With fast development of technology in present times new materials are introduced in construction, which properties are known but there is no necessary experience as to their durability and resistance to influence long actions of atmospheric factors. Basing of the known physical and chemical properties of these materials we can only within certain degree predict durability of facial walls. Exploitation of these walls for some years and specially small objects of architecture show therefore problems with their durability. On most objects even in the starting period after finishing salt efflorescence appear as first symptoms of their destruction. It should be paid attention that European construction regulations concerning architectural design and rules of work performance, including also requirements and scope of wall elements usage have not been yet prepared in such state, to be a sufficient base for evaluation of durability during usage of erected finished facial wall. This element was left in designers' hand which in consequence the choice of component materials is sometimes done by chance. Thus durability is forecast basing on properties of component materials. As decisive the following properties of facial wall elements and mortars are mentioned: water absorption, permeability of water vapour, resistance to freezing-melting, contain of soluble salts.

Facial wall is a construction which in definition works in special usage conditions. Eurocode EN 1996-2:2006 *Design of masonry structures – Part 2: Design of masonry structures. Design considerations, selection of materials and execution of masonry* classifies them as raw – F2, where they are vulnerable to water saturation associated with frequent freezing-melting cycles. Thus a special approach is needed in choice of material sets. According to Eurocode 6 for external facial walls it is proper to adapt exposition classes from MX3.1 to MX5. In all above mentioned classes it is acceptable to allow rain water penetration. As a result the facial wall should be prepared to work in bordering humidity and temperature conditions. This results in a big meaning of the mortar type. Some suggestions concerning the mortar choice were contained in Eurocode 6, but they do not exploit the matter of wall integrity. This work presents a proposition for methodology of facial walls durability forecast basing on integrity of aggregated elements, based on laboratory tests

2. Efflorescence – a symptom of facial walls destruction

Efflorescence definition met in bibliography (Bensted, 2001) formulated as salt extracting from supersaturated

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salt solution on a surface of material does not reflect the entire phenomenon. Besides salt in the wall there are functioning compounds originating from mortar (mostly $Ca(OH)_2$), or from improperly protected steel inserts. In presence of water they are dissolved and transported to surface and degrade the wall aesthetics, and under influence of compounds coming from outer environment they undergo further changes.

Except for presence of soluble salts in water and mechanisms causing movement of salt solutions, a factor causing efflorescences is penetration of rain water to the wall, where salts are solved. Rain water gets to wall through:

a) Water filtration inside the wall under rain pressure through facial wall defects, i.e. cracks and bursts and broken joint between mortar and facial element. The amount of rain hitting a certain part of outer wall surface depends on rainfall value and velocity of wind, building exposition and architectural and construction details of surface (PN-EN 12865:2004 *Hygro-thermal performance of building components and building elements. Determination of the resistance of external wall systems to driving rain under pulsating air pressure*)
b) Surface flow, creating possibility of capillary penetration, which range depends on structures of used materials.

In laboratory tests it was focused on analysis of water migration:

– Into interior of samples through surface flow and hydrostatic pressure,
– Into exterior of samples through water filtration by the joint.

3. Research methodology

Until now in standardizing wall elements have been analysed separately. Requirements showed in standards refer only to particular products not referring to results of their mutual relations (Fig. 1).

The scope of research shows a gap in requirements for facial wall durability, which because of special work conditions must be solved in a way which eliminate vulnerability to environment. The designed material sets should be characterized with resistance to secondary efflorescence being consequence of rain water penetration into wall interior. So the durability of wall construction should be discussed not only in relation material – environment but first of all material – environment set (Fig. 2).

Methodology proposed below contains a series of simple elimination tests which let make proper choice of mortar to ceramic wall element.

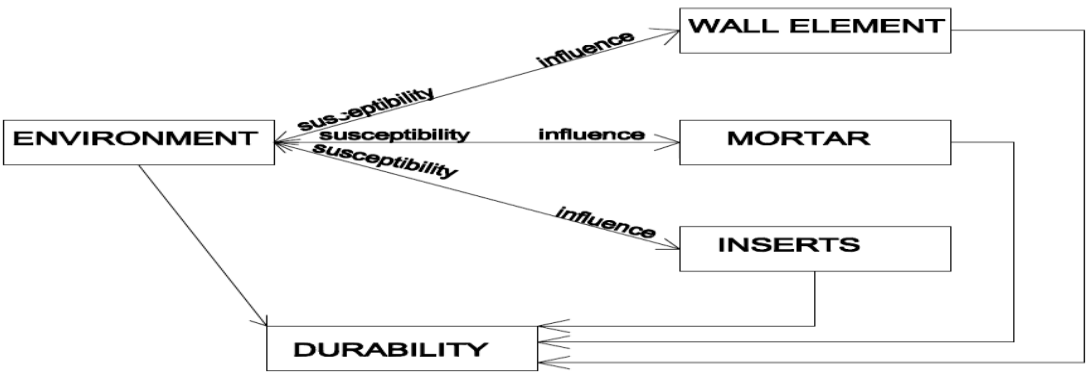

Fig. 1. Facial wall durability according to requirements of Eurocode 6 i and associated standards.

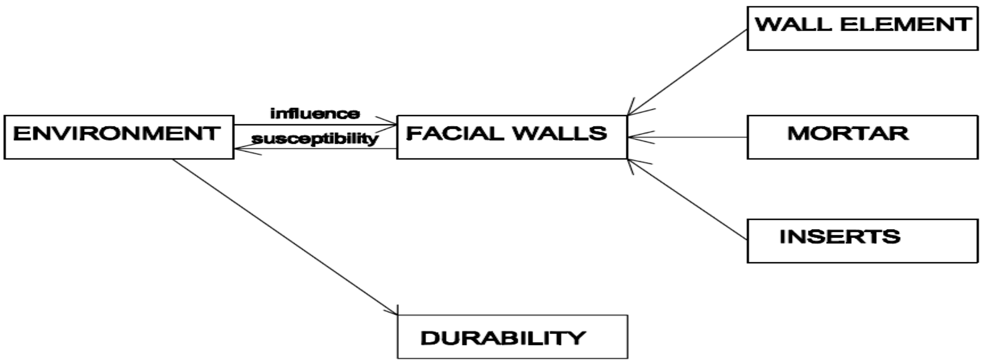

Fig. 2. Wall construction in relation material – environment set.

3.1 Introductory material tests

For tests there was used full clinker brick (250×120×65 mm) and eight different types of mortars from which six had known material compositions (CEM I cement, CEM II cement, CEM I cement with a plasticizer, CEM II cement with plasticizer, cement and lime, lime), and the other two were ready-made – set mortars designated for facial walls to eliminate efflorescence (Tab. 1).

The materials used in tests were subjected to tests which define wall durability. These tests were:

a) tests made for ceramic elements: absorption test by immersing, test of harmful presence of soluble salts, examination of structure,
b) tests made for mortars: examination of fresh mortar consistence, absorption tests by immersing, examination of structure, definition of water absorption coefficient caused by capillary rising,
c) additionally basic tests were made of aggregates used in mortars: examination of granulation, tests for humus presence.

The performed tests of basic features of component materials of facial walls showed that they are in accordance with declarations stated by producers and binding national standards (Tab. 2). As a results of tests performed in order to determine presence of harmful soluble salts, efflorescences in shape of yellow deposit were noticed only on samples not protected against water penetration. There was not found migration of salts through facial surface. Amount of water used to produce set mortars resulted from producer recommendations, while for traditional mortars according to recommendations by Polish standards.

3.2 Tests of aggregate Samales

The proposed tests are aimed at showing sets of materials which ensure tightness of clinker – mortar joint, frost durability of joint (keeping joint integrity) and lack of susceptibility to efflorescence.

I Stage of Tests – water migration on surface of clinker – mortar set joint

The aim is to determine mortar types which produce joints characterized with low susceptibility to water penetration to facial wall interior.

The evaluated quantity is quality of joint defined by:

– number of samples showing entire joint during tests,
– water penetration range under presser in aggregate samples.

Tab. 1. Composition of mortars for tests.

Mortar	Proportions of components	Contents in $10\ dm^3$			
		Cement	Lime/plasticizer	Sand	Water
		[kg]	[kg]	[dm^3]	[dm^3]
Cement 1	(c:p) = 1:3.5	3.78, CEM I 42.5N	-	10.5	2.53
Cement 2	(c:p) = 1:3.5	3.78, CEM I 42.5N	0.004	10.5	2.33
Cement 3	(c:p) = 1:3	4.13, CEM II/B-M (V-LL) 32.5 R	-	10.3	2.53
Cement 4	(c:p) = 1:3	4.13, CEM II/B-M (V-LL) 32.5 R	0.004	10.3	2.33
C – L	(c:l:p) = 1:1.25:6.75	1.65, CEMI 42.5N	0.97	9.5	3.04
L	(l:p) = 1:1	-	4.13	6.8	3.88

Tab. 2. Properties of component materials of aggregate samples.

Tested Material	Bulk Density	Specific Density	Porosity	Volume Average Pore Size	Absorptivity	Water Absorption Coefficient
	[kg/m^3]	[kg/m^3]	[%]	[μm]	[%]	[$kg/m^2 \cdot \sqrt{min}$]
Cement 1	1837	2158	14.87	0.316	3.0	0.77
Cement 2	1957	2545	23.08	0.179	3.0	0.66
Cement 3	2154	2534	15.00	0.063	4.0	0.37
Cement 4	2112	2525	16.37	0.059	4.0	0.20
C - L	2052	2610	21.43	0.320	6.0	1.55
Clink. C	2230	2520	11.51	3.362	5.9	1.70

Samples were subjected to hydrostatic pressure of water column 150 mm high directed perpendicularly to facial wall surface so that it covered both mortar, brick and surface of mortar joint – wall element. During tests the water level was not refilled. After 24 h humidity tests were performed on six levels of brick bases (marked as surface A and B), equal respectively 2, 4, 6, 8, 10 and 12 cm. For humidity evaluation dielectric method was used with measurement density to 3 cm. In order to establish the share of humidity stream flowing through a clinker brick caused by action of hydrostatic pressure of the water column on facial wall surface additional tests were made on two wall elements joined with sealing material. It was established that from the initial humidity value of 1% samples reached maximum value of 4%. For each type of mortar six tests were made. As results of tests showed in aggregated samples the discriminated joint A and B are characterized with different water filtration rate under hydrostatic pressure influence. The upper surface of joint proved to be more susceptible to water penetration. Part of samples showed entire permeability of joint, resulting from insufficient adhesion of mortar to brick – filtration followed by defects of joint in the upper joint surface. That is why intense humidity of ceramic on surface A was noticed (Fig. 3). Tendency for joint leak was showed mostly by cement mortars (cement mortar 1 and 3). Adding plasticizers did not result in expected improvement of workability (cement mortar 2 and 4).

In samples of cement – lime mortar (Fig. 4) these type of defects were noticed only in single cases. Irregularity of humidity distribution is observed also in other samples on cement mortar. This fact can result from susceptibility of mortar to delamination during correction of laying wall element on mortar. Cement-lime mortar because of grain composition is less susceptible to breaking of joint during laying correction.

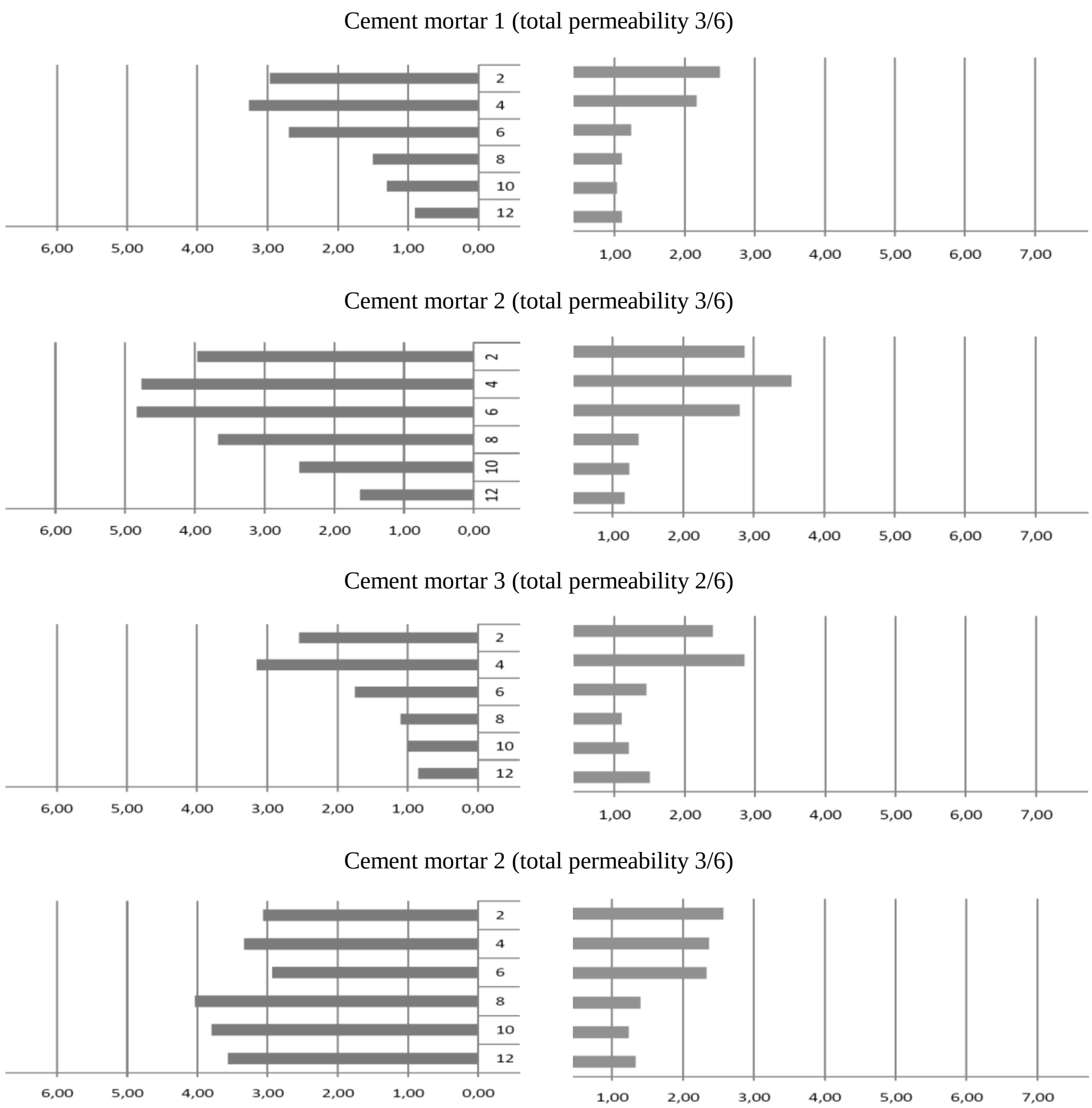

Fig. 3. Humidity distribution of ceramic elements with total permeability of cement mortars, resulting from joint defects: left) surface A, right) surface B.

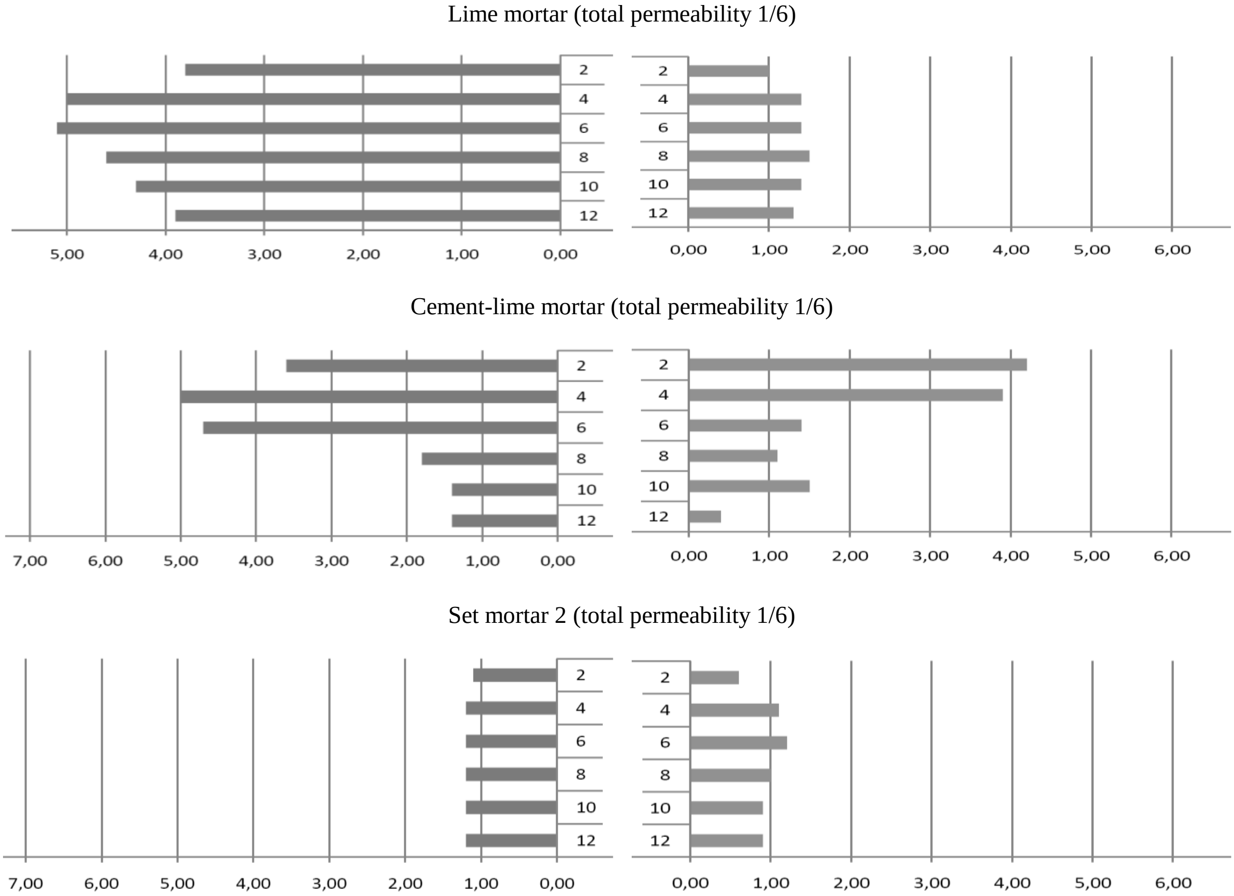

Fig. 4. Humidity distribution of ceramic elements with total permeability of mortars with addition of lime and nanoparticles, resulting from joint defects: left) surface A, right) surface B.

Samples characterized with total joint permeability are evaluated as unfit to further research. All remedies for decreasing of water penetration should be directed into preventing scratches and hollow spaces in the wall. Although clinker is material which does not let water penetration at least until cracks appear, but it is not able to store water and let it evaporate later. Low Absorptivity of this material diminishes mortar adhesion and interfere with performance of proper wall joints (especially vertical ones).

II research stage – repeating freezing and melting of clinker-mortar sets

In the second stage samples (3 pieces) were subjected to repeating freezing and melting (25 cycles). The freezing process was run in temperature – 20°C ± 2°C during 4h, then for next 4h the frame put on the analysed sample was poured with water of temperature of +20°C ±2°C until the level of 150 mm. After performing 25 cycles the PVC frame was removed and samples were dried in laboratory conditions during period of 14 days (i.e. temperature of 20°C ±2°C and air humidity of 50%).

The samples showing the total destruction of joint or mortar not adhesive to ceramic are unfit to further research. Positive result was recognized as 2/3.

III stage of tests – filtration and surface flow of water on face of clinker – mortar set

In samples (at least two pieces) holes of Ø 6 mm were made in distance of 15 mm from brick face, so that wall of thickness 12 mm will correspond to requirements set for facial hollow bricks (filtration), and gouge on surface of upper base of brick, which are aimed to direct of water stream from dosing device directly on sample face (surface flow).

The base surface with holes and gouges need to be separated by using braid of silicone resistant to temperature within range of –25°C do +50°C, in order to secure against water spreading outside designated action field.

To each of so prepared holes distilled water was poured and cables for supplying water during tests. Samples were subjected to filtration and surface flow for period of 48 hours. After this time water supply was cut and samples were dried in laboratory conditions (i.e. temperature 20°C ±2°C and air humidity 50%) for period at least one month (it is suggested to extend drying to three months).

The test result is recognized positive when on the analysed face surface (brick face with joint) the material set is free from efflorescences.

4. Summary

Essential role in limiting of rain water inflow into wall interior is played by mortar and its properties. It should constitute a barrier for water penetration into wall interior and let it easy escape in case when it appears. The quality of mortar joint is extremely important, as it provides sealing. In literature on the subject there were presented some research methods in which the main reason of rain penetration into wall was recognized low workmanship quality and probable climate changes (PN-EN 845-1:2003+A1:2008. *Specification for ancillary components for masonry. Ties, tension straps, hangers and brackets*). Additionally it is needed to mention the mortar type and its adhesion to wall elements (PN-EN 771-1:2011 *Specification for masonry units. Clay masonry units*).

Good properties of water capillary rising by wall material and mortar do not constitute their defect from the point of view of requirements set for a wall concerning resistance to atmospheric rainfall because materials of the above mentions properties not only quickly absorb and store water but also give it back. Harmful moisturizing of facial layers are caused mostly by leaks through open joints and space not filled with mortar.

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PROPOZYCJA METODYKI BADAŃ PROGNOZUJĄCA TRWAŁOŚĆ WSPÓŁCZESNYCH MURÓW LICOWYCH

Streszczenie: Artykuł dotyczy propozycji metodyki badawczej prognozowania trwałości murów licowych. Przy obecnym szybkim rozwoju technologii wprowadza się do budownictwa coraz to nowe materiały, których chociaż właściwości są znane, to nie ma jednak wystarczających doświadczeń co do ich trwałości i odporności na wpływy wieloletniego oddziaływania środowiska. W dotychczasowych badaniach autorki rozpatrzyły możliwość migracji rozpuszczalnych związków pochodzących z samego materiału ceramicznego jak również z zapraw w warunkach laboratoryjnych i poligonowych. Po analizie europejskich przepisów budowlanych stwierdziły, że nie zostały dotychczas przygotowane w takim stopniu, aby mogły być wystarczającą podstawą do oceny trwałości muru licowego. Ten element pozostawiono w gestii projektantów, w konsekwencji czego dobór materiałów składowych jest często dziełem przypadku.

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