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EXPERIMENTAL EVALUATION OF ETICS RELIABILITY FACTORS

ABSTRACT

The paper covers analysis of regulations and documents regarding the façade thermal insulation, methodological grounds for the system of regulations and standards and further development of national legal framework for design of insulating sheeting for buildings. This problem is actual for Ukraine where takes place a large-scale thermal modernization of existing residential and public buildings. The paper continues the series on previous scientific studies of the author with main ones given in the references. The national system of regulations and standards on the façade thermal insulation has a strong methodological structure which includes both national regulative framework and European standards. Being combined this way, the system makes it possible to assess and to design insulating sheeting for buildings according up-to-date world's practice and with regard to climate, technologies and market of Ukraine. The paper states main principles for standard setting concerning suitability assessment of new building envelope. The standard on constructions of outward walls with facade heat-insulation with stucco facing what is called ETICS (Exterior Thermal Insulation Composite System) in Europe was developed and adopted in Ukraine as early as in 2008. The author analyses the provisions from this standard and says those need to be revised with regard to experience and knowledge gained since it is in force. The main problems that arise in the application of facade thermal insulation in new buildings are identified, the insufficiency of assessment only in terms of heat transfer resistance of the structure is proved and the need of assessment in terms of air permeability resistance of the building envelope is provided. The experimental data regarding the infiltration effect on the thermal properties of external walls are given. The consideration and evaluation of ETICS as a system or as a kit are featured, as well as regulation of criteria of ETICS thermal reliability are reviewed.
KEY WORDS: thermal modernization, façade thermal insulation, criteria of thermal reliability, building envelope, national regulations, air permeability.

ЕКСПЕРИМЕНТАЛЬНА ОЦІНКА ПОКАЗНИКІВ НАДІЙНОСТІ ETICS

АНОТАЦІЯ

Стаття присвячена аналізу стану нормативних актів та документів стосовно конструкцій фасадної теплоізоляції, методичних основ створення системи норм та стандартів, та визначенню напрямків розвитку національної нормативної системи проектування теплоізоляційної оболонки будівель. Ця проблема є актуальною для України, де починається дійсно масштабна термомодернізація існуючих житлових та громадських будівель. Стаття є продовженням попередніх наукових робіт автора, основні з яких наведено у бібліографії. Вітчизняна система норм та стандартів з фасадної теплоізоляції має чітку методологічну структуру, яка включає як національні нормативні документи, так і європейські. Саме таке поєднання дозволяє здійснювати оцінку та проектування теплоізоляційної оболонки будівель за сучас-

ними світовими практиками з урахуванням кліматичних, технологічних, ринкових умов України. В статті наведені основні положення встановлення критеріїв оцінки придатності нових конструктивних принципів побудови зовнішніх стінових огороджувальних конструкцій. В Україні ще у 2008 р. був розроблений та прийнятий стандарт на конструкції фасадної теплоізоляції з опорядженням штукатурками, які у Європі мають назву ETICS (Exterior Thermal Insulation Composite System). Автор проводить аналіз положень цього стандарту та зазначається необхідність його перегляду з урахуванням отриманого досвіду та нових знань, які були отримані під час його дії. Визначено основні проблеми, які виникають при застосуванні конструкцій фасадної теплоізоляції при новому будівництві, та обгрунтовано недостатність оцінки тільки за показником опору теплопередачі конструкції і необхідність обов'язкової оцінки за показником опору повітропроникності стінової огороджувальної конструкції. Наведено експериментальні дані впливу інфільтрації на теплові властивості зовнішніх стін. Розглянуто особливості розгляду та оцінки ETICS як системи, чи як комплекту, та питання регламентації критеріїв теплової надійності збірних конструктивних систем.
КЛЮЧОВІ СЛОВА: термомодернізація, фасадна теплоізоляція, критерії теплової надійності, огороджувальні конструкції, національні нормативні документи, повітропроникність

Figure 1 - Façade thermal insulation of modern buildings

INTRODUCTION

The strategic purpose of the national economy is to ensure the sustainable use of energy resources. The successful solution to this problem depends heavily on the change in energy status of residential and public buildings with the energy consumption being up to 40% in the energy balance of the country. One of effective ways to increase the energy efficiency of buildings is the use of façade thermal insulation (Fig. 1).

As a composite system of the facade, thermal insulation appeared in the process of reconstruction of buildings and facilities and was firstly presented in the national technical publications [1]. In national construction practice, the façade thermal insulation is widely used in new structures, due to the fact that the principle of facade thermal insulation [2] makes possible to meet the requirements to reducing specific heat loss for heating of buildings while ensuring the necessary thermal reliability of structures [3] in operation [4].

Despite the crisis in the national economy, the market of thermal insulation materials is constantly growing. At the same time, more than 40 per cent of all thermal insulation materials are used for the facade thermal insulation. The most widely used one is ETICS (Exterior Thermal Insulation Composite System) which applies mainly due to the economic performance, so ETICS will be the main focus of this paper. At the same time, the last 5 or 6 years the share of structures with ventilated air layer and curtain walls has been growing rapidly in the national construction area. It should be borne in mind that the use of facade thermal insulation structures do not provide high performance of buildings by default. In [5], there are examples of how thermal failures of facade thermal insulation appear, how they are classified and the expenses due to the occurrence of the failures are given. This is the reason why the problem of ensuring the required ETICS operation characteristics is of big importance in Ukraine.

PURPOSE

Determination of the basic methodological principles for the development of a regulatory framework on the normalization of safety indices of the facade thermal insulation

MAIN PART

In Ukraine, there are two interconnected branches of regulation and standardization, the national and European ones. The criteria defining the safety of structures and buildings are set in the public construction norms, which are mandatory for all members of the construction market. And standards have a voluntary nature, however in case if standards are referenced in the state building rules, the requirements of the standards become mandatory.

On Fig 2. there is a system regulating (Fig.2) the requirements to the structures of facade heat insulation and it consists of national building rules, harmonized European standards which set the design requirements with regard to energy efficiency, regulations which establish the design requirements for the façade heat insulation structures, and standards setting parameters for ETICS and suspended facades.

DBN V.1.2-11-2008 [6] sets the requirements for the incorporation of durability parameters of construction products in the relevant regulatory documents. The requirements are implemented in the following building regulations:

- DBN V.2.6-31-2016 [7] establishes requirements for heat insulation parameters of envelope structures and buildings [1].
- DBN V.2.6-33:2018 [8] sets mandatory requirements for reliability parameters of facade heat insulation. Regulatory documents (Fig.3) provide a detailed description of the requirements depending on the class systems.

DSTU B.V.2.6-34 [9] sets ETICS design classes such as suspended facades and transparent facades. DSTU B.V.2.6-88 [10] gives procedures of technical assessment and monitoring.

Requirements for ETICS and their test methods are regulated also by DSTU B.V.2.6-36 [11] and pr DSTU-N B ETAG 004.

Requirements for suspended façades and their test methods are prescribed in DSTU B.V.2.6-35 [12], DSTU B EN 13830 [13] and DSTU-N B ETAG 17 [14].

The framework for design concept of facade heat insulation is taken from the approach to composite system established in European standards. The composite system consists of a supporting part of the exterior wall and a thermal insulation structure that is placed on the external surface of the wall and includes such products and components as a thermal insulation layer, a finishing coat and means of attaching those to the bearing element. The list, type and set of products and components are strictly fixed in the kit and their quantity may vary according to the demands of a project.

An important issue is also fire safety requirements, which are based on the flammability rate of materials [3] according to the Ukrainian current classification, which does not agree with the European system yet. In the existing system of rules and standards there

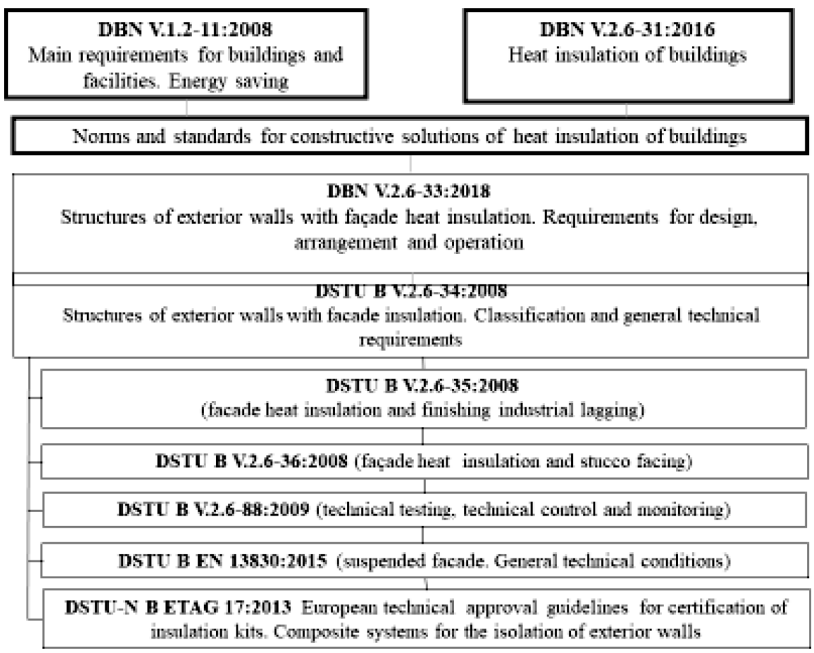

Figure 2 - System of regulations for façade thermal insulation

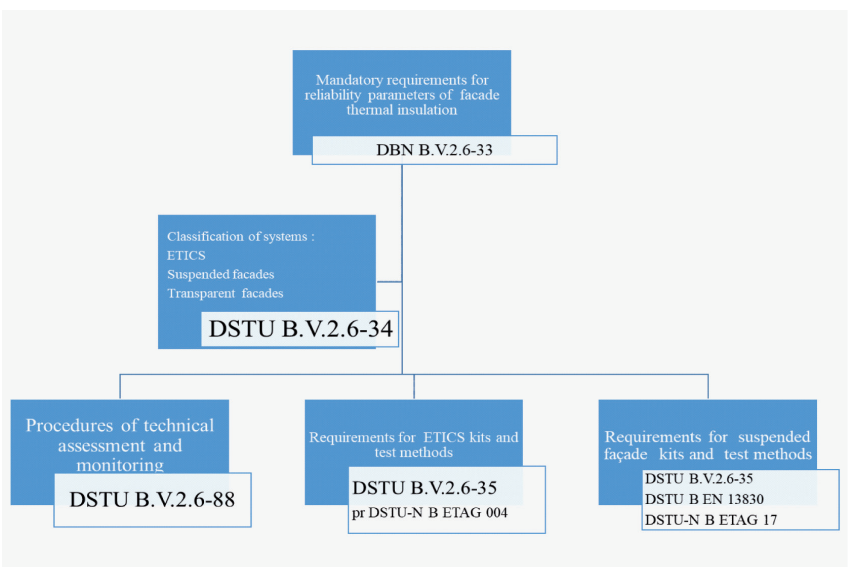

Figure 3 - Regulations for facade thermal insulation

are 24 indicators for the fit for use assessment based on the design concept of façade heat insulation [10].

One of the indicators is the stability of ETICS thermal-insulating properties. A prerequisite for energy performance is the thermal reliability condition, as a house cannot be energy efficient if its thermal insulation envelope is not reliable in terms of thermal performance. Changing the structural principles of the thermal envelope, i.e. the transition from single-layer brick or concrete walls to multilayer walls with the façade heat insulation requires a fundamental change in the methodology for assessing the operational suitability of modern envelope structures. We introduce the definition of the thermal failure concept as a key concept of thermal reliability.

The main criterion of thermal reliability is the structural property to maintain in time the level of the resistance to heat transfer [3]

$$Rr = 1 - \frac{R_{\Sigma пр}(0) - R_{\Sigma пр}(N)}{R_{\Sigma пр}(0)},$$

were Rr is a criterion of heat reliability, $R_{\Sigma пр(0)}$ is a corrected resistance of heat transfer of the structure at the initial stage, $R_{\Sigma пр(N)}$ is a corrected resistance of heat transfer of the structure in N cycles of climatic effects.

The physical essence of the criterion is to determine the effectiveness of enclosing structure during the target service life with possible changes in the state of the structural elements under the influence of various (climatic, mounting, operational, etc.) factors [15].

The criterion is experimentally determined by testing ETICS (Fig.4) for the climatic influences resistance such as the effects of high and low temperatures, soaking with water and with weak acidic and alkaline solutions, which simulate precipitation of the urban environment (Fig.5).

The system of regulations shown in Fig. 2 establishes the factors of thermal reliability for structures and structural systems. DBN V.2.6-33 sets the requirements to structural systems with façade thermal insulation (see Fig.3) and DSTU B.V.2.6-35 and DSTU B.V.2.6-36 provide the requirements to kits and their components. Conformity assessment or determination of fitness for use are implemented according to the last standards but this is not always sufficient - even in case of positive results of such assessment – for the ensuring of thermal reliability of end product such as structural system or the whole building.

ETICS was developed for the heat insulation of existing buildings with the external walls made of bricks being at

Figure 4 - Testing procedure of facade heat insulation structures with rendering for resistance to climatic influence

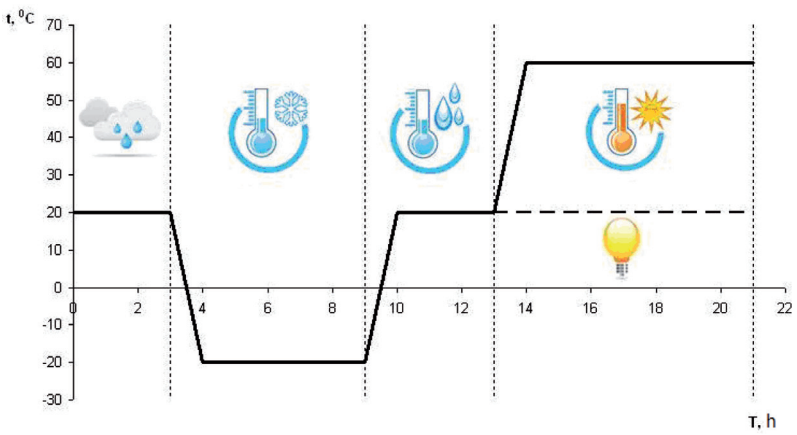

Figure 5 - Tests of resistance to climatic factors: requirements of DSTU B.V.2.6-36, ETAG 004

least 510 mm thick or of 320 mm thick concrete panels etc. In Ukraine ETICS is widely applied in new buildings, for instance, in masonry structures made of 250 mm thick single bricks having ETICS fixed on the external surface without any special preparation of joints between the bricks.

Determination of resistance to climatic effect (see fig. 4,5) is sufficient to find the stability over time of heat transfer resistance of the composite system because ETICS reveals basically the value of this indicator.

Figure 5 - NIISK has investigated the influences of air flows caused by the natural air infiltration on ETICS operational characteristics [8]. The investigations have been performed for the various systems, including those with concrete blocks bases, ceramic blocks, bricks etc. (Fig.6).

The results of the study indicate the high air permeability of ETICS when applying it to an unprepared brick or block masonry surface. With a pressure drop of 50 Pa only, the outside air flow through the design system ranged from 1.01 to 2.27 m^3 through 1 square meter of the external wall (Table 1,2).

The experimental data show that in terms of resistance to air permeability, the structure of the wall does not meet the regulatory requirements but in this case the decisive characteristics has not ETICS but the bearing part of the wall, which ETICS is installed to. Accordingly, in terms of resistance to air permeability ETICS should be considered as a kit unlike a composite system which should satisfy the requirements of DBN B.2.6-31.

In the system of regulations shown in Fig. 2 this metho-dological procedure is provided, it means that para.6.3.1, DBN B.2.6-33: 2018 establishes the follows [6] - thermal characteristics of composite system such as corrected heat transfer resistance, air permeability and heat resistance - are determined according to DBN B .2.6-31. But in practice the given requirements are not satisfied what leads to thermal conditions where it is ignored the special consideration of ETICS as a kit or a system when applying apparently certified ETICS.

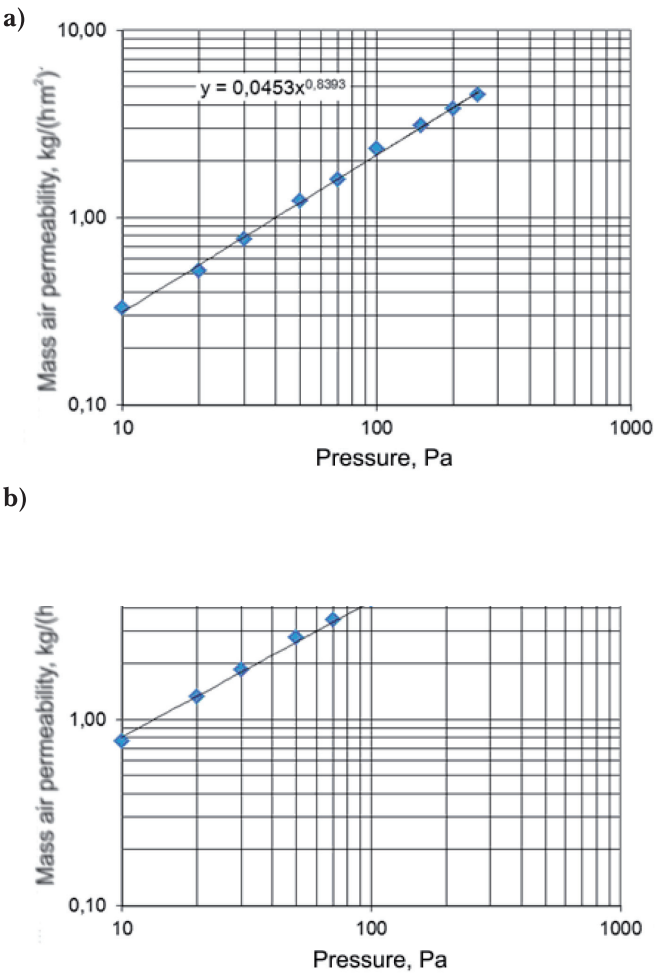

Figure 6 - Dependency of mass air permeability from pressure drop in ETICS with 120 mm thick rock wool and base made of 250 mm thick ceramic void blocks (a) and loam bricksº(b)

Table 1 - The investigation results of air permeability of ETICS structural system with 120 mm thick rock wool and base made of 250 mm thick ceramic void blocks

Indicator of filtration mode	0,84					
Pressure drop, ΔP Pa	10	20	30	50	70	100
Volume air permeability, $m^3/(hour \cdot m^2)$	0,27	0,43	0,63	1,01	1,32	1,91
Mass air permeability, $kg/(hour \cdot m^2)$	0,33	0,52	0,76	1,22	1,60	2,31
Relevant height of building	30,56	38,38	39,29	40,85	43,75	45,20
Standard resistance of air permeability, $(m^2 \cdot hour \cdot Pa)/kg$	20	40	60	100	140	200
Compliance to the standard requirements	+	-	-	-	-	-

CONCLUSIONS

The developed system of norms and standards for the regulation of safety requirements to the facade thermal insulation takes

Table 2 - The investigation results of air permeability of ETICS structural system with 120 mm thick rock wool and base made of 250 mm thick loam bricks

Indicator of filtration mode	0,73					
Pressure drop, ΔP Pa	10	20	30	50	70	100
Volume air permeability, $m^3/(hour \cdot m^2)$	0,63	1,1	1,52	2,27	2,85	3,65
Mass air permeability, $kg/(hour \cdot m^2)$	0,76	1,33	1,84	2,75	3,45	4,42
Air permeability resistance, $(m^2 \cdot hour \cdot Pa)/kg$	13,10	15,00	16,28	18,17	20,27	22,61
Standard resistance of air permeability, $(m^2 \cdot hour \cdot Pa)/kg$	20	40	60	100	140	200
Compliance to the standard requirements	-	-	-	-	-	-

into account the European experience, practice of national construction and thermal modernization of buildings. This system was designed in 2007-2009 and since it is in force new knowledge has been generated. This is the reason why it is necessary to make changes in the relevant norms and standards. DBN V.2.6-33:2018 needs revision as requirements to the prefabricated composite systems should be given in details. DSTU B V.2.6-34: 2008 has lost the relevance because it repeats the provisions of DBN B.2.6033: 2018 and contains an outdated classification of composite systems. DSTU B V.2.6-35: 2008 and DSTU B V.2.6-36: 2008 should list the requirements to the composite systems and its components as well as the test methods for the parameters provided by these standards. For this purpose the European approach aimed at assessing the intended use rather than the compliance of the composite systems should be used more widely because composite systems of facade thermal insulation have a significant innovative component.

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