ГОДИШНИК НА УНИВЕРСИТЕТА ПО АРХИТЕКТУРА, СТРОИТЕЛСТВО И ГЕОДЕЗИЯ СОФИЯ

Том Volume 59 2026 Брой Issue 3

ANNUAL OF THE UNIVERSITY OF ARCHITECTURE, CIVIL ENGINEERING AND GEODESY SOFIA

DOI: 10.71167/uaceg.2026.590309

Received: 28.03.2026
Accepted: 16.04.2026

TECHNICAL SOLUTIONS FOR TESTING THE PULL-THROUGH RESISTANCE OF ETICS INSULATION ANCHORS

I.-A. Conev[1]

Keywords: *insulation anchors, ETICS, EPS, external thermal insulation system, pull-through resistance, long nut, specialized steel jaws, epoxy adhesive*

ABSTRACT

This study examines the requirements and recommendations of the European Assessment Document EAD 040083-00-0404 concerning the wind load resistance of External Thermal Insulation Composite Systems (ETICS). Particular emphasis is placed on pull-through resistance under wind action. The analysis identifies practical issues and challenges observed during specimen testing in accordance with the referenced document. Although not explicitly addressed in the standards, these issues arise during experimental implementation and may significantly influence the reliability of the test results.

The identified challenges are analysed in relation to both the pull-through resistance of the thermal insulation layer and the performance of mechanical fixings (insulation anchors). Based on experimental investigation and subsequent analysis, specific technical solutions are proposed. The study identifies the most technically appropriate approach for testing insulation anchors in ETICS and provides recommendations for future research and methodological improvements.

1. Introduction

Modern requirements for energy-efficient buildings require the application of appropriate technical solutions for the thermal insulation of building envelopes and their components [1]. Among these solutions, external thermal insulation composite systems (ETICS), incorporating

[1] Ivan-Aleksandar Conev, Assist. Prof. Eng., Dept. “Construction Technology and Mechanization”, Faculty of Structural Engineering, UACEG, 1 H. Smirnenski Blvd., Sofia 1046, e-mail: ivan_conev_fce@uacg.bg

various types of insulation materials, represent the most widely used approach to facade thermal protection [2].

The durability, long-term performance, and overall resistance of ETICS have been investigated in the scientific literature [3 – 8]. An experimental study reported in [9] examined systems incorporating expanded polystyrene (EPS) layers of different thicknesses. The study placed particular emphasis on the influence of service conditions. The applied methodology ensured test repeatability. The reliability of the obtained results supported the practical implementation of the findings in engineering practice.

The growing research interest in this field has also motivated the authors of [10] to investigate the pull-through resistance of ETICS. After a comparative review of several national and European standards [11 – 16], the European Assessment Document EAD 040083-00-0404 [17] was selected as the principal reference methodology.

As stated in [18], the assessment of pull-through resistance within the thermal insulation layer must comply with the requirements of [17]. The pull-through resistance of insulation anchors is determined in accordance with the procedures specified in [19 – 21]. In cases where no national guidelines exist or insufficient information on the base material is available, the methodology presented in [22] and further developed in [23] is applied.

The objective of the present study is to analyse the practical issues and difficulties encountered during specimen testing performed in accordance with [17]. Identifying these challenges enables the development of effective technical solutions and improvements to existing testing procedures. This, in turn, enhances the reliability and wind resistance of facade thermal insulation systems [24, 25].

In addition, the study identifies gaps in current testing practice and proposes optimised techniques aimed at improving test accuracy, repeatability, and methodological consistency.

2. Technical issues in testing the pull-through resistance of ETICS according to EAD 040083-00-0404 [17]

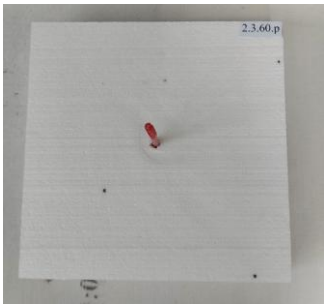
2.1. Preparation of test specimens

A series of test specimens were prepared and examined. Each specimen consisted of a rigid substrate, an adhesive layer, a thermal insulation board, and an insulation anchor. According to the requirements of [17], at least five specimens have to be tested for each configuration. The nominal dimensions of the specimens are 350 mm × 350 mm. The overall thickness was equal to the thickness of the insulation product specified in the relevant European Technical Assessments (ETA). A separate rigid base plate is used for each insulation thickness.

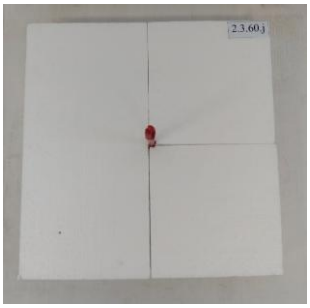
In total, fifty test specimens were manufactured for the experimental programme. The specimens consisted of expanded polystyrene (EPS) boards with thicknesses of 60 mm (Fig. 1), 80 mm, 100 mm, 120 mm, and 140 mm. Each specimen was assigned an individual identification code.

The mechanical fastening device investigated in this study was a plastic insulation anchor with a plastic impact pin, intended for fixing EPS boards to external facade substrates. The anchors had a shank diameter of 8 mm, a plate diameter of 60 mm, and an overall length of 195 mm. In accordance with [17], the anchor plate was covered with adhesive tape prior to installation. This was done to prevent direct bonding between the plate and the adhesive layer.

The prepared EPS panels were bonded to the rigid base, made of glass-fibre mesh-reinforced cement board, using a cement-based adhesive mortar. Prior to adhesive application, the substrate surface was cleaned to remove dust and then primed to ensure proper adhesion.



a) insulation anchor installed at the center of the panel



b) insulation anchor installed at the panel joint

Figure 1. EPS test specimen with an insulation anchor

2.2. Testing of the specimens

After curing of the adhesive layer under laboratory conditions, the specimens were positioned centrally on a stable laboratory table. A testing frame, consisting of threaded rods, washers, nuts, base supports, and a rigid steel frame, was then assembled and aligned with the glass-fibre mesh-reinforced cement board.

The base frame of the testing rig consisted of two parallel hollow metal profiles with a rectangular cross-section, into which four Ø16 threaded rods were installed as vertical stabilizing members. The height of the rods was adjusted using nuts and washers. After the required height was set, the rigid steel frame was installed and further stabilized with an additional set of washers and nuts. Proper levelling of the system was ensured.

After alignment and stabilization of the testing frame, the measuring device and the required connecting elements, including hooks, adapters, and bolts, were installed.



a) Type 1



b) Type 2

Figure 2. Experimental setup for pull-through resistance testing

At the start of the test, a tensile force was applied between the rigid substrate and the end of the insulation anchor passing through the thermal insulation layer until failure occurred in the EPS material.

The complete testing setups are shown in Fig. 2. The first configuration (“Type 1”) shows the testing frame mounted on a rigid substrate. It also shows the threaded rods used for levelling and stabilization, as well as the measuring device connected to the insulation anchor via an adapter [26]. The second configuration (“Type 2”) is described in detail in [27].

The experimental results reported in [26] and [27] show a clear relationship between the thickness of the thermal insulation layer and the measured pull-through resistance. The increase of the insulation thickness leads to higher resistance values, with the lowest values recorded for 60 mm EPS and the highest for 140 mm EPS. These results confirm that insulation thickness is one of the key parameters governing the pull-through resistance.



a) insulation anchor installed at the center of the panel

b) insulation anchor installed at the panel joint

Figure 3. Failure patterns of EPS specimens with an insulation thickness of 60 mm

Figure 3 illustrates the failure patterns observed during the pull-through tests.

When the insulation anchor is installed at the center of the EPS specimens, failure initiates around the anchor head. It then propagates in depth through the insulation material, forming a well-defined truncated cone.

When the anchor is positioned in the joint between adjacent EPS boards, the failure mode differs slightly. Reduced stiffness in the joint region leads to an asymmetric failure zone, and partial deformation of the anchor head is observed.

For specimens with greater insulation thickness, and consequently higher tensile forces, significant deformation of the anchor head was recorded. In these cases, the typical truncated-cone failure of the thermal insulation layer was not clearly developed. Similar, but less pronounced, deformation effects were also observed when the anchor was installed in the joint between adjacent insulation panels.

2.3. Issues encountered during testing

2.3.1. Defects in the substrate

Several issues related to the behaviour of the test specimens were observed during the experimental programme. According to the standard requirements, the specimens must be bonded to a rigid substrate using a suitable adhesive. However, the standard does not prescribe a specific type or class of adhesive, as its scope is limited to defining general requirements rather than providing detailed application guidance.

During testing, the application of tensile force may lead to complete detachment of the thermal insulation layer from the substrate. This failure mode is primarily caused by insufficient

adhesion between the cement-based adhesive mortar and the surface of either the insulation material or the substrate. Similar adhesion-related issues have been reported for flooring systems [28 – 30].



Figure 4. Examples of EPS detachment from the substrate due to insufficient adhesive bonding

As illustrated in Fig. 4, the cement-based adhesive mortar was not uniformly distributed over the bonding surface. This resulted in areas of poor contact and, consequently, reduced adhesion. Although a high-grade adhesive was used in the experimental programme, detachment of the thermal insulation layer from the substrate was still observed. This behaviour can be attributed to deviations from the recommended application procedure.

Possible causes include an improper water-to-dry-mortar ratio during mixing. Additional factors are an excessive delay between mixing and application and the use of a notched trowel with unsuitable size or tooth geometry. Insufficient pressing of the insulation board onto the substrate immediately after placement may also contribute to this behaviour.

2.3.2. Defects in insulation anchors

Visual inspection during testing revealed two primary failure modes related to the clamping of the insulation anchors. The first mode was pull-out of the anchor from the clamping mechanism. The second mode involved failure within the anchor body caused by transverse forces introduced by the clamping device. Representative examples of these failure mechanisms are shown in Fig. 5. Pull-out failure typically occurred at an applied load of 0,69 kN. In tests where the insulation anchors were clamped using a long nut with bolts, failure most frequently occurred within the anchor body. This failure mode developed in a locally weakened cross-section due to stress concentrations introduced by bolt tightening.



a) failure within the anchor body caused by applied shear forces

b) pull-out (slippage) of the insulation anchor from the clamping mechanism

Figure 5. Defects in insulation anchors due to clamping

3. Possible technical solutions for preventing EPS detachment

As discussed in Section 2.3.1 above, detachment of the EPS layer from the rigid substrate was identified as one of the main issues encountered during experimental testing. This section reviews technical solutions aimed at improving the reliability of chemical bonding in ETICS and preventing premature failure during testing. Three different bonding approaches are examined, based on experimental application and analysis of data reported in the scientific literature.

3.1. Chemical bonding with primer and adhesive mortar

One established approach for reducing the risk of EPS detachment from the substrate is the use of a primer in combination with a cement-based (mineral) adhesive mortar. The primer is a single-component dispersion product applied as a preliminary treatment of mineral substrates. Its main functions are to reduce surface absorbency, homogenize the substrate structure, and improve adhesion between the substrate and the subsequent construction layer. In ETICS, primers play a key role in achieving a durable and reliable bond between the facade substrate and the insulation material.

The main advantage of this approach lies in the use of a widely available and well-proven adhesive system with documented performance. Cement-based adhesive mortars typically consist of cement, graded quartz sand, and mineral fillers. In addition, they contain modifying additives that improve workability and adhesion. These products are supplied as dry mixes and are combined with water immediately prior to application. In some formulations, fibres are added to enhance mechanical strength and crack resistance.

Cement-based adhesive mortars are suitable for bonding both expanded polystyrene (EPS) and mineral wool (MW). This is valid provided that the mortars meet the compatibility and shear-strength requirements specified for the selected insulation material.

3.2. Chemical bonding with primer and adhesive mortar followed by the sand-scattering method

An additional method for improving the performance of cement-based adhesive systems in ETICS is the sand-scattering method. This technique involves applying a thin layer of dry quartz sand (grain size 0,4 – 1,2 mm) onto the freshly applied adhesive or plaster surface. The sand particles partially embed into the adhesive layer, and excess material is removed after curing. Similar methods have been reported in [31, 32].

The purpose of sand-scattering is to enhance adhesion between successive layers by creating a micro-textured surface. This improves mechanical interlocking with subsequent coatings and leads to more uniform moisture absorption, thereby increasing the durability of the facade finish.

Sand-scattering is not mandatory in standard ETICS installation. However, it is recommended in specific cases. These include situations with delayed application of the final coating or when increased adhesion performance is required. Proper application in accordance with the manufacturer’s instructions is essential to ensure reliable system performance.

3.3. Chemical bonding with polyurethane foam for thermal insulation

An alternative bonding approach involves replacing conventional cement-based adhesive mortars with polyurethane foam designed for fixing thermal insulation boards to rigid substrates. When properly applied, polyurethane foam provides effective adhesion and reduces the risk of insulation layer detachment. It also allows greater flexibility in insulation thickness without significantly affecting bond stability.

The main disadvantage of this approach is the higher material cost, as polyurethane foam is considerably more expensive than traditional adhesive mortars. Consequently, its use is typically limited to specific applications and is less common for large facade areas or cost-sensitive projects.

3.4. Summary of the types of chemical bonding

Based on the conducted study and experimental investigations, no single chemical bonding method can be identified as universally optimal for the tested insulation system. Each analysed approach has specific advantages and limitations. The selection of an appropriate method depends on the required performance, the technological conditions, and the economic considerations.

A comparative overview of the evaluated chemical bonding methods, including their main characteristics, advantages, and limitations, is presented in Table 1.

Among the analysed approaches, chemical bonding with a primer and cement-based adhesive mortar proved to be the most suitable solution. This method was the most appropriate for the experimental testing performed in this study. When the application procedure was properly followed, this method ensured reliable adhesion without detachment and represented the most cost-effective option. The sand-scattering method and the use of polyurethane foam may provide additional benefits under specific conditions. However, their application should be justified by project-specific requirements and constraints.

Table 1. Characteristics of chemical bonding methods applied in ETICS

Parameter	Chemical bonding with primer and adhesive mortar (with or without the sand-scattering method)	Chemical bonding with polyurethane foam for thermal insulation
Adhesion performance	High adhesion achieved through chemical bonding between the substrate, adhesive mortar, and insulation material. Sand scattering further enhances bonding by increasing surface roughness and mechanical interlocking.	Adhesion is achieved through polyurethane foam expansion and subsequent hardening. This process forms a stable mechanical contact zone between the insulation and the substrate.
Curing time	Curing time depends on adhesive type and ambient conditions and typically ranges from several hours to several days. The sand-scattering method does not significantly affect overall curing time.	Rapid curing, typically within 15 – 60 minutes, allowing faster installation and shorter technological breaks.
Thermal and mechanical resistance	High resistance to temperature variations and mechanical loading. Sand scattering may further improve crack resistance and moisture-related performance.	Provides good thermal insulation properties but may be sensitive to prolonged UV exposure and unfavourable environmental conditions.
Cost-effectiveness	Low material cost and wide availability. Sand scattering requires additional materials and labour, but the overall cost increase remains moderate.	Significantly higher material cost, limiting its application in large facade areas and cost-sensitive projects.
Environmental and safety aspects	Mainly composed of cement and mineral components, with low risk of hazardous emissions when properly handled. Appropriate waste management is required.	The material contains chemical components, such as isocyanates. Improper use may pose health risks and therefore requires strict safety measures and controlled storage.
Applicability	Suitable for a wide range of facade substrates and insulation materials. Sand scattering is recommended under specific conditions to enhance adhesion.	This method is suitable for applications requiring rapid setting. It can be used for bonding on uneven substrates or when variable insulation thicknesses are involved. It is not applicable to all substrate types.

4. Technical solutions for the clamping of ETICS anchors during component testing

4.1. Clamping of the insulation anchor using a long nut and bolts

In this clamping method, the insulation anchor is mechanically connected to the testing device using a long nut. An M10 nut with a length of 50 mm was used. Four holes with a diameter Ø8 mm were drilled into the nut body at equal spacing and arranged in two opposing pairs. After drilling, the nut was thoroughly cleaned to remove metal residues and contaminants.

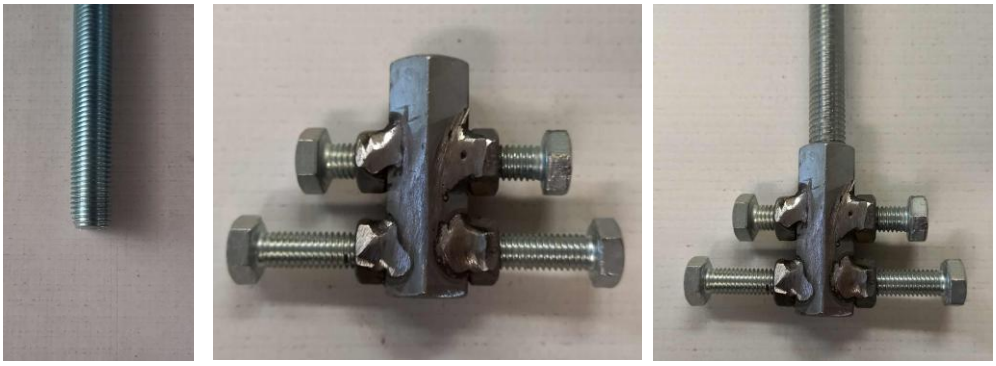
A standard M6 nut was welded over each drilled opening. Four M6 bolts were then installed, two of them having different lengths to facilitate tightening during testing.

After insertion of the insulation anchor into the central opening of the long nut, the bolts were tightened gradually and uniformly, starting with the opposing pair. This clamping technique can be classified as localized mechanical clamping. Excessive tightening torque may introduce transverse shear forces and cause damage to the insulation anchor. Insufficient tightening, on the other hand, may lead to slippage during testing.

4.1.1. Clamping using a threaded rod and a long nut with bolts

This clamping configuration is based on the previously described long nut with bolts, supplemented by an additional threaded rod (Fig. 6). After inserting the insulation anchor into the central opening of the nut and securing it by tightening the clamping bolts, a steel threaded rod with an external thread is screwed into the opposite end of the nut.

The main advantages of this method are its structural simplicity, straightforward implementation in laboratory conditions, and high cost-effectiveness.



a) threaded rod *b) long nut with bolts* *c) threaded rod connected to the long nut with bolts*

Figure 6. Mechanical clamping of the insulation anchor using a long nut with bolts

4.1.2. Clamping using a ring bolt and a long nut with bolts

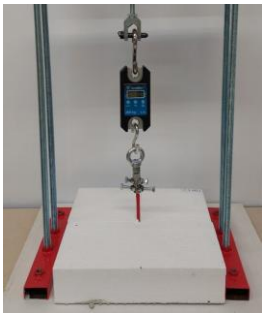
This clamping configuration is similar to the method described in Section 4.1.1. A long nut with fixing bolts is again used to secure the insulation anchor. The main difference is the use of a metal ring bolt (eye bolt) instead of a standard threaded rod (Fig. 7).



a) ring bolt



b) long nut with bolts



c) test setup showing the complete coupling between the insulation anchor and the measuring device

Figure 7. Mechanical clamping of the insulation anchor using a ring bolt and a long nut with bolts

The primary advantage of this configuration is the factory-defined threaded length of the ring bolt, which ensures sufficient thread engagement when screwed into the long nut. In addition, the ring bolt allows manual tightening with improved control, thereby reducing the risk of thread pull-out or unintended loosening under tensile loading during testing.

4.2. Mechanical clamping of insulation anchors using specialized jaws

In this clamping method, the insulation anchors are connected to the testing device using specialized steel jaws. These jaws are commonly used for mechanical clamping of reinforcement bars, thin-walled PVC pipes, and other cylindrical specimens.

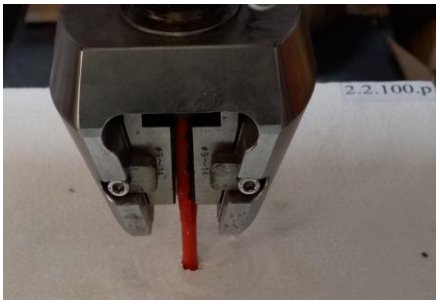
The main advantage of this approach is that the clamping mechanism engages the entire contact surface of the anchor. This increases frictional resistance and provides higher holding capacity. As a result, more stable fixation is achieved during tensile testing.

4.2.1. Specialized steel jaws “Type 1”

At the initial stage of the experimental programme, the specimens were tested using specialized steel jaws, hereafter referred to as “Type 1” (Fig. 8*a*). These jaws are typically designed for clamping construction materials such as smooth or ribbed steel reinforcing bars. In the present study, they were adapted to clamp the plastic insulation anchor by establishing contact with its anchoring zone.



a) Type 1, originally intended for steel reinforcing bars



b) Type 2, designed for polymer and PVC pipes (Ø 9 – 14 mm)

Figure 8. Clamping of the insulation anchor using specialized steel jaws

When this clamping method is applied, the frictional resistance generated by the jaws exceeds the force required to initiate pull-through failure.

A major limitation of the “Type 1” jaw configuration is that, with decreasing anchoring depth (as in specimens with greater insulation thickness), the effective contact area between the jaws and the anchor is reduced. This leads to lower frictional resistance and increases the likelihood of slippage or extraction of the anchor from the steel jaws. Consequently, this method is not suitable for testing specimens with greater insulation thicknesses.

4.2.2. Specialized steel jaws “Type 2”

In the second stage of the experimental programme, the specimens were tested using specialized steel jaws, hereafter referred to as “Type 2” (Fig. 8*b*). These jaws are designed for clamping construction elements such as plastic pipes and other polyethylene components with diameters up to Ø14 mm. Owing to their serrated contact surface and clamping mechanism, the jaws provide stable and uniform contact with the anchoring zone of the insulation anchor.

These characteristics make the “Type 2” jaws particularly suitable for the objectives of the present study. The effectiveness of the clamping mechanism was confirmed experimentally. No slippage or extraction of the insulation anchor was observed in any of the tested specimens throughout the testing programme.

4.3. Chemical clamping of the insulation anchor using an extended nut and epoxy adhesive

In this clamping method, the insulation anchor is connected to the testing rig using an extended nut, without laterally welded nuts or mechanical clamping bolts. Instead of mechanical fixation, a chemical bonding approach is applied by filling the extended nut with a two-component epoxy adhesive. The adhesive bonds to the insulation anchor and ensures continuous fixation along the entire embedded length. This promotes uniform load transfer and minimizes local stress concentrations at the clamping interface during tensile testing (Fig. 9).

The main disadvantage of this method is its limited cost-effectiveness, as each test specimen requires a new extended nut that cannot be reused after adhesive application. Compared to localized mechanical clamping, chemical fixation ensures uniform load transfer along the full embedded length of the insulation anchor. This significantly improves the reliability and stability of the clamping connection during testing.



a) epoxy adhesive *b) extended nut* *c) extended nut filled with epoxy adhesive*

Figure 9. Chemical clamping of the insulation anchor

4.3.1. Clamping using an extended nut and a threaded rod

This clamping configuration is implemented using an extended nut filled with epoxy adhesive in combination with a metal threaded rod. Initially, a small amount of modelling clay

or another suitable sealing material is applied around the insulation anchor. The anchor is then inserted into the nut opening until a tight fit is achieved. If necessary, additional sealing material, such as modelling clay, butyl rubber, or wax, is used to prevent adhesive leakage during filling (Fig. 9*c*).

The two-component epoxy adhesive is prepared in accordance with the manufacturer's instructions. After activation, the interior of the extended nut is filled to ensure complete encapsulation of the anchor within the bonding zone. Subsequently, the metal threaded rod is carefully screwed into the nut, while avoiding direct contact between the rod and the adhesive (Fig. 10).

This solution ensures more uniform load distribution and reduces the risk of localized stress concentrations at the interface between the insulation anchor and the clamping element. The main limitation of this method is the time required for the adhesive to reach full curing strength. In addition, the epoxy adhesive must be compatible with the polymer material of the insulation anchor.

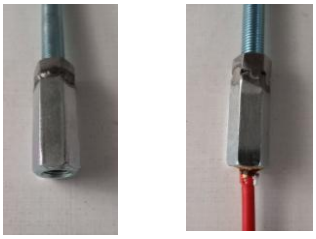


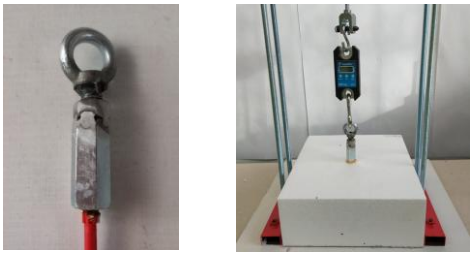
Figure 10. Chemical clamping of the insulation anchor using an extended nut and a threaded rod

4.3.2. Clamping using a ring bolt and an extended nut

This clamping configuration is similar to the method described in Section 4.3.1. An extended nut filled with epoxy adhesive is again used to secure the insulation anchor, with the main difference being the use of a metal ring bolt instead of a standard threaded rod (Fig. 11).

The main advantage of this variant is the factory-defined threaded length of the ring bolt, which ensures adequate and consistent thread engagement within the extended nut. In addition, the ring bolt allows manual tightening with improved control, thereby reducing the risk of loosening or pull-out under tensile loading during testing.

A limitation of this method is the potential contact between the threaded portion of the ring bolt and the epoxy adhesive, which may result in permanent bonding of the components. Consequently, the clamping assembly cannot be reused, reducing the cost-effectiveness of this approach.



a) ring bolt with an extended nut and epoxy adhesive

b) experimental setup using a ring bolt and an extended nut

Figure 11. Chemical clamping of the insulation anchor

5. Results and analysis

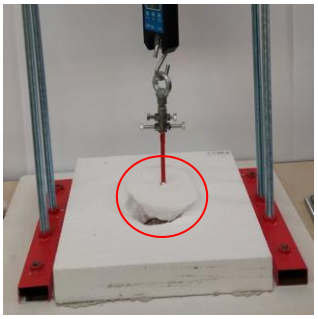
5.1. Results from clamping the insulation anchor using a long nut and bolts

This subsection presents the test results obtained from specimens in which the insulation anchors were secured using a long nut with bolts. It also describes the characteristic failure modes observed when this configuration was combined with either a ring bolt or a threaded rod.

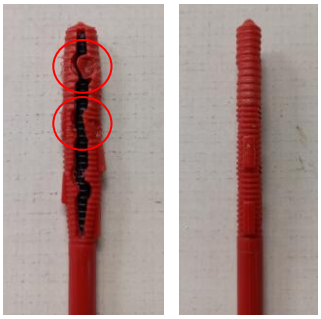
Visual examination of the failed EPS specimens shows that failure initiates near the insulation anchor head. It then propagates diagonally at an angle of approximately 45° relative to the anchor axis (Fig. 12*a*). As a result of the pull-through process, a truncated conical failure zone is formed. The smaller base of this cone corresponds to the diameter of the insulation anchor head.

Localized deformations were observed in the body of the insulation anchor, including circular indentations and a reduction in the effective cross-sectional area. These effects are attributed to local shear stresses induced by excessive tightening of the clamping bolts. The metal components penetrate into the plastic body of the insulation anchor. This penetration leads to partial or complete rupture, similar to the failure patterns shown in Fig. 12*b*. In contrast, no deformation was observed on the opposite side of the anchor. This indicates that this region does not actively participate in load transfer.

As a result, a significant portion of the insulation anchor length remains mechanically inactive. Consequently, clamping using a long nut with bolts does not ensure uniform force distribution or full engagement of the anchor's resisting surface. This limits the applicability and effectiveness of the method for tensile resistance testing of ETICS.



a) truncated cone failure in the EPS specimen



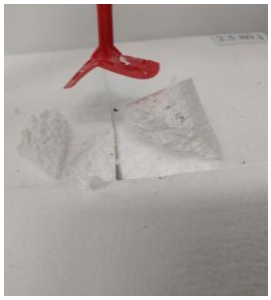
b) local damage to the anchor body caused by concentrated shear stresses induced by bolt tightening

Figure 12. Failure modes observed when clamping the insulation anchor with a long nut and bolts

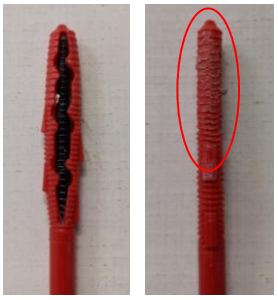
5.2. Results from clamping the insulation anchor using specialized jaws

This subsection presents the results and characteristic failure mechanisms observed during tests in which insulation anchors were clamped using specialized steel jaws.

Failure of the expanded polystyrene specimens initiates near the anchor head. The failure then propagates diagonally through the insulation material (Fig. 13*a*). This indicates that the general failure geometry within the insulation material is largely independent of the clamping technique applied.



a) failure of an EPS specimen with a thickness of 80 mm

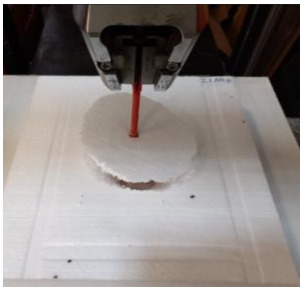


b) uniform stress distribution along the insulation anchor surface, with no visible local damage in the clamping zone

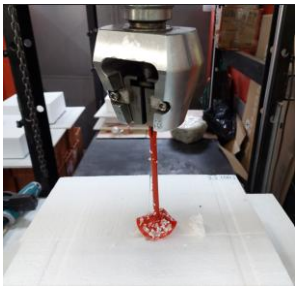
Figure 13. Results obtained using specialized steel jaws "Type 1" for clamping the insulation anchor

In contrast to the method employing long nuts with bolts, no localized deformations were observed in the body of the insulation anchor during testing. The holding force is generated exclusively by friction between the jaws and the anchor, which enables a more uniform load distribution along the engaged length of the tested element (Fig. 13*b*). As a result, stress concentrations in the clamping zone are significantly reduced, leading to a lower risk of local damage and improved reliability and repeatability of the obtained test results.

Certain limitations were nevertheless identified. When "Type 1" specialized steel jaws are used (Fig. 14*a*), a greater clamping length is required to develop sufficient friction and prevent slippage. This requirement may compromise test stability in cases involving shorter insulation anchors. In contrast, the "Type 2" specialized steel jaws (Fig. 14*b*) exhibit better adaptability and more reliable performance when the available anchoring length is limited.



a) specimen with a thickness of 60 mm



b) specimen with a thickness of 100 mm, demonstrating stable anchorage and absence of slippage

Figure 14. Results obtained using specialized steel jaws "Type 2" for clamping the insulation anchor

For specimens with greater insulation thicknesses, higher destructive tensile forces were recorded, which led to visible deformation of the insulation anchor head during pull-through. Under these conditions, a clearly defined truncated conical failure of the insulation layer was not always observed. Similar, though less pronounced, deformation effects were also identified when the anchor was installed in the joint between adjacent insulation panels. This behaviour is likely associated with stress concentration in the anchor head, particularly in the joint regions. It highlights the need for insulation anchors used in ETICS applications to comply with the performance requirements specified in [33].

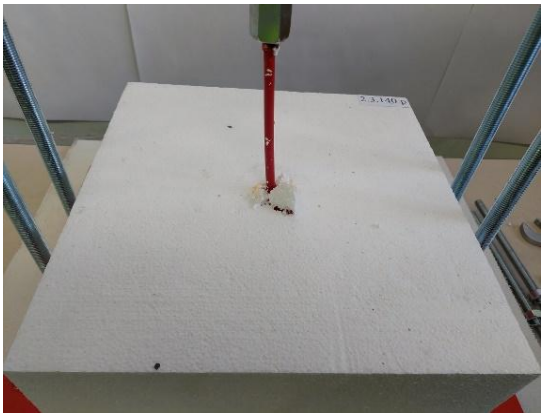
5.3. Results from clamping the insulation anchor using an extended nut and epoxy adhesive

In the final evaluated clamping configuration, chemical fixation of the insulation anchor was achieved using an extended nut filled with a two-component epoxy adhesive (Fig. 15). Unlike mechanically based methods employing bolts or specialized jaws, this approach relies on adhesive bonding along the internal surface of the extended nut.

The main advantage of this method is the uniform distribution of the applied tensile load along the bonded section, which improves the stability and repeatability of the test results. This configuration is particularly suitable for tests in which localized overloading or damage to plastic anchor components must be avoided.

Several limitations were nevertheless identified. Insufficient sealing of the extended nut may lead to leakage of the epoxy adhesive. This increases material consumption and may compromise the quality of the bond. In addition, the required curing period extends the overall testing time. From an economic perspective, the method is inefficient, as each extended nut can be used only once after adhesive filling.

Despite its advantages in terms of contact area and uniform adhesion, this method does not exceed the effectiveness or cost-efficiency of the clamping approach using specialized steel jaws “Type 2”, which provides comparable reliability while reducing material costs and eliminating delays related to adhesive curing.



a) specimen with a thickness of 140 mm during testing



b) specimen with a thickness of 140 mm after testing without cone type failure of the insulation layer

Figure 15. Failure modes observed in EPS specimens tested using chemical fixation with epoxy adhesive and an extended nut

5.4. Summary of identified problems and proposed technical solutions

The results obtained using the different insulation anchor clamping methods are summarised in Table 2. The table presents experimentally determined pull-through resistance values for various insulation thicknesses and anchor positions. These data provide a quantitative basis for comparing the applicability, limitations, and reliability of the evaluated clamping techniques.

Table 2. Summary of single-test pull-through resistance results for different insulation anchor clamping methods

№	Method of anchorage during the experimental study	Pull-through resistance (kN) of insulation anchor fixed at:									
		Center of the panel (d = 60 mm)	Joint (d = 60 mm)	Center of the panel (d = 80 mm)	Joint (d = 80 mm)	Center of the panel (d = 100 mm)	Joint (d = 100 mm)	Center of the panel (d = 120 mm)	Joint (d = 120 mm)	Center of the panel (d = 140 mm)	Joint (d = 140 mm)
1	Clamping the insulation anchor with a long nut and bolts	0,63	0,54	0,69	0,55	–	–	–	–	–	–
2	Mechanical clamping of the insulation anchor with specialized jaws “Type 1”	0,62	0,55	0,67	0,58	0,69	0,63	0,71	0,67	–	–
3	Mechanical clamping of the insulation anchor with specialized jaws “Type 2”	0,65	0,53	0,73	0,56	0,74	0,63	0,77	0,65	0,75	0,65
4	Chemical clamping of the insulation anchor with an extended nut and epoxy adhesive	0,63	0,60	0,69	0,61	0,71	0,63	0,72	0,67	0,76	0,68

Table 2 presents the force levels at which failure of the test specimens occurred for the different clamping methods and insulation thicknesses (d = 60 ÷ 140 mm). The results allow a direct quantitative comparison between the investigated approaches and clearly show the influence of both the clamping technique and the insulation thickness on the measured pull-through resistance. However, these values should not be considered as the only criterion for selecting the most appropriate clamping method, since their applicability strongly depends on the specific testing conditions, boundary constraints, and insulation configuration.

For example, mechanical clamping of the insulation anchor using a long nut with bolts can be reliably applied for EPS insulation thicknesses of up to 60 mm, where the achieved force levels are comparable to those obtained with more advanced methods. For insulation thicknesses of 80 mm and greater, this method may lead to an increased risk of anchor damage or deformation, which adversely affects test reliability and repeatability. Nevertheless, its main advantage lies in its high cost-effectiveness and simple execution, making it the most economically favourable option among the evaluated methods for preliminary tests or low-load testing scenarios.

Similarly, chemical clamping of the insulation anchor using an extended nut filled with a two-component epoxy adhesive yields favourable results in terms of pull-through resistance. Uniform adhesion along the entire embedded length ensures stable load transfer, reduces the risk of slippage, and limits localized stress concentrations in the insulation anchor.

Despite these technical advantages, the method presents several practical limitations. High material consumption, the single-use nature of the extended nut after adhesive filling, and the required curing time significantly increase both the cost and duration of the testing process. Moreover, careful sealing and precise technological control are required to prevent adhesive leakage or incomplete bonding. Consequently, this approach may be less suitable for routine laboratory testing or large experimental programmes where efficiency and repeatability are essential.

In line with the methodology adopted in Table 8 of [7], Tables 3 and 4 synthesise the technical solutions applied to address the issues identified during the experimental study, together with their main advantages and limitations. The following symbols are used:

✓ = fulfilled; ✗ = not fulfilled.

Table 3. Comparison of chemical bonding methods for preventing EPS detachment based on key operational performance criteria

№	Method of anchorage during the experimental study	Adhesion performance	No curing time required for strength development	Thermal and mechanical resistance	Cost-effectiveness	Environmental and safety aspects	Applicability
1	Chemical bonding of EPS with primer and adhesive mortar	✓	✗	✓	✓	✓	✓
2	Chemical bonding with primer and adhesive mortar followed by the sand-scattering method	✓	✗	✓	✓	✓	✓
3	Chemical bonding with polyurethane foam for thermal insulation	✓	✓	✓	✗	✗	✓

Table 4. Comparison of insulation anchor clamping methods based on key operational performance criteria

№	Method of anchorage during the experimental study	Type of anchorage (mechanical / chemical)	Resistance against slippage	Resistance against anchor failure	Cost-effectiveness	Suitable for multiple use	No curing time required for strength development
1	Clamping the insulation anchor with a long nut and bolts	mech.	✗	✗	✓	✓	✓
2	Mechanical clamping of the insulation anchor with specialized jaws “Type 1”	mech.	✗	✓	✓	✓	✓
3	Mechanical clamping of the insulation anchor with specialized jaws “Type 2”	mech.	✓	✓	✓	✓	✓
4	Chemical clamping of the insulation anchor with an extended nut and epoxy adhesive	chem.	✓	✓	✗	✗	✗

Based on the data presented, mechanical clamping methods show greater versatility and applicability in experimental testing than chemical fixation approaches. Among the evaluated solutions, specialized steel jaws “Type 2” represent the most balanced option, fulfilling all key criteria and making them suitable for systematic laboratory use.

Mechanical clamping using extended nuts with bolts and specialized steel jaws “Type 1”, although reusable, provides insufficient resistance at higher tensile loads and is therefore limited in applicability. Chemical bonding with primer and cement-based adhesive mortar offers reliable fixation of insulation materials, while polyurethane foam enables faster application but at a higher cost and with potential long-term performance limitations.

Overall, mechanical clamping methods are preferable for laboratory testing due to their reusability and cost efficiency.

6. Conclusions

Based on the laboratory experiment and analysis of the pull-through resistance of ETICS, the following conclusions can be made:

- The European Assessment Document EAD 040083-00-0404 defines general testing requirements but does not adequately address several practical issues encountered during experimental implementation, which may affect test consistency and reliability.
- Mechanical clamping of insulation anchors using a long nut with bolts introduces localized stresses and deformations in the anchor body and is therefore suitable only for tests conducted at relatively low tensile force levels.
- Chemical fixation using an extended nut and epoxy adhesive provides a uniform load transfer and reliable clamping conditions but is limited by high material consumption, single-use components, and extended curing times.
- Clamping methods based on specialized steel jaws provide stable fixation, even force distribution, and high repeatability, making them well suited for laboratory testing of pull-through resistance.
- Among the investigated solutions, specialized steel jaws “Type 2” offer the most balanced combination of technical performance, reliability, reusability, and cost-effectiveness.
- The selection of the clamping method has a direct impact on the accuracy, repeatability, and representativeness of pull-through resistance test results and should therefore be carefully considered in ETICS testing.

Based on the conducted experimental investigation, clamping insulation anchors using specialized steel jaws, particularly the “Type 2” configuration, is identified as the most appropriate approach for reliable and efficient pull-through resistance testing of ETICS.

Acknowledgments

The author thanks **Baumit Bulgaria Ltd.** and **Austrotherm Bulgaria Ltd.** for providing materials, as well as **LABKONSULT PLUS** for the experimental support.

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ТЕХНИЧЕСКИ РЕШЕНИЯ ПРИ ИЗПИТВАНЕ НА СЪПРОТИВЛЕНИЕТО НА РАЗКЪСВАНЕ НА ДЮБЕЛИ ЗА ETICS

И.-А. Цонев[1]

Ключови думи: *дюбели, ETICS, EPS, топлоизолационна система, съпротивление на изтръгване, удължена гайка, метални челюсти, епоксидно лепило*

РЕЗЮМЕ

Изследването анализира изискванията на Европейския документ за оценяване на EAD 040083-00-0404, свързани със съпротивлението на външните топлоизолационни композитни системи (ETICS) при ветрово натоварване, с акцент върху съпротивлението на изтръгване. Разгледани са практически проблеми, възникващи при експерименталното изпитване на образци, които не са изрично регламентирани в стандартите и могат да повлияят върху надеждността на резултатите.

Въз основа на експериментални изследвания са предложени технически решения и е определен най-подходящият от техническа гледна точка метод за изпитване на топлоизолационни дюбели в ETICS, както и насоки за бъдещи методологични подобрения.

[1] Иван-Александър Цонев, ас. инж., кат. „Технология и механизация на строителството“, УАСГ, бул. „Хр. Смирненски“ № 1, 1046 София, e-mail: ivan_conev_fce@uacg.bg