ACTA SCIENTIARUM POLONORUM Architectura 5 (1) 2006, 11–24

LONG-TERM PERFORMANCE OF EXTERNAL THERMAL INSULATION SYSTEMS (ETICS)

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Abstract. More than 500 million m² of External Thermal Insulation Composite Systems (ETICS) have been employed to insulate buildings in Germany since the early 1960s. In the last decade the application of ETICS became a popular measure to improve the energy performance and the weather resistance of façades in the building stock. Naturally this raises questions about the durability of ETICS compared to other types of thermal insulation. Therefore a substantial number of multi-storey houses with ETICS have been inspected several times since 1975 by the Fraunhofer Institute for Building Physics. The results of these repeated inspections may be summarized as follows: Damage or degradation of ETICS façades are no more frequent than with conventional rendered masonry walls. A slightly greater susceptibility of ETICS to microbial growth due to rain or condensation water can be detected. Costs and frequency of maintenance for ETICS are comparable to those of traditional wall structures. The same holds for other durability aspects.

Key words: external insulation, durability, façade inspection, maintenance effort

INTRODUCTION

From the early 1960s, External Thermal Insulation Composite Systems (ETICS) – also called External Wall Insulation Systems in Ireland and the United Kingdom or Exterior Insulation and Finish Systems (EIFS) in Canada and the USA – have been applied as external insulation of façades in Central Europe. Because of the innovative character of this insulation system, which was at first executed only in form of foamed plastic boards and synthetic resin plasters, the Fraunhofer Institute for Building Physics (IBP) started scientific investigations in the early 1970s [Künzel 1975]. Due to the gradually growing importance of external wall insulation systems in Germany multiple examinations at the IBP followed during the next decades, e.g. [Böhm and Künzel 1987, Künzel 1998, Zirkelbach et al. 2004].

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The IBP, which was founded 1929 in Stuttgart, is dealing with all aspects of Building Physics including energy savings, moisture protection and acoustics of buildings. However, most of the investigations concerning ETICS and their performance were carried out at the field test site of the IBP in Holzkirchen located close to the Bavarian Alps. This location was chosen as weathering test site for the IBP in 1951 because of its rather severe climate concerning temperature fluctuations and wind driven rain loads. Building products showing satisfactory hygrothermal performance and durability when exposed to the natural weather at this test site were assumed to work well also in other parts of Germany. This assumption proved to be valid during the past 50 years [Künzel 2003] and therefore the location in Holzkirchen, which was originally planned for temporary use only, still exists and employs now almost as many scientific and technical staff (approx. 80) as the mother institute in Stuttgart.

This paper deals mainly with the results of periodical inspections of buildings with External Thermal Insulation Composite Systems (ETICS) in Central Europe. In 1975, a first investigation of 93 buildings took place in Germany, Austria and Switzerland [Künzel 1976]. In 1983, this investigation was repeated on 87 buildings [Mayer 1984]. In 1989, equivalent evaluations were carried out on ETICS with mineral insulation materials [Künzel 1991]. Further inspections were made in 1995 [Künzel 1997] and on a selected number of larger buildings in 2004 to assess the long-term behaviour and to record the necessity for refurbishment measures. At the end of 2004, the latest investigations, whose results are summarized below, were carried out on 12 larger buildings with ETICS from different manufacturers.

MODALITY OF ASSESSMENT

After a detailed inspection, the state of the façades was classified according to three assessment groups, whereby the ground floor areas were closely examined and the upper floors were viewed with binoculars:

Group 1 – Virtually without Defects

No visible defects. Small groove cracks, hardly visible at a normal distance, are grouped in here.

Group 2 – Minor Defects

Few cracks, e.g. starting at window corners, longer groove cracks or isolated cracks along insulation boards joints, hardly noticeable, only visible at closer examination.

Group 3 – Major Defects

Frequent or longer cracks, for the most part along insulation board joints, blistering or de-lamination of coatings, clearly visible.

Small cracks found at the corners of window and door openings are not system specific, and may also occur with other types of construction, yet, as a rule, they do not cause further damage. However, cracks along insulation board joints must be assessed as system specific. According to the available analyses, such cracks do not have any influence on the moisture content or on the insulating effect of the system. Therefore no consequential damage must be feared [Künzel 1995]. The development of algae is not assessed as technical defect but as a "visually adverse effect." In the following, the term "algae" means diverse microbial vegetation without closer differentiation, and was not carried out within the context of our examinations.

TESTED OBJECTS AND RESULTS

The investigated objects together with details regarding location, the type of applied External Thermal Insulation Composite System (ETICS), data on the building and refurbishment measures are indicated in Table 1. The diagram in Figure 1 shows the times of ETICS application, inspection and the assessment of the state. As a result the following may be deduced:

The age of the ETICS investigated varies from 18 to 35 years. Some buildings were designed and constructed with ETICS from the start, in the majority of cases, however, the ETICS are an addition, an improvement of the thermal insulation already in place. For this reason, and because of lower thermal requirements in the past, the thickness of the insulation layers is relatively low when compared to currently applied systems (minimum thickness 20 mm). All ETICS, older than 20 years, were refurbished using one or two new coatings. According to Figure 2, half of the buildings had to be classified within the group 2 or 3 (minor to major defects) after inspection in 1975; assessing all inspected buildings at that time [Künzel and Mayer 1976], the number would even be considerably higher. After the latest inspection at the end of 2004, however, all buildings were assessed „without defect" (group 1) after refurbishment. The refurbishment essentially consisted of applying new coatings, only in one case was an additional insulation layer applied. Consequently, the state of the façades has improved over the years. This may be a result from the fact that in the early 1970s, the techniques to apply ETICS were yet to be optimised and the resulting defects were removed by refurbishment measures. The following photographic documentation shows and explains the actual visual changes on the façades.

Pollution – Development of Algae

In former decades, the pollution of façades was the main cause for refurbishment by applying new coatings. Air pollution was considerably higher at that time than nowadays; this is especially true of industrial centres and main traffic areas. The pollution of the façades was mainly visible at wall areas with differing exposure to rain: Areas with a high exposure to rain were explicitly cleaner than protected areas, e.g. below projecting roofs or window sills. By filtering the exhaust air of industrial plants, air pollution was reduced as well as the concentration of gaseous pollutants in the air, especially the concentration of sulphur dioxide SO_2. Because SO_2 is a strong biocide the consequence of its disappearance was that the growth of micro-organisms on façades, such as algae, fungi and bacteria, was stimulated [Künzel 2000]. This is the reason why those areas of the façades which are frequently exposed to rain might be infested with algae growth, because moisture is a prerequisite for the development of algae. With respect to External

Table 1. Data on the inspected objects
Tabela 1. Dane badanych obiektów

Object No Nr obiektu	Location Położenie	Address use of the building Adres i sposób użytkowania budynku	Insulation material type and thickness Materiał izolacyjny, typ i grubość	Application / Wykonanie: Building Budynku	Application / Wykonanie: ETICS Izolacji	Refurbishment Modernizacja
16	Munich	Burgkmaierstr. 9 old people's home dom starców	mineral wool wełna min. 60 mm	1960	1986	no nie
18	Munich	Schleißheimerstr. 393 depot – magazyn	mineral wool wełna min. 60 mm	1945	1985	no nie
96	Nuremberg	Thumenberger Weg 11 residential building budynek mieszkalny	expanded polystyrene styropian 60 mm	1982	1982	in 1995 coating (silicone resin paint) – w 1995 roku powłoka malarska (farba silikonowa)
95	Nuremberg	Feinitzer Platz residential building budynek mieszkalny	expanded polystyrene styropian 60 mm	1979	1979	in 2002 coating because of pollution – w 2002 roku powłoka malarska z powodu zabrudzenia
51	Nuremberg	Krugstr. 17–23 residential building budynek mieszkalny	expanded polystyrene styropian 50 mm	?	1969	in 1987 coating all over, in 2001 only ground floor adjacent to road (north) in 2004 only walls adjacent to garden (south) w roku 1987 powłoka na całym budynku, w 2001 r. tylko na parterze od strony drogi (północ), w 2004 r. ściany od strony ogrodu (południe)
56	Neumarkt/Opf.	Efastr. 2 residential building budynek mieszkalny	expanded polystyrene styropian 50 + 40 mm	1970	1970	in 1993 second insulation layer 40 mm with plaster w roku 1993 druga warstwa izolacji 40 mm z tynkiem

54		Mühlstr. 1–3 residential and commercial building budynek mieszkalny i komercyjny	expanded polystyrene styropian 20 mm	1972	1972	in 1988 coating w 1988 r. powłoka malarska
34	Geislingen/Steige	Bolzstr. 6–8 residential building budynek mieszkalny	expanded polystyrene styropian 30 mm	1961	1970	in 1981 coating, in 2000 coating w 1981 r. powłoka malarska w 2000 r. powłoka malarska
33		Bolzstr. 9–12 residential building budynek mieszkalny	expanded polystyrene styropian 30 mm	1961	1970	in 1981 coating w 1981 r. powłoka malarska
32		Ebertstr. 1–7 residential building budynek mieszkalny	expanded polystyrene styropian 30 mm	1961	1970	in 1981 coating w 1981 r. powłoka malarska
31		Brüningstr. 2–8 residential building budynek mieszkalny	expanded polystyrene styropian 30 mm	1961	1970	in 1981 coating w 1981 r. powłoka malarska
30		Stresemannstr. 2–6 residential building budynek mieszkalny	expanded polystyrene styropian 30 mm	1961	1970	in 1981 coating w 1981 r. powłoka malarska

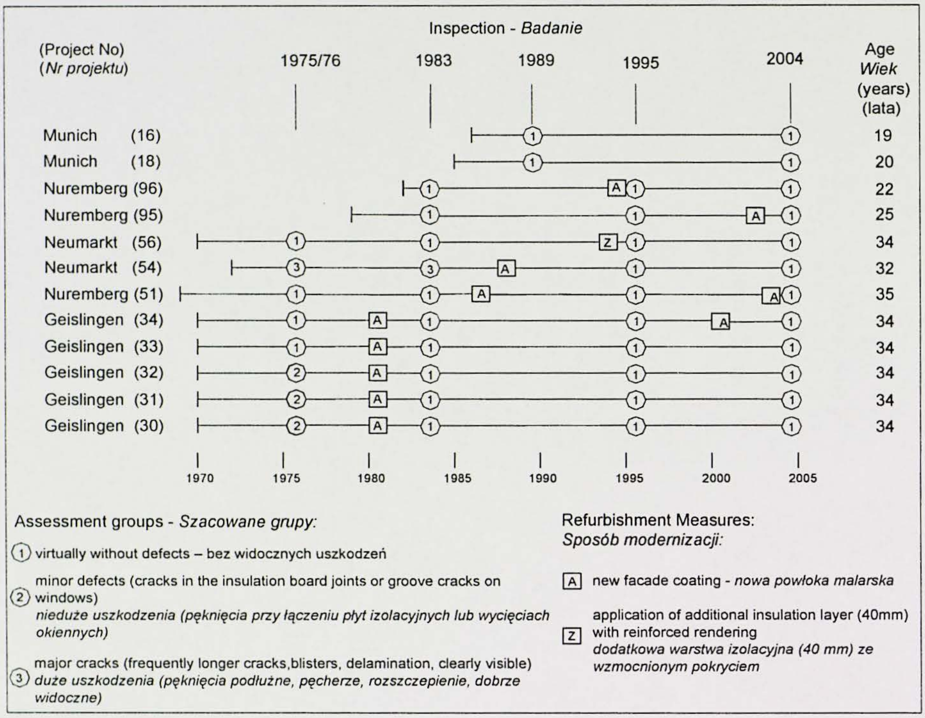


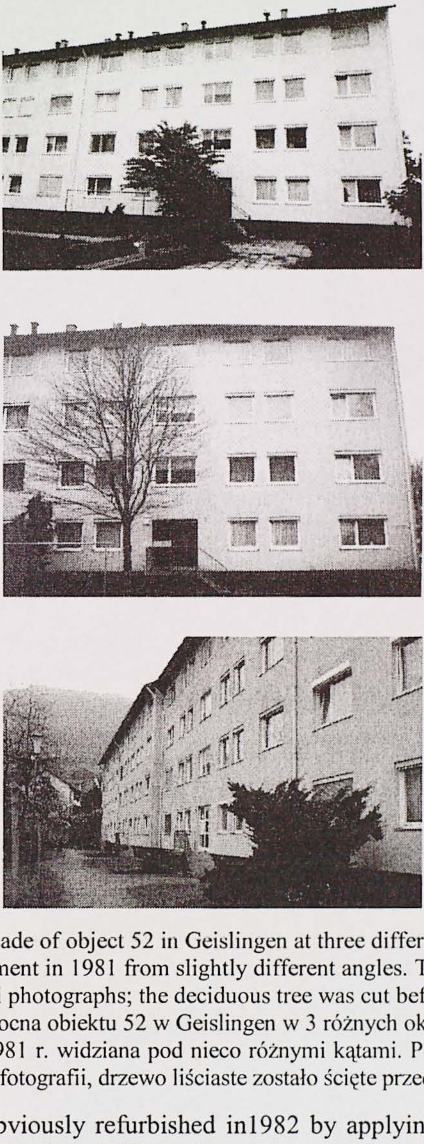
Fig. 1. Diagram showing the times of application, inspection and refurbishment of External Wall Insulation Systems in practice with notes on the state of the façades classified by means of the assessment groups specified above

Rys. 1. Diagram pokazujący czas wykonania, inspekcji i modernizacji systemu izolacji zewnętrznych ścian z uwagami o ich stanie według przyjętych grup szacunkowych

Wall Insulation Systems condensation on façades during the night may be a further reason for additional moisture, again stimulating the growth of algae [Künzel and Sedlbauer 2001].

Changes on the surfaces of façades, caused by dirt or microbial growth, are generally accepted as "patina" as long as they are evenly spread, whereas local concentrations of pollution or algae are frequently assessed as being a "visually adverse effect." The inspected buildings showed a "cleaning effect" as well as the development of algae on surfaces, frequently exposed to rain. This may refer to the local air quality or to the kind of fungicide additives in plasters or protective coatings. This context, however, was not analysed. The following examples explain some results of the inspected façades.

Figure 2 shows the northern façade of object 52 (residential building in Geislingen) at three different times. Despite variations in the quality of the photographs, no important or harmful change is to be observed over a period of 23 years. On the western sides of parallel located residential buildings in Geislingen (objects 30 to 33), however, partial development of algae has occurred. It is remarkable that the algae growth did not change within the period between the two inspections (Fig. 3). The neighbouring object,



1983

1995

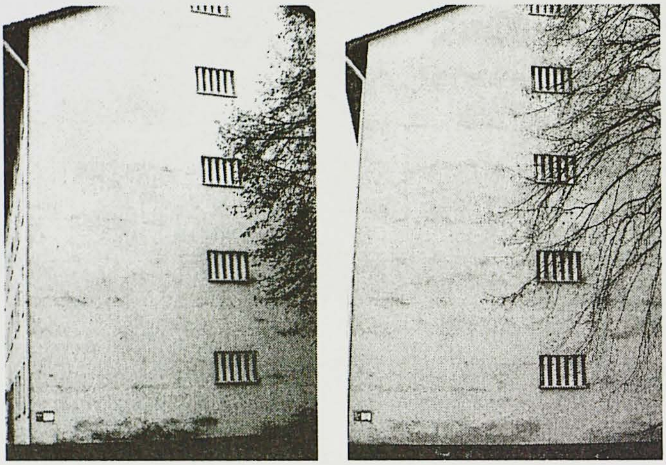
2004

Fig. 2. Northern façade of object 52 in Geislingen at three different times: 2, 14 and 23 years after refurbishment in 1981 from slightly different angles. The slowly growing conifer can be seen in all photographs; the deciduous tree was cut before 2004

Rys. 2. Fasada północna obiektu 52 w Geislingen w 3 różnych okresach: 2, 14 i 23 lata po modernizacji w 1981 r. widziana pod nieco różnymi kątami. Powoli rosnący iglak jest widoczny na każdej fotografii, drzewo liściaste zostało ścięte przed 2004 r.

34, which was obviously refurbished in1982 by applying another coating as all other neighbouring residential buildings, had to be renovated due to an intense development of algae already in 2000 (Table 1).

Figure 4 shows the eastern and southern façades of object 54 in Neumarkt. The evenly spread pollution provided a kind of patina within a period of 16 years. On the northern façade (adjacent to the road) of object 51 in Nuremberg no microbial growth occurred after a first refurbishment by applying a coating 17 years ago. In this case, the cleaning effect prevails due to the drainage of rain water, concentrating between the windows (Fig. 5).



1995 2004

Fig. 3. Western gable side of object 31 in Geislingen 14 years (left) and 23 years (right) after refurbishment in 1981 with algae growth in the plinth area and some horizontal stripes, caused by irregularities in the plaster structure in relation with the working levels of the scaffold. The tree has grown visibly; the algae infestation remained unchanged with a slight increase in the upper façade area

Rys. 3. Ściana szczytowa obiektu 31 o wystawie zachodniej w Geislingen 14 lat (po lewej) i 23 lata (po prawej) po modernizacji w 1981 r. z algami w okolicach cokołu i kilkoma poziomymi paskami związanymi z niejednorodnością tynku na poziomach byłego rusztowania roboczego. Drzewo wyraźnie urosło, wysyp alg pozostał niezmieniony z lekkim przyrostem w górnej części fasady

Fig. 4. Eastern and southern façade (from right to left) of object 54 in Neumarkt in December 2004, 16 years after refurbishment in 1988 by applying a new coating, close-up view of the plaster at the small window

Rys. 4. Wschodnia i południowa (od prawej do lewej) fasada obiektu 54 w Neumarku w grudniu 2004 r. 16 lat po modernizacji w 1988 r. i położeniu nowej powłoki, przybliżeniu tynku w małym oknie

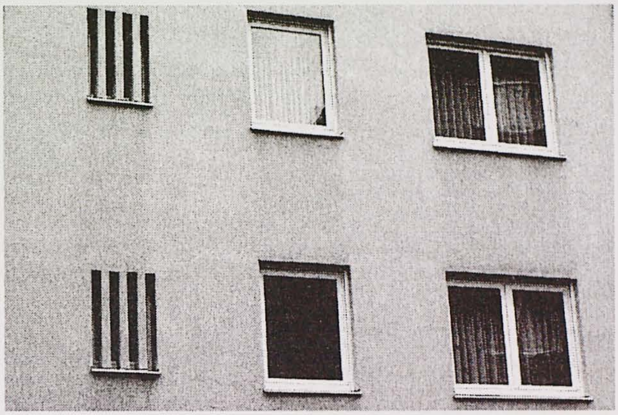


Fig. 5. Partial view of the northern façade of object 51 in Nuremberg, 17 years after refurbishment by applying a new coating in 1987. The areas between the windows, which are exposed to intense rain, are somewhat lighter, meaning that the exposure to rain did not cause the growth of algae but had a cleaning effect

Rys. 5. Częściowy widok północnej fasady obiektu 51 w Norymberdze 17 lat po modernizacji i położeniu nowej powłoki w 1987 r. Wystawiony na działanie deszczu obszar między oknami jest nieco jaśniejszy, co oznacza, że deszcz nie powoduje wzrostu alg, ale daje efekt „czyszczący"

The state of the western façade of object 16 (old people's home in Munich) in 1989, three years after the application of an ETICS, is documented by Figure 6 above. There were no visible defects. But during the inspection in 2004, 15 years later, algae growth could clearly be observed (Fig. 6, below), especially in areas with a intense exposure to rain (Fig. 7).

Resistance and Durability

It is frequently supposed that the small thickness of the exterior plaster and a smooth insulation material as substrate are possible causes for damage from mechanical impact. Yet, even after several inspections, there were no signs of a special susceptibility to any real damage. On the contrary: conventionally constructed buildings in the immediate neighbourhood of the inspected objects frequently showed damage of the plaster due to deformation of the masonry. Such deformations cannot be totally avoided with masonry of large-size blockwork or combinations between masonry and constructive concrete elements. An example is a residential building in the housing estate of Geislingen, executed in the same type of construction as the objects 30 the 34 but without ETICS. This building is the only one in the housing estate with damage of the masonry and the plaster (Fig. 8). By mechanical "de-coupling" of the finishing plaster from the structural masonry by means of a smooth insulation material, ETICS are much less susceptible than conventionally rendered facades to that kind of damage.

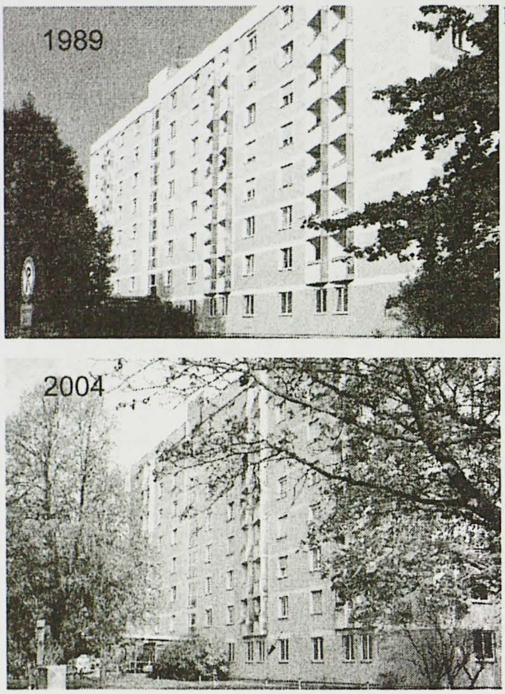


Fig. 6. Western façade of object 16 (old people's home in Munich) in September 1989, three years after application of an ETICS and another 15 years later in November 2004 (the difference in colour does not mean that the façade has been repainted, it is due to coloration problems with digital photography). The formation of algae is clearly visible especially in areas intensely exposed to rain (see arrow and Fig. 7)

Rys. 6. Zachodnia fasada obiektu 16 (dom starców w Monachium) we wrześniu 1989 r., trzy lata po zastosowaniu systemu ETICS oraz 15 lat później w listopadzie 2004 r. (różnica koloru nie oznacza, że fasada została pomalowana, jest to raczej problem koloru w fotografii cyfrowej). Formacje alg wyraźnie widoczne w miejscach bardziej wystawionych na działanie deszczu (zob. strzałkę oraz por. rys. 7)

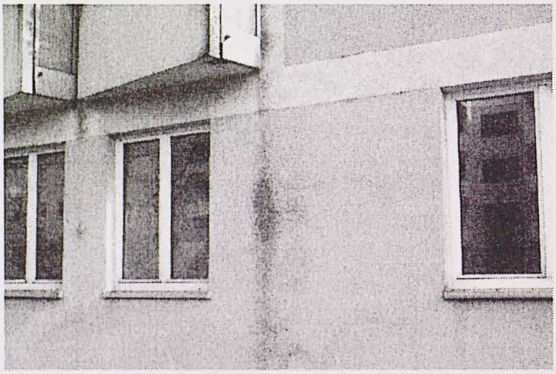


Fig. 7. Local growth of algae along areas with a concentration at the rain water runoff path, caused by the lateral limitation of the balconies and the wind. The growth of algae is clearly smaller in the area immediately below the balcony plate than in the unprotected wall areas

Rys. 7. Lokalny wzrost alg wzdłuż powierzchni ze skoncentrowanym spływem wody deszczowej uwarunkowanym usytuowaniem balkonów i wiatrem. Wzrost alg jest wyraźnie mniejszy bezpośrednio pod płytą balkonową niż na nieosłoniętej powierzchni ściany

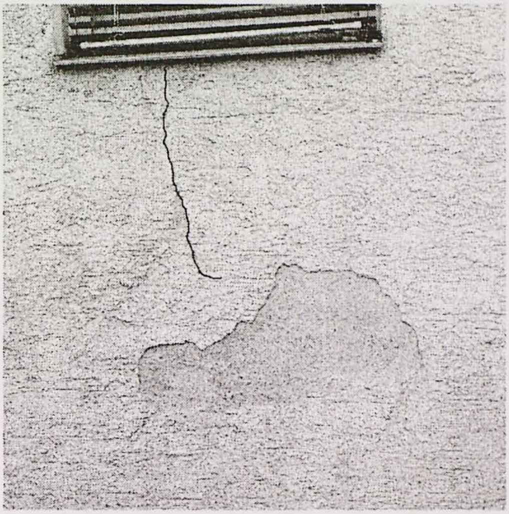


Fig. 8. Crack in the wall and damage of plaster on the western façade of the neighbouring building of object 32 without an External Wall Insulation System (Ebertstraße 2). A crack in the wall below the window is occurring in the plaster. The final rendering has partially separated from the undercoat plaster. Such damage can generally be avoided by means of a thermal insulation composite system with the help of the de-coupling effect of the soft insulation layer as well as plastic additives and the reinforcement of the plaster

Rys. 8. Pęknięcie i uszkodzenie tynku na zachodniej fasadzie sąsiedniego do obiektu 32 budynku bez systemu ocieplenia (ul. Eberstraße 2). Pęknięcie w ścianie pod oknem przenosi się na tynk. Powłoka końcowa oderwała się od spodniego tynku. Takie uszkodzenia mogą być generalnie wyeliminowane w systemie bezspoinowego ocieplenia za pomocą „odsprzęgającego" efektu miękkiej warstwy izolacji termicznej jak również dodatków plastycznych i zbrojenia tynku

Maintenance Effort

Continuous maintenance is necessary for the façades of buildings. It is not only necessary to renew the façade coating due to pollution and weathering from time to time, but also to check and repair the "weak spots" on all façades, where necessary. Such weak spots may be connections around windows or façade connections as shown in Figure 9.

It may be assumed that – as concerns the inspected objects and as described above – that the first renovating coating served, at least partially, to correct "initial defects" which occurred. However, period between the first and the second coating – if carried out – provides information on the frequency of maintenance to preserve the desired view of the façade. Considering the objects 16 and 18, which urgently need refurbishment, and the objects 30 to 33, where refurbishment is planned, we get a mean value for this period of approximately 20 years for the frequency of refurbishment of the inspected external wall insulation systems. This value is within the range of the upper limit values for the refurbishment periods of façade coatings and synthetic resin plasters in general according to a previous investigation (Table 2, see Künzel [1980]).

Fig. 9. Example of a damage in the lower area of the façade on the western side of object 31 by permeation of moisture at the connection profile (maybe influenced by a defective rainwater pipe). Such damages should be repaired early enough and separately from other general façade refurbishments

Rys. 9. Przykład uszkodzenia w dolnej części, zachodniej fasady obiektu 31 spowodowane penetracją wilgoci przy profilu łącznikowym (możliwe, że pod wpływem uszkodzonej rury spustowej). Takie szkody powinny być usuwane od razu, niezależnie od generalnych modernizacji fasad

Table 2. Reference values on the period until inspection or refurbishment of rain-protecting façade layers after consultation of building experts according to Künzel [1980]

Tabela 2. Wartości referencyjne okresów do badania lub modernizacji warstw ochronnych przed deszczem fasad po konsultacji z ekspertami budowlanymi według Künzla [1980]

Type of external layer Typ warstwy zewnętrznej	Period until refurbishment [years] Czas do modernizacji, [lata]	
	Limit values Zakres przyjmowany	Mean values Wartości średnie uzyskane
Mineral external plaster Mineralny tynk zewnętrzny	15–50	35
Façade coating Powłoka malarska, fasadowa	5–20	10
Synthetic resin plaster on masonry or insulation layer Tynk akrylowy na ścianie murowanej lub warstwie izolacji	10–25	18
Fibre cement cladding Okładzina cementowa wzmocniona włóknem	10–30	20

SUMMARY AND CONCLUSIONS

The results of a repeated inspection over longer periods of time of multi-storey and larger buildings with an External Thermal Insulation Composite System (ETICS) with a service life currently of up to 35 years are as follows:

1. Damages of façades occur more scarcely than with conventional masonry with plaster as a result of the de-coupling effect of the soft insulation layer from the brick-work / blockwork. Damage caused by natural weathering is generally negligible.

2. A greater susceptibility of ETICS to microbial growth due to rain or night-time surface condensation can obviously be compensated by appropriate additives in the plaster or coating. In some cases, the formation of algae was visible, in other cases, however, the cleaning effect due to rain prevailed. It is important to provide an adequate drainage of the rain water onto the façade in order to avoid a local concentration of water running down the façade. Prolonged surface wetness is a possible cause for algae growth which may be judged to be visually unacceptable.

3. Costs and frequency of maintenance for External Wall Insulation Systems (ETICS) are equivalent to those of conventional wall structures consisting of rendered masonry. The same holds for the durability and life expectancy which is generally accepted to be at least 60 years for masonry walls.

– The favourable long-term performance together with an excellent driving rain protection and a high thermal insulation quality are the reasons why ETICS have become so popular in Central Europe. Currently more than 30 million square meters of ETICS are installed in Germany every year.

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DŁUGOTERMINOWA TRWAŁOŚĆ SYSTEMÓW ZEWNĘTRZNEJ IZOLACJI TERMICZNEJ BUDYNKÓW TYPU ETICS

Streszczenie. Od wczesnych lat 60. ubiegłego wieku zastosowano w Niemczech ponad 500 mln m^2 bezspoinowego systemu dociepleń budynków (tzw. ETICS – External Thermal Insulation Composite Systems). W ostatniej dekadzie system ETICS stał się popularnym sposobem poprawy termicznych własności budynków oraz zabezpieczenia fasad zewnętrznych przed niekorzystnym wpływem czynników klimatycznych. Naturalne jest więc pojawienie się pytania o trwałość tego systemu w porównaniu z innymi metodami ociepleń. W Instytucie Fraunhofera Fizyki Budowli przeprowadzono, poczynając od 1975 roku, szereg badań budynków wielopiętrowych ocieplonych systemem bezspoinowym. Wyniki tych badań można podsumować następująco. Uszkodzenia oraz degradacja fasad z systemem ETICS nie występuje częściej niż w budynkach z tradycyjnymi, pokrytymi tynkiem ścianami murowanymi. Stwierdzono jednak nieco większą podatność na zagrożenie mikrobiologiczne z powodu deszczu czy wilgoci kondensacyjnej. Koszty oraz częstotliwość prac związanych z utrzymaniem systemu ETICS są porównywalne z tradycyjnymi systemami przegród. To samo dotyczy pozostałych aspektów trwałości fasad.

Słowa kluczowe: izolacja zewnętrzna, trwałość, fasada, koszty utrzymania

Accepted for print – Zaakceptowano do druku: 30.05.2006