Deutsches Fachwerkzentrum Quedlinburg e.V.

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Short report to the research project

Consequential damages after redevelopment measures at selected buildings

Supported by:

Bundesamt
für Bauwesen und
Raumordnung

This research project was supported by:

- Bundesamt für Bauwesen und Raumordnung (BBR)
- Deutsche Bundesstiftung Umwelt (DBU)
- Land Sachsen-Anhalt, Ministerium für Landesentwicklung und Verkehr
- BauBeCon Sanierungsträger GmbH

1. Aim of research assignment

The present paper of Deutschen Fachwerkzentrum Quedlinburg e.V. „Consequential damages after redevelopment measures at selected buildings“ is about timber framed constructions, which after an extensive refurbishment again had shown damages.

As a “consequential damage” of refurbishment measures a structural damage is defined, which had not existed before the redevelopment, but appeared after ending the procedure and led to a value decreasing of the construction in a period of time lower than the normal useful life of the building. In addition to technical (e.g. product properties and their interaction with other products, modification of building climatic situation), also nontechnical factors (e.g. false estimation in the technical area, user and owner behavior) were incorporated to the evaluation. Therefore situations were evaluated, which assumedly weren’t appeared in this manner with the selection of materials and methods matching with the historical stock resp. with a professional construction work and suitable user behavior.

The aim of research was to identify the reasons of the damage of historical substance of already finished refurbishments and consequential damages resulting out of it. Furthermore, by adding more research results, suggestions resp. alternatives for sustainable, professional and careful to substance rehabilitation measures should be presented. These are prepared comprehendible in a separated booklet mainly for the house builder. With it, an important contribution for the preservation of in urban design regard particularly valuable old buildings should be achieved as for an economic and responsible use with subsidies.

2. Execution of research assignment

The main focus of the research was the collection and analysis of consequential damages after redevelopment measures of selected frame houses in which the last relevant measure of rehabilitation should not be before 1990 as far as possible.

For this purpose, redevelopment agencies, building authorities of cities and communities with a high framework house stock, monument conservators and architects from different federal states were contacted resp. asked. In the cities and communities, where it was possible and desired to take damaged frame houses in our project processing, the object selection happened in cooperation with the authorities named above.

Generally the cautious contacting with the owner, the user resp. the designer took place with the beginning of the object processing, presenting the project, localizing the problems and defining the next proceedings. In the first conversations the owner resp. user reported us about currently existing damages and about basic data of the process of redevelopment.

The damaged elements at the frontage and in the interior rooms were photographed, handwritten noticed and sketched to list it later into a room book. In the course of the project this method became better and better structured by self-developing for the initial reception a questionnaire for a fast inventory (checklist as multiple-choice system). The questionnaire was incorporated into the stock-check and served as a statistical analysis of the damage symptoms resp. the causes of damage.

With the consulting of other expert opinions in situ, expert's reports, technical measuring and laboratory analyses by the Rathgen-research - laboratory in Berlin, the results were concretized. As far as possible, single structural element were excavated resp. opened to document on the one hand the real construction and on the other hand the causes of the damage, such as sources of moisture or execution deficiencies. For a preferably reliable evaluation of damages patterns an intensive screening of documents, procedures, notes, calculations and illustrations as well as their evaluation was necessary. The results were incorporated in the room book for damage survey, which was enhanced as part of this project. It explains all relevant data and reports to the point of detail drawings constructional related and clearly.

To protect the personal rights the evaluation of the research results was made anonymous. The structural elements were subdivided on the basis of the civil engineering common cost types 100 to 700. In the evaluation of the damage reasons to us, next to the technical reasons, e.g. product-specific, mechanical and building climatic factors, particularly the non-technical reasons as planning, erection and user-based factors were important.

Additionally to the final report of the project, our guideline for owners and people which are interested in timber frame constructions was published, entitled „Hilfe – ich habe ein Fachwerkhaus“ (Help – I have a timbered house), as booklet and web presence on the website of the Deutsches Fachwerkzentrum.

www.deutsches-fachwerkzentrum.de)

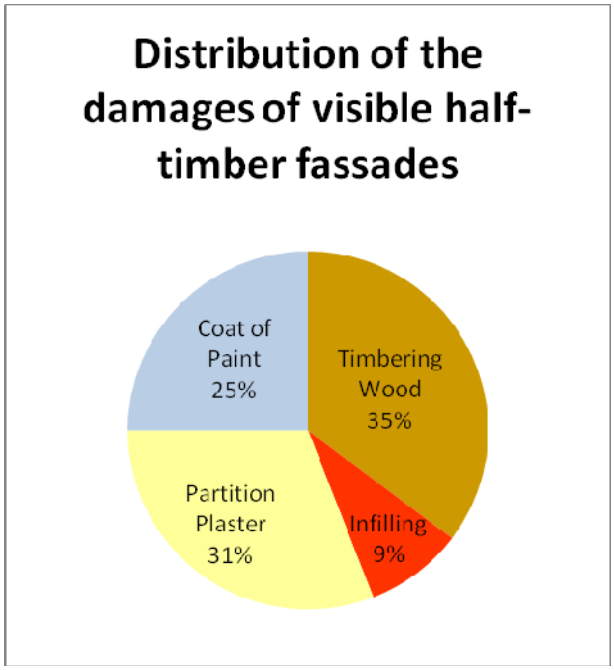

Diagram 1 Percental apportionment of the documented damages at timber framed construction - without architrave blocks, windows, roofs and outbuildings (B. Stöckicht, DFWZ)

Pic. 1 Excavated wall construction, clearly visible is the extremely damage of the sill plates and the rising upright caused by brown and white pocket rot. The glass fibre-glass-insulation layer is viewable in the background. (private, wood preservation expert)

3. Summary of the results

Of circa 30 more intensive analyzed timber-framed constructions, which also involved into the balance, ⅔ are private property and ⅓ are public property.

More than three-quarter of the analyzed houses are designed as exposed timber framework. Of the non exposed timber framework objects (83% private and 17% public client) were one half each plastered and the other half each with a one-third covered with an additional sheathing of heraklith plates, slate or wood.

Most damages of the exposed timber framework houses were at the external façade itself, without inclusion of the base areas, windows, roofs and outbuildings. The damage potential for half-timbered wood is with 35% the highest, closely followed by damages at the framework plaster with 31% and the paint with 25%. The infill itself was affected with 9%.

The most frequent damage symptoms at half-timbered wood could be identified with more than 70% as fractional attack of animal pests, wood-destroying fungi resp. mildew rottenness. Based on the disadvantageous material properties, chemical refined dispersion coatings that are often applied, on timbers as well as on infillings are often embrittled extensively, cracked and consequently chipped off. Because of that moisture could penetrate deeply into the texture.

The impairments of the infillings continuously were proved as a result of long-lasting moisture penetration of the infilling material and the adjacent timber and hence resulting material-specific stresses resp. expansion forces.

The inhomogeneous expansion-properties of the different materials, the mostly unprofessional execution of the connection from plaster to timber elements and the composition of the plaster were to more than 90% the activator for cracks in the plaster level and for uncontrolled breaks of edges at the joint timber-framework.

More than $^1/_5$ of the half-timbered houses showed damages at the base wall masonry, which were to 90% made of natural stone. The biggest problem was the moisture[1] impact intruding from several sides. The damages manifested it selves in moist masonry mainly. A high contamination with structural damaging salts in connection with absorption of humidity, increasing environmental pollution as well as pollutions of the air resulted in salt efflorescence and brick-spalling in 17% of the damage cases. By the influence of shading and planting in the surrounding area, whereby a drying of the moist masonry was restrained, another 17% of the base masonry were grown over with algae and moss. The potential for damages at subsequent plastered bases was the same. Because of his chemical composition the cementitious plaster, which was used in all cases, not only is strong and stiff, but also affects a blocking of the drying. Stress cracks and spalling of plasters were the result.

One-third of the analyzed houses showed external damages of the windows. At nearly ¾ of the damaged windows an inappropriate colour system was the decisive factor for brittleness, crack formation and finally the chipping of the colour coating. Because of that in lumbers a too high moisture load was reached, which effected at extreme cases in mould growth at sheathings as well as corrosion of window fittings (already underneath the colour coating).

Pic. 2 The cement plaster discoidal scales off from the sandstone. Additionally, the moisture load was forced by defective roof drainage, so that in the sill plates and in vertical pillars timber-destroying fungi could spread. The sandstones are grown over by algae and moss. (DFWZ)

In contrast to obvious damages of exterior structural elements, only one forth of the amount of damage inside the half-timbered houses could be discovered.

However, this relation[2] is relative as at approximately 20% of the examined objects an additional excavation of internal construction layers to control the state of the material resp. construction would have been revealing, but not has been possible due to the continuous use.

[1] *e.g. ascending humidity, splash water, condensate, enclosure of moisture in masonry by external sealing with subsequent applied cement plasters and at approximately ⅓ of these objects the sealing of the cellar underneath from the inside by cementitious plasters, hygroscopic moisture, too.*

[2] *80% damages outer shell and 20% damages indoor*

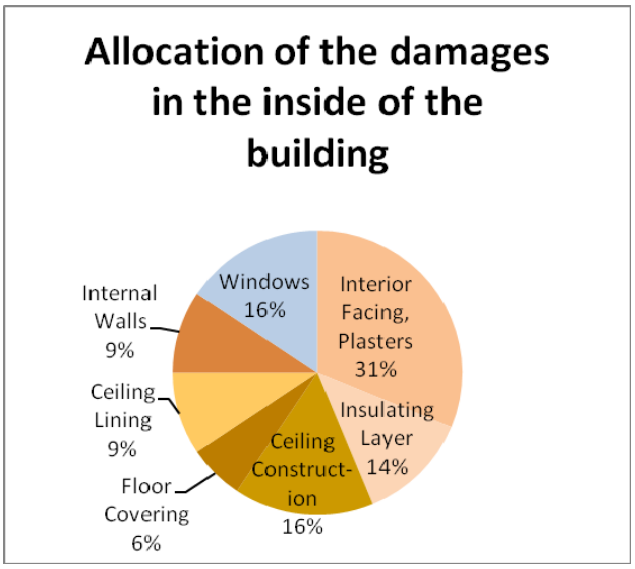

Diagram 2 Percental allocation of the damages in the inside of the building (B. Stöckicht, DFWZ)

Anyhow, with the help of the allocation of the damages can be derivated, that serious damages at external walls are mirrored on their inner surfaces (diagram 2). Once again, to 50% moisture related damages could be located at internal plasters, in the insulation layer and at window sahses. Nearly 10% of the internal coatings was disturbed by cracks. The consequences of a high moisture concentration in the cross-section manifest to 50% by the infestation of mould fungi at internal plasters, at fibre or sandwich insulation and plaster board walls.

Pic. 3 Distinctive fungus mycelium at the back side of a gypsum board layer of a sandwich insulation board of polystyrene and gypsum board (DFWZ QLB)

If all comprised damages are balanced an account after causes of damage one determines, that two thirds of the damage potential can be found in exceeding, long lasting moisture respectively encumbered drying potential capacity.

With nearly 60 % the influence of planning related misinterpretations on the part of the owner or specialist planner and the therewith associated choice of inappropriate products and material combinations on the formation of building defects can be evaluated as comparatively high.

The critical questioning of tender patterns of producers, cost-efficient expertises and thereon basing refurbishment recommendations as well as product qualities can move even stronger into the center of awareness.

A product information though not always is orientated at the information demand of the users and planners. For these the retention of information about the mass and completeness of ingredients of convenience products in the consequence often is damage-prone.

It is notably, that especially these damage-proning convenience products are preferred for the refurbishment of half-timbered houses or modernisation by approx. 90 % of on their own planning and working owners. As detailed designations regarding the construction work are not arrogated in the building applications resp. the measures partly are not subject to approval, a higher-ranking exercise of influence or even control is excluded beforehand.

At the choice of the material and structural systems the question on the compliance of guidelines, laws and rules can lead to uncertainty at architects and engineers as well.

Seen from the judicial point of view all people participating at the construction are obliged to follow the „generally accepted technical rules“.[3] These are rules that theoretically are esteemed as good by scientists and are certain, that in practice consistently are known to skilled engineers with the recent level of knowledge and are proved of value because of continuous practical experiences. At framework refurbishments additionally important rules of sustainability as the application of ecologically sensitive and sanitary unobjectionable building materials have to be taken into account.[4]

According to BGH[5] it depends on the compliance with the accepted technical rules. By no means, these should be set identically to DIN standards. Not every time, faultlessness can be achieved by the use of DIN guidelines without further ado. It is not authoritative, which DIN standard is valid, but whether the construction work at the time of the acceptance complied with accepted technical rules.

Additional deficiencies due to bad workmanship with a percentage of at least 30% certainly could be reduced with a sustainable and in short intervals occurring control of the construction site.

Pic. 4 Performance deficiency: The fabric insert in the plaster coating ends approximately 2 cm before the external corner and is not fixed around it. The corner profile is not conform to the system and has been fixed insufficiently on the subsurface. (DFWZ QLB)

Insufficient craftsman qualities respectively carelessness at the accomplishment of sealing methods against moisture e.g. at walls and floors in moist rooms, connection of balconies, window connection joints and the fragmentary performance of air tightness measures, particularly at light internal insulation leafs, has to be named as repeated source of errors.

Todays established practice to commission the most economically priced offertory, with the benefit of hindsight turned out to be a fault. Due to lack of time workings are finished grubby or not at all. This rather could be avoided, if at the decision about a commission the most economic and the most expensive offers are not weighed that much and if among the remaining offers under technical respects intensifiedly is picked out.

[3] *see e.g. Bulidling regulation of federal state Sachsen-Anhalt, Vordruckverlag Weise GmbH Dresden, 2001, § 3 (4) General requirements*

[4] *Eßmann, F., Gänßelmann, J., Geburtig, G.; Energetische Sanierung von Fachwerkhäusern, Die richtige Anwendung der EnEV, Fraunhofer IRB Verlag, 2005, S. 81 ff.*

[5] *BGB § 633 (Mangelbeseitigung). [IBR 1998, Privates Baurecht, S. 377]*

Pic. 5 Surface of infill and framework lumbers (coating and plastering) have been affected by anchoring roots of plants. (DFWZ QLB)

Likewise, circa $^{1}/_{10}$ of the damages could have been avoided by regular fostering, maintenance und repairs of half-timbered houses.

4. Conclusions

As from both the 3rd Building Deficiency Report („Bauschadensbericht“, 1996) of the federal ministry for civil engineering and land use regulation and the 2nd Building Deficiency Report by DEKRA (2008) can be gathered, parallel to tightened energy saving demands a considerably growing loss of historic house building stock, above all of half-timbered building house stock have been occurred.

Increasing refurbishment activities and simultaneous take over of new building standards, that are mostly not suitable for the refurbishment of half-timbered houses however, can be implicated in politics around the end of the 20th century.

- 1970s Energy crises (oil crisis)
- 1976 Energy saving bill (EnEG)
- 1977 First heat protection ordinance (WSchV)
- Thereafter state-run funded agendas for future investitions
- 1990s Growing construction activity in newly-formed German states
- 2002 Union of WSchV + Heating system bill = EnEV
- Amendments of EnEV - today EnEV 2009

In consequence of several coincident reasons it turned out that mainly basic, building-physical basic principles were broken. Because of that the moisture balance of the whole structure was destabilized and caused considerable damages.

Regarding the increasing requirements of the EnEV enacted by the federal government in comparison with the developed bulletins 8-1 to 8-9 and supplementary sheets for the repair of frameworks by the “Wissenschaftlich-Technischen Arbeitsgemeinschaft für Bauwerkserhaltung und Denkmalpflege e.V.” (WTA, www.wta.de), an increasing discrepancy of an implementation without damage, particularly of additional insulating measures, as well as increasing uncertainty of planners, craftsmen, energy consultants and owners becomes visible.

The WTA advises the usage of capillary-active building materials for infillings, insulations and

coatings and heat-storing building materials for interior insulation as well as aiming the minimal thermal insulation according to DIN 4108-2 and the waiving of interior insulated constructions with static air layers and opened connecting joint (e.g. lightweight wall constructions with fibre insulating material). Therefore, construction materials with a heat conductivity class (WLG) of 045 to 170 are suitable. These hardly can fulfill the requirements of EnEV 2009, because due to the increasing layer thickness on the one hand the humidity balance inside the exterior wall degrades and on the other hand an unacceptable loss of the usable floor space connected with additional static problems is to be expected.

In contrast, if the meeting of EnEV 2009 requirements is wished or forced, e.g. for the interior cladding of an external wall (AW3-cladding, formworks, interior insulation), with a needed coefficient of heat transmission U of 0,35 W/m²K, generally fibre insulations or polystyrene composites would be applied, which would due to the not existing capillarity reduce or inhibit a drying out of moisture (in liquid phase) outwards or inwards – whereby an asset erosion is preprogramed mostly.

To solve this conflict currently possible exemptions and exception from the requirements of the EnEV exist, which may not be known to all planners and rarely known to craftsmen and owners.

The results of the building deficiency project point up, that still deficits at planning services and the manual implementation of the framework refurbishments persist. Although basically the coincidence of several unfavourable factors led to the damage in the end, the begin of the chain of damages is in the planning of refurbishment measures by 75%. Above all, this is related to the method of choosing and combining building materials, building components and system, as well as the misinterpretation of therefore resulting building climatical changes. The aspect of a “low-cost refurbishment” mostly is in the foreground of the considerations; constructional relevant viewpoints, as e.g. influences of atmospheric conditions, influences rising from the user behaviour, technical possibilities and limits of a durable joint sealing in half-timbered houses, use of calculation methods and simulation software in their significance are underestimated.

From there the level of knowledge of craftsmen, planners and institutions should be improved notedly with the aid of extra-occupational qualification measures, but also vocational preparational yet with the aid of tutorials and lecture courses for students a higher standard of knowledge should be aspired.

To collect more damage-dealing refurbishment objects on the one hand the questionnaire is published in the appendix of the guideline, and, on the other hand, will be handed out respectively forwarded to planners and monument conservators on the part of the framework centre – with the asking for the use at particular damage documentations by the processor and return consignment for the evaluation of the results.