

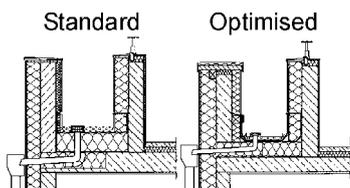


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*Sample from German study.  
Component joint of a roof terrace  
in standard (left) and optimised  
(right) design.*

## Analysis of Execution Quality Related to Thermal Bridges

Execution quality can have a significant effect on the energy consumption of buildings. The occurrence of thermal bridges due to faulty execution can increase heat losses dramatically and in the worst case even result in moisture problems and have a drastic impact on the indoor climate. At present, there is little or no information available on this topic. Therefore, a study has been set up within the framework of the ASIEPI project funded by the Community's Intelligent Energy Europe programme, to collect information from each of the participating Member States (MS) concerning execution quality. This paper presents the results of that study along with a proposal for stimulating and checking execution quality.

### 1 > Effect of thermal bridges due to faulty execution

It is a well-known fact that thermal bridges can increase the transmission heat loss of buildings significantly, especially as we move towards higher and higher insulation levels in both our new and existing buildings. Thermal bridges have been the focus of many studies in Europe over the last decades and today we have at our disposal highly developed calculation tools along with thermal bridge atlases for assessing their effect. This presents an opportunity to minimise thermal bridge effects during the design phase of a building project; however, in the transition from theory to practice there is a risk of introducing thermal bridges due to faulty execution.

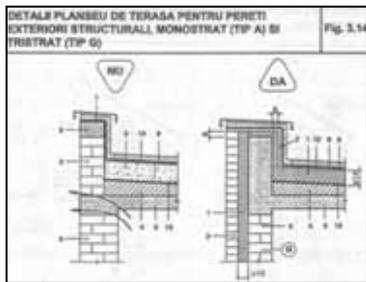
This paper does not include thermal bridges occurring due to air movement inside constructions (convection), air tightness etc. The latter are dealt with in a separate work package of the ASIEPI project.

A study was set up to quantify the effect of thermal bridges due to faulty execution. The study encompasses two different analyses: 1) a survey among the participating MS concerning previous individual national studies on the influence of execution quality and 2) a questionnaire containing questions pertaining to methods for assessing and stimulating execution quality, i.e. an attempt to quantify what affects the execution quality.

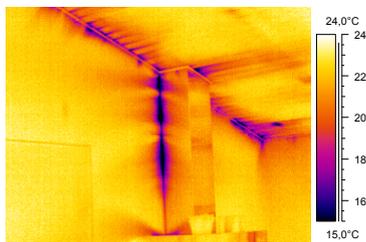
### 2 > Summary of existing studies concerning execution quality related to thermal bridges

Only a few studies exist on execution quality with regard to thermal bridges among the participating MS.

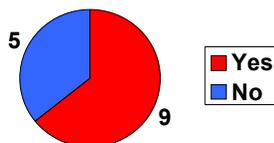
In Germany, a study was made on Burgholzof in Stuttgart where approximately 800 low energy accommodation units were built [1]. The building process of 39 multi-family houses was monitored and the purpose of the study was to supervise 3 parts of the building process, i.e. 1) energy



Sample from Romanian study. Detail of the connection between external wall and terrace, bad (NU) and good (DA) solution.



Determining positions of thermal bridges in building constructions by infrared thermography.



Is infrared thermography used on new buildings in your country?

performance certification, 2) check of building joints in both the design and realisation phases and 3) check of building materials used on the construction site. The study showed that there were on average 2.8 critical design details per building that needed to be corrected. On-site visits resulted in more than 100 protocols concerning both material choices and execution of building details. All in all execution quality was good; however, the recommendation was to have building inspections during execution in future buildings to avoid defects and increased energy losses.

Romania reports three studies that were performed nationally; two studies deal with experiences from existing buildings (retrofitting) and one deals with experiences from new buildings. The first study [2] contains general solutions for increasing the energy performance of existing buildings by renovating especially construction joints (thermal bridges). The study focuses on 37 details that are critical parts of the construction. The second study [3] shows typical building details for 23 cases that are relevant for new buildings. This study shows both good and bad solutions in order to emphasise the importance of correct execution. The third study [4] from Romania is a normative reference concerning methods for assessing the execution quality in existing buildings. Among others, infrared thermography is suggested as a method to assess execution quality.

The England and Wales 2010 proposals include inclusion of so-called safety factors for claimed thermal bridge heat losses that are not accredited and well-tried details. These safety factors are introduced because they might cause problems with regard to execution quality (i.e. since builders have not used them before they are more likely to make mistakes), and furthermore hence their values (linear thermal transmittances or point thermal transmittances) are uncertain. Evidence for theoretical values will be required - in principle - so that uncertainty should not be any greater than for accredited details. Execution quality is certainly a concern for unfamiliar/untested details.

### 3 > Summary of questionnaire concerning assessment and stimulation of improved execution quality

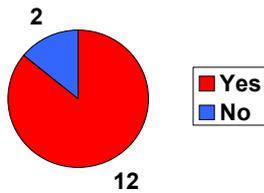
A questionnaire was distributed among the participating MS in the ASIEPI project, in order to establish the state of assessing and improving the execution quality. The results are summarised in the following.

#### Infrared thermography

Infrared thermography is the most powerful technique for determining position and to some extent magnitude of thermal bridges in existing buildings. The technology has developed a lot over the last decades, and today everyone can operate FLIR (Forward Looking InfraRed) cameras. Prices have also plummeted, and today cameras can be purchased at prices below €3,000, making it a cheap and easily accessible technology.

Infrared thermography is not a legal requirement in any of the participating Member States. Infrared thermography is in general not used extensively anywhere and is primarily used in connection with low energy buildings, research or education projects or under circumstances where there are judicial disputes concerning building execution quality. Either infrared thermography is used by itself to locate thermal bridges -or it is used in connection with blower door tests to establish the location of air leakages.

In Denmark, infrared thermography is used on some new buildings. There is a legal requirement in the Danish Building Regulations stipulating that at least 5 % of new buildings should be tested for airtightness by blower door,



Are inspections carried out during and/or after the building process of new buildings in your country?



and that this test should always be accompanied by infrared thermography in order to pinpoint the location of any leakages. It is the responsibility of the local authorities to ensure that this part of the Building Regulations is fulfilled.

Finland lists infrared thermography as part of the normal quality control for new buildings; however, there is still no legal requirement to perform the analysis and it is up to the future building owner to request a test.

### Building inspections (during and after the building process)

Building inspections with focus on energy during and after the building process of new buildings is a method for ensuring that the building is realised as originally planned. In opposition to infrared thermography, building inspections can be carried out during the building process, making it possible to pinpoint and correct any faulty execution before the building is finished.

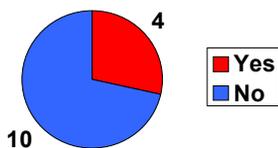
In the MS, there is a general tendency towards the use of inspections during and after the building process - especially for larger buildings. In most countries, there are legal requirements for inspections; however, these inspections seldom/never focus on energy consumption and thermal bridges, but rather on health, safety, structural elements and load-bearing capabilities. In some MS, the inspections also serve the purpose of ensuring that the realised building follows the design specifications used for obtaining the building permit.

In Italy there is a legal requirement for inspections during the building process and it is the responsibility of the local authorities that they are performed. In practice, however, inspections are rarely carried out due to limited resources (financial and human) of the local authorities/provinces.

Romania has mandatory inspections during the most important phases of the building process, but they do not include focus on energy use or thermal bridges. At the end of the building process, the local authorities and the Government Building Inspectorate will perform inspections to ensure that the realised building is as originally planned.

Norway has recently drafted new rules, proposing compulsory independent third party inspections after the building process. The rules are expected to be introduced in 2010.

Denmark uses a third party energy certification scheme for all new buildings. The certification covers all energy-related installations/parts of the building that can be inspected visually (pipe insulation, boiler characteristics, fan power usage etc.).



Do you have any other specific methods for assessing execution quality in your country?

### Alternative methods for assessing and stimulating execution quality

The participating MS were asked to list any alternative methods used in their individual countries for assessing and stimulating execution quality.

Finland mentions that a few specialised consultants have equipment for performing gas-concentration measurements of gas-filled windows.

In Germany, visual checks (inspections) are performed with specific focus on checking for thermal bridges if requested by the building owner. Comparing details on the construction site with design drawings makes this task easier.

For some building projects, Norway uses especially trained people to

investigate the building design before the building process is initiated. This investigation focuses on weeding out details that may cause problems. Any problematic details found through the investigation can then be redesigned. The investigation will typically also result in a series of suggestions concerning specific inspections or measurements that should be carried out during the building process.

#### **Incentives or penalties to stimulate/ensure good execution quality**

A method for stimulating/ensuring good execution quality is to have incentives and/or penalties. The participating MS were asked in the questionnaire to list any incentives/penalties used in their respective countries.

All countries penalise bad execution quality and most have penalties that have direct (fines) or indirect (halting the building process or prohibiting building use) economic consequences for the building contractor. In the most serious cases, the responsible executive manager and/or technical supervisor may lose their certificates/licenses.

Only a few countries have incentives for stimulating good execution quality. Typical incentives come in the form of governmental funding or reduced taxes for building low-energy buildings or passive houses. The incentives are typically connected with time-limited programmes.

#### **4 > Proposal for stimulating and assessing execution quality**

The final question of the questionnaire asked the participating MS to list any suggestions they had for stimulating and assessing execution quality. Based on their answers we have drawn up a proposal for stimulating and assessing good execution quality.

##### **Sticks:**

- > Inspections by energy specialists before, during and after the building process (photos, measurements)
- > Increase number of mandatory blower door (IR thermography) tests (e.g. to 15% of all new buildings), and utilise the IR results.
- > Possibility of withdrawing license of designer/contractor
- > Bad examples done by building contractors should be published

Having inspections before, during and after the building process would be the best solution; however, for economical reasons this will not be viable for all new buildings. The extent of the inspections should be adjusted for each building project, yet energy specialists should always be included.

Building contractors will be forced to focus on execution quality by increasing the number of mandatory blower door tests and at the same time use IR thermography for thermal bridges rather than just air tightness.

Introducing the possibility of withdrawing the license of a designer/-contractor for repeatedly providing poor execution quality could centre their focus on this issue significantly. However, it is a question whether this could function in practice (maybe in some MS). Instead, making information publicly available concerning a contractor's level of execution quality - both good and bad - could have a more positive effect on execution quality.

### **Carrots:**

- > Funding programmes
- > Reduction of green taxes and interest rates for low energy buildings/passive houses
- > Good examples done by building contractors should be published

Funding programmes are powerful incentives for increasing focus on execution quality, and previous experience has clearly shown that economic incentives work well. The reduction of green taxes and/or interest rates for low energy/passive houses will reduce the operational cost of the houses further. This will increase the demand for this type of houses and thereby decrease their price, meaning that construction companies can cover the extra expenses associated with low energy buildings.

### **Other:**

- > Courses for designers and construction company staff or craftsmen on how to design and realise building joints with focus on air tightness and thermal bridges
- > Good practice guidelines. In general passing on expert knowledge concerning the understanding of the key elements of low energy building and good workmanship
- > Introduction of U-Values that take into account the installation of windows. This would motivate the window manufacturers to have stronger guidelines for installation, and thereby more training for installers

The continued education of designers, construction company staff and craftsmen with respect to execution quality will help realise future goals concerning the further reduction of building energy consumption. In addition to education, good practice guidelines will be helpful in passing on the latest expert knowledge from theory to practice. A specific information paper on good practice guidelines for preventing thermal bridges written by IEE ASIEPI will soon be available.

## **5 > Conclusion**

This IP deals with execution quality and in particular with methods for assessing thermal bridge effects due to faulty/poor execution quality, and methods for stimulating improved execution quality to avoid/reduce thermal bridge effects.

A questionnaire distributed among the participating MS shows that only a few studies have been carried out concerning the relationship between execution quality and thermal bridge effects. These studies indicate that there is a need for increased focus on execution quality.

The questionnaire also shows that the MS use more or less similar methods for assessing and stimulating improved execution quality. Infrared thermography is used to some extent, but is not yet a legal requirement anywhere. Inspections during and after the building process are used quite extensively in all MS, especially for large buildings. Most MS have legal requirements regulating inspections; however, these do not focus on energy consumption or thermal bridges. There are only very few alternatives to inspections and infrared thermography and they include gas concentration measurements on windows and pre-building process inspections of drawings by specialists. Finally, the questionnaire shows that most MS use sanctions rather than incentives to ensure good execution quality.

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Based on suggestions from the participating MS, the IP presents a "proposal for stimulating and assessing execution quality". The proposal contains different measures described as sticks and carrots, which contribute to better quality. The proposed measures are aimed at different target groups but for most of them, it is the policy makers, who will be responsible. Establishing requirements for a specific amount of inspections and for mandatory blower door test, for the possibility of withdrawing a license; all this is something that requires rules. Furthermore, reduction of green taxes and interest rates for low energy buildings/passive houses and funding programmes are also the responsibility of policy makers. Then the standardisation bodies have to follow up and prepare the standards. The building industry and the building practitioners have to arrange courses for designers and construction company staff or craftsmen on how to design and realise building joints with focus on air tightness and thermal bridges. In addition to education, good practice guidelines will be helpful in passing the newest expert knowledge from theory to practice and this is the responsibility of building industry.

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