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A METHOD FOR BLIND VALIDATION OF HYGROTHERMAL CALCULATION TOOLS

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Abstract

The use of hygrothermal calculation tools for dimensional purposes in the design phase is common. However, used tools are usually not blindly verified in real, on-site conditions.

This paper present a method for verification of hygrothermal calculation tools for real-life, situations. In the method calculations become carried out before the measurement results are known, i.e. by blind calculations, which afterwards are compared with measurements.

The main conclusion is that blind validations are reliable since intentional or unintentional adjustments of calculated results, to obtain better correlations to the measured values, are impossible. Other positive effect is that information about how the user perceives the tool could be found since the blind calculations are similar to the designer situation in daily work.

1 INTRODUCTION

1.1 Background

Laws and regulations require that energy need, indoor climate conditions and moisture safety should be estimated and analysed during the design phase, before a house is built [1]. There are several available calculation tools that could fulfil this purpose, such as IDA ICE, VIP-Energy, DEROB, WUFI, DELPHIN, HAM-tools etc. [2, 3, 4].

Known calculation tools are based on physical laws using established equations calculating the relationship between different factors affecting energy need, indoor climate or moisture distribution. After complete calculation the tools return an answer of calculated parameters, such as energy need, temperature, moisture distribution, indoor climate or moisture transport.

In general, known calculation tools are verified according to standards, BESTEST (Building Energy Simulation TEST) or other methods which contains comparative-, analytical- and empirical validation process [5, 6, 7, 8, 9]. A comparative validation is based on calculation results compared with results from other equivalent tools. In an analytical validation the results become controlled, often in different parts, to reference results taken from established equations. An empirical validation include laboratory-, field- or on-site field

test. Some validation methods show weaknesses in the empirical validation process [9]. In many situations there is a lack of available experimental empirical investigations [10].

Lack of complete knowledge and reliable equations complicate analytical and numerical methods in some situations, such as moisture transport in materials. Simplifications have been made where there was a lack of knowledge, in parts with minor influence on the results or parts of less importance. There are hygrothermal calculation tools that besides physical laws and established equations focus on empirical validations in laboratory and field test including initial boundary conditions and surrounding climate boundary data [10, 11, 12, 13]. One tested tool showed good correlations in a real situation with real conditions [14, 15].

Compared to other areas, such as medicine or drug-, foods and drinks-, animal food, cosmetics, safety-, pesticides and chemicals development and testing used validations were based on the framework of Good Laboratory Practice, GLP. Principles for GLP are governed by law in compliance with EU directive, which include inspection programs [16]. In science, several of those areas were treated using different kind of blind or double-blind tests in order to reach safe and reliable results. GPL requirements for the computerized systems consist of documentation, training, back up, security etc. However, GLP also introduce the term "acceptance testing". This means that computerized systems should be tested in its anticipated operating environment to determine whether the system is acceptable for operational use [17].

In the construction industry, hygrothermal calculation tools are used in the design process for dimensional purposes, i.e. estimating the outcome in unknown future on-site conditions. The users are not aware of, and could not estimate, precise future real upcoming outcome in designed building, depending on surrounding factors such as, climate, material properties, human behaviour etc. Hygrothermal calculation tools for dimensional purposes in the design phase are therefore in a context carried out blind, i.e. the user could only guess future results.

Empirical validations are mentioned in standards for hygrothermal calculation tools, but it is not specified if they should be carried out in laboratory, field tests or real on-site conditions. Developer also point out the problem with lack of empirical, especially on-site, tests [10]. Furthermore, standards do not mention that tests should be blind, as the case when using the tools in reality. Non-blind tests make it possible for the developer to consciously or unconsciously adjust calculated results to get better correlation with expected or wanted results. In a context this means that standards for verification of hygrothermal calculation tools do not fulfil the requirements within GLP since the calculation tools not become blindly verified and not tested in real on-site situations. Interior factors within the calculation tool or exterior factors, such as a varied vegetation shading, that are impossible to take into account in a tool might affect the calculation results on a significant manner.

Standards for validation of hygrothermal calculation tools do not consider limitations in usability. Some reports indicate that simplified and inappropriate input data is responsible to more deviations from real, wanted or expected values than defects in the calculation tool [18]. Lack of correct applied input data may depend on unsuitable users, poor usability or both.

This paper presents a blind method to validate hygrothermal calculation tools under real on-site conditions, or laboratory situations, including possible influences of usability using real climate boundary conditions.

1.2 Aim

The aim of this study was to present a blind method in a real context, including simulation of real situations for the users, in order to validate hygrothermal calculation tools in a reliable

manner. The purpose was also to show examples of important findings by using blind method and other positive effects that could be reached using blind validation methods.

1.3 Limitations

This study does not deal with developer sensitive tests. The software development process for the hygrothermal calculation tools, such as equations, numerical technique etc., was not considered in detailed. The examples in the paper were limited to a blind case study carried out in wooden framed houses in northern European climate conditions.

2 BLIND METHOD

A blind method means that calculations are made without knowing the results from the measurements. By definition the blind comparisons in this paper could also be called single-blind. Notice that the method used is not double-blind since it is possible to guess the measured results before the calculations are made. Examples where the single-blind method has been used are an empirical study where the unknown values consist of measured values.

Using blind calculations the situation become equivalent to when the designers calculate energy need, indoor climate or heat- and moisture transport before a house is built. Below presented blind method is rather simple and it makes you think why it is not more often used.

2.1 Ambient factors

In order to reach reliable output running the blind validation of hygrothermal tools, there was a need to take into account a number of ambient factors mentioned below.

1. Calculator - The person that runs the calculations in evaluated tool.
   To get a reliable situation the blind calculations should be carried out by a person (calculator) that are independent from the developer. The calculator should be a possible user and his level of knowledge corresponding to the lowest limit for a user.
2. Test objects, i.e. houses - Houses where calculations are carried out to validate the tool.
3. Measurements equipment - Measurement equipment to collect data to be compared with blind calculated values.
4. Measurement collector - The person that collects measurement data and keeps it hidden from the calculator until the calculation were finished and reported.
   The measurement collector should be independent from the developer.

2.2 The blind validation method – step by step

This section presents a step by step "manual" how a blind validation can be done. Especially important factors that have to be fulfilled are found in step 11-16.

1. Determination of test objects, i.e. houses.
   The test houses in which measurements and blind calculations are carried out should be representative for cases where evaluated tool aims to be used. Since the outdoor climate conditions will influence the results it is recommended that test houses are located in different regions, i.e. north-, east-, coast- and inland climate conditions [15].
2. Determination of positions to be used for validation in selected houses and envelopes.
   Depending on the purpose of the validation different positions could be chosen. The positions should be selected in a manner that they cover the purpose of the validation, i.e. all parameters included in the validated tool should be included. Each position should be motivated for the specific case. Relevant in- and outdoor climate boundary

conditions should be continuously measured. Other factors, which might affect the results, such as two-dimensional effects in one-dimensional calculations, should be documented and if possible be included in the measurements.

3. Calibration and testing of measurement equipment.
Calibrate measuring sensors and control measurement equipment before mounting.

4. Installation of measurement sensors in chosen positions.
Each position where measurement sensors are mounted should be documented, preferably both with drawings and photos. Chosen positions can be known for the calculator. Sensors could be mounted in the construction phase to study the influence of initial incidents during construction. Possibilities for a second calibration should be taken into account when mounting sensors, especially in occupied houses.

5. Monitor the construction phase.
In order to notice possible deviations between the drawings and the real conditions in studied positions the construction phases in studied houses might be monitored. Factors and boundary conditions that affect the results, such as a high level of construction moisture etc. should be noticed and if possible applied in upcoming calculation model.

6. Start and maintain measurements.
Measurements preferably start as soon as possible, even before the houses are completely built and occupied. The measurement collector controls that the measurements start and independently stores all results inaccessible to the calculator. The measurement collector should control the quality of the measurements during the measurement period and if necessary ensure that measurement equipment is repaired.

7. Design and calculation model.
When measurements are carried out, calculation models of studied positions are made. Calculation models are based on drawings and photos etc. from the construction phase and sensor mounting with the intention of reflecting real conditions as well as possible. Parameters, boundary conditions etc. should be documented. Deviations from reality, such as one-dimensional calculations in a two-dimensional situation should be noticed.

8. Perform test calculations.
As a part of a real situation in the design phase, test calculations of made calculation models are made, preferably using similar climate data. The reliability of the results should be evaluated and needed adjustments in calculation model should be made [19].

9. Sensitivity tests.
As a part of a real situation in the design phase a sensitivity test of the parameters that might have a high influence on the results should be made [19]. The sensitivity test could be made as a parametric study and should be documented.

10. Receive real in- and outdoor climate boundary conditions.
When the measuring period is completed, real in- and outdoor climate boundary conditions are received. Real climate boundary conditions are needed in calculation models to obtain calculated results that are comparable to on-site measurements [15].

11. Calculations for validation.
When real in- and outdoor climate boundary conditions are received (10) these are used in calculations for each studied position, without knowing the measured results.

12. Calculator deliver calculation results to the measurement collector.
After completed blind calculations (11), the results are sent to measurement collector.

13. Measurement collector receives results from measurements.

After calculation results have been received (12), the measurement collector compiles measured results and if possible makes a second calibration of measurement results.

14. Measurement collector sends measurement results to the calculator.

When the measurement collector receives the blindly calculated results (12) from the calculator the previously inaccessible measurements are open and sent to the calculator.

15. Calculator compare measured results with calculated values.

When received previously inaccessible measured values (14), measured and calculated values are compared and published together. This must be done regardless of possible correlation or deviations. The comparison also could be carried out by a third person.

16. Control of published measured and blindly calculated values to original values.

The measurement collector check that published values (15) are consistent with originally sent (14) and received (12) values, i.e. control that no adjustments are made.

17. Analyse and report deviations between measured and blind calculated results.

Possible reasons for deviations are analysed, documented and if possible explained.

3 EXAMPLES AND COMMENTS OF RESULTS FROM BLIND COMPARISONS

In this section some examples of results from a blind validation of a hygrothermal calculation tool are presented and briefly commented in a context to above presented method. The results were presented using the Folos 2D visual mold chart [20]. A simple figure of the conditions for each presented figure was given together with each chart. A complete description of studied cases could be found in separate reports and papers [14, 15, 21].

3.1 Influence of air flow in the air gap behind a cladding

Comparison of measured (black), blindly calculated (turquoise) and non-blind calculated (brown) temperature and relative humidity (RH) in a wood framed wall.
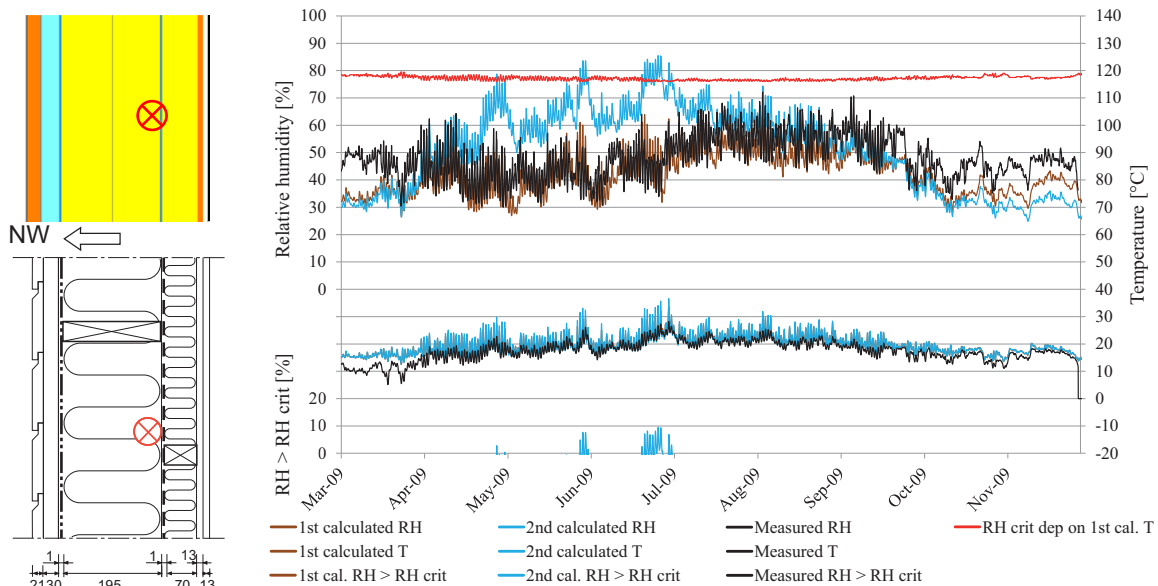

Figure 1: Comparison of measured (black), blindly calculated (turquoise) and non-blind calculated (brown), with adjusted air flow in the air gap, temperature and relative humidity in a point located outside the vapor barrier.

The results are taken from a paper in which more detailed information can be found [15, 21]. The difference between the blind and non-blind calculations was that the air flow in the air gap behind the cladding was increased. If the validation in Figure 1 was non-blind and/or performed by the developer it is probable that only the good results in the second case are presented. This would have hidden the important information that the air flow is of high importance for the moisture conditions in the wall and to obtain reliable results.

3.2   Deviations in relative humidity caused by differences in temperature

Comparison of measured and blind calculated temperature and RH in a wood framed wall. The results are taken from a paper in which more detailed information can be found [14, 15].
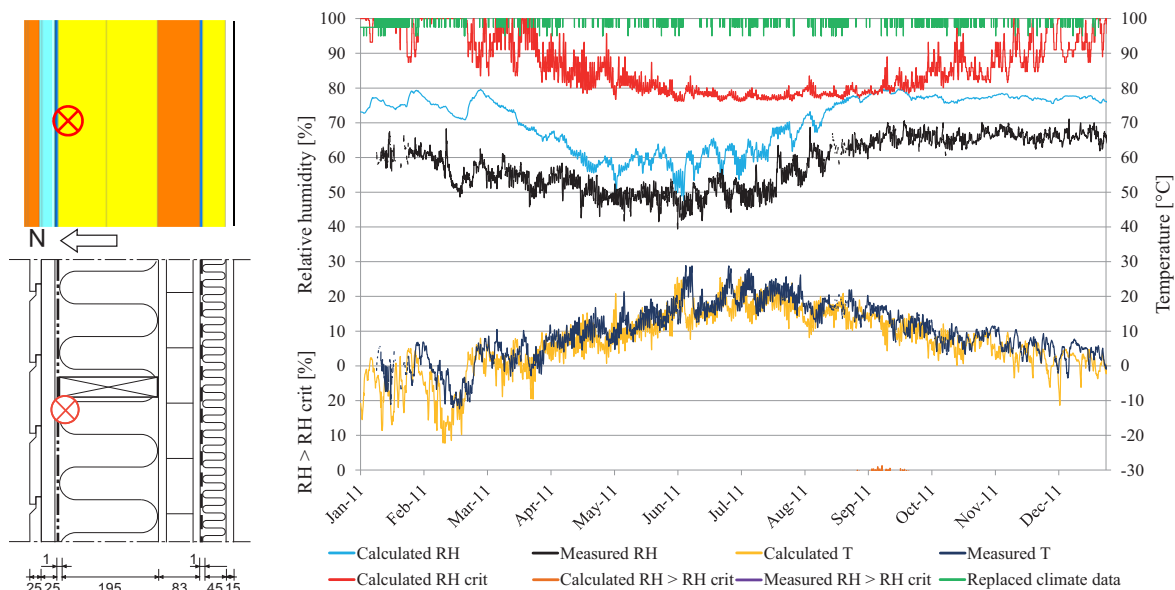

Figure 2: Comparisons of measured and calculated RH and temperature in the exterior part of a wall. Calculated RH (turquoise) and measured RH (black). Calculated temperature (yellow) and measured temperature (dark blue). RH_{crit} derived from the calculated temperature (red). Calculated RH > RH_{crit} (light brown) and measured RH > RH_{crit} (purple). Periods with artificial climate boundary data (green).

The lower measured relative humidity in Figure 2 depends on a higher measured temperature. I.e. the vapor content is the same but different measured and calculated temperatures give different vapor contents at saturation. However, minor adjustments of precise studied point in the calculation model gives a higher calculated temperature and later on create better correlation between measured and blindly calculated values, which might have been the case with non-blind calculation carried out by the user. Besides that it might be an imprecise location of studied position in the calculation model the divergence between measured and blind calculated values might depend on a thinner insulation thickness caused by the measuring sensor size or the air space around the measurement sensor [22]. Furthermore, in this case there were not any possibilities for a second calibration [15].

3.3   Differences in measured and calculated amplitude

Figure 2 also show that measured RH and temperature have higher amplitude compared to calculated values. This could be adjusted for in the calculation model by decreasing the heat

and moisture capacity for the insulation material. However, the most probable reason for the higher amplitude in measured values is the air gap which surrounds the sensors [22].

4   DISCUSSION

The main reasons for blind validations are that they give a higher reliability to evaluated tool. A blind evaluated tool also creates reliability for upcoming parametric studies using the same tool. Using blind validations reduces the focus on only reaching correlation to measurements or other results, into finding and explains important factors affecting the results; understand how the tool works both theoretically and by the users. After the house is built it is important to investigate which significant factors that is important for deviations to calculate values. For researchers it is also the deviations that lead to new findings and discoveries.

Blind validations indicate if and during what conditions evaluated tool is possible to use in reality. In commercial hygrothermal calculation tools there are also financial purposes which may create reasons to adjust calculation results. It is helpful to point out useful boundary conditions and other input data, such as relevant air flows in façade air gaps, as showed in Figure 1. Recommendation of reliable input data might also limit the problem with inaccurately applied input data to reach a wanted, but incorrect result. Unconscious applied defect input data could also ruin the results from a good calculation tool [18].

Blind on-site validations give a direction on sensitivities to be expected dependent on factors that not is possible to control, such as in- and outdoor climate and occupant behaviour. Studies show that those factors might have a significant influence on the results [15, 18].

In general, houses of today become evaluated when steady state conditions are reached. By implementing the validation in the construction phase the influence of possible incidents during the construction phase that can affect the house during several years might be visible.

It should be mentioned that non-blind comparisons might be needed in the development phase of calculation tools. However, blind methods force developers, researchers or testers to reflect in a kind of trial and error situation during the validations process. By practicing this it can be assumed that the persons gaining experience, which may be valuable in future work.

5   CONCLUSIONS

Hygrothermal calculation tools used in the design phase, before a house is built, ought to be blindly verified and without being influenced by the program developer. This can be fulfilled by carrying out the calculations before the results of the measurement are known, i.e. by blind calculations, which afterwards are compared with measurements.

Blind validations are reliable since intentional or unintentional adjustments of calculated results, to obtain better correlations to the measured values, are impossible. There are also other positive effects since the blind calculations are similar to the designer situation before a house is built. This provides important information about how the user perceives the tool and trains users, researches and developer to make accurate estimations and improvements.

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