ANALYSIS OF CLIMATE CONDITIONS IN CRAWL SPACES WITH HIGH INSULATED WOODEN FLOOR PLATES FOR PREVENTION OF STRUCTURAL DAMAGES

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ABSTRACT: Highly insulated wooden floor plates in combination with crawl space constructions for foundations of residential and functional timber-buildings were more frequently applied in the last years. Missing knowledge of micro-climatologically conditions in crawl spaces and the resulting boundary conditions for timber and wood-based panels led to various constructional designs. By long term in-situ measurements and laboratory tests, design principles which guarantee a durable use of wooden floor plates in combination with air ventilated crawl spaces were developed. For German climate a rating to use class 1, of EN 335 (class 0 according DIN 68800) becomes possible.

KEYWORDS: Crawl space, Durability, Moisture, Wood preservation

1 INITIAL SITUATION

Common foundation types of timber buildings are foundations with cellars and reinforced concrete floor plates. Raised constructions on point or line foundations are typical as well. In the last years the most common foundation type with reinforced concrete floor plates showed some disadvantages, particularly in combination with energetically very efficient constructions. In alternative to these, constructions with wooden floor plates above crawl spaces (Figure 1, Figure 2) or steel girders with point foundations were frequently carried out. Especially ventilated crawl spaces offer new possibilities in combination with wooden floor plates. This kind of construction has a long tradition and distribution in North America, Scotland, the Netherlands and primarily Scandinavia and opens new opportunities for wood constructions in Germany as well.

In comparison to foundations with cellars or reinforced concrete floor plates these constructions have the following advantages:

- All wood components are raised from the splashing water endangered area.
- The reduction of concrete work leads to a decrease of moisture in buildings.
- A wooden floor plate gives easy the possibility for a high insulation.
- Raising the construction makes additional installations, the revision and if necessary the change of supplying lines possible.
- The air ventilation leads to the diminution of harmful gases (radon) in the crawl space and its entry to the living areas.

Figure 1: *Residential building with wooden floor plate and crawl space*

Figure 2: *Erection of wooden floor plate on concrete line-foundation*

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Due to missing experience and applications and caused by cases of damages in the seventies in Germany [1], no reliable information exist about the hygric and thermal situations (microclimate) in crawl spaces. Information about the service life of wooden floor plates - durability of timber and wood based panels and risk of mould - in dependence of outer climate, ground covering and ventilation conditions are not available.
In German standards and guidelines information is currently missing (according DIN 68800 and DIN 4108), therefore different types of construction of wooden floor plates over crawl spaces are erected
To be able to establish conditions for ventilated crawl spaces with highly insulated wooden floor plates, a research project of Technical University Munich and Leipzig Institute for Materials Research and Testing (MFPA Leipzig), with extensive laboratory examinations and several field studies at existing objects has been carried out. The examinations took into account different types of ground covers in the crawl space, different coverings of the wooden floor plates and varying ventilation situations under changing climate conditions.

2 BACKGROUND

The wooden floor plate is not an achievement of the modern kind of construction it was already used in a similar way in the Netherlands, Scandinavia and North America since the middle of the 19th century. In combination with crawl spaces this kind of construction currently belongs to the building standard.
Especially for wooden floor plates over crawl spaces the need of corresponding measures for the wood preservation has to be taken with care, to ensure a durable and damage free construction. International experiences [3] primarily place the ground covering and ventilation into the centre of the constructive arrangements, to influence the climate in the crawl spaces.
Primarily the degree of evaporation from the ground represents an important moisture source to the microclimate in the crawl space and therefore must be minimised.
The ventilation of the crawl space areas can reduce the moisture content by air circulation and avoid a continuous increase of moisture content of the building-materials. Moisture sources are: influx of moisture by outdoor air, condensation, ascending ground moisture, diffusion from the living areas and moisture from the erection of the building.
According to the international experiences [2], the most critical conditions for ventilated crawl space constructions appears in the summer months, warm outdoor air flow in through the ventilation and cools down in the cellar areas and leads to an increase in relative air humidity.
The air ventilation represents a thoroughly positive effect in the winter months, the cold and dry outdoor air flow in to the warmer cellar and leads a dehumidification of the crawl space.
Therefore air ventilation is always useful when the absolute outdoor air humidity is under the humidity of the crawl space.

3 EXPERIMENTAL RESEARCH

3.1 LABORATORY TESTS

The laboratory test building consisted of six single chambers, each with a area of 6,25 m², which allowed statements concerning to the exterior lining of the wooden floor plate, the type of ground covering and to the ventilating condition over the examination period.
The chambers were hermetically separated from each other, except chamber areas with the same ground covering.
For ground covering of crawl space three different types were analysed.

- Without ground covering (ground)
- Covering of polyethylene foil and gravel filling
- Covering of polyethylene foil and thermal insulation

The ventilating conditions under consideration of the insect protecting covering were between 4.5 cm²/m² and 13.5 cm²/m² in the examination periods.
Above the crawl space chambers the wooden floor plate with a mean U-value of 0,2 W/m²*K, with two different linings (cement particle board / wood fibre board) was erected.
The constructive details of the individual examination areas can be discerned from Figure 3 and Figure 4.

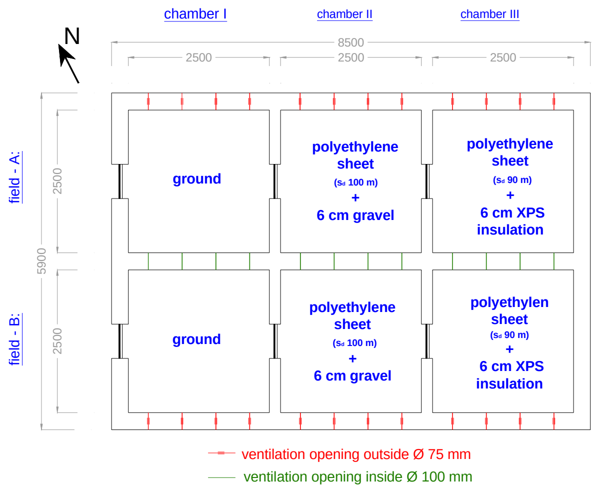

Figure 3: *Constructive detail – ground plan*

In the laboratory examination the climate conditions were controlled in the interior room to a temperature of 20°C and relative humidity of 50 %. Additionally the climate conditions in crawl space chambers and outdoor area as well as the air flow rate, amount of precipitation and the humidity of timber and wood based panels have been measured.

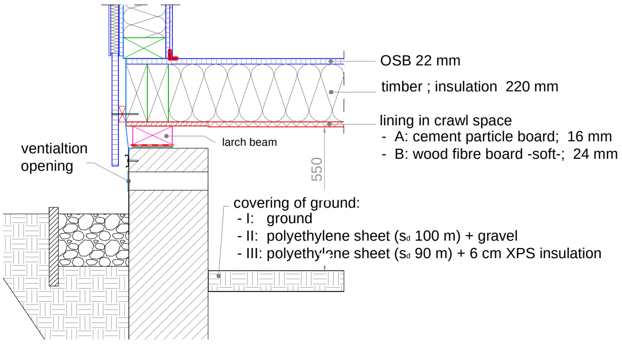

Figure 4: *Constructive detail – section*

3.2 FIELD STUDIES

In addition to the laboratory examinations in Leipzig, secondary examinations were carried out at existing objects with crawl spaces. All objects were examined visually and four also equipped with measurement instrumentation to evaluate and compare the influence of various construction conditions for the climate situation of crawl spaces. To achieve this, data logger were installed in the area of the crawl space, interior room and outside area which registered the temperature and relative humidity in the examination periods.

4 EXPERIMENTAL RESULTS

The test results from the laboratory and field studies can be summarized as follows [5]:

The climatic conditions in the crawl spaces are influenced by numerous conditions. Primarily the outdoor climate, the kind of the ground covering, the ventilation situation, the moisture during erection, the kind of construction of the wooden floor plate and diffusion have an importance.

With the measured results, a correlation of outer climate and crawl space climate could be derived from all examined objects. The ventilating led to a sinusoidal temperature run in the crawl space over a year and showed a clear amplitude recession of crawl space temperature in comparison with the outside temperature.

The reason for this is the additional influence of the ground temperature in crawl spaces which leads to warmer conditions in the winter season and to colder conditions in the summer season in comparison to the outside area. The average crawl space temperatures appeared at approximately 13 -14 °C for all examined objects.

The relative air humidity in crawl spaces runs asynchronously to the relative air humidity in outdoor areas. The most critical and moist conditions appeared as expected in the summer decades in ventilated crawl spaces. Especially in uncovered ground areas critical situations appeared. The relative humidity rose to 90 – 95 %, which led to mould growth in the wood fibre-board (Figure 5, Figure 6).

Figure 5: *Start of mould on wooden fibre board (07/2007)*

The additional covering of the ground with polyethylene - foil led to a reduction of relative air humidity by 10 - 15 % in the crawl space and minimised the maximum relative humidity too approximately 80% in the summer period. Another reduction of the relative humidity in crawl spaces for the summer period was achieved by an additional insulation of the ground. For the laboratory examinations in Leipzig, a further reduction of relative humidity of 2 - 3 % appeared in summer. In accordance to Scandinavian research work and in an additional field study, a greater diminution was not identified. The reason may be the high rate of boundary foundation area to base area. In all examinations, the ventilation of the crawl space in combination with the ground covering led to an average relative air humidity of approximately 70 % in the winter and therefore can be classified as uncritical. For the areas with additional ground insulation, insignificantly higher relative air humidity was recorded in the winter, due to the lower temperature in this crawl space area in comparison to the area with polyethylene foil covering. For all examined objects with ground cover and ventilation, no mould growth was recorded in the construction or crawl space.

The absolute crawl space air humidity of all examined objects differed only to a low extent from each other and showed as expected over one year a synchronous run with the temperatures. The absolute crawl space air humidity in the covered areas was approximately 1 g/m ³ over those of the outdoor areas. The difference minimised itself within the summer decades. For the uncovered ground areas in comparison with the covered areas an additional rate of absolute humidity by 1 - 2 g/m³ was recorded from the free ground evaporation.

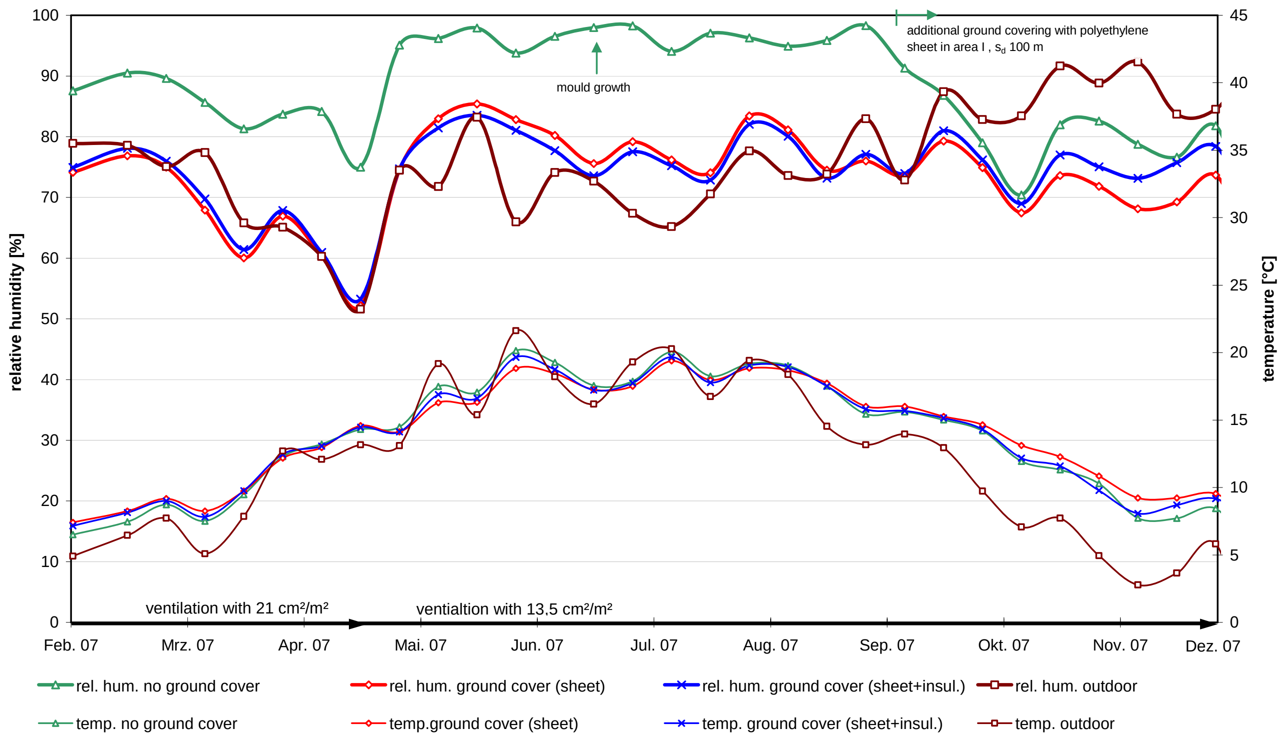

Figure 6: *Relative humidity and temperature in crawl space of laboratory examination – decade value*

The difference between absolute outdoor and crawl space humidity clarifies the influence of further moisture sources. Besides the diffusion through the foil covering and evaporation in the side areas between foundation and ground cover, the diffusion influence caused by interior climate conditions must be mentioned. In the examinations, the necessity of crawl space ventilation was also confirmed. The aforementioned climate conditions appeared for ventilating situations of 4.5 – 13.5 cm ²/m² (consideration of the diminution by insect protecting covers of ventilation holes). An air change rate > 0.5 per hour was recorded in the laboratory examinations. A low rate of ventilation with uniform distribution of ventilation openings over the foundation areas led to the most constant conditions in the examination periods. A completely unventilated period showed as expected a continuous increase of crawl space air humidity to critical conditions.

The examinations of ventilated and ground covered crawl spaces with wooden floor plates showed climate constitutions correspond to service class 2 according EN 1995-1-1. The moisture content under 20 % of wood materials in ventilated and ground covered crawl spaces exclude the rot of wood. A complete exclusion of the mould attack is not given on basis of these experimental examinations and international knowledge [4].

On basis of the research results for German climate conditions, the application of a capillarity not absorbent and vapour densities layers for ground coverings in crawl spaces is necessary. The further diminution of the humidity in crawl spaces in the critical summer seasons can primarily be reached by the additional application of ground and foundation insulation.

For the ventilation, a cross section area of 10 – 20 cm²/m² can be recommended, a consideration of the limitation by a usual covering (mesh) for insect protection is already contained in these values. The arrangement of the ventilation openings shall equally via the base. Per foundation chamber at least two openings shall be provided. Wood-based panels in direct contact with the crawl space air have to fulfil the requirements for use in service class 2 of EN 1995-1-1. This is given by boards classified for service environment - humid condition - in accordance to EN 13986. Boards of this type are suitable for use in hazard classes 1 and 2 of EN 335 - 3. Boards with special additive, composite or kind of production can additionally exclude a mould growth.

The beams inside the floor plate can dedicated to use class 1, according to EN 335-2, so no chemical treatment is needed.

The authors advise of - in addition to these specifications - an increased care and quality assurance of the planning until the erection when constructing crawl spaces with wooden floor plates.

5 CONCLUSIONS

On the basis of these research results, design principles which guarantee climate conditions in air ventilated crawl spaces, corresponding to service class 2 (according EN 1995-1-1) were developed. An exclusion of rot, resulting from a moisture content of wood materials under 20 %, is given. Furthermore an assignment of beams inside the wooden floor plate to the use class 1, according to EN 335 (class 0 according DIN 68800) is possible now.

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