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abridged report

Analysis of climate conditions in crawl spaces with high insulated wooden floor plates for the prevention of structural damages

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This work was promoted by Deutsche Gesellschaft für Holzforschung e.V. with funds of the Bundesamt für Bauwesen und Raumordnung.
BBR: Z6 – 10.07.03-05.18 / II 13 – 800105-18

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The responsibility for the content of the report lies with the authors.

Leipzig, 23rd of June 2008

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 over crawl spaces 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.

illus. 1 residential building with wooden floor plate and crawl space

illus. 2 erecting of wooden floor plate over concrete foundation

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.

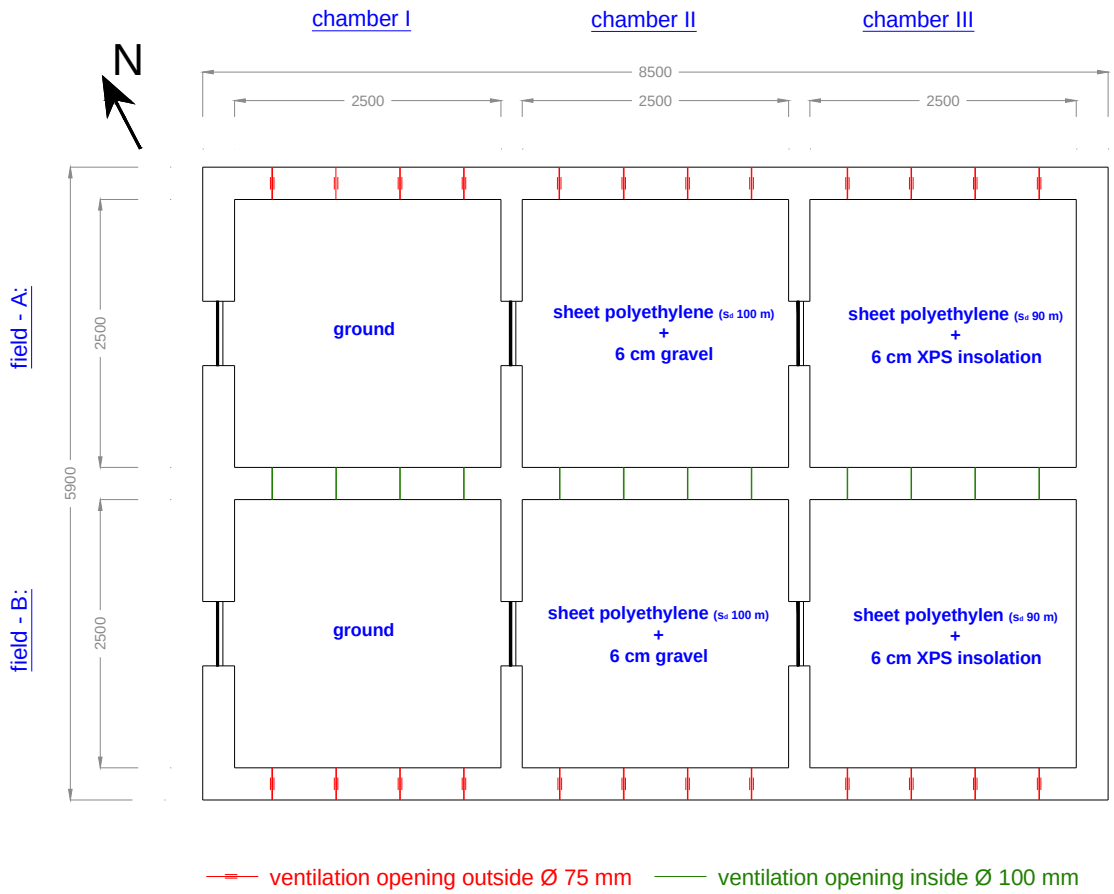
Due to missing experiences and applications in Germany, no reliable information exist about the hygric and thermal situation (microclimate) in crawl spaces.
Information about the serviceable life of wooden floor plates - durability of wood materials and risk of mould - in dependence of outer climate, 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 wooden floor plates a research project, with extensive laboratory examinations and several field studies at existing objects has been carried out from 2006 until June 2008.
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.

Background, international experience:

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 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 - penetrated outdoor air moisture, condensate, ascending ground moisture, diffusion from the living areas and moisture from the erection of the building.
According to the international experiences, the most critical conditions for ventilated crawl space constructions appear in the summer months, warm outdoor air penetrates 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 penetrates to the warmer cellar and leads a dehumidification of the crawl space.
A air ventilation is always useful when the absolute outdoor air humidity lies under the humidity of the crawl space.

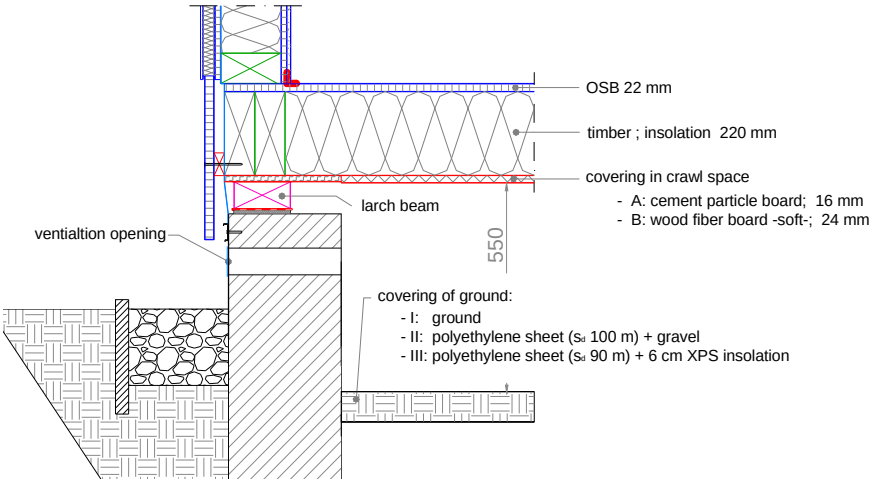
Description of experimental research:

The laboratory test building consisted of six single chamber areas, which allowed statements concerning to the kind of outer covering of the wooden floor plate, to the kind 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.
The ventilating conditions under consideration of the insect protected covering were between 4.5 cm²/m² 13.5 cm²/m² in the two examination periods. The constructive details of the individual examination areas can be discerned from illus. 3 and illus. 4.



illus. 3 constructive details

In the laboratory examination the climate conditions, including temperature and relative humidity were measured in the interior room, crawl space and outdoor area as well as the air flow rate, height of precipitation and the humidity of wood material



U-value:

(under consideration of wood areas)

$U_{m\ A}$ = 0.21 W/m²·K

$U_{m\ B}$ = 0.19 W/m²·K

illus. 4 constructive details

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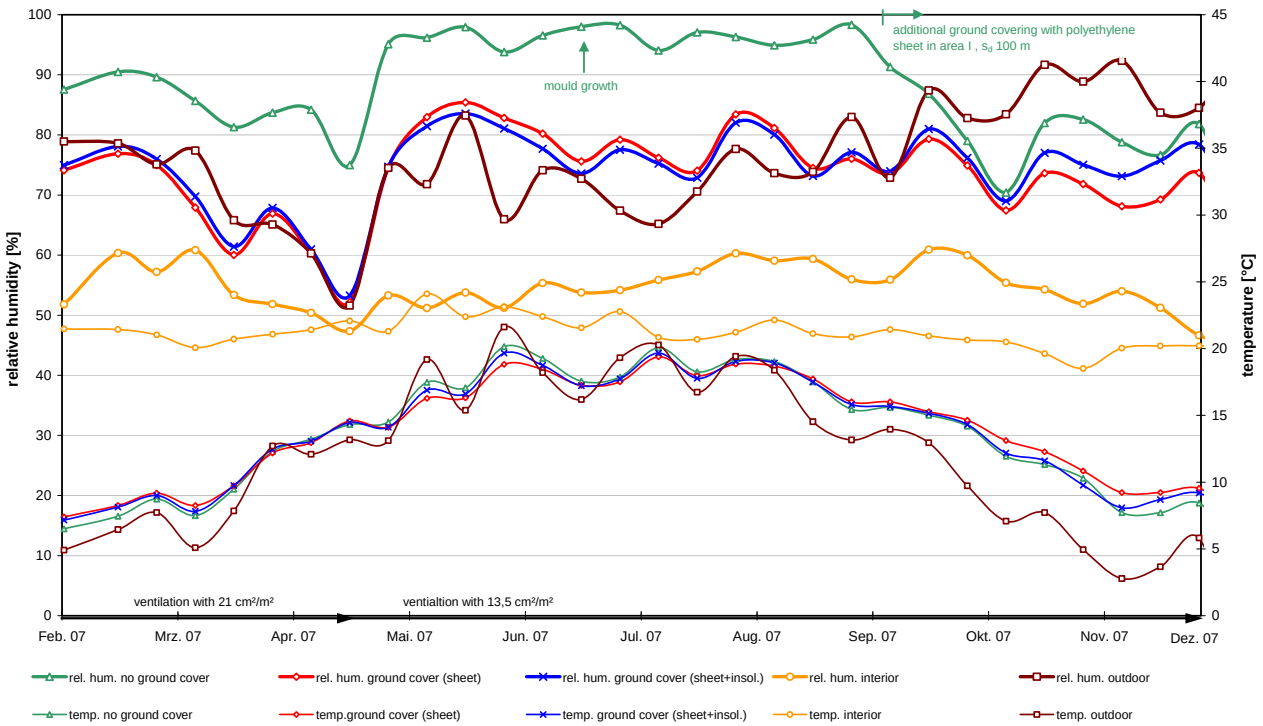
In addition to the laboratory examination in Leipzig, secondary examinations were carried out at existing objects with crawl spaces. All objects were examined visually and four also equipped with measurement instrumentation to evaluate and compare the influence of various construction conditions for the climate situation of crawl spaces. To achive 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 period.

Results of research :

The test results from the laboratory and field studies can be summarized as follows:
The climatic conditions in the crawl spaces are influenced by numerous conditions. Primarily the outdoor climate, the kind of the ground covering, the ventilating 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 examination 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 month of winter and to colder conditions in the month of summer 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 primarily led to mould growth in the soft wood fibre-board (illus. 5).
The additional covering of the ground with polyethylene - sheets led to a reduction of relative air humidity by 10 - 15 % in the crawl space and minimised the maximum relative humidity of approximately 80% in the summer months. Another reduction of the relative humidity in crawl spaces for the summer months 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 and in an additional field study, a greater diminution was not identified. The cause can 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, an 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 sheet covering. For all examined objects with ground cover and ventilating, no mould growth was recorded in the construction or crawl space.



illus. 5 relative humidity and temperature in crawl space of laboratory examination – decade value

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/m ^{3} was recorded from the free ground evaporation. The difference between absolute outdoor and crawl space humidity clarifies the influence of further moisture sources. Besides the flat diffusion by the sheet cover and evaporation in the side areas between foundation and ground cover, the influence of the interior climate with the diffusion must especially 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}/m^2 (consideration of the diminution by insect protected covers of ventilation holes). An air change rate > 0.5 per hour was recorded in the laboratory examinations. A low rate of ventilating with uniform distribution of ventilation holes over the foundation areas led to the most constant conditions in examination period. 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.

On basis of the research results, 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 can primarily be reached by the additional application of ground and foundation insulation in the critical summer months.
For the ventilation, a crosscut of 10 – 20 cm^2/m^2 can be recommended, a consideration of the limitation by a usual covering 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 must be provided. Wood and wood materials in the direct contact with the crawl space air must fulfil the requirements for use in the hazard class 2, according to EN 335. For outer wood panels an exclude of mould growth by their composite or kind of production is additionally required.

The authors advise - 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.