

Typical moisture failures of the slab-on-ground structures in Finland

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Abstract: This paper includes a summary of several case studies on moisture damaged slab-on-ground structures. The object of the paper is to suggest a classification of the causes for moisture damages and introduce the typical moisture failure of the slab-on-ground structures in Finland. The common causes for moisture damages in the slab-on-ground structure can be classified into four categories: design, construction, repair and maintenance. According to the studied moisture damage cases the most common cause is design fault. Usually the slab-on-ground structure is unfit in the light of present knowledge. The most common design faults are lack of capillary breaking drainage layer under the slab, lack of thermal insulation and incorrect placement of the vapor barrier.

CE DATABASE SUBJECT HEADINGS

Concrete slabs, failures, moisture, case reports, Finland

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INTRODUCTION

The background and motivation of this study were the numerous moisture related problems detected in the slab-on-ground structures in Finland. According to a study commissioned by the National Public Health Institute (Partanen 1995), in 25% of all detached, semi-detached or row houses the slab-on-ground structures have some degree of damages caused by the moisture. Another survey for the Association of Finnish Local and Regional Authorities (Suomen kuntaliitto 2000) reports that moisture damages detected in municipal office, school and health care buildings are related to slab-on-ground structures (26%) just as often as to roofs (26%). The same survey reports also that the most common reasons for the moisture problems were found to be: construction (29%), design (27%) and incorrect occupant use of the building or space (16%).

The first slab-on-ground structures were constructed in the 1940's in Finland. In the 1970's and the 1980's the vapor barrier (plastic sheet) was commonly advised to be used in slab-on-ground structure according to published literature. Some advised that the excess moisture in the structure should have been dried out before installing the floor covering. The thermal insulation, (if placed) was placed either above or under the concrete slab. As early as the middle of 1970's some warning of moisture and mould problems were recognized in Sweden (Kreuger 1985). The problems manifested themselves as: odor smell, visible moisture and visible mould growth. The cause of the moisture problems were the moisture from the moist ground which was transmitted in different states (vapor, water) to the slab-on-ground structure and caused high moisture levels under the floor covering (Adamson 1973). At this time it was commonly thought that only the free water could cause moisture problems. The water vapor mechanism was not understood.

The approved slab-on ground structure according to existing building standards in Finland is presented in Figure 1. The approved slab-on-ground structure in Finland and Sweden (Swedish Building Code 1980, Byggnadsstyrelsen 1991) differ from some other countries. Many countries (USA, Canada, Great Britain and German) require a vapor or moisture barrier be installed in the slab-on-ground structure (International Building Code 2000, NRC-CNRC 1995, CP 102 1973, DIN 18195-4 2000, DIN 4095 1990). To minimize moisture impacts to the structure requires that the excess moisture from construction process should have been dried out before installing the floor covering materials. This is not emphasized enough in regulations and guides. The

thermal insulation is usually not used under the slab even in northern Europe (German, Great Britain). The thermal insulation is usually installed under the slab in cold regions of both the USA and Canada. The required insulation in North America is thinner than that usually used in Finland. The drainage layer, 100...200 mm gravel is usually required in all countries.

This paper includes a summary of several case studies on moisture damaged slab-on-ground structures. The objective was to gather up the available information on previously detected moisture problems and to draw some conclusions of the typical moisture damages in slab-on-ground structures.

TYPICAL MOISTURE DAMAGES IN SLAB-ON-GROUND STRUCTURES IN FINLAND

Case study review

The data for the case study was from the research material of the Tampere University of Technology, who sent data request to some public construction management units in large cities and consultant companies specialized in moisture problems.

The referenced case study material included some sort of a damage or condition report of the structure, which was edited into the report card. The report card information (Leivo 2003) includes the general information of the building: age, purpose of use, size, repair history, detailed information on the slab-on-ground structure: structural layers and materials as well as the results of performed temperature and moisture measurements and an estimation of the possible cause or mechanism causing the moisture damage in each studied structure.

The root causes of moisture damages in slab-on-ground structures are diverse. The ultimate cause may lie in structural faults as well as in overall conditions or changes in occupancy of the space or building. To facilitate the understanding of these varying causes a simple classification of the moisture damages of slab-on-ground structures is presented.

Classification of the moisture damages of slab-on-ground structures

The common causes for the moisture damages of slab-on-ground structures may be divided as follows:

- **Design**

A structure or a combination of structural materials does not satisfy the standards under existing conditions. The structure may have been built according to the valid standards of the construction time but does not now behave correctly in the light of modern knowledge. Typical errors found are the lack of capillary barrier under the slab, lack of drainage and wrongly placed moisture barrier inside the slab structure.

- **Construction**

The actual construction of a structure does not follow the plan or instructions. A typical mistake is premature coating of the concrete floor prior to the drying of the “construction moisture” in the concrete.

- **Repair**

A structure is repaired without precise knowledge of the root causes of the moisture damage. The wrong repair method may produce more severe and more extensive problems with the slab. A repair fault is often caused by rashly performed alterations in structure surfaces and coatings as the occupancy of the space or building changes. A classical example is the conversion of a basement storage into residential use.

- **Conditions and maintenance related**

Unexpected changes in surrounding conditions or negligence in maintenance may lead to an increase in the moisture load and moisture damage. Typical unexpected conditions changes are pipe leaks or fire fighting waters as well as excessive use of water in cleaning processes. A common maintenance related damage is the plugging of drainage pipes or rainwater drains.

Case studies

The studied cases (Table 1) include public buildings, such as schools, day-care centers, shopping malls and hospitals. This is due to the fact that most of the case reports were returned by the municipal organizations responsible for the real estate of the towns and municipalities or institutions and companies mainly employed by the public offices. Moisture damages are also less common in detached and row houses than in Finland’s public buildings and shopping malls.

Analysis of the case studies

One of the primary reasons (34% of all cases) for moisture damages in slab-on-ground structures is the lack of thermal insulation (Table 2). Insufficient or absent slab insulation leads to extensive warming of the subsoil and an increasing diffusion flow through the slab structure. The increased moisture flow may cause an exceeding of the critical moisture content in some structural layer, often at the lower surface of the floor coating. The critical moisture content (relative humidity, RH %) is individual for each floor coating material. Usually this kind of damage manifest itself in color changes or loss of adhesion of the floor covering (Figure 2). This type of problem is typically connected to the repair and conservation work of a building where a vapor permeable floor covering is for some reason changed to a highly vapor resistant material.

Another clear structural cause (28% of all cases) for moisture damages is the incorrect placement of the vapor barrier (Table 2). It is recommended according to the existing Finnish building standards not to place a vapor barrier in a slab-on-ground structure at all. The direction of the moisture flow varies during the lifespan of the structure as the flow is directed downwards during the drying period of the concrete slab and is reversed towards the drier indoor air when the equilibrium state is attained. A vapor barrier is especially problematic in damage cases where a pipe leak wets the concrete slab and the barrier is placed underneath the slab. The excess moisture is now trapped between two high-resistance vapor barriers, the floor covering and the vapor barrier under the slab.

In several cases (38% of all cases) the drainage layer under the slab structure does not form a sufficient or complete barrier against the capillary flow from the subsoil (Table 2).

Often the increased moisture potential around the slab-on-ground structure is due to the ineffectiveness of the drainage layers and drainage pipes around the building foundations.

Many studied cases had more than one of the above mentioned root causes.

Most common causes of moisture damages in studied cases

In most cases more than a single cause is responsible for the exceeding of the moisture capacity of the slab structure. Therefore it is usually impossible to point out the most significant factor among many causes.

The most probable causes of the detected moisture damages in the studied cases (many have multiple causes) are here divided according to the classification presented earlier:

- Design: about 80 % of all cases. The structure, as it exist, does not meet current codes or standards.

- Construction: about 15 % of all cases. In most cases the concrete slab is not allowed to dry and is coated too early.
- Repair: about 35 % of all cases. Repairs are commonly performed without knowledge of the true reasons causing the problem.
- Conditions and maintenance: about 30 % of all cases. Pipe leaks and insufficient drainage to create a capillary break are very common.

DISCUSSION

The common causes for moisture damages in the slab-on-ground structure can be classified into four categories: design, construction, repair and maintenance.

The main reason for moisture and mould problems, the moisture flow exceeding the critical maximum moisture content (usually at the lower surface of the floor coating) is the same in our days as it was in the past. In the past decades the improper capillary drainage layer under the structure and incorrect placement of the vapor barrier were the main causes of the problems. Today the acceleration in construction schedules which do not allow adequate drying out of the construction moisture from the concrete floor slab and the new very water vapor tight floor coverings materials are perhaps the main causes of the moisture and mould problems in new slab-on-ground structures.

CONCLUSION AND IMPLICATIONS

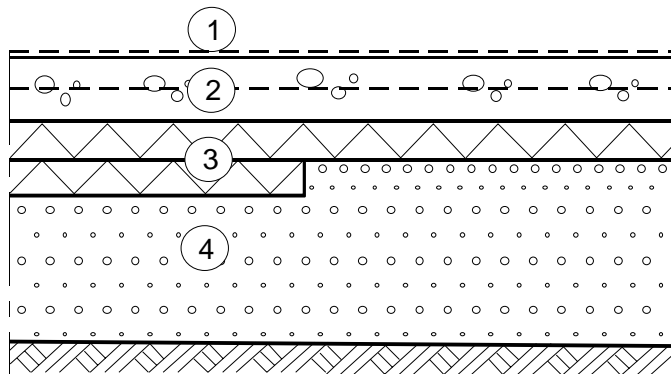
According to the studied moisture damage case histories the most common cause is design. The slab-on-ground structure does not meet current codes or standards. The most common design faults are lack of capillary breaking drainage layer under the slab, lack of thermal insulation and incorrect placement vapor barrier.

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1 Floor covering material. If the floor covering is water vapor tight the excess water from cast concrete must have been dried out before installing floor covering.

2 Concrete slab, about 80 mm

3 Thermal insulation. Expanded polystyrene 50 mm, at the outer edge zone 100 mm ($\lambda_n=0,041$ W/mK)

4 Capillary break drainage layer (gravel), 200 mm

Figure 1.



Figure 2.

Table 1

Building type	Cases	
	Amount	%
Day-care centers	4	15.4
Other health care or social service buildings	2	7.7
Sport related buildings	2	7.7
Schoolings	11	42.3
Industrial buildings	1	3.8
Shopping malls	1	3.8
Other buildings	2	7.7
- museum		
- library		
Row houses	3	11.5
Total	26	100

Table 2

Root cause (some cases multiple causes)	Cases, amount	Cases, %
Lack or insufficiency of thermal insulation	10	34.5
Lack of capillary barrier	11	37.9
Incorrect placement of the vapor barrier	8	27.6
Total	29	100

Figure 1 Cross section of a common slab-on-ground in Finland.

Figure 2 Loss of adhesion of the floor covering in restaurant building caused by the excess moisture flow from the soil. The slab-on-ground structure: 100 x 100 mm glued natural rubber plates, 100 mm concrete floor slab, 800 mm expanded clay aggregate drainage layer.

Table 1 The building types of the studied cases of moisture damaged slab-on-ground structures.

Table 2 The most common root causes found in the moisture damage cases.