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Testimonials about Damages in Construction Resulting in Need for Rework– Cases in Sweden - Part 1

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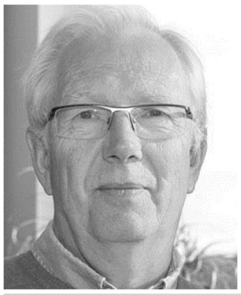

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ABSTRACT

We collected testimonials about cases ending up in the need for rework. People working at construction sites and from a provider of insurances gave us the information. Some of the cases show how damp when released from young concrete results in the need for rework. Other cases show how leakages not only result in repair for membranes, roofs and faulty pipes but also need for drying of concrete and replacement of damaged material. When slopes and altitudes in the structures or in the sewer lines are faulty considerable costs for rework will follow. The trade rules for plumbing work point out actions that could help to avoid some of the problems that recurrently occur among the cases in the testimonials. Education is a way to avoid rework in case of skill-based reasons. When violation to any instruction or principle is the reason responsibility should be placed with the person who can influence the outcome. All cases show the need for great care in the construction process.

Keywords: construction, damage, concrete, moisture, rework

1. INTRODUCTION AND AIM OF THE STUDY

Rework is an issue in the construction sector. Love and co-workers have defined rework as “the unnecessary effort of re-doing a process or activity that was incorrectly implemented the first time [1]”. There are a number of examples on how data from construction projects can be collected for the study of rework. One way is to do full time monitoring at construction sites with one person making observations 8 h/day [2]. Other options are questionnaires to construction practioners [3-8], interviews [9-10], evaluation of archival data [5 and 11] and literature reviews [6 and 9-13].

The aim of this study was to collect information about errors and failures that actually happened in Sweden in recent time and resulted in rework. The study was part of a task for the Swedish National Board of Housing and Planning to collect, quality-assure and disseminate information with the aim to increase awareness of deficiencies occurring in the indoor environment of buildings, common causes of these deficiencies and how they can be avoided or remedied.

2. PURPOSE OF THIS REPORT

This is the first part of the report from the study. Here we focus on: transport of damp or moisture; water flow, not under pressure; water flow, under pressure; floors, related to slope and altitude; and also leakage in sewers. In the companion report [14] more cases are presented, such as problems with freezing, ventilation, technical details and also disasters are presented along with a discussion with other researchers views on who can be responsible. We think the observations and cases we present in this first part will be useful within the construction sector in Sweden and in Europe. It will give input for the focus for improving competence and for how construction companies can develop their quality assurance.

3. METHOD

The information was provided by people in the construction business in Sweden having recent experiences, either by projects where they had been active themselves, or reliable information within their organisations. We used a few different sources:

1. A Facebook group for students who examined from the master program program Civil- and Architectural engineering at KTH- Royal Institute of Technology and studied a course dealing with building damages. This ended up in 60 contacts and a number of first hand testimonials about specific cases.
2. The authors of the study involved their own professional networks with people who provided first hand information about specific cases from construction projects where they had been active.
3. One of the authors of the study had been working by an insurance company who provided a so called "Latent construction defects insurance" (SE: Byggfelsförsäkring). It was a legal requirement to have such an insurance when raising new buildings during a period of 21 years, starting from 1993. The testimonials given from this second hand source are of good quality and are indicated with the text: "in a number of cases".

We asked the informants to provide the cases and give information about the following aspects:

- The indication that shows that the problem exist
- An idea about the cause of the problem.
- Some words about the consequences.
- An idea about how to avoid the problem.

In this way we received information of good quality about real damages resulting in need for rework in the construction sector in Sweden. All the cases are about residential buildings.
This investigation was done in early 2020. The informants were asked about recent experiences, so the cases are never more than 10 years back in time from 2020, and most of them newer than that. We did not ask about the date when damage happened. All information is impersonalised to make it impossible to track informants or objects.

4. RESULTS AND DISCUSSION

In total, we collected 49 testimonials. We present and discuss 26 of them in this paper and the rest in a companion paper in this journal.

4.1 Transport of damp or moisture

1 Mould appeared in the attic after additional insulation was assembled in a building

One reason for this is because the user chooses to put additional thermal insulation in the attic without actions for moisture safety such as installing a vapor barrier.

The consequence was mold in the attic and, in the worst case, both roof trusses and underlayment roof will rot.

This type of damage could be avoided by making an expert assessment before additional insulation about the need for a vapor barrier on the floor of the attic and also whether a vapor barrier is needed in the wall construction.

2 Mould in the attic in a new building

When a self levelling compound was laid on top of the concrete slabs and at the same time, to speed up the drying out, extra heaters were placed on the entrance floor and heated a total of 5 floors including the attic. In addition, this was done in December/January, with sometimes sub-zero temperatures. There were openings between the attic and the rest of the building so the damp air with a temperature about 25 to 30°C, did flow up in the attic. The moisture in this air condensed on the underlayment roof of tunged and grooved lumber, that had a temperature about -2 to +5°C. The lumber became damp and mould started to grow.

Costs were now in the early stages about SEK 100,000. The time delay was about 5-6 weeks.

To avoid this, a different type of construction would have been chosen with less risk with moisture. One option could be to hinder the air from the inner of the building to reach the attic.

3 Mold growth on the lumber of the underlayment roof in a two storey house, in a late stage of the construction process

Moisture from the concrete slab rose up to the underlayment roof of tunged and grooved lumber so that condensation occurred. It was no seal between the building and the attic space at the time. When the attic space was later sealed, no one thought about the moisture in the lumber of the underlayment roof.

The moisture was not measured and no attempts were done to facilitate for drying. Therefore, mould started to grow.

The consequences were costs of approximately SEK 100,000 to clean up the lumber, besides the irritation from the builders.

To avoid the damage, the attic should be sealed early in the construction process so that the underlayment roof would not be affected by moisture from the building. In addition, the moisture level in the attic should be measured so that actions could be taken to prevent mould growth.

4 A cast in place concrete slab was very wet when cast

The slab was not weather-protected during casting, so rain fell directly on the newly cast slab.

The consequence was that the slab got problems with drying out and as a result dehumidifiers had to used, which did cost money, and the time for drying become significantly longer than expected.

This had been avoided by weather protection of the slab, which also could have protected more of the materials during the construction process.

5 Heavy mold growth on the underlayment roof of lumber above attic joists when building a slatted house with a concrete frame

The reason was that the moist concrete structure was dried out by blowing hot air in the bottom plane. All windows were already airtight and sealed. However, connection to the attic was open. Any openings for ventilating the attic were closed. The temperature in the attic became quite high. This combination of high temperature and moist conditions was the reason for mold growth.

The consequence was that the cost for the roof was doubled, with demolition and a new roof, and took twice as long time to complete.

This could have been avoided by considering the need for sufficient air exchange to remove damp from the building frame and thus avoid damp air to reach the attic.

6 A column made of wood absorbed moisture from a floor slab

The reason was that the wood column did stand with direct contact to the concrete floor slab and so did absorb moisture from this substrate.

The consequence was that the column did rot in the lower part and had to be cut off, repaired or replaced completely.

It takes understanding of how the materials work together to avoid this.

A dampproof membrane under the column or a distance between wood column and the concrete floor is required.

7 Moisture damage in massive wood (cross laminated timber - CLT) in new buildings is noted in a number of cases.

One reason is that massive wood is believed not to be sensitive to rain during construction and can be allowed to stand without weather protection during rainy periods. However, end wood surfaces in solid wood still may absorb water when it rains. If they are not protected, water may penetrate the construction and will remain for an extended time in the building structure.

The consequence will be future moisture-related damage.

To avoid this, adequate weather protection is required during construction. The end timbers should not be exposed to rain in the finished construction.

In apartment buildings concrete is a normal material choice for floor slabs and structures.

For transport of damp or moisture all cases except one have a concrete slab acting as a moisture source. The moisture can only be released from the concrete to the surrounding air through a diffusion process. Hassan and Anderstedt have described the problem with drying of concrete slabs [15].

When this happen the air will have an increased level of dampness. This damp can be transferred to any material or component being in contact with the air, and condensation will happen on material surfaces when they have temperatures lower than the dew point for the damp air. Next step will be water uptake by sorption in these materials and possible damages coming out of this. These cases show the need for understanding of risks related to transport of damp and moisture in concrete. The process of moisture in CLT is described by Kalbe et al. [16].

4.2 Water flow, not under pressure

8 Leakage between the floor and the threshold in a bathroom is noted in a number of cases.

The reason was that the waterproofing membrane under the bathroom floor does not connect watertight to the threshold. The height of the threshold can also be quite low due to accessibility requirements, and the slope of the bathroom floor is quite flat. So, it may happen that shower water give flooding on the whole floor and when it passes under the threshold it will flow to the flooring of the rest of the apartment.

The consequence is that water flows into the construction with risk for all kinds of damage related to damp or water; rot in wood components, degradation of adhesives, etc.

This can be avoided by careful connection between the waterproof membrane in the bathroom and the threshold, so that water will not have an opportunity to flow under the threshold. There may also be a need for careful control of the work execution. This was in a concrete structure that will need drying.

9 Deficient sheet metal flashings in a roof, resulting in leakages in a metal connection to the chimney.

The reason, was sheet metal work carried out by carpenters who, had neither the right knowledge nor the tools needed.

The consequence when the roof is leaking is, in the first place, that the thermal insulation will became wet. In the present case, this was discovered before damage occurred.

This could be avoided by hiring competent craftsmen. Often scarcity in the time available forces carpenters to do work they don’t really cope with.

10 Leakage in a terrace slab

The reason was punctured waterproofing membrane on top of a the terrace floor made of concrete.

The consequence was that all the terrace area had to be dug up to remove and redo the broken membrane. Trees and bushes had to be earthed up to protect them to survive drying, frost and sun light during the work process. There was a lot of inconvenience for the tenants.

To avoid this, it is required that the construction documents are really followed and that the site management carefully follows what is being done. In addition the contractor should have self monitoring to guarantee the waterproofing.

These cases will be discussed in next section.

4.3 Water flow, under pressure

11 Water leaks in kitchens. This is noticed in a number of cases.

The context is that leaks may happen when tap water is connected to kitchen equipment such as dishwashers, freezers with ice machines, ovens with steam, coffee makers, etc. The reason for the leaks are connection not done properly. The consequence is that floors and kitchen furniture are damaged by water. Also the concrete has to dry out. Many kitchens have wooden floors on a concrete slab. Almost no kitchen has a floor drain. Water can also flow on the concrete slab and further under the flooring and cause more damage.

Well-executed assembly is one way to avoid these damages. It should be ensured that products that are connected are approved for permanent connection to tap water installations. A waterproof lining under the dishwasher, fridge, freezer etc. saves the situation. A shut-off valve can be fitted to the equipment for preventive purposes to be used in the event of, for example, longer absences from the house.

12 Bubbles in the parquet floor in a newly built house with water borne underfloor heating.

The reason was that pipes in the underfloor heating, that are cast in a concrete slab, had cracks and leaks because of a frost damage that happened before heating of the building started. The pipes were filled with water when they were tested for leakages in a pressurization test, done before the slab was casted. The pipe system was approved in a leakage test, but the pressure gauge used was later found to be defective, so the result of the test was not reliable.

The consequence was that the parquet had to be removed on the entire floor, the concrete slab had to be torned up and new pipes were installed. The cost ended up at about 400,000 SEK

This could have been avoided by using frost protection in the water and by a careful follow up of the equipment for the pressure test.

13 Leakage of hot district heating water which was poured all over an entire basement.

The reason was an incorrectly fitted gasket in a temporary energy meter for the district heating installed by the district heating supplier.

The result was water damage, need for extra drying of damaged material, eg steel doors, electrical installations, wall panels and the concrete slab. This could have been avoided through better self-monitoring from the technician doing the installation.

14 A number of faucets for tap water were not properly installed.

The reason was deficiencies in the installation work. The consequence was that the installation had to be done again with extra costs for the contractors for repair and drying of the concrete, as well as irritation from property owners and customers.

In order to avoid the damage, good basic training, a clear job description and a method description are required.

15 Water damage when tap water pipe connections came loose.

The reason was that the press couplings were not fitted correctly.

The cost of the damage was approximately SEK 200,000.

To avoid the damage, it is necessary that all connections of pipes are made in a correct way. In the first place through self-monitoring by the craftsmen.

16 A washbasin faucet came loose in a bathroom when the resident was away, water gushed out for at least a day and caused damage.

The reason was that the mixer was not rated to withstand such high water pressure as could be expected with municipal water in Sweden, even though it had a European "EC-rating".

The consequences were costs, SEK 300,000 and and 4 months evacuation, for repair and drying of concrete, with need for temporary accommodation for the inhabitants.

This damage could have been avoided by a conscientious check before the selection of the installation product. It might be a special risk in cases when a private person orders goods with a striking design.

17 Water pipes come apart and flooding comes as a result. This is noted in a number of cases.

Press coupled connections could go apart either as soon as the water is connected or within a period of 6 months (or so). The latter might result in more serious damages as they are perhaps not noted immediately.

The reason is that the installation is not done with enough care. The problem often occurs in the manifolds in the distribution cabinets.

In this context it can be noted that the cabinet can be narrow and difficult to access with the pressing tool. After flooding drying of concrete and exchange of damaged material is needed.

This can be avoided by developing the assembly method to make it easier to get it right. Also to test tightness might help, preferably with compressed air.

18 Suddenly, water started pouring out of a plugged tap in a kitchen.

The reason was that a temporary plug in the tap water did not hold tight.

The consequence was extensive water damage and that the damaged floor and damaged joinery had to be replaced. The concrete slab had to be dried.

This could be avoided by careful plugging. It must be solutions available to plug a tap water pipe in a safe way.

19 Press couplings connections start to leak. This is noted in a number of cases.

One reason for this is that the connection is done with the wrong equipment and that materials from different connection systems are mixed together. One comment is that press couplings require the right combination of products, the right tools and good knowledge. It is never allowed to mix systems from different suppliers.

The consequence is that pressurized water lines leak and the building is damaged by water. The concrete floors needed drying and damaged material had to be replaced.

This can primarily be avoided by keeping an eye on which products and tools are used during assembly and that this is done by trained personnel. This kind of damage is often related to work that the subcontractor does, so self-monitoring is one need.

20 Water flows out of the pipes for an underfloor heating system that was installed during a renovation work.

This underfloor heating pipe system was installed above the concrete floor slab during the renovation of the house. The construction workers who installed the flooring happened to cut holes in the pipe, probably because they didn't know about the pipes. The concrete slab had to be dried and the flooring replaced. Coordination and exchange of information between the installer of the heating pipes and the installer of the floor would have helped. A leak test of the floor heating system with compressed air before connecting the water is also a good idea.

21 The concrete workers accidentally damaged a pipe for underfloor heating cast in the floor slab while sanding the floor.

The consequence was that the pipes leaked. The floor slab had to be teared up for installation of new pipes.

The reason may be that the pipes were placed too close to the upper surface and thus were vulnerable to be damaged when the floor was sanded.

This could be avoided by placing the pipes in a safe way before casting, they must not be moved out of position during concrete work, and when sanding floors. Coordination is needed.

The cases under Sections 4,2 "Water flow not under pressure" and here "Water flow under pressure" both include concrete structures being moisturised. A flow of water not under pressure can go on for a long time without being noticed. When water is under pressure the leakage should be revealed after a shorter time. In both cases a tedious process of drying of concrete is needed in addition to other rework. It can be noted, out of these experiences, how a good understanding of the drying behaviour of concrete along with care related to the risk of moisturizing of the concrete would help to reduce the problems.

These cases also relate to the quality of plumbing work. In Sweden a certified plumbing installer should have 3 years basic education that includes experience in all important types of installation and also up to date-approval from the trade organisation "Säker vatteninstallation [17] " (Eng: Safe water installation) that also include a written test. This is part of a trade rule that ensures that the plumbing fulfils the Swedish building code and the requirements for professional execution in accordance to the Swedish consumer service act. This quality system says that all appliances have to be type approved and also installed in accordance to the suppliers' instructions. Pressurisation test and tightness control shall be done and the outcome shall be documented. According to standard contracts used in Sweden the services have to be installed by authorised contractors. This is also a prerequisite for the insurances to be valid. To become authorised the contractor shall have at least one full time certified installer employed and all the installers working shall be certified as described above. So, the construction sector in Sweden is making serious efforts to avoid the problems under headings 4.2 and 4.3. For the risk of water leaks in kitchens, the rules says it should be a

waterproof lining under sink cabinets, under dishwashers and also under other kitchen equipment such as freezers and refrigerators. This lining should cover all the area under the appliances and end up in front of them, to make any water leakage visible immediately. If a pipe needs to protrude through this lining the connection has to be sealed with care.

4.4 Floors, related to slope and altitude

22 Balconys and terraces outdoors are almost exactly at the same altitude as the floor of the dwelling. This is noted in a number of cases.

It is a demand for outdoor areas being in perfect connection to the indoor. This is also an advantage in terms of accessibility for the disabled.

A consequence is the risk of water damage because of driving rain, storm water overflow or melting snow when the difference in altitude between surfaces outside and inside is very small. Water might flow into the house. The concrete slab need to be dried and the damaged material need to be replaced.

This can be avoided by prioritizing water protection as high as accessibility and maintain a difference in altitude that still give acceptable access. It may also be an idea to investigate other solutions for the accessibility requirement to keep the building protected against moisture damage. It is necessary to plan carefully through all the detailed solutions and ensure that the assembling is correct.

23 In a bathroom, the floor drain is not in the right level, so water does not flow away from the floor as it should.

The floor drain was inserted in the formwork before casting the concrete slab. It was not in level because someone had stepped on it before or during casting of concrete.

The consequence was that the concrete floor slab had to be teared up and the floor drain re-positioned. This meant costs and delayed moving in.

This could be avoided by carefully checking the position of the drain before casting and also by doing the casting work carefully.

24 Water ponds were formed in front of the door to the stairwell

The reason was that the draining wells were at a too high altitude and the slab was sloping away from the drains. This was because setting out, before casting concrete, was not done in a proper way. The consequence was that the concrete floors had to be redone.

In order to avoid this, better control is required from site management as well as a functioning self-monitoring by the technician doing the setting out.

The issues about slopes and altitudes are special problems because floors are fixed parts of the building structures that cannot be easily changed. Therefore, rebuild of these will take big resources.

4.5 Leakage in sewers

25 Sewer pipes under a concrete slab that are piled can suffer from counter falls. This is noted in a number of cases.

The reason is that under a piled base plate the ground eventually sinks. If the sewer pipes are not carefully connected to the slab, they might be dragged along and fall back, which will hinder the waste water flow. In the worst case pipe breaks can occur.

The consequence is that the drain does not work as intended, or even begins to leak under the house. A complicated and costly excavation is required under the slab.

This could be avoided by taking the utmost care when placing and anchoring pipes in and under the base plate before casting the concrete. This takes planning.

26 Leakage in waste water pipes under a floor slab. This is noted in a number of cases.

The waste water pipes are often loosely pushed into each other. If they are moved out of position water may flow out at some of the joints.

This gives rise to leaks that are not visible and so not noticed until after a long time when their consequences become apparent.

This can be avoided by careful clamping of the pipes and by careful inspection of all joints of the drainage system.

Leakages in sewers is a big problem because it will be demand for considerable resources to make the leaking pipes accessible for repair and for the cleaning up after the leakage. The rebuild may include some demolishment of concrete structures. This show the importance of careful adjustments of all levelling before fixation of a structure, for example when casting concrete.

5. GENERAL DISCUSSION

In a construction project plenty of different activities are ongoing at the same time and a big spectrum of faults could happen. Most of these have only minor consequences or will be easy to correct. These testimonials are about real cases in residential construction from first hand or second hand sources. They have resulted in notable problems and the need for rework. Substantial costs have followed. The 26 testimonials presented in this first part of the report are presented under the five headings given above. Several of the cases are about damp and moisture in concrete and how this can influence on other construction parts. There are also cases where construction parts are exposed to water from leakages or because of errors in inclinations of the building frame.

Aljassmi and Han [18] noticed two main causes for rework; skill based reasons and violation based reasons. In case skill is missing, education would contribute to a better outcome and less need for rework. Here the knowledge about moisture processes in concrete, the skill in installation of services and a respect to the challenges in casting concrete would help. In case violation is the reason it should be very clear who is responsible, and important to place responsibility with the person who can influence the outcome. We think our method for getting

the testimonials was very effective. We received several cases from people who felt free to tell us in an open way when they could come with confidence to their old teachers.

6, CONCLUDING REMARKS

Many of the cases described in this study relates to concrete. They show how damp when released from young concrete result in the need for repair and rework in construction parts damaged by this damp. They also show how leakages not only result in need for repair for membranes, roofs or faulty pipes but also need for drying of concrete and replacement of damaged material. When the slopes and altitudes in the structures or in the sewer lines are faulty considerable costs for rework will follow.

The trade rules for plumbing work point out actions that could help to avoid some of the problems that recurrently occur among the cases in the testimonials. All cases show the need for great care in the construction process. Education is a way to avoid rework in case of skill based reasons. When violation is the reason the responsibility should be placed with the person who can influence the outcome.

To send questions to former students was an advantageous way to collect information about cases of rework in the construction sector. We believe this collection of testimonials can be useful for risk assessment in construction projects. Other researchers can also use them as a basis for further work to improve quality. In part 2 of the report, we will present more conclusions.

DATA AVAILABILITY STATEMENT

All data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request. The names or companies of those who provided information about rework cases will be kept confidential because we promised the informants this.

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