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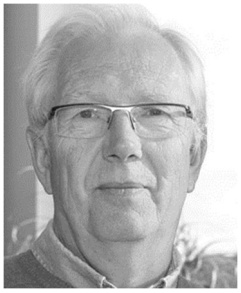
Testimonials About Damages in Construction Resulting in Need for Rework – Cases in Sweden - Part 2

Folke Björk, PhD
Professor in Building technology
Department of Civil and Architectural Engineering
KTH – Royal Institute of Technology, Stockholm, Sweden
Folke.bjork@byv.kth.se



Rolf Kling,
Swedish trade organization for HVAC-companies
(VVS-företagen) (formerly, now retired).
rolf.kling@alsvik.nu.

Peter Wipp
Punkthöjden AB, Sweden.
peter.wipp@punkthojden.se

Ulf Viktorsson
Nykvarnsbostäder, Nykvarn, Sweden
ulf.viktorsson@nybo.se

ABSTRACT

This is a study about damage resulting in rework in residential construction in Sweden. They are assorted under 13 headings that mention physical facts without taking a position on cause of the problem. This second part of the report presents information considering water freezing in the building envelope, water in the facades, stained facades, construction parts that not fulfil the system performance anticipated and also real disasters. Preparation before casting concrete takes care because any need for demolishment consumes considerable resources. In general, to avoid damage it is good to; have up to date knowledge about problems that emerge; have a leadership that favours commitment to a well-built product; and to follow up the details that are critical, like those that could result in leakage of water. We also think it is good to be open about things that go wrong. In case skill is missing, education would contribute to a better outcome and less need for rework. In case violation to any instruction or principle is the reason, it should be very clear who is responsible, and important to place responsibility with the person who can influence the outcome.

Keywords: construction, damage, concrete, facades, construction details, ventilation and heating, freezing, rework, testimonials

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]”. In the discussion, we will reflect on other researchers’ views on reasons for rework. This study is 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 second report from the study. We present 23 testimonials under these headings: freezing water; water in facades; stained facades; problems with ventilation ducts; ventilation and heating; technical details; acoustic problems; and disasters. In this second part we also discuss the context behind the need for rework. In the companion paper being the first part, [2] the cases are related to transport of damp or moisture, water flow and water flow under pressure, floors related to slope and altitude and to leakage in sewers.

We present these cases and observations with the intention to guide construction companies to identify details that are critical for the building to function properly. A result from this can be inspiration for improvement of planning and design of buildings, developed processes on construction sites and some clear targets for education. The results can also be used by other researchers as a basis for further studies about rework.

3. METHOD

The method for data collection is described in Part 1 [2]. Testimonials were from former students, the authors professional networks and experiences from an insurance company providing "Latent construction defects insurances". The latter is indicated with the text "in a number of cases". All information is impersonalised to make it impossible to track informants or objects. The investigation was done in early 2020.

4. RESULTS AND DISCUSSION

Here we present 23 cases under their headings. In total, there are 49 cases are assorted under 13 headings based on physical facts. In the discussion, we will explain more about this.

4.1 Freezing water

27 Freezing in tap water pipes that are placed in the fabric of the walls or in the attics is noted in a number of cases.

The pipes will reach temperatures below the freezing point in cold weather either because the thermal insulation to the outside is not installed correctly, or because the pipes happened to be placed too far out in the wall.

The consequence is both small and large leaks of water into the structure resulting in water related damage on materials and need for drying of concrete.

This could be avoided by careful design work when planning assembly of the pipes, as well as corresponding care when pipes and thermal insulation are installed.

28 In apartment buildings, freeze damage has occurred on a fan coil heater connected to a hydronic system at the intake of outdoor air. This was noted in a number of cases.

The cause could possibly be too little of water flow in the system, perhaps caused by impurities clogging the pipes. Another aspect is that a frost guard may be needed which prevents the air from flowing when the temperature gets too low. The consequence is leakage in the heater. This could have been avoided by testing that the flow in the heater is sufficient, or to design a system that shuts off the airflow at low temperatures.

The issues with freezing water will only appear when the cold weather arrives even if the fault has been there all along. The pipes in facades or in other parts of the building envelope need to be installed in a way taking the risk for cold from outside seriously. In the documentation for authorisation and certification, from the Swedish trade organisation "Safe water installation" [3] presented in part 1 of this report, also the risk of freezing is included with examples on how to avoid damage.

4.2 Water in facades

29 Water flow between the wall modules in a house made of concrete elements.

The reason was that concrete wall modules were installed without reasonable space for movement joints. It was not possible to install movement joints between elements in an adequate way.

The consequence was that the joint between the elements became leaky.

This could be avoided by taking into account the need for space for joints between concrete elements in planning and assembling.

30 Moisture damage around windows and on the sill in a 9–10 year old apartment building

The reason was moisture problems in the ETICS facade. The acronym ETICS stands for "External Thermal Insulation Composite System". The method with ETICS-facades requires an extremely careful work performance in the assembly, which was not the case here. Neither those who performed the work, nor the work management or the designer, did fully understand the degree of accuracy needed. The consequence was that the façade got severe damage by moisture. The façade was torn down totally and replaced with a new façade. . Cost for this was approximately SEK 100,000,000 for 250 apartments = SEK 400,000 per apartment.

This could have been avoided by choosing construction solutions that are long-term sustainable and can be assembled correctly by the craftsmen available.

31 The requirement for a certain green area factor means the need for green areas, with plants, on the walls as well on the roofs. This might result in discoloration due to the growth of algae or other microorganisms. This is noted in a number of cases.

The green walls are types of construction with their own requirements for material selection, care and maintenance. This discoloration might be a consequence of deficiencies in the management of plant surfaces on the walls. Whether other damage to the structure may follow is not yet clear. To avoid problems, at least the recommendations in the handbooks for green roofs and walls should be followed to the extent applicable. Facade materials that are not susceptible to attack must be used behind the green walls. Wang et al have made a literature review about the use of different kinds of green infrastructure in cities [4].

Water in facades is a first step to coming problems in buildings. The problems will not be noticed at once but after some time, probably after a number of years. Then the repair will be troublesome because the damage may affect construction parts that are difficult to change. The assembling of concrete elements for facades need to highlight the space needed for making good dilatation joints. Several ETICS-facades had severe problems in Sweden. Care for water protection is needed in all details such as steel sheet flashings around windows. The green walls are not very common so far, but upcoming problems need to be understood in order to obtain good detail solutions. A description of the problem with ETICS-facades is given by Olsson [5].

4.3 Stained facades

32 Discoloration and damage to new rendered facades. To enliven facades, combinations of different facade materials and surface treatments are used. It happens that these do not work well together. This is noted in a number of cases.

The reason may be a lack of knowledge when installing and maintaining new facade materials or facades with several different materials on the same wall. It could also be that, during planning, there was a lack of competence regarding the proper detailing when combining different types of facade materials on the same wall.

The consequence is moisture damage and discoloration. The facades become unattractive and must be repaired. To avoid the problems, consideration must be given to the different properties in materials when they are combined in a facade. It must be taken into account that different materials have different behavior with regard to thermal and moisture movements. For that reason careful planning and in-depth knowledge are needed.

33 Rough and ugly plastering on a rendered façade is noted in a number of cases.

The cause can be things like incorrect mixing of the mortar, the wrong types of mortar, too thick or too thin layer of rendering and not well done leveling. Well trained craftsmen should contribute to avoid this. The consequence is that the façade looks ugly, which lowers the status of the area. Service life will probably also be short. This can be avoided by better self-monitoring in the first place.

Stained facades may result in annoyance in the first place; facades looking dirty is bad for the reputation of a built district. This may also be an early warning for further damages.

4.4 Problems with ventilation ducts etc

34 Spiral ducts were rusty and dirty, and full of water. They were also punctured by screws right through

The reason was incorrect storage of the spiral ducts on the construction site. The screws punctured because of mistakes during the construction process. The consequence was that air quality and air tightness could not be guaranteed, so the ducts had to be cleaned and also repaired. This could be avoided by having the pipes safely stored on the construction site. Usually they are shipped with plastic caps that should remain as long as they are needed. During the construction process any assembling with nails or screws must be well planned to avoid damaging the ducts.

35 Unmotivated side strokes and strange crooked trunks of the services

The reason was that the lay out from the drawing had errors and so the pipes and ducts did not fit into the shaft where they should be installed. The consequence was that the concrete floor slab had to be teared up for installing the services. Also after this the sidestrokes remained and so the building became more difficult to maintain. This could be avoided by better review during planning, preferably by 3D-BIM, and also more accuracy when doing the setting out.

36 Large installation routes that are not well planned. This is noted in a number of cases.

The demand for cables for signals and control has increased, with a need for a considerable amount of electrical wiring and cables that require penetrations and installation paths in modern buildings. The consequence is a risk of air leakage, risk of acoustic problems and difficulties in getting an effective fireproofing. When it comes to the vapor barrier, products that can maintain air tightness also after being perforated is a need. It can help to spread the penetrations and not gather them all to one point. Detailed planning and precise location of important details are needed here. Likewise, coordination of the planning for different installations and services is required.

37 Nails or screws hits water conduit pipes or electric wiring during construction work. This is noted in a number of cases.

This happens, for example, when installing skirting boards. One reason is that the services are placed in areas where nailing or screwing must be done. Or, the person doing the nailing or screwing does not know where the the pipes or cables are situated. The consequence will be that the pipes will leak, small amounts of water may flow out over a long period of time. For electrical wiring, the result may be electrical shock or fuses blowing. This can be avoided by having the services in a safe places where nailing and screwing will not take place. In addition, the installers of building parts must be informed about location of pipes and wires.

These problems with ventilation ducts etc are in some cases related to how they were handled on the construction site and in some cases to how the planning of the building was done. In the latter cases problems will remain during the lifetime of the building because it is not possible to redo them in a better way because that would take a need to adjust too much of the structure.

4.5 Ventilation and heating

38 Odor problems in apartments in an apartment building, mainly on the top floor

The reason was that the air intake for the fresh air had been mounted too close to the air outlet. The consequence was that the air intake and air outlet had to be moved further apart after the house was finished. This could have been avoided by a planning process that also highlights how ventilation systems work.

39 Problems with smell and bad air.

The reason is an imbalance in the ventilation system with excess of negative pressure in the apartment. The consequence is that smells enter the home from neighbors and outside, and the windows fog up. This could have been avoided by correct adjustment with 1-3 Pa negative pressure indoors. This should be done in the manifolds, not in the valves at the inlets in the rooms.

40 Cold draught at large windows is noted in a number of cases

Reasons can be air leakage at the windows or that the heating at the windows does not give sufficient power. The consequence is poor comfort at the windows. To avoid the problem, the window should be mounted exactly according to the manufacturer's instructions and the heating should be arranged for an upward air flow at the inner pane. This problem is probably to a large extent related to the design of the building and only to a minor degree to the building process.

The issues with ventilation and heating are related to design of the building, and hard to cope with, or related to how the system is adjusted, which should be possible improve.

4.6 Technical details

41 A floor drain was removed when the floor was laid and then not restored - due to forgetfulness.

The reason was that the floor drain had to be removed for one reason or another during the building process, but nobody put it back. The consequence was that the floor drain was missing, so the work had to be redone. This could have been avoided if the floor installer had thought about the matter, and if the site management had followed up the work at an early stage so that the floor drain was reassembled.

42 Solar panels mounted on older roofs are subject to problems noted in a number of cases.

Causes of problems can be that solar panels are not well anchored. The consequence is that the solar panels can blow down. In addition, they can contribute to the roof starting to leak. There may also be problems with roof safety and the possibility of snow removal. To avoid these problems, it must be ensured that the solar panels have a safe attachment regarding both strength and tightness against leakage through the roof. The roof must also have safety devices that allow for service work. There must also be snow protection and the possibility of safe snow removal from the roof after installation of solar panels.

43 Electrical problems with solar panels installed on roofs are noted in a number of cases.

The cause of problems incorrect installation. It may be about loose unprotected cables, or that a live cable cannot be disconnected. The consequence can be that the installed solar panels ignites, and also the building can start to burn. If the building's solar power plant cannot be disconnected, the consequence may be that fire protection and rescue services are hindered in their work. These problems can be avoided if it can be ensured that the cabling is well anchored and protected against sun and rain. The solar power plant should have the possibility to be disconnected and de-energized. If a fire safety inspection is required, the plant should also have fire safety documentation. Gomes et al. have discussed the issues about fire and roof top mounted solar panels [6].

44 A low-sloped roof could not withstand the wind loads.

The reason was an incorrect wind load calculation that resulted in too large distances between the fasteners and incorrect craftmans work. The consequence was that the entire roof had to be redone. This could have been avoided by careful wind load calculation and a follow up regarding how fasteners are installed with control that the material supplier's instructions are followed.

The problems with technical details relates to different construction parts. The problem with floor drains relates to the case with concrete slabs that are hard to change. The use of solar panels is still an emerging technology and we can anticipate some development errors related to this. The solar panels are usually placed on top of roofs, so the quality of the roof will influence the solar panels. One of the testimonials also relate to the need of care for making a roof cover function in a proper way. The process of wind load damage to roof membranes is described by Gränne et al. [7] and Oba and Björk [8].

4.7. Acoustic problems

45 The sound from flushing the toilets was far too loud.

The reason was that the system was not properly designed. The consequence was a need for subsequent supplement with soundproofing measures. The cost is difficult to estimate, but of course, there is a cost in both time and money. This could have been avoided by highlighting the acoustics in the design phase.

46 Poor step sound insulation, swaying and floor creaks in parquet floors.

The reason was poor laying of the sound mat under the parquet. As a consequence the floor had to be laid again. In this construction, first plastic foil is laid on the concrete slab, then a sound mat, which also makes the parquet lie still. The sound mat should preferably not be spliced but if needed, the edges must overlap at least 15 cm. This can be avoided by checking the work of the craftsmen.

The acoustic problems are not easy to handle because they won't emerge until the inhabitants have moved in to the building. It may take considerable changes before the problems are solved.

4.8. Disasters

47 Fire in an older building during renovation work

The reason is unclear, but fires in older buildings take off more easily than in new buildings.

The consequence was costs of many millions of SEK. Lots of time to restore, even longer than building new. Cultural heritage was lost because it was a listed building. It is important to pay close attention to fire protection during a renovation process.

48 Blasting accident

During blasting work, the charges were made the same size by every blast, but eventually a situation came where a significantly smaller charge would have been suitable. So, the permitted vibrations were exceeded. The reason was insufficient control, the work proceeded without careful examining characteristics of the rock

The consequences were damaged facades in three apartments in an adjacent building, damaged balconies with glazing, damage on roof resulting in leakages and also damaged doors in an adjacent garage. After this some tenants had to be evacuated to hotels. In addition to the damages, the negotiations with insurance companies took a lot of resources. This could have been avoided by inspection of the rock by a skilled rock blasting technician.

49 Collapsing in shaft pits and settlement due to incorrectly performed sheet piles

The reason for this collapse and the settlement was that the sheet pile wall in the pit was only 9 meter deep even though 14 meters had been prescribed.

The consequence was a landslide, an adjacent building had to be evacuated. Extra costs of around SEK 2 million, 1 year delay and general bad will. To avoid a problem of this kind requires measures from the client to avoid having contractors being deceiving or careless.

The disasters are there because of the lack of care somewhere during the construction process. In next section, we will look more on the contexts resulting in need for rework.

4.9 About context behind rework cases

In our study, we have mainly focused on descriptions about real errors that give a need for rework. There are a number of good studies with more discussion about the contexts behind cases resulting in rework. Here we will look at three of them.

A study by Aljassmi and Han [9] involved investigation of 272 defects from 81 disputes that occurred in the Dubai residential construction industry in 2009. In these responsibilities were clear because the defective acts were collected from resolved disputes. They were separated into nine classes or reasons; poor workmanship; impaired material usage, task sequence omission, deviation from intended dimension, instructions contravention, professional principles noncompliance, official rule noncompliance, items interdependence disregard and adoption of misbuilding instructions. They give finally two main classes of reasons for disputes: skill based reasons and violation reasons.

In the paper: Analysis of construction delay for delivering quality project in Bangladesh, Hoque et al [10] investigated views from engineers, project managers and contractors on the causes of delay during a construction phase. That study included an extensive literature review that identified 40 potential delay factors. These delay factors were collected under 8 headings; owner related, contractor related, consultant related, design related, equipment related, materials related, labor-related and externally related. A group of 102 engineers, project managers and contractors from Bangladesh responded to a questionnaire about their experience of these delay factors.

Asadi et al [11] made a systematic literature study with a careful review in detail of 212 relevant articles. Aim of this work was to investigate, identify, and prioritize the organizational-based reasons for rework. They found 37 root causes and grouped them into five main categories: process, human resources, material and equipment, technical, and general/external-related factors. They ranked these rework indicators in each based on how often they were mentioned in the literature.

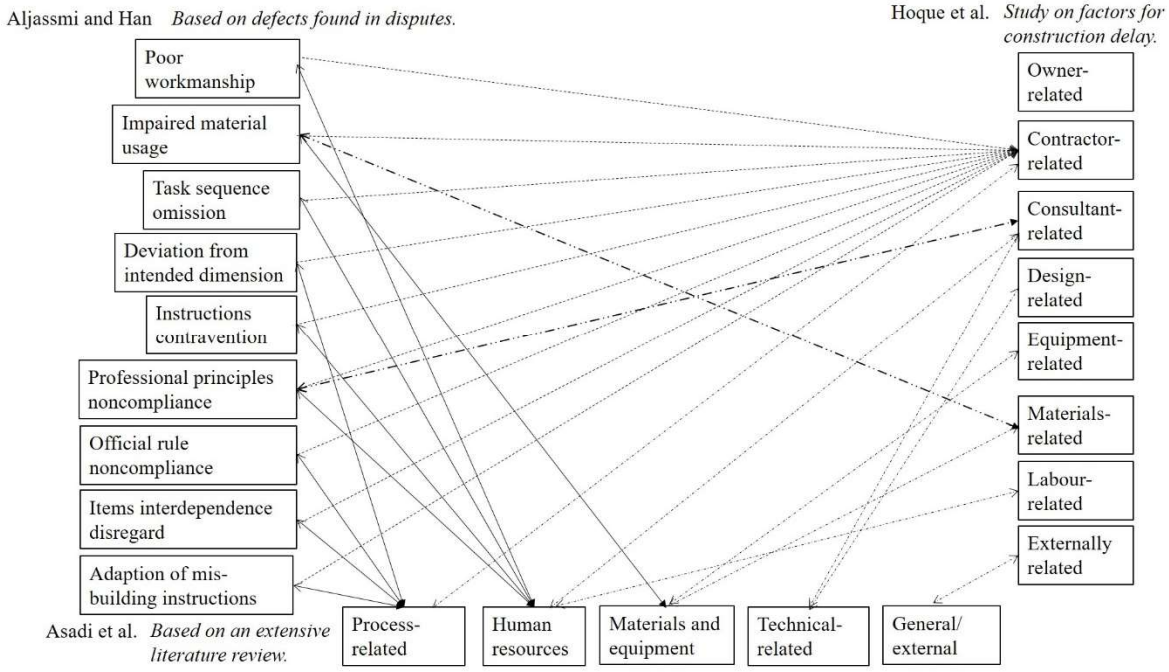


Figure 1
Comparison of three examples for classification of reason for rework.

It is interesting to see how these different perspectives co-operate. Asadi with the focus on organisation, Aljassi with the focus on real reasons for disputes and and Hoque with focus on factors relating to construction delays. Figure 1 illustrates our comparison.

The matching between Aljassmi and Hoque is not very clear. One could state that almost all the defect types listed by Aljassmi can be contractor-related in Hoque's list. Going in the other direction Hoque's heading consultant related can also match to Aljassmis professional

principles noncompliance and both lists mentions materials as an issue. The other items mentioned by Hoque don't really match to Aljassmi's list.

When we look at Asadi's five headings, the heading process related connect to four headings in Aljassmi; adaption of misbuilding instructions, items interdependence disregard, official rule noncompliance and deviation from intended dimensions. Asadi's heading human resources connect to Aljassmi's professional principles disregard, instructions contravention, task sequence omission and poor workmanship. Asadi has materials and equipment as a heading which connects well to impaired material usage in Aljasmi's list. When comparing Asadi with Hoque, the process related issues in Asadi relates to contractor related in Hoque. Asadi's human resources connect to consultant related and labour related in Hoque and Asadi's materials and equipment matches equipment related and materials related respectively in Hoque. Asadis technical related can match to consultant related and design related in Hoque. General/external in Asadi match to externally related in Hoque. Hoque's factor owner related has no match in the other two studies.

Of course, our comparison is somewhat deliberate but still it elucidates how different the classifications can be. We think these three studies match fairly well, but we also think this kind of categorisations reflect how these authors have different scopes of their classifications.

4.10 Classification without pointing out responsibility.

One thing to remember is that the role of the person giving the report will biase the idea about responsibility. From the reporting persons view the reasons might be obvious, but other actors involved might have other explanations. So, the responsibility will not be clear until when these cases have been the subject to a legal investigation.

In our study we classify the cases under 13 headings and express physical facts:

1. Transport of damp or moisture
2. Water flow, not under pressure
3. Water flow, under pressure
4. Floors, related to slope and altitude
5. Leakage in sewers
6. Freezing water
7. Water in facades
8. Stained facades
9. Problems with ventilation ducts
10. Ventilation and heating
11. Technical details
12. Acoustic problems
13. Disasters

This is a way to report without taking a position on what or who caused the problem. We believe this way of thinking can be helpful for a focus on actions for less need for rework. It is more

important to react to upcoming problems in a rapid way than having a detailed understanding of responsibilities.

4.11. General discussion

All the cases we have collected deal with ordinary processes that happen every day in the construction sector. In this study, the cases are presented with indication of the problem, cause and consequence of the problem and the rework or the action to avoid the problem. The indication is what makes us notice that an error or failure exists. The cause is the context of errors or failures that result in the indication. The consequence is the damage or accident resulting from the error or failure. It can also be a financial consequence. The action is what should be done in the future to avoid current errors or failures.

The cases we present show a big diversity in things that might result in the need for rework. Some the problem probably have their origin in decisions about how things are to be done at the construction site. For other cases there are probably deviations from what was planned with the origin from the management on the construction site. Some cases relate to faults that could be traced back to an individual craftsman. At the same time, current requirements for low energy use mean that the constructions can become quite complex. This may involve risks of damage and rework.

As we express in part 1 of our report Aljassmi and Han [9] 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. In case violation to any instruction or principle 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 trade rules such as those about plumbing work in “Safe water installation” described in part 1 are important for guidance.

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We have some ideas about how to avoid damage, it is good to;

- have up to date knowledge about problems that emerge.
- have a leadership that favours commitment to a well-built product.
- to always follow up the details that are critical, like those that could result in leakage of water.
- be open about things that go wrong

All of this is of course easy to say, but very challenging to do.

5. CONCLUDING REMARKS

In conclusion, all the 49 damage cases described in the two reports from the study are picked up by first hand sources, by people in the project team or by reports from an insurance company, being a second hand source. To send questions to former students was an advantageous way to

collect information about cases of rework in the construction sector. All cases belong to residential construction on Sweden, being a Nordic country. They have resulted in notable problems and the need for rework. Substantial costs have followed. Several of the cases relates to concrete.

From the conclusions, in part 1 of the report we can bring that many of the cases described under headings 1 to 5 show how damp when released from young concrete result in the need for rework in other parts of the building. 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.

Headings for the cases in the second part of the report deal with water freezing in the building envelope, water in the facades by different processes and stained facades. Ventilation might be handled in the wrong way on the construction site or placed in the wrong way in the building. Construction parts did in several cases not fulfil the system performance anticipated. This was for ventilation and heating systems", technical details and also acoustic problems. Ventilation or heating might not fulfil the system performance anticipated. The disasters are there because of lack of care somewhere in the construction process.

In general, big respect has to be paid to the preparation before casting concrete because any need for demolishment consumes considerable resources. When we read studies discussing about reasons for rework we note how categorisations are to some extent influenced by the reporters own intentions.

Here the cases are assorted under 13 headings that mention physical facts without taking a position on what or who caused the problem. We think these headings are useful for understanding the rework problem. We think the description of these cases can be useful for risk assessment in construction projects. Other researchers can also use them as a basis for further studies about rework, and for further work to improve quality.

In general, to avoid damage it is good to; have up to date knowledge about problems that emerge; have a leadership that favours commitment to a well-built product; and to always follow up the details that are critical, like those that could result in leakage of water. We also think it is good to be open about things that can go wrong. In case skill is missing, education would contribute to a better outcome and less need for rework. In case violation to any instruction or principle is the reason, it should be very clear who is responsible, and important to place responsibility with the person who can influence the outcome.

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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