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Comparison of two weather cover systems for multi-storey wood building

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Keeping a wooden frame dry is key for a successful building project of multi-storey wood building. A cover system used for such a purpose has high requirements to meet and can play a key role in time, costs and safety of a construction project. This bachelor's thesis compared two currently used weather cover systems.

The assembly of both systems and the use of one of them was observed and studied. Information was gathered by observing the phases of the project, taking time and interviewing the designated foremen on-site. Installation times of wooden frame elements were discussed and compared between the systems. Differences in costs and safety were also discussed, pointing out the main advantages and challenges of both systems.

The aim of the thesis was to find the advantages and disadvantages of both weather cover systems. The two systems were found to have significant differences in reliability, time efficiency, costs and possibly even in safety. Recommendations for action are given for the main contractor as well as the supplier of the weather cover systems.

Keywords	weather cover, wood building, dry chain

Contents

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1 Introduction

The final year project compares two systems currently on the market for protecting a structure being built from the weather. These systems ensure a continuous dry chain, which is necessary when building from wooden elements. The dry chain begins at the element factory and has to continue throughout the building process until the building envelope is waterproof. As the covering systems surrounds the buildings from the finishing of the foundations until a water proof roof is in place, the rental times of the systems are long. Therefore, the rents are expensive and represent an important portion in the budget of a project. The systems are also very different technically, which may affect time and safety aspects. The two systems can be seen side by side in figure 1.

This bachelor’s thesis is made in co-operation with the construction company Rakennusliike Reponen Oy. Reponen is Finland’s leading builder of multi-storey wood buildings and is, therefore, interested in comparing the currently used covering systems to establish which one is the most viable for projects of various sizes. The main factors focused in the project are time and cost efficiency, and safety.

Figure 1. The two systems assembled. Layher on the left, Gibson Tower on the right.

The thesis was written in the time between the beginning of January and end of May. During this time the building phase of this project was started but did not end. The weather cover systems that are the focus of the thesis are meant to be used in the frame building phase of construction. In the time frame of this project, the wooden element installation reached the end of the second storey at the Gibson Tower cover system, and the installation work of wooden elements did not yet begin at the Layher cover system. The thesis is written on the basis of the information that could be collected about work conducted.

The second chapter describes the two weather cover systems compared in the project. Third chapter discusses time spent with different phases of works. It considers the amount of cargo, assembly time, use phase and disassembly of the systems. In the fourth chapter costs of the two systems are shortly discussed. Differences in costs of assembly, use and disassembly, as well as cover system specific differences in costs are included. The fifth chapter discusses safety and its differences from the perspective of the systems' differences. The sixth chapter gathers the results and concludes the key findings. Some details are left unmentioned on purpose for the protection of privacy of the businesses mentioned in the project. All pictures presented in the thesis are taken by Aleksi Heikkinen.

2 The protection systems compared

2.1 Gibson Tower

The first cover system discussed is Gibson Tower. It combines a weather cover and a bridge crane. Experience has shown it is possible to deploy the system in a narrow space, as scaffolding is not needed. The cover and crane combination is lifted by electrical motors connected to steel pillars. Number of motors depends on the amount of pillars. The number of pillars needed depends on the size of covered area. The cover rises up as needed simultaneously with more storeys built to the building. At the same time more space is freed underneath. The crane's lifting capacity is 3.2 metric tons and maximum span 25 m. One end of the cover is further from the building's wall and serves as an opening for elements to be lifted up from underneath the cover. Elements can also be delivered directly from a truck to the installation position by the bridge crane which is operated by a worker inside the cover using a hand controller. [1.]

Figure 2. Gibson Tower in use. Wooden elements of the first floor are partially installed.

The perimeter of the system is 28 meters by 80 meters. The maximum height the system can reach is approximately 25 meters after all pillar modules are in place and the roof elements of the building are installed. The pillars sit on top of large concrete base blocks each weighting between three and four tons. Therefore the system does not need additional weights to stabilize itself against wind loads in the beginning of use. However as the cover is lifted higher, vertical braces are added to attach the pillars to the building frame for stabilization. Each longer side of the cover has nine steel pillars at about 9.2 meter intervals. These pillars, 18 in total, have two one horse power electric motors attached to them, excluding the corner pillars that have only one motor. In total the scaffolding system has 32 electric one horse power motors in it to lift or lower the cover. All of these parts can be seen in the figure above.

2.2 Layher Allround with Layher Keder Roof

The second system discussed is Layher's Allround Scaffolding system. It is a German scaffolding system used widely by the construction industry not only in Europe but all around the world. It is built by Wilhelm Layher GmbH & Co KG. All Layher products are manufactured in Germany, which the company uses as an advertisement of quality. [2.] For covering the top a roof product called Layher Keder Roof is used.

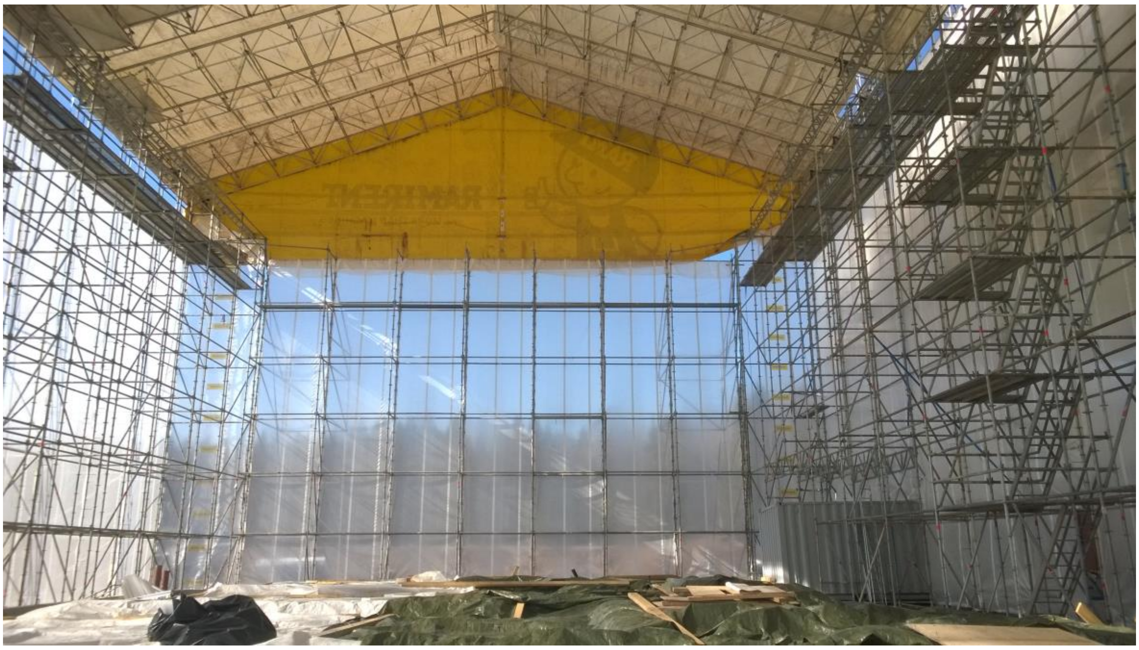

Figure 3. Inside of the finished Keder weather cover system.

The basic scaffolding frame constructed with the Allround product can be seen above and is 12 meters high, made with six two-meter high modules stacked on top of each other. On top of the two-meter modules the scaffolding has two one-meter modules more of vertical height. Between the roof cover and scaffolding rails are used. The lower one of these one-meter modules has the inner railing on top of it and the second, one meter higher, modules have another set of rails on top of them, placed on the outer side. This gives the ability to move part of the roof underneath or on top of one another for elements to be lowered inside the cover system. The elements are lifted inside by a separate car crane.

Figure 4. A finished Keder weather cover.

The overall dimensions of the system are 22.5 meters by 32.5 meters. The overall height is approximately 18 meters. The scaffolding is held to its place against wind by fourteen anchoring positions where a line is attached from the top of the scaffolding to concrete weights on ground with approximately one metric ton mass. The finished system can be seen in the figure above.

3 Time requirements

3.1 Gibson Tower

3.1.1 Delivery

The provider of the protection systems had not calculated needed amount transports to deliver all needed parts for the Gibson Tower accurately. Material is brought until all parts are delivered, without a number of transports needed accurately calculated. [3.] Gibson Tower's pillars are brought in height pieces of three and six meters. Materials are brought and unloaded with a boom truck. A single boom truck without a trailer car delivers conveniently for example 72 meters of pillar by transporting twelve pieces of six meter tall modules in the truck, two pillars on top of each other. Underneath each tower, there is a concrete base block. Some of these blocks were brought as prefabricated, previously used blocks and four of them were poured on-site. A single boom truck can bring two of these bases in its six meter long platform and three more on an extended trailer.

3.1.2 Assembly

Transportation of the parts of the Gibson Tower to the site started two days before the installation began. After the two days, during the next ten work days all concrete blocks were set to their places and all preparations before the roof modules could be started to work on were done. This included the connecting of pillar mounts to the blocks, first pillar modules, electrical motors, horizontal beams (on top of which the rails are),rails, walking platforms and railings. Supplying the concrete blocks and connecting the pillar mounts to the blocks were agreed to be the main constructor's responsibility. Locations and guiding lines for placing the base blocks were marked by main contactor's measure man. Four out of 18 base blocks were poured on-site. On the previous construction site the same system was in use but less base blocks were needed and, therefore, more had to be poured. Setting base blocks to their places did not slow down the weather cover system supplier's work as the installation of system parts could begin right after the first blocks were in place. After the ten days the installation of roof modules began and took nine work days.

Figure 5. Last one of the roof modules being lowered to its place.

Apart from the pouring of four of the concrete base blocks and attaching the pillar mounts on the base blocks with bolts, all work and machinery used to raise the system was performed by the supplier of the weather cover system.

Figure 6. A derailing damaged a horizontal brace and caused a danger of the roof module falling down on its side.

The roof cover of the system is assembled with 16 five meter wide modules. They need to be first assembled on the ground, then lifted on the rails and pushed to their place as seen in figure 5. The roof modules are moved by two workers pushing it each from one side. The wheels of the modules are small and do not require much force to derai. In the beginning of the roof installation, one of the roof modules derailed, causing it to tilt strongly forward. A risk of the module falling was present but fortunately, this did not happen. The weight of the module bent a horizontal brace which had to be replaced. The situation can be seen in figure 6. The replacing and repositioning work consumed close to one full day of work for the supplier of the weather cover system. In total, it took four weeks and four days to erect the system. The progress of assembly can be seen in more detail in Appendix 1.

During the assembly period, the supplier of the weather cover systems had a car crane on-site for 10 work days to complete the roof module works. Throughout the whole period it was necessary to move pieces of equipment from place to another and do installations that high above ground. For this reason a telehandler had been kept on-site since the beginning of installation. The telehandler is kept on-site throughout the period of assembly, renting period and disassembly as it is an important machine in the occasions of repair works.

3.1.3 Use phase

The planned erection time for the Gibson Tower was four weeks. In practice the time from the arrival of the first pieces of the system on site to the point when the weather cover was finished and ready to be operated (lifted upwards and bridge crane functioning) was four weeks and four days. The delay was created by two separate problems, crucial for the functioning of the system. Firstly, the span between the rails that the bridge crane sits and is moved on was slightly larger than it had been during the previous use of the system. The problem was fixed within a week by adjusting the crane frame.

Figure 7. An electrical motor stuck lower compared to the other motors.

The second problem was connected to the electric motors connected to the pillars. Two of them would not function. However the lifting system has been designed so that one of the 32 motors can malfunction and not interrupt the raising of the cover, as long as it is not a corner pillar’s motor. The lift system allows for one motor malfunctioning, if the motor is not that of a corner pillar. One of the two malfunctioning motors was in a corner pillar. Therefore, it was not possible to raise the cover before the motors were repaired. As the cover could not be raised, there was not enough vertical space between the foundations of the building and the bridge crane to move the wooden elements to their places. The installation of the first wooden elements was delayed by four work days. A motor stuck can be seen in figure 7.

During the use phase of the cover system several different problems appeared and had to be solved. An issue that occurred twice during the installation of the elements of the first floor was the power cable of the bridge crane getting cut by its own wheel. The bridge crane can be seen in figure 8. The cable rests on top of the horizontal beam on one of the long sides of the cover system. It is brought there from the other end of the beam where the opening for elements to be lifted from is. When the bridge crane is at the opening, the cable is fully winded up on a roll. When the crane is moved to the other end of the cover on its rails, the roll winds open and the cable is laid on the horizontal beam the whole width of the cover. The problems being when the crane is moved back towards the opening end of the cover and the cable has to wind back to its roll.

Figure 8. Operator of the bridge crane preparing to lift a balcony floor element. A worker of the company providing the weather cover systems up at the crane making sure the cable stays on right track.

There are two main factors that together result the cable getting cut. The cable gets too close to the wheels of the crane and the roll the cable is supposed to be winded around does not pull the cable with enough force to pull it away from the way of the wheels and rail. The issue was tried to be solved by building a short spout for the cable to travel inside close to the crane, but the sheet metal spout built for the purpose by the contactor did not always serve its purpose.

Once the cut cable could not be replaced immediately with a new one. Because of this, the cable had to be shortened. This led to a situation where the bridge crane could not reach one end of the cover all the way and thus interfered with installation of the elements. The installation order of the elements had to be changed according to the range the bridge crane could reach. This caused issues not only with the installation but also with the storage of the elements. The elements are delivered in packages of two to six elements per package from the factory. The wooden elements can be fifteen meters long, and their positioning on-site and the schedule of arrival to the construction site has to be carefully planned. If an element package is taken to the cover system and is opened but it turns out that these elements cannot be installed, it takes time to rearrange the elements aside and temporarily support them with wooden joists. In figure 9 an element being prepared for lifting can be seen.

Figure 9. Wall elements moved underneath the cover system for lifting. An element is being prepared for moving to its place. The elements are temporarily supported.

The supplier of the weather cover systems had difficulties to obtain the correct type of replacing power cable for the bridge crane. Once a heavier duty cable was installed. This resulted in problems as the heavier cable would not wind on the roll as well as the original being a thicker, stiffer cable. After trying to cope with the heavier cable for a day, it was changed back to the cut, too short of cable since there were fewer problems with it. A correct cable was ordered and installed once it arrived on-site. The spring inside the cable roll broke once due to the use of the heavier gauge cable. This made the crane completely inoperative and halted the moving of elements under the weather cover until the spring was replaced in one work day.

Another problem with the bridge crane had to do with its lifting capacity. The same cover system had been used on a previous construction site of Rakennusliike Repo-nen. There the lifting limit of the crane itself had been customized to allow problem-free moving of the heaviest wall elements. However, between the two projects the limit had been reset to its default value. This caused another problem that consumed time; the lowered crane lifting weight limit was so slightly exceeded that windows and doors had to be taken off the heaviest exterior wall elements for the crane to lift them. The work of taking off and reinstalling the doors and windows not only took time but also increased the risk of the new windows and doors being marked or scratched. The lifting limit was later raised from the incorrect value to the correct one used at the earlier construction site.

Not all modules need to be in place for the cover system to be raised at the beginning of the use of the cover system. However, at some point more pillars need to be added in order to lift the roof as more floors to the building being built underneath the cover are assembled. While the first floor of elements was installed, the height of the cover allowed the elements to be moved from the ground to the correct position on the base of the building. As previously mentioned the elements come in packages of multiple elements per package. Often the element to be installed next is not the outermost but between other elements. As the system was still quite low, it was not possible to lift an element out of the package vertically but it had to be slid horizontally from between other elements. This put the elements at a risk of being more easily damaged as parts such as window ledges might scratch another element and painted surfaces may be damaged.

Problems with the cover system played an important role in the delay of the beginning of the element installation phase in the building process. The effects cannot only be measured in time and money, but also in frustration of workers, effecting work morale. The installation of the wooden elements of the first floor was completed three weeks behind schedule. Approximately two weeks of this time was caused by problems with the weather cover system. [4.]

Table 1. Times for element installation of four different types of wooden elements. Units of time are in minutes, distance in meters.

Element → **Phase ↓**	External wall, small	External wall, large	Partition wall, large	Floor element
Lift preparations and attaching to crane	3	5	4	7
Lift	3	4	9	7
Securing the element and detaching from crane	6	5	3	4
Total time [min]	12	14	16	18
Distance [m]	15	12	23	36

The time for the installation of one element was calculated by observing the work of the installation team and using a timer. The “Lift preparations and attaching to crane” phase comprises the removal of a protective plastic from the element and attaching the crane’s horizontal lifting beam to the element. The timing of the phase begins when the removal of the protective plastic is started and ends when the worker attaching the crane’s beam to the elements has lowered down from the top of the element and the bridge crane operator begins lifting the element. The “Lift” phase is the time from when the crane is starting to lift the element until the element is lowered to its position. The time for the “Securing the element and detaching from crane” phase covers the element being in its place but still relying on the crane in order to not fall over, the attachment of temporary vertical braces to the element, and detaching the crane’s lifting beam.

The “Lift” phase partially depends on the installation of a given element. Wall elements are always lifted from the end of the weather cover designed for the purpose. As some elements are installed further from that end of the cover, the distance is different. The distance between the end of the building and the installation position of the element is given in the “Distance” row of table 1. Floor elements are sometimes lifted from the wider sides of the cover system. They are transported underneath the cover, next to the building by a fork lift. This is done because the space at the lifting end of the cover is limited and floor elements take more ground area. Therefore, it is easier and simpler for the installation team to organize the elements for the job this way. This is why the times and distance presented for the floor element's lift above are not calculated from the same physical position than with the wall elements, but from one wider side of the cover system – where it was lifted from.

The measured times do not represent the total times of installing elements. After all wall elements are in place, the next layer of floor elements is installed. Only after the new floor layer is in place, long wood screw attachments are driven through the newly laid floor elements to the wall elements underneath. This takes time. After this is done, the temporary vertical braces set to keep the wall elements in place are removed. In addition to the screw attachments, there are also other preliminary tasks implemented that are not included in the timed phases. For instance, a rubber seal is attached to the floor element, to seal the space between the floor and the wall element coming on top.

Larger elements have more mass and require more precision when moved in the air simply for their size. This reflects to the duration of the "Lift" phase, but also on the first phase of preparations. The large elements have move plastic covering to be taken off them and require more lifting line attachments between the element and the crane's lifting beam.

Partition walls do not have any overhangs on their smooth gypsum wall surfaces, which makes it easier to pack several of them one package. As the elements are not packed in the order of installation, it is often necessary to lift wall elements that are between others in the packages. This slows down the removal of the plastic covering from the lifted element as well as the beginning of the lift, as it has to be done very carefully in order to not damage other elements. Works of table's phase "Securing the element and detaching from crane" can be seen conducted in figure 10.

Figure 10. The bridge crane operator detaching the crane from a small external wall element after the element is temporarily supported.

Only one lift per a certain type of an element presented in the table was timed because of lack of time. Timing the same type of lift multiple times would have given more precision for the generalization of results.

3.1.4 Disassembly

As the system was not disassembled within the timeframe of this project, the times given are based on estimations given by the on-site foreman of the supplier of the weather cover systems. There are two differing disassembles taking place on the construction site at issue. Two close to identical buildings are built with both weather cover systems. As the first building's frame is ready and the building envelope is waterproof, the disassembly of the cover system begins and the system is moved to the second similar building. Many parts of the system can be transported partly assembled when taken to the second building unlike the time when the materials were first delivered to the site. When the envelope of the second building is waterproof all modules of the cover system are fully separated to be transported from the construction site as once delivered.

The foreman of the the supplier of the weather cover systems estimated that the interphase disassembly of the Gibson Tower would take approximately two weeks and the reassembly another two weeks. Therefore, the moving of the system to cover the second building would take about the same time as the original assembly of the system. The final disassembly of the system was estimated to take three weeks. The time is longer than the interphase disassembly because all pieces of the system are fully taken apart again, leaving only some of the pillar modules connected to form pieces suitable for the cargo length of a boom truck. [3.]

3.2 Layher

3.2.1 Delivery

All material, excluding the concrete weights, could be transported to the site with four boom truck transportations without the truck using a trailer. The material was taken directly to the location where the cover system was built as the number of deliveries was notably smaller than that of Gibson Tower. The first delivery arrived on the same day as the assembly began. As the frame is built of light modules and designed to be quick to assemble, no machinery was needed to begin the assembly.

3.2.2 Assembly

The overall assembly time for the system was 12 work days. A telehandler was used throughout the assembly phase as it helps to reach high and makes it easy to take tools to a high working position. It was used especially when attaching tarps on the sides and the roof structure of the system. The tarps make the structure water and windproof. A car crane was used in the last three work days of assembly to lift the Keder Roof’s modules on top of the rails. This can be seen taking place in figure 11. The car crane also helped keeping the roof trusses of the weather cover’s modules in their form while they were pieced together. There are in total eight roof trusses used in this Layher Keder Roof, three of them being part of and shaping the higher one of the two separate roofs.

Figure 11. First Keder Roof module being lifted to its place after being assembled next to the cover system. The two separate rails for the separate roofs can be seen on top of the scaffolding.

The Layher weather cover system was assembled within the planned assembly time of two weeks, including both Saturdays although the supplier of the weather cover system was forbidden to work during the weekends as the workers had been seen working in high altitudes on top of the scaffolding without safety harnesses. The workers had neglected the instructions of the main contractor in order to stay in schedule. The proceeding of the assembly can be seen in more detail in Appendix 1.

3.2.3 Use phase

As mentioned in chapter 1 above, the installation of wooden elements did not begin during the thesis was written. Therefore information in this part of the thesis is based on estimation.

The cover system itself does not have any electrical components as does the Gibson Tower. The two separate roofs are moved by two men pushing the roofs one from each side. The roofs can be moved freely to any position on the rails that reach both ends of the cover. The roofs and rails can be seen in figure 12. Therefore the only challenge to be expected is how the cover system and car crane work together.

Figure 12. The two separate roofs on their own rails. The higher roof rests on the outer rails.

Unlike with the Gibson Tower, the crane operator cannot see the inside of the weather cover. The crane operator relies on the information provided by the installation team through walkie-talkies. This slows down the lift time as the elements in air have to be moved slower and with more care, the crane operator waiting for the team's commands. The lift is also slower because of the physical distance. Each element has to be first lifted all the way up over the top of the cover system and then lowered down through an opening made in the roof. Days with high wind complicate the process as the element will move more aggressively in the air while lifted.

Except the differences in the lifting process of elements, the times for phases "Lift preparations and attaching to crane" and "Securing the elements and detaching from crane", as presented earlier in the chapter where Gibson Tower's time was discussed, can be expected to be nearly identical. Attaching and detaching the crane to and from an element, as well as other tasks related to the elements are identical, and the differences of the cover system do not affect them.

3.2.4 Disassembly

As with the Gibson Tower, the disassembly of this system did not happen within the timeframe of this thesis. The on-site foreman of the supplier of the weather cover systems estimated the disassembly of the Layher system to take approximately the same time as its assembly took, perhaps a day less. [3.] Unlike with Gibson Tower, the assembly and disassembly are identical for both buildings it is used at. All modules the cover is built from will be taken apart to the same extent as they were when arriving on the job site. Therefore, it is a lot easier to estimate the time of the second assembly and disassembly of the Layher system than those of Gibson Tower. There are not as many different kinds of parts and modules in the Layher weather cover compared to the Gibson Tower system.

4 Costs

The subject of costs is discussed only briefly because the commissioner of the project can always calculate costs by multiplying known costs with time. However, for the sake of giving picture in relation to the topics of this thesis simple cost comparison is conducted and discussed.

For confidentiality reasons costs are presented in ratios in table 2. The relations are denoted in ratios of one another. The costs of Gibson Tower are presented as one, or 100 %, as they are the higher ones.

Table 2. Relation of costs of weather cover systems.

	Gibson Tower	Layher Allround & Keder
Rent	1	0.30
Assembly	1	0.45
Disassembly	1	0.35
Crane	1	0.75

In Gibson Tower the bridge crane comes from the supplier of the weather cover systems. For the Layher system, on the other hand, the main contractor provided the car crane from another source. Therefore the cost of the crane for the Layher system is calculated by multiplying the approximated daily cost of the car crane by the estimated assembly time of the wooden element frame of the building in days.

The supplier of the weather cover systems is interested in assembling and disassembling the systems as quickly as possible. This is because the rental times of the systems begin once the system is fully erected and ready to be used.

As can be seen from the table above, the Layher system is much cheaper than the Gibson Tower. However the Layher system is less than half of the size of the Gibson Tower as well as lower. The buildings built with the use of the Layher system are three storey high whereas Gibson Tower's buildings are four storey high. Although the Gibson Tower's crane system is approximately 25 % more expensive compared to Layher's crane solution, it at least partially pays itself back being more user friendly and possibly even a safer solution. Costs of assemblies and disassembles are understandably higher with Gibson Tower as the components it is built from are more complex, heavier and larger. There is also more different type of components in the Gibson Tower system compared to the Layher system. This reflects to the assembly and disassembly prices of Gibson Tower.

The earlier discussed delays with the Gibson Tower in its assembly and use phases became expensive for the supplier of the weather cover system. For the approximated two weeks of total delay created by the end of the first floor's element installation the main contractor is not required to pay rent for the cover system. In addition the supplier of the weather cover system is required to pay salaries of the element installation team for the days the team was not able to perform their planned work. On top of this comes the additional costs the supplier creates for itself, needing to pay for machinery used and salaries for more days.

5 Safety

While installation of wooden elements is ongoing there are hazardous areas with a risk of falling when the floor elements are installed but no external wall elements are yet in place. With use of both weather cover systems streamer line is used to border an area which is safe to move inside of without use of a safety harness. The area which needs to be limited changes on an hourly basis as new elements are installed. Therefore, the streamer line, held in place with cones, is an ideal solution for the purpose. It is light, fast and easy to move and carry to a higher floor when the installation of one storey is completed. When a person needs to go outside of the area limited by the stream line in order to carry out a task, he is required to wear a safety harness. The streamer line method is also useful with visitors to the construction site, as it is clear where walking is allowed and where not. The streamer line can be seen in use in figure 13. At the beginning of stairs of the Layher system there are signs stating that people entering the scaffolding are required to wear and use a safety harness.

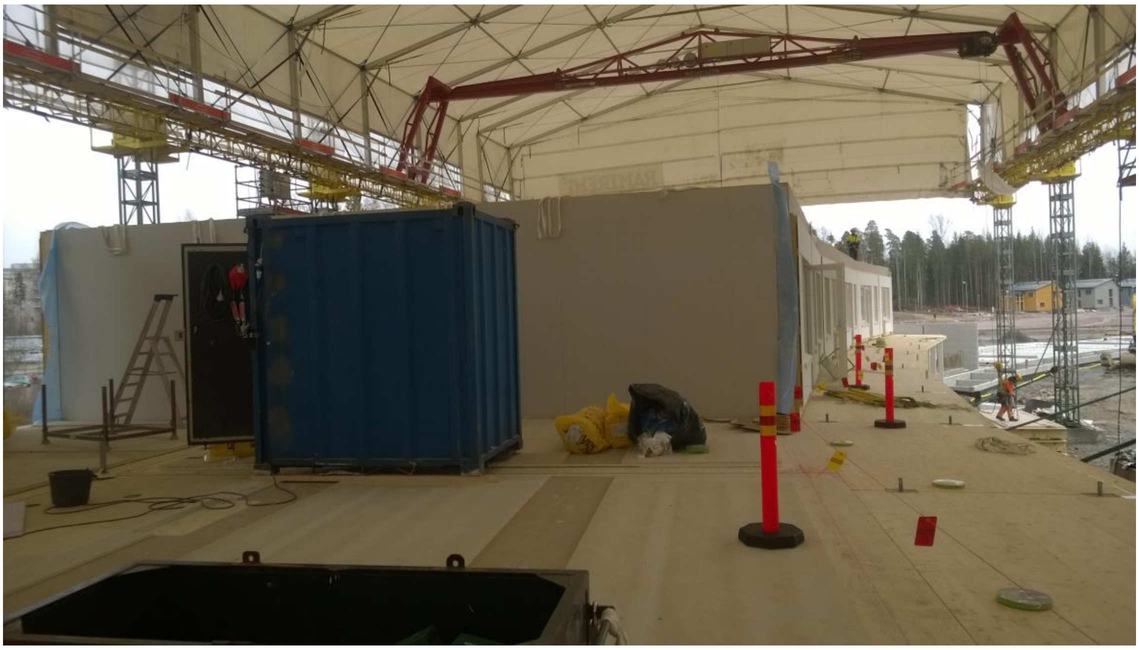

Figure 13. Streamer line limiting free moving close to the edge.

As mentioned in chapter 3 about the construction times with the Layher system, the crane operator at the Layher system cannot see where the element is lowered inside the cover and installed to. The crane operator relies on information received through a walkie-talkie and cameras of the crane. In comparison to Gibson Tower, where the operator is close to the element, sees the element and can talk with other workers, the procedure required with the Layher system has its disadvantages.

When using a separate car crane, there are additional checks that need to be conducted concerning the soil. The buildings discussed are built on top of clay-dominant soil type and only the necessary areas of ground around the buildings are stabilized. The surface ground material should preferably be crushed stone. In addition, it is good to use steel plates and underneath them large square timber logs to ensure a stable placement of the support legs of the car crane. An unreliably set car crane is a risk to everyone on a construction site.

6 Conclusion

This thesis has given a simple opening to the advantages and disadvantages of two weather cover systems. It has discussed how the systems behaved within the timeframe of this project and what kind of challenges can be associated with them.

Gibson Tower has not yet been used widely by the construction sector in Finland, Rakennusliike Reponen Oy being the first company to use it. Limited experience with the system is a clear component for the reasons why some of the problems occurred and why fixing them took as long as it did.

The width of the Gibson Tower cover can be up to 40 meters. In other words, the maximum span of the roof truss modules for the Gibson Tower is 40 meters. However, the bridge crane for the system is only available up to a width of 25 meters. This limits the usability of the Gibson Tower system with the integrated bridge crane to buildings that fit underneath the cover; the width of the building must be less than 25 meters on one of the directions. If the Gibson Tower is to be used for buildings with a wider structure, the system loses one of its key advantages – the integrated bridge crane. Even though element installation times for the Layher system could not be carried out for this thesis, the Gibson Tower's crane solution can be expected to be quicker in installation times, as well as safer – as long as it works. Gibson Tower has also the advantage that it can be used although it is not fully finished. Pillars not needed for the first raise of the cover can be installed later, together with vertical braces.

The Layher Allround with Layher Keder Roof system can be expected to perform more reliably. It does not have many mechanical parts, the only ones being the rail-wheel system of the roof modules. However, installation times for elements can be expected to be slightly longer. The system is also not as comfortable for the installation team to use as the Gibson Tower, because of the challenges of no direct line of sight to the lowered element by the crane operator, longer lift heights and the walkie-talkie communication with crane operator.

Shortcomings such as missing deadlines and machinery failing become expensive for the supplier of the systems as the main contractor charges the cost of the delays from the supplier. These expenses come on top of the supplier's own extra costs, which consist of possible extended periods of using a car crane, labor costs, equipment and materials. The workers who fix the weather cover were maybe originally assigned for a different location. The supplier of the weather cover will, of course, learn from the mistakes and improve the quality of service with the Gibson Tower weather cover system over time.

Gibson Tower has multiple spots in its system which require improved maintenance and product development. The multiple failures with the electrical motors raising the cover along the pillars indicate that there is more to the rate of failures than bad luck. Maintenance of these motors should be routine-like. The other spot that endured multiple failures during the time frame of the project was the bridge crane with its power cable. It is clear that the way the cable is handled close to the crane requires product development. A working solution is a combination of using the right type of cable, cable roll with tight enough spring and a better functioning spout guiding the cable. The company providing the weather cover systems could improve their on-site service and the reliability of their product by having spare parts for some of the parts of Gibson Tower on-site. There are small components, such as the spring inside the cable roll of the bridge crane, that are inexpensive and small but a key to the operation of the system.

Rakennusliike Reponen Oy is recommended to calculate the installation times of the elements for the Layher system in the same way as done in this thesis for the Gibson Tower in order to receive comparable data between the use of the two different systems. This data can be used to estimate installation times in the future. Another use for the data is to take it into consideration when deciding which one of the two systems to use for a new project. If a project with a building where size is between the buildings in this project is planned, the advantages and disadvantages of the systems studied in this final year project should be evaluated.

Another area with potential for improvement is the packing of the wall elements. The manufacturer of the elements and the on-site manager of frame construction should discuss how to improve the packaging and which would be the optimal order of elements inside the packages. Having the elements packed in a more precise order of installation would simplify the work of the element installation team. This would result in shorter installation times and less damage made to elements as they would not need to be taken out off the packages from between each other.

References

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3 Peitsoma, Jarkko. On-site foreman of weather cover systems providing company. Helsinki; 2016. Interview 5 April 2016.

4 Mäkitalo, Matti. On-site manager corresponding for wooden element installation. Helsinki; 2016. Interview 4 April 2016.

Record of assembly and use of the weather covers

Gibson Tower - calendar of events

February 2016

1-Feb		(Example: 1+4 = 1 foreman and 4 workers on-site.)
2-Feb		
3-Feb		
4-Feb		
5-Feb		First pieces of Gibson Tower arrived on-site.
6-Feb		
7-Feb		
8-Feb		
9-Feb		
10-Feb	1+0	Installation of concrete base blocks began.
11-Feb	1+2	Contractor brought telehandler. Will stay on-site.
12-Feb	1+2	
13-Feb		
14-Feb		
15-Feb	1+3	
16-Feb	1+4	
17-Feb	1+4	
18-Feb	1+4	
19-Feb	1+4	Contractor brought a car crane.
20-Feb		
21-Feb		
22-Feb	1+4	All concrete base blocks in place.
23-Feb	1+4	First roof module in place.
24-Feb	1+4	
25-Feb	1+4	Accident with a roof module's wheel derailing.
26-Feb	1+4	
27-Feb		
28-Feb		
29-Feb	1+4	Bridge crane arrived on-site.
1-Mar	1+4	
2-Mar	1+4	First wooden elements arrived on-site.
3-Mar	1+4	Last roof module in place. Element installation planned to begin today. Car crane left.
4-Mar	1+4	Bridge crane still not functioning.
5-Mar		
6-Mar		
7-Mar	1+4	Raising weather cover blocked by two broken lifting engines.
8-Mar	1+4	Bridge crane functioning. First wooden element installed.
9-Mar	1+4	
10-Mar	1+4	
11-Mar	1+4	
12-Mar		
13-Mar		

14-Mar		
15-Mar		
16-Mar	1+0	Problems with the hand controller. Electric relay broken.
17-Mar	1+2	Relay issue fixed at 4 pm.
18-Mar		
19-Mar		
20-Mar		
21-Mar	1+0	Bridge crane's cable cut by its wheel, replaced.
22-Mar	1+0	Cable roll's spring breaks, fixed by evening.
23-Mar		
24-Mar		
25-Mar		
26-Mar		
27-Mar		
28-Mar		
29-Mar	1+0	Bridge crane's cable cut by its wheel for a second time. Fixed cable 10 meters short.
30-Mar	1+1	Power cable replaced with thicker, too stiff cable. Will not roll properly.
31-Mar	1+1	Thicker power cable replaced with proper cable.
1-Apr	1+1	Worker continuously holding the power cable to keep it from getting cut.
2-Apr		
3-Apr		
4-Apr		Power cable will need to be replaced once again in the future.
5-Apr		Current cable not designed to withstand enough power.
6-Apr		
7-Apr		
8-Apr		
9-Apr		
10-Apr		
11-Apr		
12-Apr		
13-Apr		
14-Apr		
15-Apr		
16-Apr		
17-Apr		

Estimation of total used man hours by cover systems providing contractor (with 8 hour work days) = 952 man hours, including foreman's hours.

Layher Allround with Layher Keder Roof - calendar of events

March 2016

1-Mar		
2-Mar		
3-Mar		
4-Mar		
5-Mar		
6-Mar		
7-Mar		
8-Mar		
9-Mar		
10-Mar		
11-Mar		
12-Mar		
13-Mar		
14-Mar	1+2	First boom truck of scaffolding material brought on-site. Assembly begins.
15-Mar	1+2	Second transport of material brought.
16-Mar	1+2	
17-Mar	1+2	
18-Mar	1+2	
19-Mar	0+2	
20-Mar		
21-Mar	1+2	The third and fourth transports of matrial brought. Covering the sides of the system
22-Mar	1+2	with tarp began.
23-Mar	1+2	Car crane arrived on-site. First roof module lifted to its place.
24-Mar	0+2	
25-Mar	0+2	All roof modules in place. Sides fully covered with tarp. Car crane left.
26-Mar	0+2	Roof covered with tarp. Layher weather cover system ready to be used.
27-Mar		
28-Mar		
29-Mar		
30-Mar		
31-Mar		
1-Apr		
2-Apr		
3-Apr		

Estimation of total used man hours by cover system providing contractor (with 8 hour work days) = 256 man hours, including foreman's hours.