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DEVELOPMENT OF THE IMPLEMENTATION OF BUILDING SKINS DURING INSTALLATION: "CASE STUDY OF A HOTEL IN CAIRO, EGYPT"

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ABSTRACT

Building skin has a major role in protecting the building interior from several elements. The installation of these skins can be easily degraded by poor installation and low-quality site working conditions. Also, a great many factors and activities that impact the quality of installation must be considered during installation. On the other hand, the success of installing building skin depends on the well-implemented implementation of the different installation methods and consideration of the factors that impact the quality of the installation, which lead to decreased material waste and increased skin quality and energy efficiency. This paper reviews the literature studies and results of a case study involving defects in the skin of hotel towers during installation, which resulted in many failures that caused waste of time and materials. Finally, the paper will propose a framework for implementing building skin during installation, specifying the activities and factors that must be considered with proper and timely communication between the members of the project team, which is an essential requirement of a successful installation to achieve a successful project. The friction angle in the direct shear test is less than in the triaxial test by 1.00 to 2.20 degrees.

KEYWORDS: Building skin, During installation, Defects, Methods, Performance-Improved, Factors, Activities.

" تطوير تنفيذ واجهات المباني أثناء التركيب: دراسة حالة عن فندق في مصر"

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الملخص

الواجهة او الغلاف المستخدم للمبنى له دور رئيسي في حماية داخل المبنى من عوامل عدة. يمكن أن يؤدي تركيب هذه الأغلفة بشكل سيئ أو في ظروف عمل غير جيدة إلى تدهورها بسهولة. بالإضافة إلى ذلك، هناك العديد من العوامل والأنشطة التي تؤثر على جودة

التركيب ويجب مراعاتها خلال عملية التركيب. من ناحية أخرى، نجاح تركيب غلاف المبني يعتمد على تنفيذ أساليب التركيب المختلفة بشكل جيد ومراعاة العوامل التي تؤثر على جودة التركيب، مما يؤدي إلى تقليل هدر المواد وزيادة جودة الجلد وكفاءة الطاقة.
يتناول هذا البحث استعراض الدراسات الأدبية ونتائج دراسة حالة تتعلق بالعيوب في الجلد المستخدم في أبراج الفنادق أثناء التركيب، مما أدى إلى العديد من العمليات الفاشلة التي أدت إلى هدر الوقت والمواد. وفي الختام، سيقترح البحث إطارًا لتنفيذ تركيب غلاف المبني مع تحديد الأنشطة والعوامل التي يجب مراعاتها، بالإضافة إلى التواصل المناسب وفي الوقت المناسب بين أعضاء فريق المشروع، وهو متطلب أساسي لنجاح عملية التركيب وتحقيق مشروع ناجح.

الكلمات المفتاحية: واجهة المبني، أثناء التثبيت، العيوب د، الطرق، الأداء، التحسين، العوامل، الأنشطة.

1. INTRODUCTION

The success of the several functions of building skin is linked to provide comfort and safe to the occupants of the building [1].

With the advent of new materials, technologies, and people's constant pursuit of different building appearances, building skin installation becomes bigger and bigger in size and increasingly complex in shape, accompanied by increasing of difficulties in field installation.

In this case, if the installation processes are not well managed, the skin installation activates may not success, thus causing project delay and the waste of resources with decreasing in energy efficiency which is very important for building.

Research conducted by the US Department of Energy found that a well-designed and properly installed building envelope can reduce energy consumption for heating and cooling by up to 20-30% [2].

Also, a study conducted by the National Institute of Standards and Technology (NIST) found that air leakage through the building envelope can account for up to 40% of heating and cooling costs in buildings [3].

The US Environmental Protection Agency (EPA) estimates that improving the building envelope can reduce energy consumption by up to 10-30% [4].

Overall, these studies and initiatives demonstrate that good building envelope installation is a critical factor in achieving energy efficiency in buildings.

Therefore, this paper will propose a framework to improve installing building skin for all parties to the project to be considered with a good supervision in the site reaching the goal of the project.

2. RESEARCH METHODOLOGY

This paper proposes a framework of implementing building skin during installation which contains its activities and the critical factors that effect on them to know their effects on building skin installation.

This framework is figured out from studding a case study in Egypt for a skin building installation and the theoretical studies.

In alignment with the goals of the research, during the development of the work, the following steps were followed:

The five models studied were the following:.

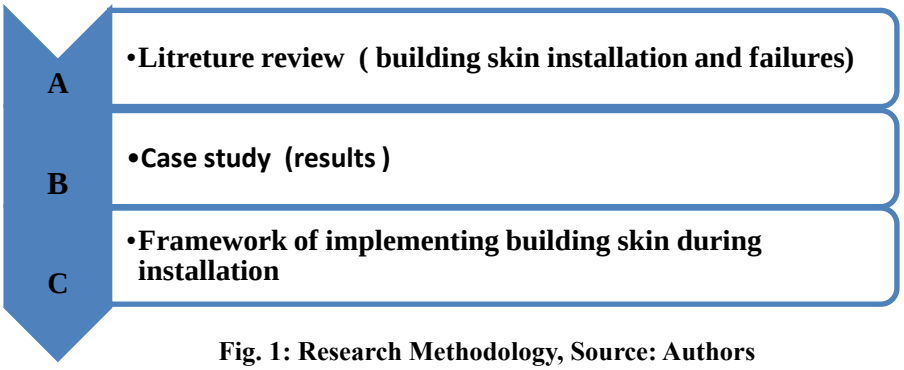

Fig. 1: Research Methodology, Source: Authors

3. LITERATURE REVIEW

3.1 Troubles of skin management

During the investigative research into managing building skin installation, were reached the main causes of problems associated with design, manufacture and Installation the building skins which can be attributed to poor management and communication. This is manifest as follows [5]:

3.1.1 Design

The main important causes and problems associated in the stage of building skin design as followed:

• Skin responsibility is not determined early enough and sometimes not until site installation. Also, in worst-case scenarios some do not want to take the responsibility

• Contactors are not appointed early enough to aid the design.

• There can be too much "over specification" of the facade, causing complicated and sometimes impossible designs.

• Lack of communication throughout the design stage.

• Incomplete design, especially of the Interface.

• Insufficient design expertise from the specialist contractors[6].

3.1.2 Manufacture

The important causes and problems associated in the stage of building skin Manufacture, as followed:

• Lack of understanding the bearing in manufacture and design becomes a problem when the skin specialists do not know the tolerances of the other products".

• Managing the lead times for materials will be on the critical path, as it can take several weeks for delivery. Problems occur when there is a change in design late in the process, there is no consideration for the delays that may happen".

• A building skin system may be complete in manufacture but often has to be altered due to insufficient design of the interface. This is either carried out at site or has to be returned to the manufacturer's factory for the modification[7].

3.1.3 Installation

Architects typically design skin conceptually; however, the manufacturers' fabricators and suppliers are responsible for the final detailing of the product. Therefore, there is a need for a structural engineer to be part of the process. So due to the fragmentation of the skin process, suggested two actions:

First, sole responsibility and effort is needed for the structural design and performance of the building skin.

Secondly, specialist solutions are needed for specific categories: (durability and integrity of the skin materials and the design of the non-structural facade and the frame) [8].

When the site problems come on the skin installation due sometimes to the nature of the design and not the Installer's inefficiency so the aspects that should be considered before the installation commences as follows:

• Considered the sufficient expansion or compression when designing heavy units
• The ability to install too big panels for the mega skins Fig. (1 (A-B)).
• Accuracy of the structure must be maintained -floor dimensions must be kept within tolerances (ex: curtain wall can only work within certain tolerances).
• The fixings must be realistic for the structural form and for the installation process.
• Inspection and installation of the waterproofing and joints
• Touching materials must be compatible with each other.

Safe construction has been considered. Fig. (2 (A-B))

• If the building leaks the time, it will be at the junction between two differing trades.
• There are "unwritten" rules or assumptions made all the time with skins.

For example, if there are windows Installed Inside precast openings, then the window installer should take the warranty of the facade, but this is rarely written down or agreed. Therefore, the warranty "falls" by default (not by agreement) in the package of the last contractor [9].

• Sealants at the skin tend to be overlooked because there is no clear identification as to whose package they are in

Fig. 2 (A): (UP) Curtain wall installation complete at Hyundai Motors Source: http://www.enclos.com/siteinfo/press/curtainwal

Fig. 2 (B): (left) Curtain wall installation at the Yale school 2012 Source: YouTube

Fig. 3 (A): Safe construction at building envelope. Source: https://smartenergy.illinois.edu/

Fig. 3 (B) : Safe construction at building envelope. Source : www.seniorarchitectural.co.uk

A great many factors impact the quality of installation. Many of these originate in the installation skin process, include [10]:

4.1 Verification that jobs are inspected

It is important to ensure that the skin is installed correctly and performs as designed. There are different ways to verify that building skin installation is inspected [11]:

- Building code requirements: Many building codes require that building skins be inspected during and after construction to ensure compliance with code requirements.
- Quality control checks: General contractors or construction managers may conduct quality control checks during skin installation to ensure that the work is being done according to the design plans and specifications.
- Testing and commissioning: Once the building skin's installed, it should be tested and commissioned to verify that it performs as designed.
- Documentation: Documentation of the installation process and inspections should be kept on file for future reference. This may include photographs, inspection reports, testing results, and other documentation that verifies that the skin was installed correctly[12].

4.2 Verification of installation site conditions

Verifying installation site conditions of a building skin is important to ensure that the skin is installed correctly and will perform as designed. Here is a way to verify installation site conditions of a building envelope:

- Site inspection: A site inspection should be conducted prior to the start of construction to assess site conditions and ensure that they are suitable for the installation of the building envelope. This may include assessing the slope of the site, the presence of nearby vegetation or trees, and the orientation of the building.
- Review of design plans: The design plans for the building skin should be reviewed to ensure that they are appropriate for the site conditions. For example, if the site is in a high-wind area, the design may need to include additional structural reinforcements or cladding fasteners.
- Testing of site conditions: Testing may be conducted to verify site conditions and ensure that they meet the requirements of the building skin design. This may include soil testing to verify the bearing capacity of the site or testing for air infiltration to assess the potential for drafts.
- Documentation: Documentation of site conditions should be kept on file for future reference. This may include photographs, inspection reports, and testing results that verify that the site conditions were suitable for the installation of the building envelope [13].

4.3 Construction Elevators (number - location - protection)

The number, location, and protection of construction elevators for building skin installation will depend on the specific requirements of the project. Following are some considerations for construction elevators during building skin installation:

- Number of elevators: The number of construction elevators needed for building skin installation will depend on the size and complexity of the project as well as the number of workers and materials that need to be transported.
- Location of elevators: The location of construction elevators for building skin installation will depend on the specific requirements of the project.
- Protection of elevators: This may include installing temporary enclosures or covers to protect the elevator from wind, rain, or snow. Additionally, elevators should be secured to prevent unauthorized access or tampering [14].

4.4 Anchors

Anchors help to secure the skin to the building structure and provide support for the weight of the skin materials. Here are main considerations for anchors during building skin installation:
- Type of anchors: There are several types of anchors that may be used in building skin installation, including mechanical anchors, adhesive anchors, and screw anchors.
- Placement of anchors: Anchors should be placed at regular intervals along the skin to ensure that the weight of the materials is evenly distributed and that the skin is securely attached to the building structure.
- Load capacity of anchors: The load capacity of anchors should be specified in the design plans and should be verified during construction to ensure that they meet the required standards.
- Testing of anchors: This may include pull-out testing or other types of load testing to ensure that the anchors meet the required specifications [15].

4.5 Supporting structure

The supporting structure should be designed to meet the specific requirements of the skin materials and the building structure. Following are some considerations for the supporting structure during building skin installation:
- Type of supporting structure: Common types of supporting structures include steel or aluminum framing, wood framing, and masonry walls.
- Design of supporting structure: The design of the supporting structure should be carefully considered to ensure that it meets the specific requirements of the skin materials and the building structure. This may include factors such as the spacing of framing members, the thickness of walls or columns, and the type of connections used to attach the skin materials to the supporting structure.
- Load capacity of supporting structure: The load capacity of the supporting structure should be carefully considered during building skin installation to ensure that it can support the weight of the skin materials and any additional loads such as wind or snow.
- Protection of supporting structure: The supporting structure should be protected from the weather and other hazards that may damage the structure or its contents [16].

4.6 Brackets and fixings

Proper selection and installation of brackets and fixings are critical to ensure that the skin is securely attached and can withstand the required loads and environmental conditions. Following some considerations for brackets and fixings during building skin installation:
- Type of brackets and fixings: There are several types of brackets and fixings that may be used in building skin installation, including mechanical fasteners, adhesive anchors, and brackets that attach to the supporting structure. The specific type of brackets and fixings used will depend on factors such as the weight and size of the skin materials, the type of supporting structure, and the environmental conditions of the installation site.
- Spacing of brackets and fixings: The spacing of brackets and fixings should be specified in the design plans and should be verified during construction to ensure that they are installed correctly.
- Load capacity of brackets and fixings: The load capacity of brackets and fixings should be specified in the design plans and should be verified during construction to ensure that they meet the required standards.
- Protection of brackets and fixings: This may include installing temporary covers or enclosures to protect the brackets and fixings from wind, rain, or snow. Additionally, the brackets and fixings should be secured to prevent unauthorized access or tampering [17].

4.7 Installation of seals

Installing seals in a building skin is an important part of ensuring the building is weather-tight and energy-efficient. Here are the general steps for installing seals:
- Identify the areas where seals are needed: This includes areas such as doors, windows, vents, and any other openings in the building envelope.
- Choose the appropriate sealant: The sealant chosen will depend on the type of material being sealed, as well as the expected movement and exposure to weather. Common sealant materials include silicone, polyurethane, and acrylic.
- Clean the surfaces: The surfaces that will be sealed should be clean and dry. Use a cleaning solution and a scrub brush to remove any dirt or debris.
- Apply the sealant: Apply the sealant in a continuous bead around the perimeter of the opening, making sure to fill any gaps or voids. Use a caulking gun or other appropriate tool to apply the sealant smoothly and evenly.
- Smooth and shape the sealant: Use a tool such as a caulking smoothing tool or a wet finger to smooth and shape the sealant, making sure it is flush with the surrounding surfaces.
- Allow the sealant to dry: The drying time for the sealant will depend on the type of sealant used. Follow the manufacturer's instructions for drying time and curing.
- Check for leaks: Once the sealant has dried, check for any leaks or gaps where the sealant did not adhere properly. If necessary, apply additional sealant to these areas [18].

4.8 Installing the glass

Installing glass as part of the building skin is a critical step in ensuring that the building is weather-tight, energy-efficient, and aesthetically pleasing. Following general steps for installing glass:
- Measure and order the glass: Measure the dimensions of the opening where the glass will be installed and order the glass from a reputable supplier. Make sure to specify the appropriate thickness, type, and any special features such as low-E coatings or insulated glass units.
-Prepare the opening: Check the opening for any irregularities or damage that may need to be repaired before installing the glass.
-Apply sealant: Apply a continuous bead of sealant around the perimeter of the opening where the glass will be installed. The sealant should be appropriate for the type of glass being installed and should provide a weather-tight seal.
-Install the glass: Use shims or other appropriate tools to adjust the position of the glass as needed.
-Secure the glass: Depending on the type of installation, the glass may need to be secured with clips, brackets, or other hardware. Make sure the hardware is appropriate for the weight and size of the glass and is installed according to the manufacturer's instructions.
-Finish the installation: Once the glass is securely in place, apply additional sealant around the perimeter of the glass to ensure a weather-tight installation. Clean any excess sealant from the glass and surrounding surfaces.
-Inspect and test: Inspect the installation for any defects, leaks, or other issues. Test the glass for proper functioning, such as opening and closing smoothly or providing the desired level of insulation.
-Repeat these steps for each area where glass is being installed [19].

4.9 Checking the clamping caps

Clamping caps helping to secure panels or other cladding materials in place and prevent moisture and air infiltration. As Following general steps for checking the clamping caps:
- Visual inspection: Check for cracks, breaks, or any other visible defects that could affect the performance of the caps.

-Tightness check: Check the tightness of the clamping caps by using a torque wrench to ensure they are properly tightened to the manufacturer's specifications. Over-tightening can cause damage or deformation, while under-tightening can cause the caps to loosen and compromise the integrity of the cladding system.
-Water test: Use a hose or other water source to simulate rain and observe the cladding for any signs of moisture infiltration. Pay particular attention to areas around the clamping caps, as these can be potential areas for leaks.
-Air leakage test: This can be done using a blower door test or other appropriate method. Pay attention to areas around the clamping caps, as these can be potential areas for air infiltration.
- Maintenance check: Regularly inspect the clamping caps for any signs of damage or wear. Replace any caps that are cracked, broken, or otherwise damaged. Check the tightness of the caps periodically to ensure they remain properly secured [20].

4.10 Tolerances

Tolerances refer to the allowable deviation from the specified dimensions or requirements for a particular component or system. Following some general guidelines for tolerances in building skin installation:
- Panel and cladding tolerances: Panels and cladding materials should be dimensionally accurate and within the specified tolerances for thickness, size, and shape. Any deviations from these to lerances can affect the performance of the system and compromise its integrity.
- Framing tolerances: Framing members should be installed within the specified tolerances for size, spacing, and alignment.
- Window and door tolerances: Deviations from these tolerances can affect the fit and installation of the surrounding cladding materials, as well as the performance of the system in terms of weather-tightness and energy efficiency.
- Sealant tolerances: Deviations from these tolerances can affect the performance of the sealant and compromise the weather-tightness of the system.
- Overall tolerances: This includes tolerances for the size, shape, and alignment of all components and systems, as well as the overall performance of the system in terms of weather-tightness and energy efficiency.

4.11 Gaskets

Gaskets helps to provide a weather-tight seal between two components or systems. Here are some general guidelines for installing gaskets in a building skin system:
- Choose the appropriate gasket: The gasket should be appropriate for the intended use and should provide a weather-tight seal.
- Prepare the surfaces: Use a cleaning solution and a scrub brush to remove any dirt or debris.
- Apply the gasket: The gasket should be flush with the surface and should not be stretched or distorted during installation.
- Install the components: Make sure the components are properly aligned and seated, and that any fasteners or hardware are installed according to the manufacturer's instructions.
- Test for leaks: Pay particular attention to areas where gaskets are installed, as these can be potential areas for leaks.
- Maintenance check: Regularly inspect the gaskets for any signs of damage or wear. Replace any gaskets that are cracked, torn, or otherwise damaged. Check that the gaskets are properly seated and aligned, and that they are providing a weather-tight seal [21].

4.12 Window frame construction

Window frame construction provides the structural support for the window and helps to maintain the weather-tight seal between the window and the surrounding cladding materials. Here are some general guidelines for window frame construction:

- Choose the appropriate framing material: The choice of material will depend on factors such as the desired level of insulation, durability, and aesthetics.
- Install flashing: The flashing should be installed in a continuous piece and should overlap the surrounding cladding materials.
- Install the frame: Install the window frame according to the manufacturer's instructions, making sure it is level, plumb, and square. Use shims or other appropriate materials to adjust the position of the frame as needed.
- Insulate the frame: The insulation should be appropriate for the framing material and should be installed according to the manufacturer's instructions.
- Install the window: install the window sashes according to the manufacturer's instructions and make sure the sashes are properly aligned and sealed to prevent air and water infiltration.
- Seal the frame: The sealant should be appropriate for the framing material and should be applied according to the manufacturer's instructions.
- Test for leaks: Perform a water test or air leakage test to check for any leaks or points of entry for moisture or air. Pay particular attention to areas around the window frame, as these can be potential areas for leaks.

By following these guidelines, you can help ensure that the window frame construction in your building skin system is properly installed and functioning as intended which improve the energy efficiency [22].

4.13 Doors

Doors are an important as they provide access to the building while also helping to maintain the weather-tight seal between the building interior and exterior. Here are some general guidelines for installing doors in a building skin system:

- Choose the appropriate door
- Prepare the opening: The opening should be clean, dry, and free of any debris.
- Install the frame: according to the manufacturer's instructions, making sure it is level, plumb, and square. Use shims or other appropriate materials to adjust the position of the frame as needed.
- Install the door: According to the manufacturer's instructions.
- Insulate the frame: Install insulation around the frame to provide additional thermal insulation and prevent air infiltration. The insulation should be appropriate for the framing material and should be installed according to the manufacturer's instructions.
- Seal the frame: Apply sealant around the perimeter of the frame to provide a weather-tight seal between the frame and the surrounding cladding materials and according to the manufacturer's instructions.
- Test for leaks: Perform a water test or air leakage test to check for any leaks or points of entry for moisture or air. Pay particular attention to areas around the door frame, as these can be potential areas for leaks.

Properly installed doors can help improve the energy efficiency and overall performance of the building, while providing a secure and accessible entry point.

5. Installation issues

Tests on real buildings and laboratory tests on individual components have demonstrated a clear relationship between the standard of cladding installation and air leakage Fig. (4 (A-B)). Indeed, the quality of construction is as important as the specification, since poor

workmanship, such as incomplete runs of sealant or missing fasteners, can ruin the thermal performance of even the highest specification system [23].
The following issues require particular attention:

• Installation sequence
• Fasteners
• Joints and seals
• Details at interfaces.
• Water penetration.

- In terms of Incorrect installation can allow water to enter by any mechanisms even if the skin is designed to prevent water penetration.
- Failure to lap components such as flashings, wrongly fitted gaskets and poor sealant joints will all create openings that allow water to flow into the skin under gravity. If drainage paths are blocked water will pond and overflow (often into the envelope) under the effect of gravity.
- Failure to seal openings that should be sealed and the incorrect fitting of gaskets leaves openings through which the wind can force water.
- Failure to install air seals correctly allows air to pass through the skin and this may carry water into the wall.
- Removal of drips and nibs from the underside of components can allow water to remain attached to the surfaces and run into the skin as a result of surface tension.

Obtaining agreement between the cladding contractor and main contractor on the cladding installation sequence is clearly important in terms of site management and the avoidance of clashes between trades on site. Less apparent is the need to involve the structural engineer in discussions regarding the cladding sequence.
However, several key design assumptions rely on the interaction between the structure and envelope.
For this reason, the cladding sequence should be shown on the appropriate contract drawings and any changes should be discussed with the structural engineer, so that the structural implications may be assessed. The cladding installation sequence may also be important in terms of forming the laps between the sheets and obtaining airtight joints at interfaces. Where the cladding manufacturers provide specific recommendations for the installation of their products, these should be followed carefully.

Fig. 4 (A): (Installation issues)Water ingress observed during laboratory static water penetration resistance testing. Source: [1]

Fig. 4 (B): (Installation issues)Unexpected water ingress at a butt joint in the horizontal mullion during the test chamber Source : [1]

6. CASE STADY

A case study was given to have a proposed framework by the literatures and some interviews with the general contractor, skin engineer and workers in site during building skin installation in the site, to improve process performance, reduce material waste and installation defects during skin installation.

The site being in Cairo, Maadi, it was under construction while preparing the research. It contains two towers connected with a bridge. Fig. 5-6.

Construction started in 2016, the planned completion date is in 2020 in the name of Secon Nile Towers.

The towers will be a hotel and apartment function, owned by Saudi Egyptian Developers and the skin installation company is Alunile.

The project has 23 floors above ground and 2 floors underground over an area of more than 10,000 square meters and the height of these towers is about 72 m. As shown in Fig. 1.

The framework and ideas were presented and explained to the contractor, project manager and skin engineer during the on-site inspection and data collection stages that took over two months (May, June 2020).

All study units were completed to identify the defects and problems of the project during installation building skin by skin project manager, project manager and their objections.

6.1 Case Study Results

Throw the interviews and observation of the construction site during installation building envelope. it was concluded:

1-It must to install the Jensen board on an aluminum unit different from the skin aluminum units but the worker neglects this step and the coordinator approve his work therefore while installing the skin glass sheet it needs this units so resulting west time and need time for rework in this unit. (Worker, coordinator, Failure to follow instructions and construction drawings) Fig. 7, 8.

2-There were water spots on building skin cladding cause of the consultant did not match the drawing with the reality and didn't take with the notes of the designer to make the owner satisfaction with neglecting this result. Fig. 9

Fig. 5: Hotel towers in Cairo Maadi Source: Researcher

Fig. 6: Hotel towers in Cairo Maadi under construction Source: Researcher

Fig.7: Installing Jebsen board on the aluminum units of the skin not on its units Source:

3-Cutting and scratch on the glass protector cause of the lack commitment of the Schedule time for construction project. This late was from the owner so it has to hiring another company to repaired the defects which lead to waste in (time, money) Fig. 10.

4-There were scratches on building skin column cladding units cause of the Jebsen boards scaffolding. The worker didn't care about the cladding column and there weren't enough coordinator about the skin works which lead to re cladding this column. Fig.11,12, 13

Fig.8: Installing Jebsen board on the aluminum units of the skinned on its units Source: Researcher

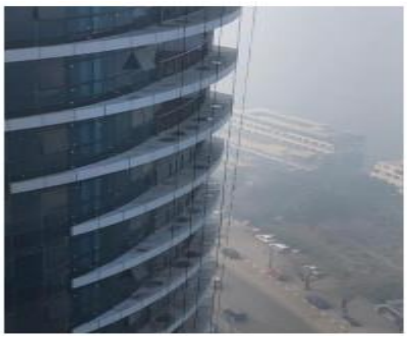

Fig.9: Water spots on building's cladding Source: Researcher

Fig.10: cutting and scratch in the glass protector Source: Researches

5- Broken at the ceiling for the electric wires of seminice company at the building skin side while installation. This problem led to wastes in (time and material) during installing building skin. Fig. 14, 15

6-Extra part in concrete must be removed so that skin engineer gives markers to the contractor to adjust the building skin level and equal the rest of the skin as required which led waste in time. Fig. 16

Fig. 11: scratches on building skin column cladding units Source: Researchers

Fig. 12: scratches on building skin column cladding units Source: Researchers

Fig.13: scratches on building skin column cladding units Source: Researchers

Fig. 14: broken at the ceiling at the skin side Source: Researcher

Fig. 15: broken at the ceiling at the skin side Source: Researcher

Fig.16: m Extra part in concrete must be removed Source: Researcher

From the previous observations the researcher proposed a framework to avoid the defects and problems during building skin installation by knowing its processes and activities and consider them whether main or sub processes.

7. PROPOSED FRAMWORK TO IMPLEMENT BUILDING SKIN DURING ARRIVING MATERIALS.

From the literature and case study the researcher proposed a framework to provide defects and waste during installing building skins.

Therefore, the best way to begin this framework is to understand and study the methods of skin installation as it has been explained previously. Then the next two tables explain the proposed framework of implementing building skins during installation.

Following - Table 1- explain the proposed framework of implementing building skins during installation.

Table 1. During building envelope installation. Source: Researcher

Table 1. During building envelope installation	**Checks during Installation unitized system**	**Tolerances and Clearness**	- checked before insh1llation - checked after installation.
		Installation the Glasses	- follow the manufacturer's instructions (Positioning) - glazing units are correctly positioned. - check the Units that include safety glass used in the correct openings and not swapped with non-safe units - check the units that have different glasses for the inner and outer panes positioned with the correct face outermost - check that the glass installed with the correct edge resting on the setting blocks so that all sheets of glass are equally supported
		Installation of seals	- verified the connection between the, modules, comply in the area near the male-female fitting, is correct and with the designated material and in compliance with the project design.
		Installation Modules	- ensure the vertical and horizontal positions - ensure the depth location of the installed, module, comply with the design plan. - verify the fitting has been executed correctly, to guarantee an efficient and harmless seal for the materials.
		Supporting structure	- verify the existence of 1narkings for the anchors. - must be correctly fixed.
	Bracket Installation		- fixed to the main structure. - Any errors should be communicated to the Main Contractor for rectification. - Finished brackets should have the completed bolts marked to indicate correct torque. - Hand tools and small items should be secured.
	Installation Equipment	**Tower crane**	- used when the ele1nent is too heavy
		Monorail	- It lifted off' the launching platform and rotated through 180 degrees, so that the glass is facing to the outside. - It forms part of the edge protection, and remains in place throughout the operation.
		Automated remote manipulator	- Once the clen1cnt is securely attached to the Vacuum lifting device of the manipulator, it is easily positioned for installation. The edge protection stays in place.
		Installation by floor crane	- It positions in one or two floors above the installation level and moved as required along the Perimeter of the building.
	Lifting Equipment		- Use light lifting equipment for final fixing, with no scaffolding.
	Installation Conditions		- Follow installation site conditions provided - Not insisting or permitting installation in inappropriate weather

-To use this framework there is a very important step which carried out a retrospective evaluation of the achieved process performance and the strategies implemented in order to develop improved procedures for better performance in the future, by using several management tools as:
Collecting data [24] - Control charts [25].
-This stage is responsible for maintaining consistent successful performance and continuous improvement which involved project management team for an unending top to bottom [26].
The following control chart illustrate the controlled processes that required specialized personnel to conduct quality assessment and benchmarking. These charts contain 4 phases of skin installation in the site on these dates (4/6/2020 - 14/6/2020 - 18/6/2020 20/6/2020) with de-coupling skin erection from other trades.

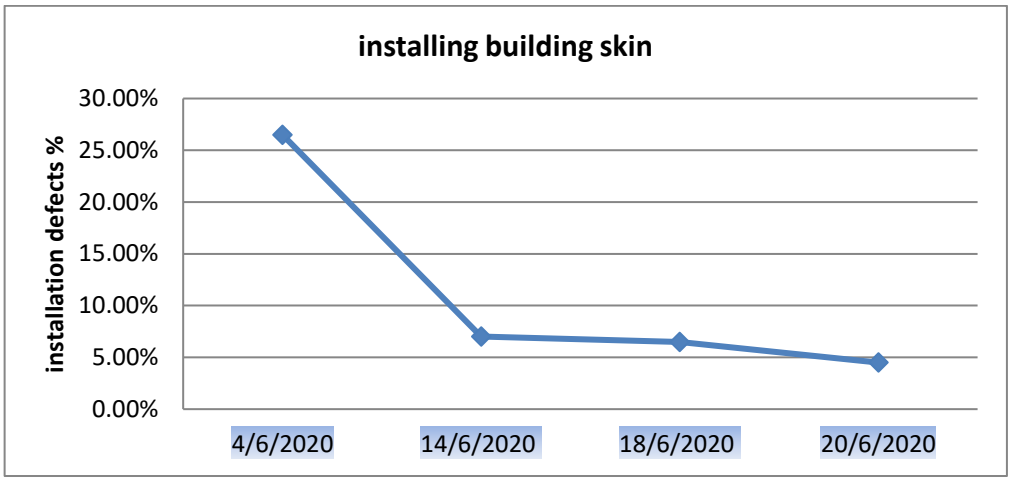

Fig.17: Control Chart of the defect percentage during building skin installation in several days.

It can be concluded from the control chart (Fig.17) that there is an improvement in the skin installation process as follow:
- The percentage of defects decreased in the mention days which will decrease material waste and increase energy efficiency.

8. SUMMARY AND CONCLUSIONS

This study has presented a proposed framework to implement building skins during installation to avoid defects and problems of it, because any failure or delay in the skin installation cause losses and wastes in time, money, material and labor as well as in human comfort.
To reach this framework the researchers explain the troubles during installation and proposed some solutions to improve them.
To achieve this framework the general contractor and the skin engineer must consider the main and sub activities of implementing building skins during installation by Identification of the activities and factors which effect on implementing building skin which helps to reach the aim of this paper (improve implementing building skins during installation).

Abbreviations

NIST National Institute of Standards and Technology
EPA Environmental Protection Agency
EEF Energy Efficiency
BCR Building code requirements
TC Testing and commissioning
QC Quality control checks

REFERENCES

[1] Hilde Breesch and Robert Ancker (2019) "Building Envelopes: A Complete Guide to the Energy Efficient Building Envelope".
[2] Zhang, Y., & Athienitis, A. K. (2014). Building envelope design for maximum energy efficiency. Energy and Buildings.
[3] Sherman, M. H., & Chan, W. R. (2017). Building Envelope Air Leakage and Heat Flow: Field Measurements and Analysis. Journal of Building Physics, 41(4).
[4] U.S. Environmental Protection Agency. (2019). ENERGY STAR Building Upgrade Manual. Retrieved from https://www.energystar.gov/buildings/tools-and-resources/building-upgrade-manual
[5] Ron C. McKinnon (2019) "Construction Site Safety: A Guide for Managing Contractors" .
[6] Rüdiger, D., & Knaack, U. (2016). Building skins: Concepts, layers, materials. Birkhäuser.
7-Li, H., & Chan, E. H. W. (2019). Off-site construction for building facade systems: Opportunities and challenges. Automation in Construction, 100.
[8] Richard H. Clough, Glenn A. Sears, S. Keoki Sears, Robert O. Segner (2018) "Construction Contracting: A Practical Guide to Company Management" .
[9] Chen, Y., Luo, X., Zhou, X., & Zhang, Y. (2018). Review of building envelope installation quality control in construction practice. Journal of Building Engineering,
[10] https://www.sciencedirect.com/science/article/pii/S2666790822001604
[11] Wang, H., & Li, H. (2020). Building envelope commissioning: A review of current practices and future directions. Building and Environment.
[12] Hua, G., Chan, P. W., & Zhang, Y. (2021). Quality control of building envelope installation: A review. Journal of Building Engineering.
[13 Knaack, U., Klein, T., Bilow, M., & Auer, T. (2014). Facades: Principles of construction. Birkhäuser.
[14] Occupational Safety and Health Administration (OSHA). (2019). Construction Industry Digest. Retrieved from https://www.osha.gov/sites/default/files/publications/OSHA3902.pdf
[15] Blodgett, O. W. (2018). Design of Welded Structures. Wiley.
[16] National Institute of Standards and Technology (NIST). (2018). Recommended Practices for Securing Loose Items for Improved Seismic Performance. NIST.
[17]" M. H. Tait, A. R. H. Rigit, and A. M. Ali (2014) ‘Experimental Investigation on the Structural Performance of Curtain Wall Brackets", published in International Journal of Engineering Research and Applications.
[18] "Installation and Quality Control of Sealed Insulating Glass Units in Commercial Buildings" by Insulating Glass Manufacturers Alliance (IGMA), 2017.
[19]"Installation Guidelines for Glass in Commercial Buildings" by Glass Magazine, 2017.
[20] Quality Control and Performance Testing of Curtain Wall Systems" by American Architectural Manufacturers Association (AAMA), 2017.
[21]"Tolerances for Building Construction" by American Society of Civil Engineers (ASCE), 2016.
[22] Window and Door Flashing: Best Practices for Design and Installation" by Building Science Corporation, 2011.
[23] Kim, J. H., & Hong, T. (2017). Building Envelope Design Guide - Curtain Walls. Whole Building Design Guide. National Institute of Building Sciences.
[24] https://www.oecd.org/sdd/na/NOE-Handbook-%20Chapter6.pdf
[25] https://balancedscorecard.org/wp-content/uploads/pdfs/control.pdf
[26] Abdul Razzak Rumane (Publication Date: 2016 "Total Quality Management in Construction Projects".