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Analysis of Long-Span Seamless Galvalume Roof Installation Using the On-Site Roll-Forming Method at the PT Amcor Tobacco Packaging Indonesia (PIER) Pasuruan Project

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ABSTRACT

The construction industry in Indonesia increasingly demands innovative methods to overcome challenges related to efficiency, safety, and quality in industrial building projects. This study investigates the on-site roll-forming method for installing long-span Galvalume roofing at the PT. Amcor Tobacco Packaging Indonesia project. Employing a qualitative case study approach, data were collected through field observations, in-depth interviews, and document analysis. The findings reveal that the method successfully produced seamless roof panels spanning 40–50 meters, shortened installation time by 35%, and resulted in zero work-related accidents. These outcomes demonstrate that on-site roll-forming is a viable and superior solution for long-span industrial roofing, effectively integrating technical performance, project efficiency, and safety considerations. The study purpose was to evaluate the effectiveness of the on-site roll-forming method for long-span seamless Galvalume roof installation in large-scale industrial projects through an integrated construction management, material performance, and occupational safety framework. This study employed a qualitative single-case study approach using field observations, in-depth interviews, and document analysis to examine the installation of long-span seamless Galvalume roofing produced by on-site roll-forming using Galvalume coil materials and supporting construction equipment at an industrial project site. The results showed that the on-site roll-forming method successfully delivered a 40–50 m seamless Galvalume roof with improved installation efficiency (30 days, 35% faster), minimal material damage (<1%), and zero accidents while maintaining high installation quality. In conclusion, the on-site roll-forming method is an effective and viable approach for long-span Galvalume roofing, integrating technical performance, construction efficiency, and occupational safety, and is well suited for large-scale industrial projects in Indonesia.

Keywords: On-site roll-forming; long-span roofing; Galvalume; construction efficiency; industrial projects; installation method; construction safety

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INTRODUCTION

The construction industry revolution over the past decade has transformed traditional paradigms toward more efficient, economical, and sustainable approaches. Innovations in construction materials have become one of the main pillars driving this efficiency, in which roofing materials have undergone a significant evolution from reliance on natural materials to engineered materials offering superior technical performance. Theoretical studies in materials science reveal that the development of roofing materials follows performance-based design principles, emphasizing the optimization of the strength-to-weight ratio, durability, and life-cycle cost. (Ashby, 1994).

Galvalume, as an innovative zinc–aluminum coated steel material, has proven to be one of the significant breakthroughs in the modern construction industry. Theoretically, the performance of galvalume can be explained through cathodic protection and barrier mechanisms provided by the coating layer. Based on electrochemical theories of metal protection, its unique metallurgical composition (55% aluminum, 43.4% zinc, and 1.6% silicon) creates a dual protection system in

which aluminum forms a passive barrier layer while zinc provides cathodic protection (Zhixiang et al., 2023). Studies conducted by LeBozec et al (2019) demonstrate that the microstructure of this coating layer results in corrosion resistance up to four times higher than that of conventional zinc coatings.

From the perspective of building performance theory, the superior characteristics of galvalume namely a high strength-to-weight ratio, durability under diverse climatic conditions, and flexibility in formation address the requirements of contemporary industrial architectural design that emphasizes large-span structures without intermediate columns (Yuliani & Setyaningsih, 2018). Delatte's (2000) theory of long-span roof design explains that roofing materials for long-span applications must satisfy criteria of limited deflection, fatigue resistance, and dimensional stability under thermal variation.

However, the adoption of this advanced material has not been accompanied by equivalent innovation in installation methods. Conventional approaches to galvalume roofing installation still rely on multi-panel joint systems with overlapping connections, which are vulnerable to water infiltration, thermal stress accumulation, and potential structural failure at joint locations. According to building envelope performance theory proposed by Zou et al (2023) each joint within the building envelope constitutes a potential weakness point that may degrade overall thermal, acoustic, and waterproofing performance.

Studies by Van Den Bossche et al. (2012); Liu et al. (2017) from a construction management perspective, identify that conventional methods face complex challenges, including prolonged installation durations, increased occupational safety risks, and logistical constraints related to the transportation of long panel materials. he theory of construction logistics and supply chain management proposed by Vrijhoef and Koskela (2000) explains that the transportation of long panel materials violates the principle of dimensional optimization in logistical efficiency, resulting in increased costs and extended mobilization time.

In response to these challenges, the roll-on-site method has emerged as a disruptive technology in the roofing construction industry. Theoretically, this method aligns with the principles of lean construction and just-in-time production, which aim to minimize waste and enhance value in construction processes (Koskela, 2020). The core concept of this method involves transforming galvalume coil material into roofing panels through an on-site forming process using a mobile roll-forming machine.

From a value engineering perspective, this approach fundamentally transforms material logistics from the transportation of finished panels to the transportation of coils, which is substantially more efficient in terms of volume, weight, and handling flexibility (Lee et al., 2022). Its potential advantages include the minimization of roofing joints (up to 50 meters without joints), which aligns with the principle of continuity in structural systems, a significant reduction in material damage during transportation, and accelerated installation time due to the elimination of multiple panel handling processes.

Based on construction innovation diffusion theory proposed by Rogers, Singhal, and Quinlan (2014), the implementation of the roll-on-site method remains at the early adoption stage within the Indonesian construction industry. Previous studies, such as Anggraini et al. (2022) have predominantly focused on analyzing the material characteristics of galvalume itself, while the implementation aspects of installation methods from a construction management perspective remain underexplored. Existing studies also tend to be fragmented, separating technical material analyses from method evaluations without adequate holistic integration.

Based on the identification of this research gap, the present study offers scientific novelty through a comprehensive analytical approach that integrates three critical aspects in the implementation of the roll-on-site method. The theoretical framework of this study is grounded in the integration of Material Performance Theory (Ashby, 2016), *Construction Innovation Theory* (Rogers, 2019), and *Lean Construction Principles* (Koskela, 2017). This integrative approach enables a holistic analysis spanning from the material level to the construction system level. The primary objective of this study is to provide an evidence-based assessment of the implementation of the roll-on-site method in large-scale industrial projects, with outputs in the form of a comprehensive evaluation of

the method's effectiveness within an integrated construction theory framework. The findings are expected to contribute theoretically to the development of construction innovation implementation models in Indonesia, as well as practically to the industry by supporting the adoption of more efficient and sustainable installation methods.

METHOD

1. Materials And Equipment

This study employed several primary materials directly related to the installation process of long-span, jointless galvalume roofing at the PT Amcor Tobacco Packaging Indonesia (PIER) Pasuruan project. The materials used included AZ-150 galvalume sheets with thicknesses ranging from 0.40 to 0.50 mm supplied by BlueScope as the main roofing material, C75 cold-formed steel sections (Kencana Steel, fy = 550 MPa) as the supporting structural frame, and galvanized SDS 12–14×55 mm roofing screws as the primary fastening system. In addition, Selleys silicone sealant was applied to ensure waterproofing at accessory connection points, while aluminum foil underlayment with a 95% reflectivity rate was used as a thermal and condensation barrier. Supporting materials in the form of galvalume coils for the roll-on-site forming process were also utilized during construction.

The equipment used in this study consisted of both primary construction machinery and auxiliary tools supporting the installation process. A portable roll-forming machine (Ese Machines Portable Roll Former) served as the core equipment for forming galvalume sheets into jointless roofing panels matching the required span lengths. Panel lifting operations were performed using a 25-ton boom crane manufactured by Kato Works, while safety equipment, including scaffolding and full-body harnesses supplied by KAPAS Safety, was employed for work at elevated heights. Roofing screw installation was carried out using a Makita DTD153 cordless impact driver, supported by measurement instruments such as a Bosch GLM 50C laser distance meter and an SNDWAY SW-335A digital level to ensure accuracy in span length, roof slope, and structural alignment. During implementation, electrical power for the roll-forming machine was supplied by a Honda EP5000CX generator set. Additional equipment, including scaffolding systems and lifting belts, was used to assist in the placement of roofing panels onto the structural framework.

2. Research Method

This study adopted a qualitative approach using a single-case study strategy. This approach was selected to achieve an in-depth understanding of the galvalume roofing installation phenomenon within its natural setting at the PT Amcor Tobacco Packaging Indonesia project, PIER Pasuruan. A case study design enables researchers to explore system boundaries through the collection of rich, in-depth data from multiple sources of evidence. (Creswell, 2009).

The research location was purposively selected based on specific criteria: a project implementing the roll-on-site method for long-span, jointless galvalume roofing; execution by a specialized contractor, PT Ometraco Arya Samanta; and an active roofing installation phase at the time of the study. The research followed the full duration of the roofing work, covering stages from material preparation and installation to final quality control.

The data sources comprised both primary and secondary data collected through methodological triangulation. Primary data were obtained through passive participant observation of on-site construction activities and in-depth interviews with nine key informants, including the project manager, site engineer, field supervisor, and construction team members. Informants were selected using a snowball sampling technique until data saturation was achieved (Creswell & Poth, 2016). Secondary data included the analysis of project documents such as construction drawings, method statements of work (SOW), weekly progress reports, photographic documentation of construction progress, and coordination meeting records. A supporting literature review was also conducted to enrich the data analysis.

Data collection was conducted using three main techniques following the case study data collection model proposed by Yin (2018). Observations focused on technical aspects of installation, workflow sequences, and on-site team interactions. Semi-structured interviews were

carried out using flexible interview guides to explore informants' experiences, perceptions, and understanding of the implementation of the roll-on-site method. Document analysis was employed to trace temporal progress and to verify data consistency across sources..

Data analysis followed the interactive model proposed by Miles, Huberman, and Saldaña (2018) which consists of data reduction, data display, and conclusion drawing. Data reduction was conducted through open coding and axial coding processes to identify patterns and themes. Data were presented in the form of descriptive narratives and thematic matrices, enabling comprehensive cross-case analysis. Data validity was ensured through source and method triangulation, member checking, and prolonged engagement. Research reliability was ensured through the use of an audit trail and the consistent application of a case study protocol. This study adhered to research ethics principles, including informant confidentiality, informed consent, and academic integrity throughout all stages of the research process.

FINDING AND DISCUSSION

1. Outer Model or Measurement Model

Based on field observations, document analysis, and in-depth interviews, the implementation of the on-site roll-forming method at the PT. Amcor Tobacco Packaging Indonesia project in PIER Pasuruan demonstrated an integrated approach. The process commenced with the mobilization of roofing materials in the form of coil sheets, delivered via trailer trucks. These coil materials, weighing 3-5 tons per roll, required specialized handling. The project team prepared a protected storage area using tarpaulins to prevent direct exposure to the elements, in strict accordance with rigorous quality assurance standards. A Logistics Officer emphasized, "Protection with tarps and wooden pallets is our mandatory procedure to maintain material quality from the supplier's warehouse right up to the installation point."



Figure 1. The coil material unloading process was conducted using a forklift at the project site. The image shows stacked coils placed on wooden pallets and covered with tarpaulins for protection. (Source: Documentation from PT. Ometraco Arya Samanta)

The installation and setup of the roll-forming machine constituted the subsequent critical phase, involving a specialist team. The selection of the machine's location and placement was based on technical considerations, including roof slope and building height, given that precision in machine positioning was crucial for determining the quality of the produced roof panels. The scaffolding, which functioned as the runway for the exiting roof panels, had to be arranged precisely according to engineering sketches. The Site Engineer explained the complexity, "Placing the machine isn't just about being able to produce panels; it must also ensure a smooth distribution flow of panels onto the roof without bending. An error of just one degree in the slope can damage an entire span of panels." The determination of the machine's position and the arrangement of the scaffolding were executed in accordance with the following schematic drawing:

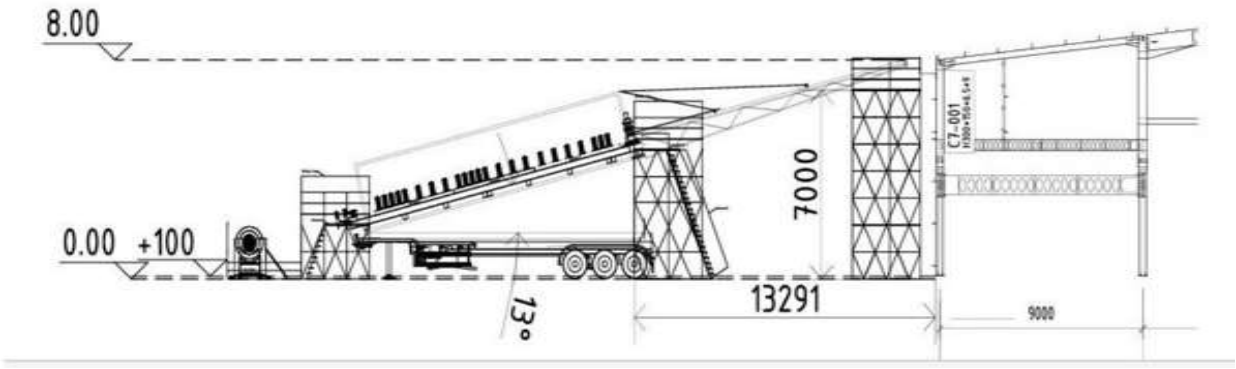


Figure 2. Technical schematic (sketch) for the placement of the roll-forming machine and scaffolding, indicating the slope angle and the distribution path of the roof panels.(Source: Working Documents of PT. Ometraco Arya Samanta)

During implementation, several significant supporting equipment innovations were developed. A custom-designed roof trolley, constructed from UNP channel steel with a precise wheel system, successfully optimized panel distribution along the purlins. Additionally, a walkway system comprised of angle iron frames and expanded metal plate decking with a wheel mechanism enabled safe work access along the 40-50 meter roof span. "We designed this roof trolley internally to address efficiency and safety issues. With this tool, the risk of worker falls or panel scratches during distribution can be minimized," explained the Project Manager regarding the rationale behind the innovation.



Figure 3. Actual photograph of the roof trolley in use for distributing roof panels atop the purlins, showing the wheel mechanism and its locking system. (Source: Documentation from PT. Ometraco Arya Samanta)



Figure 4. Detail of the walkway connection and its wheel mechanism, illustrating how this system provides safe and stable work access. (Source: Documentation from PT. Ometraco Arya Samanta)

The roll-forming and installation process itself required meticulous coordination between the machine operator and field workers. The installation phase began with the installation of Zeltech heat insulation, which was fastened to the purlins using fixing straps, followed by the placement of roof panels on top using a clip-lock system precisely secured with screws. A Supervisor added, "The critical point lies in the installation of the fixing straps. If they are not accurate, the clip-lock system will not engage perfectly and has the potential to cause leaks."





Figure 5. Installation work sequence: (a) Installation of Zeltech heat insulation, (b) Placement of the fixing strap, (c) Locking of the roof panel using the clip-lock system.(Source: Documentation from PT. Ometraco Arya Samanta)

The implemented quality control and safety system encompassed a comprehensive series of phased inspections. Occupational safety aspects were rigorously enforced, including the mandatory use of complete PPE, the application of safety harnesses for work at height, the implementation of regular safety briefings, and continuous monitoring of weather conditions. An HSE Officer emphasized their commitment, "The zero-accident target is not just a slogan. Any violation of PPE, especially body harnesses, results in immediate work stoppage. Safety is non-negotiable."



Figure 6. Documentation of the final inspection conducted by the supervisor and owner's representative, showing the process of installation quality verification.(Source: Documentation from PT. Ometraco Arya Samanta)

2. Discussions

Based on observations throughout the implementation period, the roll-on-site method proved effective in addressing the technical challenges of installing jointless long-span roofing systems spanning 40–50 meters, while maintaining occupational safety and installation quality in

accordance with established standards. The success of this implementation was strongly supported by effective integration of comprehensive engineering planning, innovative supporting equipment, and a well-functioning quality control system. As stated by the Project Manager, "The key to success lies in collaboration from detailed planning and disciplined execution to strict quality supervision at every stage."

Accordingly, the implementation of the roll-on-site method in this case study successfully demonstrated three major achievements. First, from a technical perspective, the method enabled the realization of a jointless long-span roofing system (40–50 meters) with quality approved by the project owner. Second, from a project management perspective, the method achieved efficient time performance, completing the installation within 30 days, and resulted in a very low material damage rate (<1%). Third, and most importantly, from a safety perspective, the entire complex process was completed without any accident incidents, demonstrating the effectiveness of integrating equipment innovation with strict occupational health and safety (OHS) procedures.

The successful implementation of the roll-on-site method in the PT Amcor Tobacco Packaging Indonesia project provides valuable empirical evidence for further examination through the lens of modern construction theory. Based on the lean construction framework proposed by Koskela (2020) the achievement of a 30-day installation period with a zero-accident rate can be interpreted as the result of workflow optimization and the elimination of non–value-adding activities. The principle of value stream mapping in lean construction is clearly reflected in the transformation of material delivery from finished panels to galvalume coils, which effectively reduced various forms of waste commonly associated with conventional installation methods.

The effectiveness of this method in the logistics aspect is consistent with the findings of Vrijhoef and Koskela (2000) regarding dimensional optimization in construction logistics management. The efficiency achieved where a single trailer truck can transport material equivalent to that of six conventional panel trucks—not only addresses transportation bottlenecks identified by Yang and Wei (2017) but also contributes positively to sustainability through a reduction in carbon footprint. The finding of material damage reduction to below 1% further demonstrates the superiority of the just-in-time production concept within the context of construction material supply chains.

From a technical perspective, the successful installation of a jointless roofing system spanning 40–50 meters reinforces the building envelope performance theory proposed by (Hens, 2023). The minimization of roof joints directly correlates with a reduction in weakness points within the building envelope, which explains why quality inspection results indicated no leakage. The precision in positioning the roll-forming machine and the arrangement of scaffolding identified as key success factors in the installation process align with Delatte's (2000) assertion that the success of long-span roofing systems is highly dependent on installation accuracy and component compatibility.

The most commendable aspect of this implementation was the achievement of a zero-accident rate throughout the installation process. This accomplishment demonstrates the effective application of the Hierarchy of Controls in modern occupational health and safety (OHS) management, where innovations such as the roofing trolley and walkway system functioned as engineering controls that systematically minimized workers' exposure to risk. Discipline in the implementation of safety procedures fostered a strong safety culture that became a central pillar of project success, confirming the critical role of behavioral aspects in achieving superior OHS performance.

From a project management perspective, a 35% reduction in project duration compared to conventional methods confirms the effectiveness of integrating planning and execution. The elimination of multiple panel handling processes and double-handling activities emerged as key factors in achieving this time efficiency, consistent with the principle of workflow reliability in lean construction. A 28% increase in labor productivity further reinforces the proposition that optimization of equipment and work methods can significantly enhance workforce performance.

In a broader context, the successful implementation of this method opens opportunities for wider adoption within the Indonesian construction industry. However, it must be acknowledged that adopting this method requires substantial initial investment in roll-forming machinery and workforce competency development, which presents a particular challenge for small- and medium-sized contractors. This finding is consistent with diffusion of innovations theory proposed by Rogers, Singhal, and Quinlan (2014), which identifies technological complexity as a key factor influencing the rate of innovation adoption.

Based on this comprehensive discussion, it can be concluded that the roll-on-site method represents a methodological leap that effectively addresses the modern construction industry's demands for efficiency, quality, and safety. The proven integration of engineering precision, logistics optimization, and safety culture observed in this case study warrants its consideration as a benchmark for the development of more efficient and sustainable construction methods in Indonesia, while also providing empirical contributions to the advancement of construction management theory.

CONCLUSIONS

Based on the comprehensive analysis conducted, it can be concluded that the implementation of the on-site roll-forming method at the PT. Amcor Tobacco Packaging Indonesia project in PIER Pasuruan demonstrates its effectiveness in addressing the technical challenges of installing long-span Galvalume roofing. This method not only successfully realized a seamless 40-50 meter roof system with owner-approved guaranteed quality, but also demonstrated comprehensive advantages in project management and occupational safety aspects.

From a project management perspective, the on-site roll-forming method demonstrated significant performance in terms of time and cost efficiency. The achievement of a 30-day installation duration, which is 35% faster than conventional methods, highlights this method's capability to optimize construction workflows. The support of an efficient coil material logistics system successfully reduced transportation costs by up to 45% while minimizing material damage to less than 1%, demonstrating the superiority of the just-in-time production concept within the construction supply chain.

The most prominent aspect of this implementation is the achievement of perfect occupational safety performance, with a zero accident rate throughout the installation process. This success was supported by the integration of technical engineering through supportive equipment innovations such as the roof trolley and walkway system, along with the rigorous implementation of safety procedures that reflect a safety culture which has become a core value in the project's execution.

Overall, this case study not only validates the feasibility of the on-site roll-forming method for industrial construction applications in Indonesia, but also presents an implementation model that integrates technical excellence, managerial efficiency, and occupational safety within a unified framework. This success opens opportunities for broader adoption within the Indonesian construction industry, particularly for large-scale industrial projects requiring wide spans and high standards of quality and safety.

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