




A Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces

Rosalie Grace S. De La Cruz^{1*} 

¹ College of Industrial Technology, Northern Iloilo State University, Estancia, Iloilo, Philippines.

Received 18 March 2023; Revised 15 May 2023; Accepted 21 May 2023; Published 13 June 2023

Abstract

The construction industry heavily relies on scaffolding to facilitate work at elevated heights. This study presents a new and innovative design for a collapsible, multifunctional scaffold that is suitable for both flat and irregular surfaces. The design of the scaffold was evaluated using a Likert scale survey, which revealed high acceptability across all evaluated categories. The scaffold was fabricated using a combination of steel and aluminum materials and designed using computer-aided design CAD software. The fabrication process, portability, performance, and safety of a prototype scaffold were thoroughly assessed. The evaluation methodology employed a Likert-scale questionnaire and a descriptive research approach. A total of 30 engineers, architects, and construction laborers participated in the evaluation, assessing four essential aspects of the scaffold. The results indicated a consistently high level of acceptability, with weighted mean scores ranging from 4.69 to 4.94 out of a maximum score of 5.0 in all categories. The design parameters of the scaffold, such as the footing mechanism and working platform design, were determined based on industry standards and the intended usage of the scaffold. However, this study did not include a sensitivity analysis to explore the impact of different parameter values on the scaffold's performance. This study introduces a collapsible, multifunctional scaffold that effectively addresses the limitations of traditional scaffolds by offering enhanced portability, safety, and adaptability to flat and irregular surfaces. The widespread adoption of this scaffold design is expected to have significant implications for the construction industry, improving productivity and safety in construction projects.

Keywords: Multipurpose; Collapsible; Scaffold; Regular; Irregular; Construction Industry.

1. Introduction

In the construction industry, the use of temporary structures like scaffolding is essential for providing access and support to workers during building projects. However, disregarding safety requirements can lead to unexpected circumstances and an increased risk of accidents on construction sites [1]. Neglecting precautionary measures may put workers in danger, particularly when working near or under scaffolding that has debris from upper levels [2]. The construction sector has gained a negative reputation for having one of the poorest safety records among private sector industries [1]. One contributing factor is the design of scaffolding, which often lacks convenience and safety when it comes to accommodating uneven surfaces or having illogical layouts [3]. One traditional scaffolding solution is the tube and clamp scaffold, which utilizes clamps, boards, and other scaffold equipment [4]. This type of scaffolding, known as tube and coupler scaffolding, is commonly used in building projects [5]. The system consists of vertical steel tubes connected to horizontal tubes through right-angle clamps [6]. A timber platform with crossbars for support and extended

* Corresponding author: rosaliegrace22@nisu.edu.ph

 <http://dx.doi.org/10.28991/CEJ-SP2023-09-09>



© 2023 by the authors. Licensee C.E.J, Tehran, Iran. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC-BY) license (<http://creativecommons.org/licenses/by/4.0/>).

tubular stands form the structure of the tube and coupler scaffold [7]. However, workers using this system face challenges such as the need to constantly go up and down for resources and the difficulty of storing materials and tools at higher levels [8]. The open sides of the platform on higher levels also create a sense of insecurity among workers [9]. Additionally, erecting the scaffold on uneven terrain poses another challenge [10], resulting in wasted time for workers instead of being utilized for their assigned tasks [11]. In case of accidents, the person in charge of the project is held accountable. Despite advancements in the building and scaffolding industries, the tube and clamp scaffold is still commonly used and requires improvements to ensure safety on irregular surfaces [12, 13].

However, these challenges can be mitigated through the diligence of workers, contractors, engineers, and project owners in ensuring safety and competent supervision during scaffold assembly, disassembly, and adjustments, as well as employing appropriately trained and certified workers for scaffolding activities [14]. Innovations in multipurpose collapsible scaffold designs offer the potential to provide safer, more durable, and quality structures that meet modern building standards [15]. These structures allow for easy assembly and disassembly, facilitate operations at elevated levels, and provide a comfortable working environment, particularly on irregular surfaces [16]. They offer cost-effectiveness by saving time and effort for both management and workers, benefiting project owners as well [17].

Prior art by Nesslering and Lewis Alberto Grijos Dos Santos includes a patent that focuses on ornamental design. Another relevant invention by Henry Fleischer in the United States of America introduces an Adjustable Ladder and Scaffold. However, the challenge with this design is its lack of convenience in terms of portability. Previous literature and patents have explored scaffolding ladder assemblies, adjustable scaffold ladders, and guardrails for elevated working platforms [18, 19]. However, certain challenges, such as transportation convenience and adaptation to geographic and construction demands, remain unresolved, particularly in the Philippines [20]. To address these challenges, this research proposes the development of a Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces. The scaffold design incorporates mechanically threaded extensible posts with locking screws and nuts, collapsible and removable cross balance and support frames, and a safe platform cage with a convenient walk board and storage area for materials and tools. This scaffold is ideal for small vertical construction repairs, offering lightweight construction, easy installation, and cost-effectiveness. It assists bricklayers, demolition workers, carpenters, stone masons, and steelworkers [21].

This research aims to investigate the assembly, adjustment, disassembly, storage, and transportation of the proposed scaffold. It also seeks to evaluate its compliance with safety standards, particularly P.D. 1096. The research objective is to innovate a multipurpose collapsible scaffold that can withstand regular and irregular surfaces, rotate at a 360-degree angle, incline up to 30 degrees, and provide a user-friendly working platform for construction workers. Additionally, an operating manual will be developed for scaffold installation and the scaffold.

1.1. Theoretical Underpinnings

Diagrammatic representation of the research theoretical underpinnings. The Theoretical Underpinnings employed in this research is depicted in Figure 1, which illustrates the key elements and processes involved in the development of the multipurpose collapsible scaffold for flat and irregular surfaces.

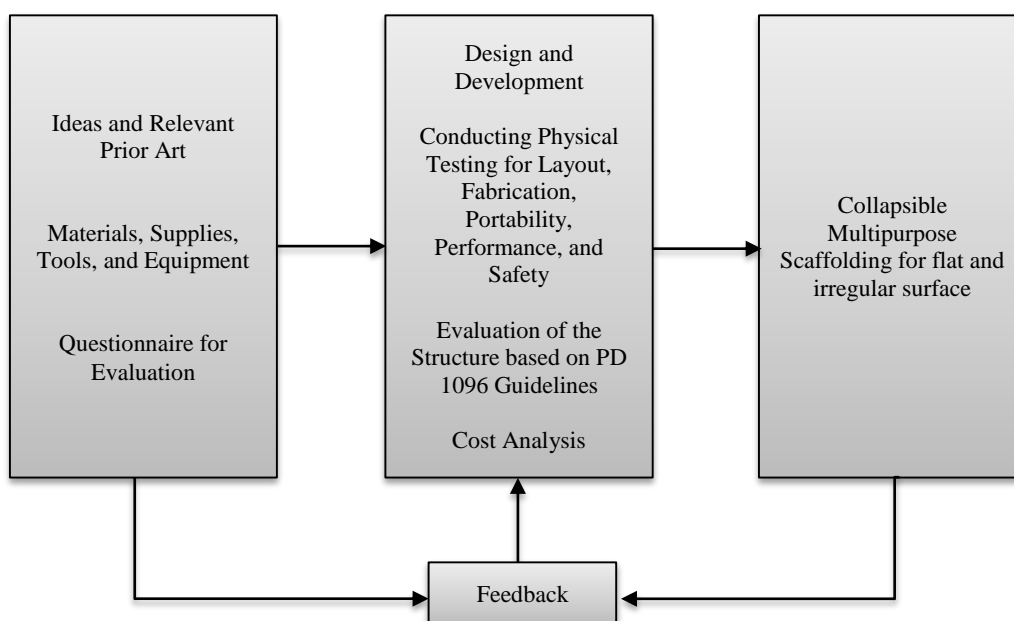


Figure 1. Theoretical underpinnings

The developmental system approach was adopted, incorporating a feedback scheme to ensure continuous monitoring and refinement of the scaffold's layout and fabrication. The researcher's ideas, along with theories and principles derived from relevant prior art, formed the basis for the scaffold's design. The fabrication phase involved the use of necessary supplies, materials, tools, and equipment. To gather relevant data, an evaluation question sheet was utilized, focusing on various aspects deemed important for the research. The overall objective of the research was to develop and test a weight-bearing, multipurpose collapsible scaffold that adheres to standard layout requirements and is capable of withstanding both flat and irregular surfaces. Testing and evaluation encompassed several dimensions, including layout, fabrication, portability, performance, and safety of the scaffold during operation. Additionally, an evaluation was conducted following the guidelines outlined in P.D. 1096 safety procedures.

The feedback scheme served as a crucial component in the evaluation process. If negative feedback or shortcomings were identified, they served as the basis for revision and correction. Suggestions from evaluators and experts were considered to devise appropriate solutions. Ultimately, the output of this research was the Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces. In the event that a negative outcome is obtained during the evaluation of the scaffold's throughput, the feedback loop feeds this information back into the process, leading to further refinement and adjustments until the research objectives are satisfactorily met.

2. Research Methodology

2.1. Design Criteria

The research employed an innovative system technique for fabricating a Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces. The layout of the scaffold was influenced by a prior art invention, aiming to address the limitations and issues of the existing structure while meeting industry standards in the local construction context. The following principles guided the fabrication process:

2.1.1. Types of Scaffolding

The scaffold structure could be of various types, such as cup lock, ring lock, Kwik stage, modular, or connector. System scaffolding, also known as modular scaffolding, consisted of horizontal and vertical components, including vertical tubes, horizontal tubes, pre-engineered joints, and supports [15]. It required proper support, diagonal bracing, and secure connections between components from compatible suppliers [21].

2.1.2. Requirements for Materials

All scaffold components needed to comply with the applicable standards, such as the Indian System or equivalent. Defective or degraded components were not permitted, and tubes had to be crack-free with smooth surfaces. The support structure had to be in excellent condition, regularly maintained, and non-tarnished [7, 22]. Only metallic boards adhering to British/European or comparable standards were allowed, while timber planks were prohibited.

2.1.3. Scaffolding Fabrication

Scaffold components were required to withstand their weight as well as four times the standard layout capacity. For taller scaffolding or specialized applications, a competent expert had to develop and certify the design with documentation. The erection of scaffolding followed specific codes, including safety guidelines and practices outlined in international safety codes and industry handbooks.

2.1.4. Footing Mechanism

The footing mechanism for the scaffold can take different forms, including foundations, base jacks, and load-bearing bases. It is crucial to ensure a solid foundation, which requires a thorough examination of the installation area [16]. Ground leveling or soil consolidation may be necessary to achieve stability. The footing mechanism should have a cross-section dimension of at least 9 inches by 112 inches (230 millimeters by 40 millimeters) to distribute the weight evenly across the ground, whether it is natural, man-made, or asphalted surfaces. It is necessary for the footing mechanism to go under a minimum pair of uprights to provide adequate support. In cases where the scaffold is supported by a concrete or steel surface without the risk of shifting or sinking, the use of a bottom base can be omitted, and the scaffold can rest directly on the surface.

2.1.5. Scaffolding Uprights and Traverse Tubes

Vertical tubes should extend high above the ground level, and the bottom base and standard couplings should be staggered between them [22]. The couplers need to be designed in a manner that they align as closely as possible with the horizontal tubes. Vertical standards are necessary for all the standards [23, 24]. Horizontal tubes were firmly fastened according to specified criteria, with a staggered layout for the scaffold's horizontal joints [21].

2.1.7. Working Platform

The workboard of a working platform should be supported by a minimum of three others, forming a platform cage configuration. The workboards on end supports should have a minimum overhang of 2 inches (50 mm) and a maximum overhang of 3 inches (75 mm). Supports for scaffold workboards must be spaced at least four times their thickness. The maximum allowed distances between scaffold supports depend on the weight carried on the working platform. The distance between scaffold supports should not exceed 5 feet, except for planks adjacent to the scaffold. When erecting workboards, they should be laid flush on the roundness of a cylinder or a sphere construction level, with no gaps greater than a quarter of an inch between adjoining planks or a scaffolding plank. All working platforms must consist of tight-fitting boards, and each plank should have a trilateral support system in place. The work platform should be kept free from unnecessary obstacles such as materials, trash, protruding nails, and any slickness caused by oil or grease. Board bedding must be secured to prevent movement, and no flammable materials or nylon should be used in the scaffolding [21].

2.1.8. Platform Cage and Debris Netting

Platform cages were constructed at the corners of the working platform where falls could occur from heights exceeding 6 feet. The height of the platform cage had minimum and maximum requirements, ensuring compliance with safety norms. Platform cages needed to be promptly reassembled if disassembled for the movement of goods [25]. Debris netting was necessary to prevent falling objects on the working platform or above the height of the workboard. Safety access points for moving materials while maintaining safety had to be provided [26].

2.1.10. Assembly and Disassembly

A competent inspector should supervise workers who have expertise in assembling, adjusting, and disassembling scaffolding components, as per regulation [27]. The assembly and disassembly process should be carefully planned to ensure stability is always maintained. Workers using scaffolds are required to wear safety harnesses and be safely positioned before unhooking and rehooking the safety ropes. Each safety harness on the scaffold must be attached to two safety ropes or lifelines [28]. It is strictly prohibited to lower, throw, tilt, or drop any materials or objects from significant heights, as this can result in severe injuries or fatalities. The drop zone must be protected. Existing scaffolding structures can be modified to accommodate new requirements or changes in the work being performed, such as adding or removing components, changing the height or shape of the structure, or making other modifications to improve safety or functionality. However, such alterations or adaptations should be carried out by qualified personnel in compliance with safety regulations and guidelines to prevent accidents or injuries [29].

2.2. Drawing Plan Preparation

The fabrication of a Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces was based on a detailed structure drawing plan, depicted in Figure 2. This drawing plan served as a crucial foundation and reference throughout the scaffold's fabrication process. Prior to initiating the fabrication, it was essential to have a well-designed and effective drawing plan in place. These drawing plans were meticulously prepared to ensure the integration of necessary measures to eliminate potential health and safety hazards (Figures 3 to 6).

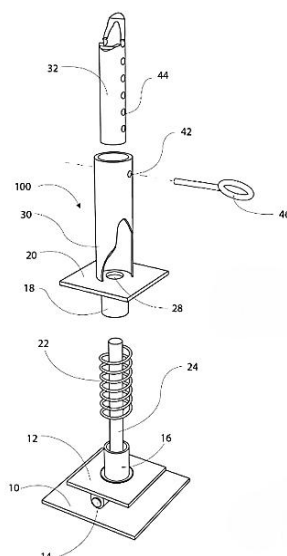


Figure 2. The isometric view of a multipurpose collapsible scaffold base plate

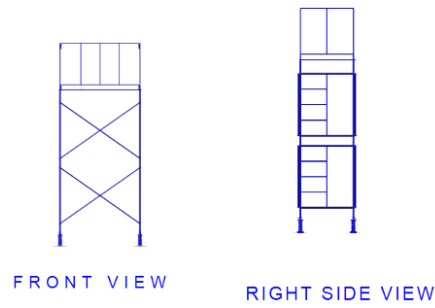


Figure 3. The front and right view of the scaffold attached to a scaffold base plate

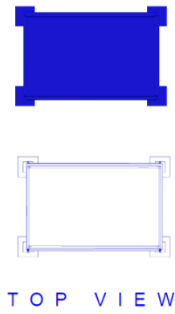


Figure 4. The Top View of the working platform that a base plate can carry



Figure 5. The perspective view of a one-storey complete set of collapsible scaffolds that can be carried by the scaffold base plate

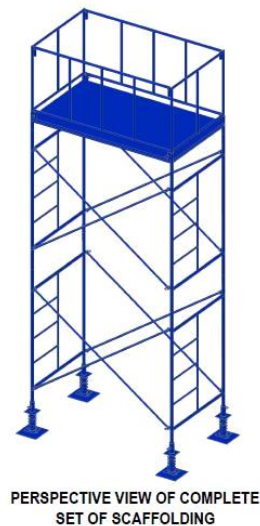
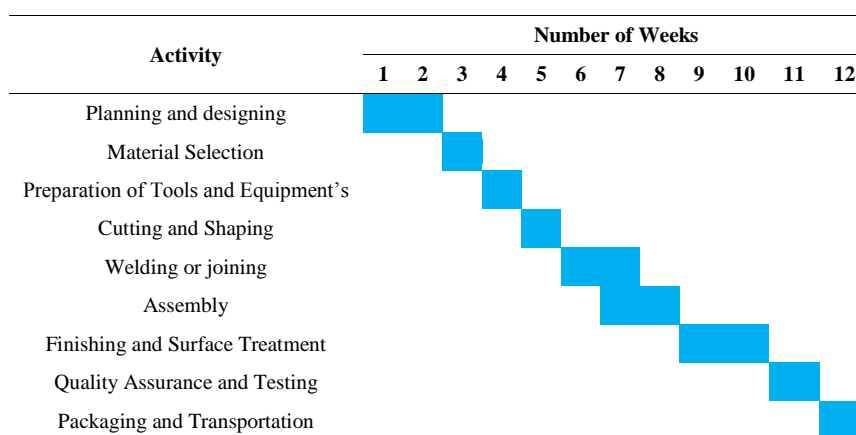


Figure 6. The perspective view of a two-storey complete set of scaffolding that can be carried by the scaffold footing mechanism

2.3. Fabrication

The construction of the structure was primarily guided by the criteria outlined in P.D.1096. The fabrication of the Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces aimed to optimize productivity by minimizing time and effort for workers assigned to elevated levels, as well as conserve materials, tools, and other necessary items used in higher-level tasks. Safety was a paramount consideration throughout the development of this research structure, ensuring the well-being of all individuals involved. Extensive time and effort were dedicated to thoroughly examining the features of existing prior art in order to carefully select suitable materials and procedures for the fabrication of the Multipurpose Collapsible Scaffold. To illustrate the planned activities involved in the scaffold's fabrication, a GANTT chart is provided in the Table 1.

Table 1. GANTT chart for fabrication of the Structure



2.4. Evaluation Procedure

Actual testing was conducted to evaluate the fabrication of the Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces and assess its overall acceptability. A self-made questionnaire was employed to gauge the level of acceptability in terms of design, fabrication, portability, performance, and safety. The gathered data were tabulated and subjected to analysis and statistical treatment [30, 31].

2.5. Pilot Testing and Revision

Following the fabrication, a pilot test was conducted to identify any flaws or setbacks encountered during the operation of the structure. The performance of the scaffold was carefully observed during the test, and valuable suggestions from evaluators and experts were willingly received and considered for further improvement [32].

2.6. Technical Evaluation

Following the completion of actual testing on the structure, specifically regarding minimum intended load and allowable spans, the proposed Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces was presented to technical experts for evaluation. This step was essential to gather valuable comments, suggestions, and feedback that would contribute to the final revision of the scaffold design. [33].

2.7. Instrumentation for Evaluation

To assess the extent to which the research objective was accomplished, a custom questionnaire was developed as a research instrument. The questionnaire utilized a Likert scale with five levels to measure the level of acceptability of the scaffold footing mechanism for flat and irregular surfaces in terms of its design, fabrication, portability, performance, and safety. This questionnaire aimed to gather quantitative data and gauge the participants' opinions on various aspects of the scaffold's acceptability [34].

2.8. Evaluation of Acceptability

The evaluation of acceptability in terms of design, fabrication, portability, performance, and safety recorded the responses of the respondents using the following format:

- Very Satisfactory (VS) 1
- Satisfactory (A) 2
- Moderately Satisfactory (MS) 3
- Satisfactory to a Small Degree (SSD) 4
- Unsatisfactory (U) 5

2.9. Interpretation Table

The interpretation of the weighted means for Design, Fabrication, Portability, Performance, and Safety was predetermined at the start of the study as follows (Table 2):

Table 2. The Interpretation Table

| Numerical Scale | Description |
|-----------------|--------------------------------------|
| 4.24 to 5.00 | Very Satisfactory (VS) |
| 3.43 to 4.24 | Satisfactory (A) |
| 2.62 to 3.42 | Moderately Satisfactory (MS) |
| 1.81 to 2.61 | Satisfactory to a Small Degree (SSD) |
| 1.00 to 1.80 | Unsatisfactory (U) |

2.10. Validation Procedure

The research instrument, designed to assess the acceptability of a Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces in terms of design, fabrication, portability, performance, and safety, underwent a validation process by a panel of examiners. The panel consisted of two experts from the construction industry, two authorities from the field of research, and one English critique. The data obtained from the instrument were computed using SPSS software.

The validity of the assessment was evaluated based on the content of the questions, aiming to determine the degree to which it accurately measures the intended topic. This assessment was conducted by expert reviewers and by surveying test-takers to gather their perception of the test's relevance. This process aimed to establish initial credibility and confidence in the resulting data [35].

2.11. Reliability of Questionnaire

Once the research instruments were validated, they underwent reliability testing to assess the consistency of participant responses over repeated measures. Reliability refers to the extent to which a measuring instrument produces consistent results for the same participants. In order to determine if the questionnaire met this criterion, homogeneity was examined. Homogeneity, which reflects the trustworthiness and consistency of the questionnaire, was evaluated to establish the reliability of the data. The questionnaire was administered to a group of thirty individuals who were engaged in construction-related roles such as engineers, foremen, painters, masons, and carpenters. This was done prior to the final evaluation of the questionnaire's acceptability. The results of the reliability testing were highly satisfactory, indicating that the questionnaire yielded consistent and reliable outcomes when administered to participants with similar job profiles [34].

2.12. The Respondents

The participants in the study consisted of five (5) masons, five (5) painters, five (5) carpenters, five (5) foremen, five (5) engineers, and five (5) individuals from various small construction firms in the Municipalities of the Northern part of Iloilo, Philippines. These participants provided valuable insights and information for the analysis.

A non-probabilistic sampling approach was employed, wherein the researcher selected the participants based on predetermined criteria. These criteria included the researcher's prior knowledge of the subject matter, the significance of the issue being studied, and the participants' willingness and ability to participate in the research. This approach allowed for a targeted and purposive selection of participants who could provide relevant perspectives and experiences [36].

2.13. Parameters of Analysis

The parameters investigated in this research pertain to the evaluation of a Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces in terms of its design, fabrication, portability, performance, and safety. The aim of this study is to offer affordable and practical scaffolding solutions for small-scale construction firms and activities. Additionally, it seeks to address the crucial aspect of scaffolding safety. The data collected served as the foundation for assessing the scaffold's actual performance and effectiveness [37].

2.14. Cost Analysis

The development of the proposed Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces adhered to standard material specifications and incurred a labor cost of 12,305.00 Php.

3. Result and Discussions

3.1. The Technology

Based on the premise, the present invention introduces the Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces. This innovative scaffold is specifically designed to adapt to uneven or irregular terrain. The primary objective of the invention is to provide a base plate that allows independent height adjustment of each leg, accommodating the characteristics of the ground. Furthermore, the invention aims to incorporate a tilting capability to adapt to the angle of irregular or uneven surfaces, along with a 360-degree rotation feature.

The base plate consists of a flange, coil spring, and steel plate, which contribute to maintaining the structure's balance under load. Serving as a load-bearing foundation, the base plate supports the scaffold's board decking components used in the working platform. The four-vertical frame with fixed ledgers functions as the main support and is securely joined through coupler fittings. These specialized components facilitate the assembly and alignment of the structure, ensuring stability and safety, even in demanding conditions (Figures 7 to 9).



Figure 7. Actual Photos of One-Storey Scaffold on a Flat and Irregular Surface

Additionally, the scaffold includes cross bracing designed to provide support for the vertical parts of the structure. The joints of the cross bracing are connected using wing nut screws, allowing for convenient assembly, material efficiency, and increased security. The ledgers, horizontal members that offer support for loads and planks, can also serve as mid rails, top handrails, and stairs. The working platform is primarily utilized for various manned aerial tasks, including maintenance, clearing, decoration, and construction activities.

This invention presents an effective and viable solution for small contractors engaged in construction works, offering an efficient and safe scaffolding system at minimal expenses. It provides small construction firms with an affordable and marketable scaffold footing mechanism for flat and irregular surfaces. Moreover, this innovative structure introduces new and valuable ideas to produce a Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces



Figure 8. Actual Photo of Base Plate



Figure 9. Actual Photo of two storey scaffold in an incline Plane

3.2. Description of the Preferred Embodiment

The current invention briefly discusses various mechanical features, which will be illustrated by reference to the accompanying drawings. Figure 10 shows a steel base plate for the present invention that is welded to the main frame 1, along with a fabricated steel hinge 4, coil spring 3, and wing bolt fastener. The steel base plate can be rotated 360 degrees in both clockwise and counterclockwise directions, and the fabricated steel hinge can incline in 300, 450, and 600 positions. This invention can carry up to 400 lbs. and is capable of withstanding an uneven surface (Figure 10).

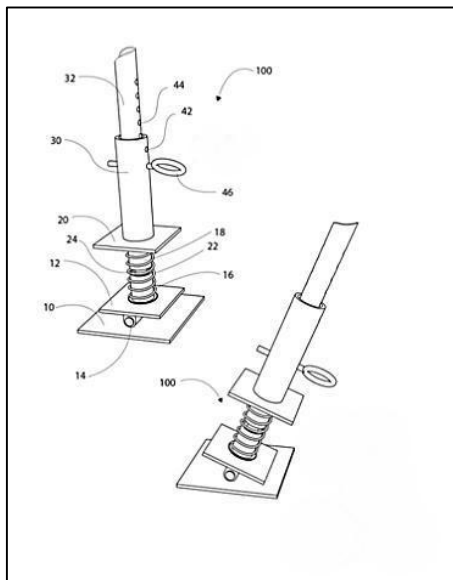


Figure 10. Detailed Diagram of Footing Base Plate

Figure 11 illustrates the front and side view of the scaffolding for a one-storey assembly. The erected scaffolding consists of two pairs of vertical main bars 5 that are connected to the steel base plate 7 through a coupler fitting. The cross braces with end hole connection 6 are formed by two large tubes, and the end portions of the smaller tubes are telescoped with the larger tubes to form coupler fitting connections. The two pairs of larger tubes 5 are fixed by welding, which allows the braces to cross over the main frame and stabilize the structure. The platform support frame 2 is then connected to the main frame 5 through a coupler fitting, and a handrail 1 is connected to the platform support frame 2 to ensure the safety of the working platform. This invention can position the structure in both flat and irregular contours, ensuring the working platform remains balanced.

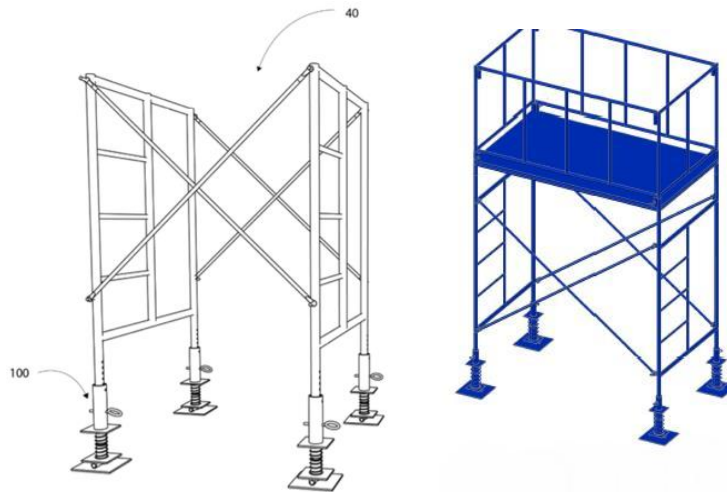


Figure 11. Detailed Description of the Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces for Ground

Figure 12 provides a detailed description of the collapsible working platform and handrail. The platform support frame 8 is connected to the vertical main frame 11 through a coupler fitting to fasten the working platform. A pair of shorter side platform handrails 12 are connected through coupler fitting 9 with the platform frame 8. After connecting the shorter side handrails, the longer side handrail 14 is connected through coupler fitting 13 to lock up the whole platform perimeter with the handrail, providing security to the worker (Figure 12).

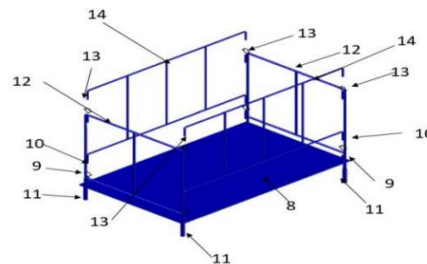


Figure 12. Detailed Description of Collapsible Platform and Handrail

Figure 13 shows the isometric view of an assembly in detail of a Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces for a one-storey activity. Two pairs of base plates 7 relate to two pairs of legs 5, carrying two pairs of cross-bracing 4 with a hole on both ends to hook with the vertical main frame 5 positioned in the middle of the vertical part. The crossbar 4 is mounted and positioned on the outer surface of the vertical main legs 5. The platform frame 3 relates to the main frame leg 5 to stabilize the working platform, and a handrail 1 and 2 relate to the platform main frame 3, respectively. This structure is designed for one-storey activity and is fabricated with cross-bracing bars to stabilize the working platform and ensure the safety of workers.

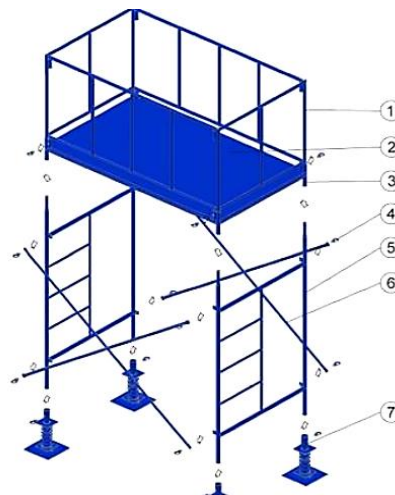


Figure 13. The Isometric View of Assembly in Detailed of Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces for One – storey Activity

Figure 14 presents a perspective view of the complete set for a two-storey activity of the Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces. The base steel plate 1, equipped with a coil and hinges as shown in figure 37, can be rotated 360 degrees in both clockwise and counter clockwise directions, allowing the structure to adapt to various contours. The steel base plate 1 is connected to two pairs of legs, forming the vertical main frame 3, using screws and hardware B for secure fastening. The vertical main frame 3 is further connected to two pairs of cross-bracing bars 4, with the end holes secured using screws and nuts (hardware A and B) to ensure proper attachment. The two sets of vertical frames 3 are connected through coupler fitting with the leg frame 3, enabling the scaffold to reach the desired height for a two-storey activity. An additional two sets of cross-bracing bars 4 are fastened to 5 using screws (hardware A) and secured with nuts (hardware B) to provide stability during second-floor assembly. The platform frame 6 is connected to handrails 7 and 8, respectively. Figure 15 is specifically designed for two-storey activities, offering a safe and convenient solution. The structure is fabricated with screws and nuts to connect the cross-bracing bars and stabilize the scaffold, while the working platform handrail ensures worker safety.

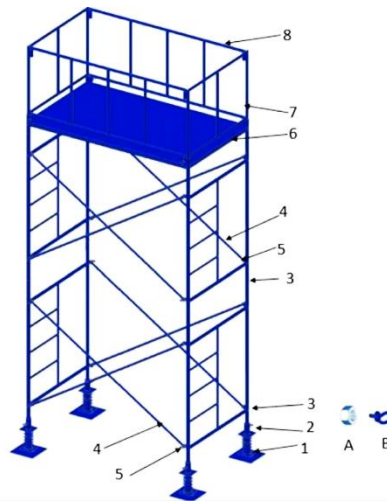


Figure 14. The Isometric View of Assembly in Detailed of Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces for Two – storey Activity

3.3. Technical Evaluation

Following the practical testing of the proposed Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces, which involved assessing its minimum intended load and allowable spans, the structure was presented to technical experts. During the evaluation, it was observed that the working platform was not collapsible and had been fabricated and fixed, making it too heavy to be installed at higher levels. As a result, it was recommended that the working platform be redesigned to incorporate collapsible features. After the revision, the structure underwent further assessment, and the results indicated its acceptability in terms of design, fabrication, portability, performance, and safety. Table 3 is the result of the test to performance.

Table 3. The Performance of the Structure

| Description | Test (minutes) with working area 2 square meter | | | |
|--|---|--------|--------|---------|
| | Test 1 | Test 2 | Test 3 | Average |
| 1 Assembly (for 2 m Height) | 11 | 13 | 15 | 13 |
| 2 Adjustment (addition of another 2 m upward of work area) | 6 | 7 | 8 | 7 |
| 3 Disassembly | 15 | 17 | 19 | 17 |

According to Table 3, the assembly speed of the structure is recorded as 13 minutes. This time includes adjustments made when incorporating an upward working area. On the other hand, the disassembly time for transportation or storage is measured at 17 minutes.

3.4. Acceptability

The participants in the study consisted of individuals from various professional backgrounds within the construction industry. Specifically, there were five (5) painters (Group I), five (5) carpenters (Group II), five (5) foremen (Group III), five (5) engineers (Group IV), and five (5) representatives from different industries (Group V). These participants were selected from small construction firms located in the Municipality of Estancia, Iloilo, Philippines.

Table 4 presents the results of the acceptability evaluation in terms of design. The data indicates that out of the ten items assessed in the acceptability evaluation, the first item received the highest weighted mean of 5.0, indicating that the collapsible multipurpose scaffolding is perceived as highly novel and innovative. On the other hand, the seventh

item obtained the lowest weighted mean of 4.6, but it is still considered very acceptable as it signifies that the structure's screw with nut is designed to securely lock the cross-bracing members

Table 4. Presented the Result of Acceptability Evaluation as to Design

| Design | Weighted Mean | Interpretation |
|--|---------------|----------------|
| 1. The collapsible multipurpose scaffolding possesses novelty. | 5 | VA |
| 2. The structure parts and components structure are properly fabricated to compliment on its function. | 4.76 | VA |
| 3. The structure is made durable enough to endure weight of worker and materials during operation. | 4.68 | VA |
| 4. The structural of the structure is design per safety of Philippines OHSC | 4.68 | VA |
| 5. The structure could be adjusted to accommodate at least two-story building | 4.84 | VA |
| 6. The structure is design for ease of erection, alteration and storing. | 4.88 | VA |
| 7. The structure screw w/nut is designed to lock the cross-bracing members securely. | 4.6 | VA |
| 8. The structure steel base plate with coil spring ensures balance of the structure. | 4.84 | VA |
| 9. The structure railing on its working platform is designed to ensure safety. | 4.92 | VA |
| 10. The structure base metal plate with flange can stand securely on irregular surfaces. | 4.72 | VA |
| Weighted Mean | 4.80 | VA |

By comparing the highest mean of 5.0 and the lowest mean of 4.6, it is evident that the structure's design overall is deemed very acceptable. This finding holds significant implications, indicating that the Design of Collapsible Multipurpose Scaffolding for Flat and Irregular Surfaces has achieved a high level of acceptability and reliability. The weighted mean of 4.80 further confirms the structure's substantial acceptability, establishing it as a reliable solution for construction activities in various contexts and surface conditions.

Table 5 presents the results of the acceptability evaluation in terms of fabrication. The data indicates that out of the fourteen items assessed in the acceptability evaluation, the seventh item obtained the highest weighted mean of 4.96. This result signifies that the structure's working platform railing protection systems are highly acceptable, as they contribute to maintaining a safe construction operation while providing maximum access for workers to the working area. On the other hand, the fourteenth item received the lowest weighted mean of 4.6, but it is still considered very acceptable, as it represents the cross bracing at an angle of 35 – 55 degrees.

Table 5. The Result of Acceptability Evaluation as to Fabrication

| Fabrication | Weighted Mean | Interpretation |
|--|---------------|----------------|
| 1. The structure can be erected, altered and stored easily. | 4.64 | VA |
| 2. The sequence pattern of the structure is particularly useful for related construction purposes. | 4.56 | VA |
| 3. The structure due to the nature of the material cannot absorb spatters from welding operation. | 4.52 | VA |
| 4. The structure is rigid enough and comparable with the industry standards. | 4.48 | VA |
| 5. The structure is a temporary structure that suitably supports a work crew and materials that helps in the construction, maintenance and repair of buildings, bridges and all other man-made structures. | 4.56 | VA |
| 6. The structure adequately provides a working platform for a variety of heights. | 4.92 | VA |
| 7. The structure has a working platform railing protection system that helps maintain a safe construction operation while allowing workers the maximum access possible to the working area. | 4.96 | VA |
| 8. The structure is fabricated per standard dimensions and load bearing capacity. | 4.88 | VA |
| 9. Scaffold can withstand irregular contour of surfaces. | 4.8 | VA |
| 10. The heavy-duty Steel plate allows sturdy positioning of the scaffold tower. | 4.72 | VA |
| 11. The structure can be erected and altered in multiple directions for work surfaces w/ irregular surfaces, dimensions and contours | 4.72 | VA |
| 12. The structure can adopt adequately on irregular surfaces and contours. | 4.84 | VA |
| 13. The structure had undergone assessment for structural requirements for erection, storage, handling and assembling. | 4.64 | VA |
| 14. Cross bracing at an angle of 35 – 55 degrees | 4.4 | VA |
| Weighted Mean | 4.69 | VA |

Comparing the highest mean of 4.96 to the lowest mean of 4.6, it is evident that the structure's fabrication is deemed very acceptable overall. This finding holds significant implications, suggesting that the fabrication of the Collapsible Multipurpose Scaffolding for Flat and Irregular Surfaces has achieved a high level of acceptability and reliability. The weighted mean of 4.69 further confirms the structure's substantial acceptability, establishing it as a reliable solution for construction activities in various contexts and surface conditions.

Table 6 presents the results of the acceptability evaluation in terms of portability. The data indicates that out of the eight items assessed in the acceptability evaluation, both the first and second items obtained the highest weighted mean of 4.88. This suggests that the precision in assembling the structure's cross bracings enhances its portability, and the collapsible nature of the parts allows for easy transportation and storage of the structure in a flat compact unit.

Table 6. The Result of Acceptability Evaluation as to Portability

| Portability | Weighted Mean | Interpretation |
|--|---------------|----------------|
| 1. The structure produces precision in assembling its cross bracings does enhances its portability. | 4.88 | VA |
| 2. The structure can be transported easily since the parts are collapsible into a flat compact unit for carrying and storage. | 4.88 | VA |
| 3. The structure function ability of individual components of joints and connections are easy to handle thereby easy to disassemble. | 4.72 | VA |
| 4. The structure legs can be assembled easily through inserting vertical parts and lifted into position by hand. | 4.56 | VA |
| 5. The mechanical concept of the structure has its capability of being erected on any irregular ground does boosting its portability. | 4.8 | VA |
| 6. Scaffolds can be erected, altered and dismantled by components easily that increases its portability. | 4.68 | VA |
| 7. The structure was structured so that it can be used both indoors and outdoors construction activities does add up to its portability. | 4.56 | VA |
| 8. The environmental loading conditions and associated cost implications for the suitability of design. | 4.72 | VA |
| Weighted Mean | 4.72 | VA |

On the other hand, the fourth and seventh items received the lowest weighted mean of 4.56. However, these scores are still considered very acceptable, as they indicate that the structure's legs can be easily assembled by inserting vertical parts and lifted into position by hand, and the structure is designed to be used both indoors and outdoors for construction activities, which further adds to its portability. By comparing the highest mean of 4.88 to the lowest mean of 4.56, it is evident that the structure's portability is deemed acceptable overall, with a leaning towards being very acceptable. This finding holds significant implications, suggesting that the Portability of the Collapsible Multipurpose Scaffolding for Flat and Irregular Surfaces has achieved a high level of acceptability and reliability. The weighted mean of 4.72 further confirms the structure's substantial acceptability, establishing it as a reliable solution for construction activities in various contexts and surface conditions in terms of its portability. Table 7 presents the results of the acceptability evaluation in terms of performance. The data indicates that out of the eight items assessed in the acceptability evaluation, both the fourth and eighth items obtained the highest weighted mean of 4.8. This indicates that the use of diagonal bracings contributes to improved stability, especially in tall buildings, and emphasizes the importance of good foundations for scaffolding on irregular surfaces.

Table 7. The Result of Acceptability Evaluation as to Performance

| Performance | Weighted Mean | Interpretation |
|---|---------------|----------------|
| 1. Performs adequately and adapt to forms for formwork and shoring, grandstand seating, concert stages, access/viewing towers, exhibition stands, ski ramps, half pipes and art projects. | 4.64 | VA |
| 2. Workers can perform effectively on operation for setting, welding and assembling in any size and shape and angle. | 4.68 | VA |
| 3. The structure tubular steel pipes with standardized dimensions, allows industrial interchange ability of parts does improving the structural stability of the scaffold. | 4.76 | VA |
| 4. The use of diagonal bracings also helped to improve stability, especially on tall building | 4.8 | VA |
| 5. The basic lightweight tube scaffolding that became the standard | 4.64 | VA |
| 6. Colour to paint the scaffolding with, in order that quick visual identification can be made in case of theft. | 4.36 | VA |
| 7. The standards, also called uprights, are the vertical tubes that transfer the entire mass of the structure to the ground where they rest on a square base plate to spread the load | 4.68 | VA |
| 8. Good foundations are essential for irregular surface. | 4.8 | VA |
| Weighted Mean | 4.67 | VA |

On the other hand, the sixth item received the lowest weighted mean of 4.36. However, this score is still considered acceptable, as it pertains to the choice of color for painting the scaffolding to enable quick visual identification in case of theft. By comparing the highest mean of 4.8 to the lowest mean of 4.36, it is evident that the structure's performance is deemed acceptable overall, with a leaning towards being very acceptable. This finding holds significant implications, suggesting that the Performance of the Collapsible Multipurpose Scaffolding for Flat and Irregular Surfaces has achieved a high level of acceptability and reliability. The weighted mean of 4.69 further confirms the structure's substantial acceptability, establishing it as a reliable solution for construction activities in various contexts and surface conditions in terms of its performance.

Table 8 presents the results of the acceptability evaluation in terms of safety. The data indicates that out of the eight items assessed in the acceptability evaluation, both the third and eighth items obtained the highest weighted mean of 5.0. This indicates that the researcher's device successfully eliminates the exposure of workers to hazardous equipment and incorporates safety procedures and the requirement of personal protective equipment (PPE) during operation, as stated in the Manual of Operation.

Table 8. Presented the Result of Acceptability Evaluation as to safety

| Safety (Executive Order No. 307 Establishing an Occupational Safety and Health Center in the Philippines) | | |
|--|---------------|----------------|
| The researcher's device does not expose the worker or users to... | Weighted Mean | Interpretation |
| 1. Ergonomic Hazards | 4.88 | VA |
| 2. Hazardous work processes | 4.96 | VA |
| 3. Hazardous equipment | 5 | VA |
| 4. Occupational Hazards | 4.96 | VA |
| 5. Imminent Danger | 4.88 | VA |
| 6. Hazardous materials or substances | 4.84 | VA |
| Safety | Weighted Mean | Interpretation |
| 7. Airborne concentrations of substances from the device and conditions under which workers may be repeatedly exposed for an 8-hours workday at a total of 48 hours per week, without adverse health effects | 4.96 | VA |
| 8. The researcher's device has safety procedures for and requires personal protective equipment (PPE) during operation. (Manual of Operation) | 5 | VA |
| Weighted Mean | 4.94 | VA |

On the other hand, the sixth item received the lowest weighted mean of 4.84. However, this score is still considered very acceptable, as it indicates that the researcher's device effectively avoids exposing workers to hazardous materials or substances. By comparing the highest mean of 5.0 to the lowest mean of 4.84, it is evident that the structure's safety is deemed very acceptable overall. This finding holds significant implications, suggesting that the Safety of the Collapsible Multipurpose Scaffolding for Flat and Irregular Surfaces has achieved a high level of acceptability and reliability. The weighted mean of 4.94 further confirms the structure's substantial acceptability, establishing it as a reliable solution for construction activities in various contexts and surface conditions in terms of safety.

According to the data presented in Table 9, the acceptability of the Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces was assessed in terms of design, fabrication, portability, performance, and safety. The weighted mean scores for these criteria were found to be 4.80, 4.69, 4.72, 4.67, and 4.94 respectively. Based on the interpretation of these scores, the overall acceptability of the scaffold was categorized as "Very Acceptable."

Table 9. Overall Acceptability in terms of design, fabrication, portability, performance, and safety

| | Weighted Average | Interpretation |
|-------------|------------------|----------------|
| Design | 4.80 | VS |
| Fabrication | 4.69 | VS |
| Portability | 4.72 | VS |
| Performance | 4.67 | VS |
| Safety | 4.94 | VS |

3.5. Disclosure of Claim

This invention presents a Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces designed specifically for construction workers. The scaffold is capable of withstanding both flat and irregular surfaces. It consists of a pair of steel base plates that can be rotated 360 degrees in either direction. The base plate is equipped with a flange, allowing for a 40-degree inclination against plane surfaces or irregular surfaces. To ensure structural balance, a coil spring is connected to the flange, capable of supporting a weight of up to 490 lbs., or 5 persons, on flat surfaces and 400 lbs., or 4 persons, on irregular surfaces. The footing mechanism can be extended between 4 to 8 inches and is connected to the vertical main frame through steel plates. Two pairs of footing steel plates are joined by a coupler fitting and connected to the vertical main frame through the end holes of the cross-bracing bars using screws and nuts to secure the structure. The platform frame is then connected to the two pairs of vertical frames, followed by the attachment of handrail 1 and handrail 2 to the platform frame using coupler fittings, ensuring the safety of workers during one- and two-story activities.

3.6. Operation Manual

A comprehensive operational manual has been developed to serve as a step-by-step guide for assembling the Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces. This manual is applicable in various contexts, such as construction, renovation, maintenance, and refurbishment projects. Its purpose is to provide workers with a reliable and standardized procedure for safely and efficiently assembling the structure. The manual is particularly valuable for employees seeking additional information to understand the tasks at hand and comply with relevant rules and regulations.

The manual includes detailed explanations of the different components and how they fit together, as well as highlighting specific areas that require prioritization during the construction process. By emphasizing proper planning for scaffold assembly and disassembly, the manual plays a crucial role in reducing scaffold-related accidents and fatalities. The focus of the manual is on sound design, fall protection measures, recommendations for correct installation, guidelines for safe usage, instructions for alterations and dismantling, as well as procedures for inspections, maintenance, and storage. By adhering to the policies and work regulations outlined in the manual, workers can ensure the safety and success of their scaffold-related activities.

3.7. Summary

The purpose of the research was to develop, fabricate, and assess new features of Multipurpose Collapsible Scaffolds for Flat and Irregular Surfaces. The structure's acceptability was also assessed in terms of layout, fabrication, portability, and safety. The objective of this research was to develop, construct, and evaluate the novel features of Multipurpose Collapsible Scaffolds for Flat and Irregular Surfaces. Additionally, the acceptability of the structure was assessed in terms of its design, fabrication, portability, and safety. The research aimed to introduce an innovative structure that addresses the safety concerns of construction workers, regardless of the geographical location or site conditions within the country. The design of the structure was inspired by the adjustable ladder scaffold commonly available on the market. This design incorporates established principles in the construction of Multipurpose Collapsible Scaffolds for Flat and Irregular Surfaces. Prior to the final evaluation, the Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces underwent pilot testing to determine its practicality and effectiveness in an industrial setting. Subsequently, experts in the fields of engineering and related disciplines, including Civil Engineers, construction workers, professors, instructors, and technicians engaged in building and engineering, conducted the final evaluation. The researcher's findings were based solely on the questionnaire specifically developed for this study.

4. Conclusion

Based on the ground-breaking and innovative findings, as well as the comprehensive evaluations conducted for the collapsible multipurpose scaffolding designed for flat and irregular surfaces, it is imperative that the academic community wholeheartedly embrace actionable, practical, and engaged scholarship. The evaluation and assessment carried out by experts in the engineering and construction industries have unequivocally demonstrated that this scaffolding design not only meets the required industry standards but surpasses them. The meticulous expertise and knowledge of these professionals have confirmed that the design aligns seamlessly with the established principles and requirements for such structures. During extensive operational testing, it became evident that the scaffolding can safely and effectively accommodate up to four individuals for construction activities. This exceptional capacity showcases the structure's ability to support heavy workloads while prioritizing the safety of workers. The overwhelmingly positive feedback and high level of acceptance expressed by the evaluators highlight the scaffolding's exceptional performance in this regard. The final evaluation conducted by industry experts further solidifies the resounding acceptability of the collapsible multipurpose scaffolding for flat and irregular surfaces.

The unequivocally positive feedback and assessments received from professionals in the engineering and construction industries provide robust support for the conclusion that the structure is not only well-designed but also reliable and perfectly suited for its intended purpose. It is crucial that the academic community recognize the immense value and potential of this collapsible multipurpose infrastructure, considering these remarkable findings. By engaging in actionable, practical engaged scholarship, researchers and scholars can contribute significantly to the advancement and practical implementation of this innovative solution. The exceptional compliance with industry standards, the capacity to support multiple workers effectively, and the resounding acceptability of the scaffolding, as evidenced by expert evaluations, make it an ideal focus for further scholarly exploration and practical application. It is time for the academic community to embrace the opportunity presented by this innovative scaffolding design. By engaging in practical, action-oriented research, scholars can actively contribute to the construction industry's safety, efficiency, and effectiveness in the pursuit of knowledge and practical solutions, working together to propel the implementation of this collapsible multipurpose scaffolding and revolutionize construction practices on flat and irregular surfaces.

4.1. Suggestions

The recommendations put forth considering the innovative findings and final conclusions are as follows: 1) With the Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces meeting industry standards and receiving high acceptance from experts, it is highly recommended that immediate steps be taken to fabricate and make this groundbreaking structure available for use at Northern Iloilo State University. By incorporating this innovative scaffold into their construction activities, the university can significantly enhance the safety and efficiency of their operations. The scaffold's adaptability to both flat and irregular surfaces ensure its versatility in a wide range of construction projects on the university campus. This implementation will not only serve as a practical demonstration of the scaffold's efficacy but also provide an opportunity for researchers and students to further explore its capabilities and contribute to its ongoing development; 2) By providing small construction firms with access to this scaffold, they can significantly improve the safety standards of their construction sites while maximizing their efficiency. Additionally, making the scaffold available in the market for other consumers who require a reliable and adaptable solution for their construction projects will contribute to its wider adoption and practical implementation across various industries; and 3) Building on the successful outcomes of this research, it is of utmost importance to foster and support the continuation of similar studies in order to address the evolving needs of the Engineering and Construction Industry. The innovative Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces represents a significant advancement in construction technology, and further research can push the boundaries of its capabilities. Future studies should focus on exploring additional design improvements, refining manufacturing processes, and investigating their potential applications in diverse construction contexts. By engaging in continued research, scholars, researchers, and industry professionals can collectively contribute to enhancing the safety, efficiency, and productivity of construction activities, ultimately driving advancements in the field.

The recommendations emphasize the need for immediate implementation of the Multipurpose Collapsible Scaffold for Flat and Irregular Surfaces at Northern Iloilo State University, the widespread availability of the scaffold for small construction firms and the market, and the importance of further research to address evolving industry needs. These actions will not only promote the practical use of this groundbreaking scaffold but also foster ongoing advancements in the construction industry, ultimately leading to enhanced safety, efficiency, and productivity in construction activities.

5. Declarations

5.1. Data Availability Statement

The data presented in this study are available in the article.

5.2. Funding

The author received no financial support for the research, authorship, and/or publication of this article.

5.3. Acknowledgements

The researcher would like to express gratitude to the following individuals: Dr. Rolando F. Jacuman: The researcher's mentor, whose guidance and expertise were invaluable throughout the research process; Dr. Carlito Porras: For providing assistance in creating the necessary gadgets required for the study, contributing to the successful execution of the research; Engr. Lex Garachico: For his assistance in creating AutoCAD designs, which played a crucial role in the development and visualization of the research project; Romeo B. Servandil Sr. and Rosalia Magbanua: The researcher's parents, for their unwavering moral support and inspiration throughout the journey; Romeo Jr., John, Josie, Magdalena, Jenette, and Rezenieve: The researcher's siblings, for their constant encouragement and support during challenging times; R-Jay and Jade Rome: The researcher's sons, whose joy and motivation provided encouragement and a sense of purpose during difficult moments; Engr. Jo-an Dela Cruz: The researcher's husband, for his continuous support, love, and encouragement throughout the research endeavor; Lastly, the researcher expresses deep gratitude to the Lord Almighty for providing guidance, strength, and inspiration throughout the entire research process.

5.4. Conflicts of Interest

The author declares no conflict of interest.

6. References

- [1] Melenbrink, N., Werfel, J., & Menges, A. (2020). On-site autonomous construction robots: Towards unsupervised building. *Automation in Construction*, 119, 103312. doi:10.1016/j.autcon.2020.103312.
- [2] Hou, L., Wu, S., Zhang, G. K., Tan, Y., & Wang, X. (2021). Literature review of digital twins applications in construction workforce safety. *Applied Sciences (Switzerland)*, 11(1), 1–21. doi:10.3390/app11010339.

- [3] Jipa, A., Giacomarra, F., Giesecke, R., Chousou, G., Pacher, M., Dillenburger, B., Lomaglio, M., & Leschok, M. (2019). 3D-printed formwork for bespoke concrete stairs. *Proceedings of the ACM Symposium on Computational Fabrication*, 1-12. doi:10.1145/3328939.3329003.
- [4] Girma, B. (2020). *Cost and Quality Comparison of Different Types of Formwork Systems in Concrete Structure Buildings Case Study in Bahir Dar*. Ph.D. Thesis, Bahir Dar University, Bahir Dar, Ethiopia.
- [5] Abbaszadeh, S., Jahangiri, M., Abbasi, M., Banaee, S., & Farhadi, P. (2022). Risk assessment of probable human errors in the scaffold erection and dismantling procedure: a fuzzy approach. *International Journal of Occupational Safety and Ergonomics*, 28(3), 1773–1778. doi:10.1080/10803548.2021.1932110.
- [6] Jang, M. (2017). Development of an Adjustable board and a Rotational Board for Scaffold. *IOP Conference Series: Materials Science and Engineering*, 216, 012057. doi:10.1088/1757-899x/216/1/012057.
- [7] Bailey, H., Hancock, D. (1990). *Scaffolding*. In: *Brickwork 3 and Associated Studies*. Palgrave, London. doi:10.1007/978-1-349-11381-1_6.
- [8] Quadri, A. I., & Fadugba, O. G. (2022). Risk Assessment and Safety Precautions for Construction Site Scaffolding. *Journal of Rehabilitation in Civil Engineering*, 10(4), 1–13. doi:10.22075/JRCE.2021.22451.1480.
- [9] Crestelo Moreno, F., Roca Gonzalez, J., Suardíaz Muro, J., & García Maza, J. A. (2022). Relationship between human factors and a safe performance of vessel traffic service operators: A systematic qualitative-based review in maritime safety. *Safety Science*, 155. doi:10.1016/j.ssci.2022.105892.
- [10] Thompson, T. (2015). *The Construction Zone: Building Scaffolds for Readers and Writers*. Stenhouse Publishers, Portsmouth, United States.
- [11] van Dijk, L. M., van Eikenhorst, L., & Wagner, C. (2022). Daily practice performance (Work-as-Done) compared to guidelines (Work-as-Imagined) of medication reconciliation at discharge: Outcomes of a FRAM study. *Safety Science*, 155. doi:10.1016/j.ssci.2022.105871.
- [12] Levy, S. M. (2018). *Project management in construction*. McGraw-Hill Education, New York, United States.
- [13] Davila Delgado, J. M., Oyedele, L., Ajayi, A., Akanbi, L., Akinade, O., Bilal, M., & Owolabi, H. (2019). Robotics and automated systems in construction: Understanding industry-specific challenges for adoption. *Journal of Building Engineering*, 26. doi:10.1016/j.job.2019.100868.
- [14] NIOSH. (2023). National Institute of Occupational Safety and Health. Selangor, Malaysia. Available online: <http://www.niosh.com.my/> (accessed in May 2023).
- [15] He, L., Liu, C., Wu, Z., & Yuan, J. (2019). Stability analysis of an aluminum alloy assembly column in a modular support structure. *Thin-Walled Structures*, 135, 548–559. doi:10.1016/j.tws.2018.11.026.
- [16] Wang, C., Zhang, H., Rasmussen, K. J. R., Reynolds, J., & Yan, S. (2020). System reliability-based limit state design of support scaffolding systems. *Engineering Structures*, 216. doi:10.1016/j.engstruct.2020.110677.
- [17] Kim, K., & Teizer, J. (2014). Automatic design and planning of scaffolding systems using building information modeling. *Advanced Engineering Informatics*, 28(1), 66–80. doi:10.1016/j.aei.2013.12.002.
- [18] Xavier, G & Perreau – Saussine, D. (2007). *Guide Tube for a Flexible pipe for transporting hydrocarbons*. Derwent Innovation Publication US7292940B1, United State.
- [19] Jiang, L., Liu M., Tang, S., Wang D., & Xu, W. (2019). *An Adjustable Scaffold Ladder*. Derwent Innovation Publication CN209723581U, China.
- [20] Fleischer Henry, Little Falls, NJ & US (1973). *Adjustable Ladder and Scaffold*. Derwent Innovation Publication US3724592A, United State.
- [21] Dong, J., Liu, H., Lei, M., Fang, Z., & Guo, L. (2022). Safety and stability analysis of variable cross-section disc-buckle type steel pipe high support system. *International Journal of Pressure Vessels and Piping*, 200. doi:10.1016/j.ijpvp.2022.104831.
- [22] Guillamón Causi, P. (2012). *Stability analysis on different type of steel scaffolds*. Final Project, Politecnico Di Torino, Turin, Italy.
- [23] Department-Order-No.-128-13. (2013). *Amending Rule 1414 on Scaffoldings of the 1989 Occupational Health and Safety Standards, As Amended*. Department of Labor and Employment, Manila, Republic of Philippines.
- [24] Hossain, M. A., Moazzem Hossain, M., Tarannum, S., & Chowdhury, T. H. (2015). Factors affecting OHS practices in private universities: An empirical study from Bangladesh. *Safety Science*, 72, 371–378. doi:10.1016/j.ssci.2014.10.007.
- [25] Fawaz, G., Waked, M., Mabsout, M., & Tarhini, K. (2017). Influence of railings on load carrying capacity of concrete slab bridges. *Bridge Structures*, 12(3–4), 85–96. doi:10.3233/BRS-170107.

- [26] Dogan, E., Yurdusev, M. A., Yildizel, S. A., & Calis, G. (2021). Investigation of scaffolding accident in a construction site: A case study analysis. *Engineering Failure Analysis*, 120. Doi:10.1016/J.Engfailanal.2020.105108.
- [27] Zeina, S. M. (2021). Investigation on Scaffolding Health and Safety Risk Management A Case of On-Going Building Construction Project in Bahir Dar City. PhD Thesis, Bahir Dar University, Bahir Dar, Ethiopia.
- [28] Awolusi, I. G., & Marks, E. D. (2017). Safety Activity Analysis Framework to Evaluate Safety Performance in Construction. *Journal of Construction Engineering and Management*, 143(3). doi:10.1061/(asce)co.1943-7862.0001265.
- [29] Sharma, A. T., Kumarason, R., Sudesh Nair, B., & Kishan, G. (2022). Investigation on the Causes of Falling from Height and Fall Protection System at Sabah. *Journal of Innovation and Technology*, 2022(07), 1-4.
- [30] P. D. 1096. Adopting a National Building Code of the Philippines Thereby Revising Republic Act Numbered Sixty-Five Hundred Forty-One. *National Building Code of the Philippines*, Manila, Republic of Philippines.
- [31] Assmann, S. F., Pocock, S. J., Enos, L. E., & Kasten, L. E. (2000). Subgroup analysis and other (mis)uses of baseline data in clinical trials. *Lancet*, 355(9209), 1064–1069. doi:10.1016/S0140-6736(00)02039-0.
- [32] Schroder, C., Medves, J., Paterson, M., Byrnes, V., Chapman, C., O’Riordan, A., Pichora, D., & Kelly, C. (2011). Development and pilot testing of the collaborative practice assessment tool. *Journal of Interprofessional Care*, 25(3), 189–195. doi:10.3109/13561820.2010.532620.
- [33] Rodriguez, J., Wu, B., Bernet, S., Zargari, N., Rebolledo, J., Pontt, J., & Steimer, P. (2008). Design and evaluation criteria for high power drives. *Conference Record - IAS Annual Meeting (IEEE Industry Applications Society)* Edmonton, AB, Canada. doi:10.1109/08IAS.2008.341.
- [34] Md Ghazali, N. H. (2016). A Reliability and Validity of an Instrument to Evaluate the School-Based Assessment System: A Pilot Study. *International Journal of Evaluation and Research in Education*, 5(2), 148. doi:10.11591/ijere.v5i2.4533.
- [35] Weiler, B., & Ham, S. H. (2010). Development of a research instrument for evaluating the visitor outcomes of face-to-face interpretation. *Visitor Studies*, 13(2), 187–205. doi:10.1080/10645578.2010.509697.
- [36] Gile, K. J., Beaudry, I. S., Handcock, M. S., & Ott, M. Q. (2018). Methods for Inference from Respondent-Driven Sampling Data. *Annual Review of Statistics and Its Application*, 5, 65–93. doi:10.1146/annurev-statistics-031017-100704.
- [37] Sedlmair, M., Heinzl, C., Bruckner, S., Piringer, H., & Moller, T. (2014). Visual Parameter Space Analysis: A Conceptual Framework. *IEEE Transactions on Visualization and Computer Graphics*, 20(12), 2161–2170. doi:10.1109/tvcg.2014.2346321.