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AUXILIARY EQUIPMENT FOR WORKING AT HEIGHTS: WORKERS' PERCEPTION OF SAFETY ISSUES

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Abstract

Falls from height are a relevant occupational health and safety problem, given the significant impact they have on an injured worker, as well as on their families and the company to which they belong. Although most countries are trying to reduce the number of accidents due to this cause, the injuries resulting from these accidents are usually severe. The causes of falls from height are varied, including lack of control by the direct supervisor, irresponsibility of the worker or wrong handling. Also, they can be caused by auxiliary elements (platforms, ladders, machinery or others) required for the execution of a task, which needs to be assembled appropriately or safely. This article provides the context of using auxiliary equipment (fixed and mobile scaffolding and safety rail) for work at height. Then, a field information survey is carried out to describe the main problems regarding their use on-site. Finally, through the application of 44 semi-structured interviews with construction professionals and supplier companies in the Chilean market, different appraisals on the safety of working at heights and the use of auxiliary equipment are described. The results show that the relevant aspects in the use of auxiliary elements to prevent the risk of falls are related to the singularity of the projects under construction, the scarcity of regulations or their updates, in addition to the lack of technical information on-site that would allow the constant verification of auxiliary equipment, among others.

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Keywords: falls, safety, safety rail, scaffolding, work at height

1. Introduction

The increase in building demand implies increased work performed on platforms or scaffolding. Work performed at a height greater than 1.8 meters from the ground is considered risky [1] and is one of the leading causes of severe accidents and mortality. For example, in 2013, in the United States, it represented mortality of 36.9% [2], while in China, from 2012 to 2016, approximately 2,850 construction employees lost their lives due to on-site accidents, with an average number of 1.57 deaths per day, where falls represent 55% of fatal accidents [3]. In Chile, in 2021, falls from different levels accounted for 26.8% of deaths due to occupational accidents [4]. Working at height is a very relevant issue for the country since, due to the scarcity of building land, the solution to housing needs has been densification through high-rise construction. This challenge requires more significant analysis, control, monitoring and recommendations for using these systems in high-rise construction projects [5].

Regulatory standards are one way to ensure that platforms and guardrails are assembled and manufactured under general conditions, are structurally responsive and meet minimum safety requirements. A study in Japan on the effectiveness of a regulatory framework on reported accidents in the construction sector showed that, within one year of implementation of regulations for platforms at height, accidents decreased by 33% [6]. Another study in Spain showed that having certified platforms for work at height through an established regulatory framework increases the safety level from 4.36 to 5 [7]. Another study conducted in the United States [8] concluded that after five years of enacting of the OSHA (Occupational Safety and Health Administration) revision of 1996, the accident rate decreased by 20%. In addition, Cheung & Chan [9] recommend some essential measures to prevent severe injuries and fatal falls while working from scaffolds, such as inspecting all its components. Specifically, they

mention the importance of supervision by competent personnel for scaffolds to be erected, moved, dismantled or altered, as well as strictly complying on-site with the scaffold manufacturers' guidance regarding these activities. For their part, Błazik-Borowa & Szer [10] specify as important the design of the scaffolding installation but indicate that, due to difficulty or absence of regulations, this phase requires time that is not necessarily available on-site. The same with the costs involved in preparing site-specific designs, so contractors forego creating the design and run the risk of assembling the scaffolding without any design.

Concerning to the use of guardrails, studies in Japan and New Zealand raise the relevance of regulation to standardize these systems and recognize the importance of using temporary edge protection to reduce the risk of falling. However, in the case of New Zealand, previous evaluations on recommendations of structural aspects still need to be completed [11]. On the other hand, the study by Çelik et al.[12] conducted in Turkey and Iran discusses the importance of guardrails having homogeneous and transparent criteria that mainly indicate the procedures for installation, assembly and disassembly, and inspection to be carried out by competent professionals, as well as guidelines for manufacturers and suppliers. In Brazil, Filho and Serra [13] compared two types of collective protection, in which, besides verifying the performance of each of them in the field, they evidenced the lack of technical information for the execution of guardrails. Penaloza et al. [14], comparing nine types of edge protection systems, show the importance of not only evaluating structural aspects of the systems but also other criteria such as safety, efficiency (in assembly and disassembly) and product flexibility (for the use of different types of projects) to choose between one or the other in an informed manner.

Since scaffolding and guardrails are temporary constructions on a construction site, they are considered of minor importance. Therefore, no relevance is given to the process of their assembly/disassembly and use, causing severe or fatal accidents. Therefore, this study seeks to describe the safety assessment in using these systems to help decision-makers evaluate specific criteria or support the implementation of new or improved regulations.

2. Methodology

The methodology used corresponds to a mixed approach, combining three data sources. First, a review of different aspects of fall hazards related to using platforms and guardrails conducted based on a bibliographic review that included national and international regulations, and existing studies on the subject. Secondly, a field information survey was carried out by observing different high-rise building projects in the Metropolitan Region (Chile) and visualizing the use and problems detected using these systems. Thirdly, a qualitative study consisted of 44 semi-structured interviews with construction professionals and suppliers in the Chilean market. The interviews sought to understand how these auxiliary systems are used in work at heights, their problems and needs regarding their use and the technical aspects that need to be reviewed.

3. Results

Four topics regroup the main results: description of fall risks in the construction sector, description of safety problems detected on-site, regulatory analysis of the use of work platforms and guardrails, and appraisals on safety in using platforms and guardrails.

3.1. Fall hazards

Slip, trip and fall incidents, mainly fall from height, are a leading cause of injury in the New Zealand residential construction industry [15]. The most common origins of falls from height in this sector are ladders, scaffolding and roofs [16]. Furthermore, accidents involving temporary access systems (mainly temporary scaffolding) account for many worldwide injuries in the construction industry [17]. A study in Malaysia [18] conducted during the period 1997- 2000 indicates that scaffolding accidents are due to construction errors, lack of protective equipment, inadequate foundations, poor technical condition and excessive load on the scaffold.

A similar situation is evident in Chile. According to data from the Asociación Chilena de Seguridad, 95% of the causes of falls are due to human cause, due to erroneous personal actions, among which the following stand out: lack of workers' knowledge regarding the risks or procedures for working at heights, as well as lack of technical skills for handling platforms (the worker only knows his job and not the functioning or operation of the equipment) or physical (dizziness, balance problems or altered health factors) [19]. The other 5% corresponds to environmental factors related to the auxiliary elements to perform work at height, such as non-existent or inadequate standards, or normal wear of the auxiliary elements; problems of design, manufacturing or defective installation of the elements or parts that make up the platforms to work at height [20]. Although using auxiliary elements only represents 5% of the causes of the problem, it becomes a critical aspect to study. Falls from different levels can cause consequences to workers' health that can often be serious and even fatal. This situation is relevant because, there are gaps in Chilean regulations related to scaffolding structures and guardrails, which expose workers to severe accidents due to falls from heights.

3.2. Safety issues on-site

Field observation of the use of scaffolding and guardrails showed that three major safety problems cause falls: human factors, environmental factors and technical aspects. Regarding human factors, the worker performs improper actions such as: (1) loosening or not using the lifelines, (2) not using all the safety elements or misusing them, (3) climbing the scaffolding structure or leaning on the railings, (4) not respecting the instructions of direct supervisors or risk prevention specialist, (5) not analyzing or observing the conditions of the task and possible risks, and (6) lacking or non-using work procedures. The environmental aspects are mainly related to the climatic conditions of the place where the work is performed, such as gusts of wind that cause the platform to sway, rain that makes the platform slippery, or glare from the sun, which interferes with the tasks. Concerning the technical aspects, there was a lack or absence of elements, such as (1) perimeter railings or structure fastening elements (Fig 1b), (2) accessories that ensure the balance, position and fixation of the structure or that ensure the vertical movement of the structure or brake, (3) scaffolding in poor condition, with wear and tear or structures that are not calculated (or poorly calculated), unstable, overloaded, with missing fastenings or incomplete (Fig. 1a), (4) incorrect assembly or insufficient working platforms.

Fig. 1. (a) first picture; (b) second picture. (CCC-caption style)

3.3. Regulatory analysis

Concerning to the analysis of international regulations, these include several documents that detail the use of scaffolding and prevention measures to avoid accidents when working at height. Also, it contains the steps for the correct assembly and disassembly of the equipment and, depending on the country, includes specific criteria for the design, type of structures and requirements for which the manufacturer is responsible. In Latin America, the level of regulations is low. In Colombia, responsibility is delegated to the manufacturer through a certification system, where platforms must also comply with resolutions updated every year [21]. Some articles on mobile scaffolds exist in Argentina, Paraguay and Ecuador. However, these are incomplete or specified only for suspended scaffolds and do not apply to

mechanically elevated platforms [22]. In Peru, Bolivia and Chile, there are regulations only for fixed scaffolds [23]. On the other hand, when comparing international regulations with Chilean regulations, it is observed that in Chile, there is a gap in terms of more detailed information on the structure and materiality of the equipment, prevention and safety measures for working at heights, and documents for checking or periodically inspecting scaffolding and guardrails indicating their condition.

3.4. Safety considerations

Semi-structured interviews were conducted with construction project workers, professionals and suppliers of national products, seeking a varied sample regarding the relationship between scaffolding and guardrails (direct operators, supervisors, managers, suppliers). A total of 44 interviews were conducted, audio-recorded and transcribed for a thematic content analysis that allowed grouping the experience of the participants in seven main sections presented: inspection, modifications, training, maintenance, security plans, normative, and product standardization.

3.4.1 Inspection

Three entities can carry out this task for inspecting these auxiliary systems: a public agency, a technical inspector who depends on the client, and a risk prevention specialist who works for the construction company. Regarding the inspections carried out by the public agency, these inspections need to be increased. On some occasions, the technical knowledge of those who carry them out need to be improved, and that there is no standard procedure to ensure that the inspection is the same for all the works and equipment. Regarding the technical inspector's supervision, several suppliers pointed out that their review is stricter abroad than in Chile since they are mainly involved in administrative tasks in Chilean projects. Regarding the work of the risk prevention specialist, he is in charge of checking that the system is installed correctly and, in several projects, he marks with coloured cards whether the system can be used. That is to say, and he gives the "green light" for its use. Unfortunately, due to cost issues, the number of risk prevention specialists must be increased for large-scale projects.

3.4.2 Modifications

Significant modifications to the platforms are related to incorporating of fabrics that cover the scaffolding, generating a sail effect, or the hanging of advertising, generating stresses that were not considered in the design. It is important that when a modification must be made, the scaffolding is closed using safety cards. Regarding the reasons for the changes, it is mainly mentioned that the solutions must be adapted/modified due to project conditions (project progress or areas with complex geometry). As project plans are usually modified several times before and during the project’s progress, the supplier companies cannot provide a quality service when they offer an edge protection system. Several times the leasing of the product does not correspond to the total perimeter of the project or with the best structural characteristics for the singular or blind points. On the side of the construction companies, as the progress of the project must be fast, they point out that the supplying companies delay the delivery of the offer and choose not to lease elements for the total perimeter that should have a protection system, using different types of protection that do not perfectly cover the perimeter.

3.4.3 Training

The mobile scaffolds delivered by the suppliers to the worksites do not include the work of operators. These personnel are dedicated to training the worksite workers who will use the scaffolds. Thus, it is mentioned that the most common accidents are linked to the danger of falls from heights and entrapment with the lifting mechanisms. In general, training is provided by the supplier, so it is important to be clear about who must attend these training, according to the responsibilities they will have in the process. Regarding the technical competencies that installers of these systems must have, they must have previous experience. In addition, when using scaffolding, workers must have specific knowledge of the model. They must also have physical conditions suitable for working at heights.

3.4.4 Maintenance

In Chile, there is no traceability procedure after the sale of guardrails or scaffolding; therefore maintenance level after the product is still being determined. Most interviewees agreed to perform preventive maintenance on the scaffolding and guardrails and the parts that may be subject more significant wear and tear, providing evidence of their performance.

3.4.5 Security plans

The primary safety shortcomings detected by the interviewees associated with the use of scaffolding were using it without being certified, not assembling it according to the plan, not respecting the information on the cards, and misuse of personal protection elements, such as the use of helmets without chinstraps or the misuse of safety harnesses. Among the problems encountered in the assembly/use/disassembly/maintenance of scaffolding, the following are mentioned: lack of scaffolding parts, misinterpretation of the plan, poor site planning and problems with cleaning associated with inadequate scaffolding maintenance. On the other hand, in the case of a critical structure, a design and a report are requested from the company that supplied the scaffolding or guardrail with its respective engineering support. Among the control points, it was found to verify that the area where the scaffolding or guardrail is to be placed is unobstructed, that it is assembled according to the supplier's instructions, and verify that the scaffolding and guardrail have all their parts and that they were correctly placed.

3.4.6 Normative

Finally, regarding scaffolding standards, it was mentioned that when scaffolding and guardrails are purchased abroad, they come with international standards and that national standards are old and should be updated or do not exist. Most of the products used in Chile are imported, so they should be certified when they arrive in the country or at least obtain a homologation in certified laboratories. However, as the homologation process can be expensive, the option of carrying out field tests should also exist. Regarding whether there are relevant elements related to the design, assembly, use and disassembly of scaffolding that should be considered in a standard but still need to be included, it was pointed out that there is a gap in safety issues rather than manufacturing or structure standardization issues. The need to go deeper into the capabilities of the personnel that assemble the equipment and into safety measures more aligned with the equipment currently in Chile was raised. It is also mentioned to consider the seismic analysis of temporary structures, since it is a different approach at the time of design, and to include more in-depth classification by materiality in the designation of scaffolding.

3.4.7 Product standardization

Regarding products, the characteristics that construction companies prioritize, in addition to cost, are the weight of the system (for easy installation or relocation), ease of modularization and configuration, additional options for unique joints (for example, in curved areas) or special projects, and the person-hours required to make changes or relocations. They also identify the need for improvements in fastener types, which could be more standard or encompass systems that do not require a specif width or spacing. In addition, they mention the support of engineers and architects to harmonize structural and architectural characteristics that allow for repetitive use of the protection system.

4. Conclusion

The article addressed the issue of falls from height in the construction industry and the importance of using auxiliary equipment, such as scaffolding and safety railings, to prevent such accidents. The study added a survey of field information in the Chilean market through 44 semi-structured interviews with construction professionals and supplier companies to describe the main problems regarding using auxiliary equipment on site. The study identified inspection, modifications, training, maintenance, security plans, regulations, and product standardization as the seven main sections of the study. The

findings indicate that the significant modifications to the scaffolding are related to incorporating fabrics that cover the scaffolding or hang advertising, showing efforts not considered in the design. The supplier provides the training, and it is important to know who should attend the training according to their responsibilities in the process. Safety issues are related to using scaffolding without certification or not erecting it according to plan. The study highlights the need to increase inspections, improve the technical knowledge of inspectors and the importance of maintenance and safety to prevent falls from height.

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References

[1] M. Tonetto and T. Saurin, T. A. “Choosing fall protection systems in construction sites: Coping with complex rather than complicated systems”. Safety Science, 143,. 2021, doi: 10.1016/J.SSCI.2021.105412
[2] E. Nadhim, C. Hon, B. Xia, I. Stewart and D.Fang. “Falls from Height in the Construction Industry: A Critical Review of the Scientific Literature”. International Journal of Environmental Research and Public Health, 13(7). 2016, doi: 10.3390/IJERPH13070638
[3] B. Shao, Z., Hu and autres six autors. “Fatal accident patterns of building construction activities in China”, Safety Science, 111, 253-263, 2019, doi: 10.1016/j.ssci.2018.07.019
[4] Superintendencia de Seguridad Social. “Estadísticas de accidentabilidad 2021 - Chile”. Presentación. 62pp. 2022
[5] M. Meza, E. Bedoya and C. Severiche-Sierra. “Aspectos técnicos de seguridad en barandas para el riesgo de caídas”, Journal of Industrial Neo-Technologies, 5(1), 22-29, 2018.
[6] K. Ohdo, Y. Hino and H. Takahashi. “Research on fall prevention and protection from heights in Japan”. Industrial Health, 52(5), 399–406. 2014, doi: 10.2486/INDHEALTH.2014-0137
[7] J. Rubio-Romero, M. Rubio and C. García-Hernández. “Analysis of construction equipment safety in temporary work at height”. Journal of Construction Engineering and Management, 139(1), 9-14. 2013, doi: 10.1061/(ASCE)CO.1943-7862.0000567
[8] A. Yassin and J. Martonik. “The effectiveness of the revised scaffold safety standard in the construction industry”. Safety Science, 42(10), 921–931. 2004, doi: 10.1016/J.SSCI.2004.05.001
[9] E. Cheung and A. Chan. “Rapid demountable platform (RDP)—A device for preventing fall from height accidents”. Accident Analysis & Prevention, 48, 235-245, 2012, doi: 10.1016/j.aap.2011.05.037,
[10] E. Błazik-Borowa and J. Szer. “The analysis of the stages of scaffolding “life” with regard to the decrease in the hazard at building works”. Archives of Civil and Mechanical Engineering, 15(2), 516–524. 2015, doi: 10.1016/J.ACME.2014.09.009
[11] A. Escamilla, M. García and N. Pérez. “Static load behavior and energy absorption of safety guardrails for construction works”. Revista de la Construcción, 15(2), 46-54, 2016, doi: 10.4067/S0718-915X2016000200005
[12] G. Çelik, S. Aydinli and S. Bazaati. “Safety net applications in developing countries: Turkey and Iran case study”. Journal of Construction Engineering, Management & Innovation, 4(1), 12-21, 2021, doi: 10.31462/jcemi.2021.01012021,
[13] M. Filho and S. Serra. “Comparison between collective protective systems in Brazil: safety platforms and safety net type V”, Applied Sciences, 2, 1-12, 2020, doi: 10.1007/s42452-020-03838-0,
[14] G. Penaloza, T. Saurin and C. Formoso. “Identification and assessment of requirements of temporary edge protection systems for buildings”. International Journal of Industrial Ergonomics, 58, 1-19, 2017, doi: 10.1016/j.ergon.2017.02.005,
[15] H. Hsiao. “Fall prevention research and practice: a total worker safety approach”. Industrial health, 52(5), 381-392. 2014, doi: 10.2486/indhealth.2014-0110
[16] S. Rokooei, B. Javan and A. Nazari.” Effects of Virtual Reality Safety Training on Critical Construction Accidents”. Proceedings of the Creative Construction e-Conference, 2022, doi: 10.3311/CCC2022-036 279-287
[17] S. Whitaker, R. Graves, M. James and P. McCann. “Safety with access scaffolds: Development of a prototype decision aid based on accident analysis”. Journal of Safety Research, 34(3), 249-261, 2003, doi: 10.1016/s0022-4375(03)00025-2
[18] N. Hamdan and H. Awang. “Safety scaffolding in the construction site”. Jurnal Teknologi, 75(5). 2015
[19] Corporación de Desarrollo Tecnológico.“Normas y elementos de protección - Seguridad en Altura”. Revista BiT N°92, 26–29. 2013
[20] A. Zermane, M.Tohir, M. Baharudin and H. Yusoff. “Risk assessment of fatal accidents due to work at heights activities using fault tree analysis: Case study in Malaysia”, Safety Science, 151, 1-12, 2022, doi: 10.1016/j.ssci.2022.105724,
[21] D. Díez Castro and L. Quintero Corzo. “Estudio de factibilidad económica y técnica para la introducción de andamios prefabricados en aluminio en el mercado colombiano” (Bachelor's thesis, Universidad de La Sabana). 2012
[22] L. Calles. “Proyecto de prevención de riesgos profesionales en obras de construcción enfocada en andamios”. Tesis de Grado. Unidad Académica de Ciencias de la Ingeniería y Aplicadas. UTC. Argentina 77 p. 2009
[23] S. Pérez-Albela Rodríguez. “Análisis comparativo técnico – económico de plataformas elevadoras y andamios colgantes en trabajos de acabados en fachadas”. Tesis de Grado. Pontificia Universidad Católica del Perú, Perú. 2020