Construction of Manufactured Homes

Understanding the Hazards & Risks

By Maryam Mirhadi Fard, Seyyed Amin Terouhid and Charles J. Kibert

IN BRIEF

- **This article presents research focused on worker safety in the manufacture, transportation and installation of manufactured homes to obtain a better understanding of safety risks and work-related hazards involved.**
- **The study investigates incident reports from the manufactured home construction sector and identifies patterns. It also examines the occupations, equipment/tools and activities involved in the referenced incidents.**
- **It provides practitioners in the manufactured home industry with a foundation for improving the safety performance of this sector.**

Manufactured home construction is a construction strategy that involves manufacturing whole buildings on a permanent chassis in controlled factory environments and transporting them to sites for final setup. It is important to differentiate between manufactured buildings (formerly known as a mobile home) and modular building construction strategies.

Manufactured buildings are constructed based on the U.S. Department of Housing and Urban Development codes (HUD Code); whereas, modular buildings, like site-built buildings, are constructed according to state, local or regional building codes. The HUD Code requires that manufactured homes be constructed on a permanent chassis to provide transportability. In contrast, when a modular building arrives at its final location, it is hoisted off its conveying trailer and installed on its foundation (Becker, Fullen & Takacs, 2003).

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Manufactured home construction started in the 1930s with the manufacture of recreational vehicles. Concerns regarding the safety, health and quality of these buildings initiated certain U.S. federal acts. In 1974, Congress passed the Federal Manufactured Housing Construction and Safety Standards Act, which resulted in the development of a national manufactured-housing code, the HUD Code.

Durability, affordability, reduced construction delays and enhanced flexibility in terms of relocation are the distinctive advantages of manufactured homes (Apgar, Calder, Collins, et al., 2002). In addition, manufactured home production is a key strategy for increasing low-income home ownership rates, which is in line with the objectives of sustainable communities. The total shipment of manufactured homes in the U.S. decreased significantly after 1999; however, it started growing after 2009 (Figure 1, p. 36). Data for other types of mobile buildings are not currently available.

Since manufactured homes are built completely in factories, the resulting structure can be relatively heavy due to the additional reinforcing required to stabilize the homes during transportation. Serious safety hazards are involved in the manufacture, transportation, installation and dismantling of these structures; therefore, it is critical that special safety standards and training programs are followed. As Weinstein, Gambatese and Hecker (2005) suggest, a comprehensive safety process with the involvement of different parties during planning, design and construction should be in place to better address safety and health hazards. Checking and detecting safety hazards in the design process with the help of construction modeling software such as building information models can also significantly reduce safety hazards during the construction and installation phases (Zhang, Teizer, Lee, et al., 2013).

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Although various safety standards are used in the manufacturing and construction industries, no comprehensive safety standard or training program exists that addresses all aspects of manufactured home construction. OSHA addresses the safety codes of only some manufactured home construction activities. Examples include 29 CFR Part 1926 Subpart N, helicopters, hoists, elevators and conveyors, and Subpart I, hand and power tools.

To provide more insight about the worker population potentially affected by manufactured home construction safety hazards, the researchers also examined the latest worker population by occupation and found that among the labor population statistics provided by U.S. Bureau of Labor Statistics (BLS), manufactured building and mobile home installers is the only occupation related to manufactured home construction. BLS (2016) estimates manufactured building and mobile home installers numbered about 3,650 individuals throughout the U.S. in May 2015 (estimates do not include self-employed workers). Table 1 (p. 36) lists industries with the highest published employment for this occupation.

The researchers aimed to investigate the safety risks and work-related hazards of manufactured home construction during manufacturing, transporting, on-site setup and dismantling. Without understanding and analyzing the dynamics of hazards, the industry's safety procedures and training programs will not be effective. Examining incidents recorded in the OSHA incident database can help improve the safety performance of this sector.

Objectives & Methodology

This study's main objective is to investigate work-related incidents in manufactured home construction and their root causes. Understanding the nature of potential hazards is the key step in effectively improving safety performance within this sector. This research does not include the safety performance of recreational vehicle manufacturing.

To closely investigate the explanations and detailed data of work-related incidents, this study uses an OSHA (2014) database, Fatality and Catastrophe Investigation Summaries. The database allows computer-based word-specific searches of incident abstracts and descriptions. The database also allows searches using the Standard Industrial Classification (SIC)/North American Industry Classification System (NAICS) codes, event dates, keywords and inspection numbers.

This study focuses on injuries and fatalities from 1984 to 2013, and was conducted based on:

- SIC code 2451 (NAICS 321991): Manufactured home (mobile home) manufacturing;
- the OSHA predefined keyword of *mobile home*;
- conducting searches on the description and abstract sections of the incidents by using the keywords *mobile building*, *HUD building*, *manufactured building*, *portable building*, *mobile home*, *mobile office*, *mobile construction*, *manufactured home* and *manufactured office*.

Results of this search formed the basis for the input database for the study: work-related incidents in manufactured home construction. The database contains 92 incidents involving 97 casualties (i.e., injuries or fatalities). Manufactured homes are sometimes modified for use as office trailers, and their main characteristics remain unchanged; therefore, the injury data associated with office trailers was not excluded from the input database. Of 92 identified incidents, 3 (3.26%) were related to office trailers.

The researchers analyzed each case description based on the following parameters:

- degree and type of the casualty;
- cause and root cause of the casualty;
- type of equipment/tool involved in the incident;

•activity/activities taking place at the time of the incident;
•year in which the incident occurred;
•location of the incident;
•type of occupation involved in the incident;
•end-use of the building under construction.

Following is an example of an OSHA-reported incident:

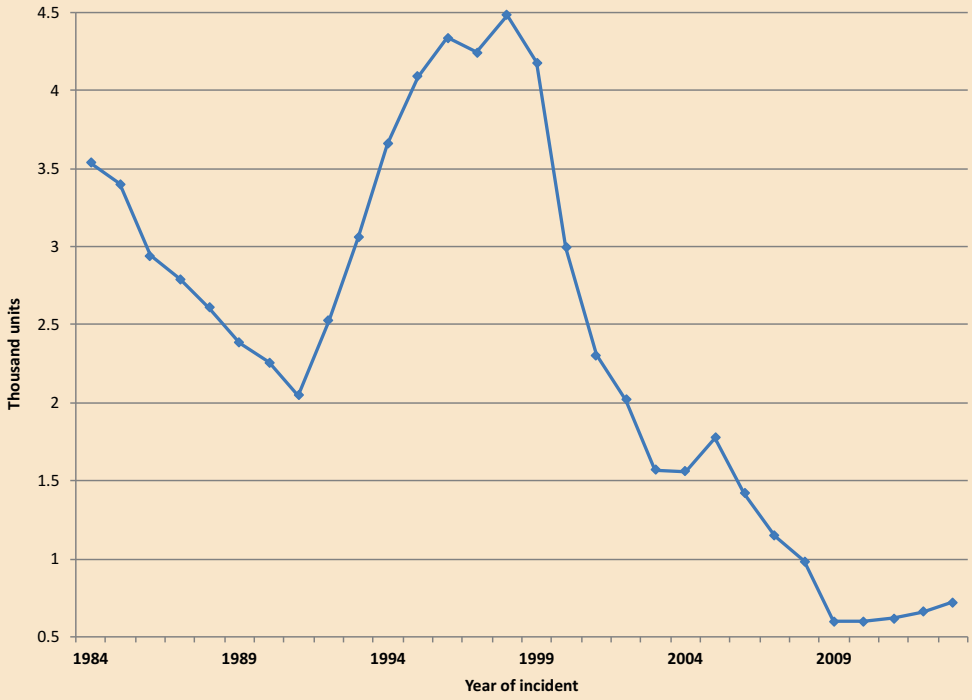
> On July 26, 2011, three employees, of Cinco Hermanos Construction, Santa Fe, NM, were building a portal addition to a mobile home. Employee #1 was working underneath the portal, and employees #2 and #3 were working on top of the portal. The portal collapsed onto employee #1. Employee #1, who suffered injuries to multiple body parts, was killed in the collapse. This accident was reported to New Mexico OSHA (state plan) on July 26, 2011. (OSHA, 2014)

Results

The researchers analyzed and categorized the details of each identified incident. No incidents were found for the years 2012 and 2013, which may be due to limitations of the publicly available database. Figure 2 shows the distribution of incidents during this period. It shows a similar trend to that of total shipments of manufactured homes (Figure 1) and indicates that the rate of incidents peaked in 1996.

The study's results indicate that the working environment in this construction sector has a high safety risk and most incidents resulted in worker death. The 97 casualties resulted in 62 (63.91%) fatalities, 30 (30.92%) hospitalized injuries and 5 (5.15%) nonhospitalized injuries.

FIGURE 1
Manufactured Homes Shipped, U.S.



Note. Data from Business and Industry: Time Series/Trend Charts, by U.S. Census Bureau, 2014.

TABLE 1
Industries With Highest Published Employment in Manufactured-Home Construction

Industry	Employment	Percent of industry employment
Other miscellaneous store retailers	2,170	70%
Other specialty trade contractors	440	7%
Other wood product manufacturing	240	11%
Specialized freight trucking	220	5%
Residential building construction	100	1%

Injury Types

Figure 3 shows that fracture was the most common type of injury in the reported incidents. As the figure indicates, the other types of injuries include asphyxia, bruise/contusion/abrasion, amputation and electric shock. The incidents categorized under the "Other" group are those for which the reports did not clearly identify injury type.

Incident Causes

To understand the hazards involved in the manufactured home construction sector, incidents were carefully analyzed to discover the cause and the cause of cause. The cause of cause identifies an incident's root and underlying cause. Figure 4 (p. 38) illustrates the causes in different categories; 62% of the incidents were the result of "struck by falling object/equipment (nonvehicle); in 86% of these incidents, the falling object was the manufactured structure. Further, the study found that "struck by falling object/equipment (nonvehicle)" was the cause of 69% of the fatalities.

Figure 5 (p. 39) shows cause of causes. In 43.5% of the incidents, the root cause was "unstable load/structure" resulting in the collapse of the load/structure. Root causes of 19.6% of the incidents could not be determined as the incident reports were not clear or detailed enough to identify root causes.

FIGURE 2

Frequency of Incidents by Year

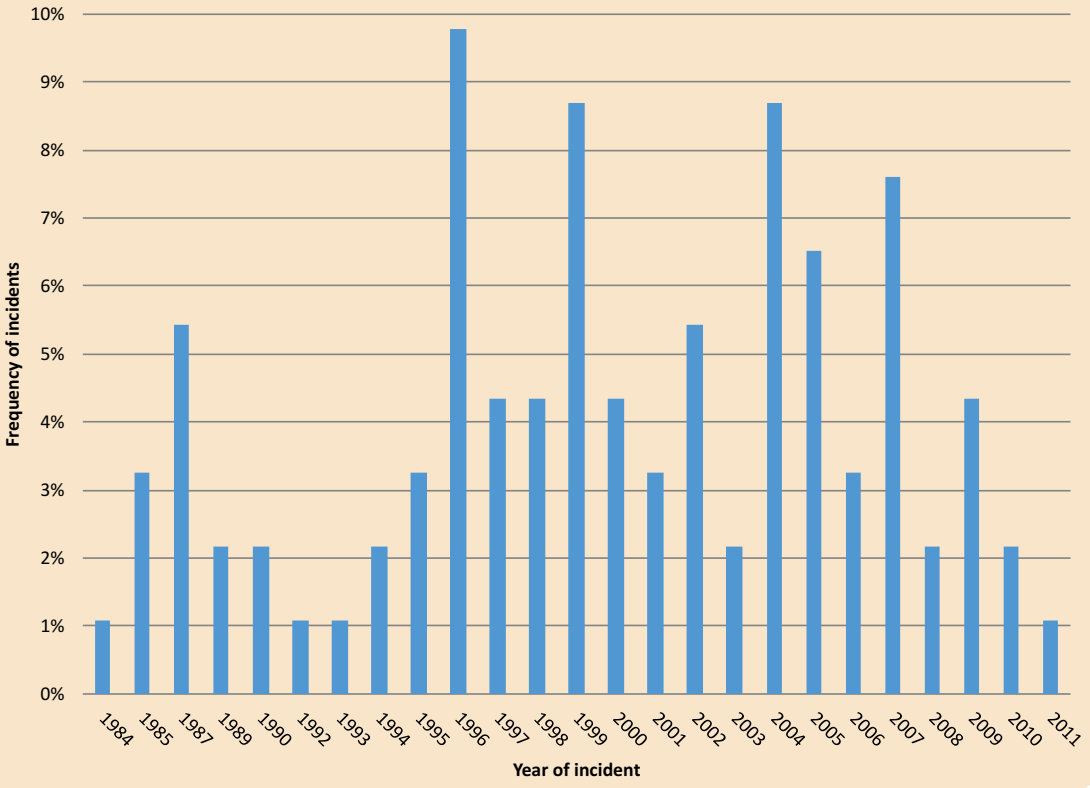
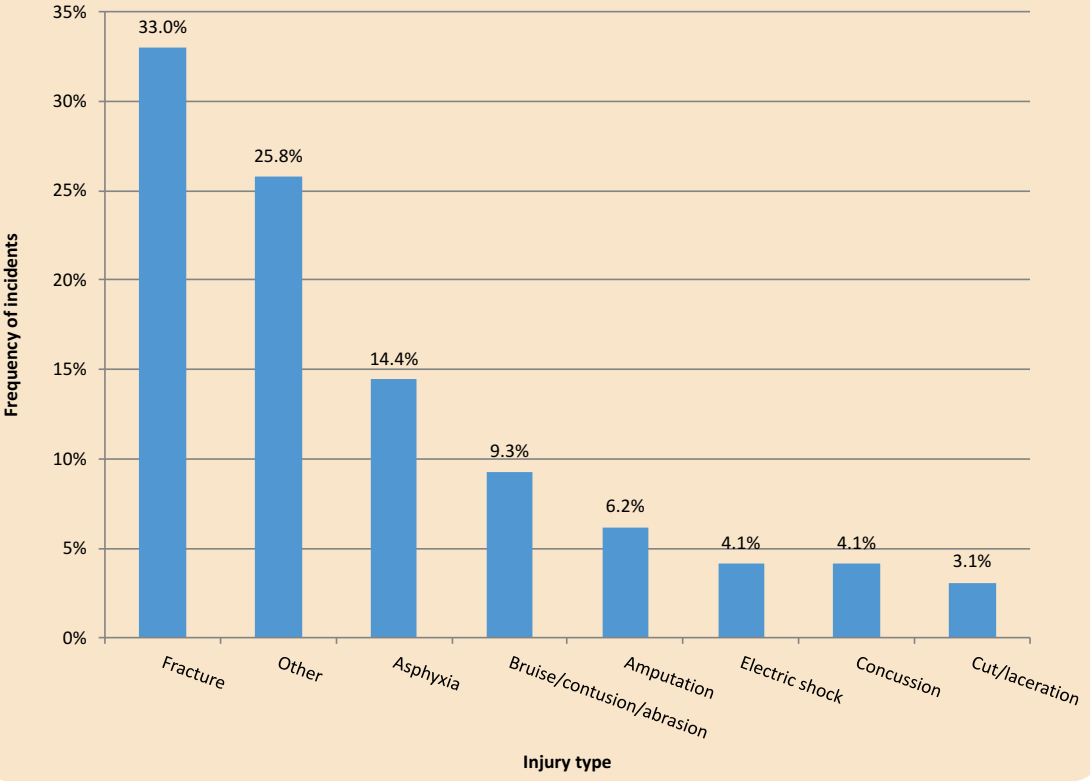


FIGURE 3

Injury Type & Frequency



Performing electrical and mechanical activities during setup while workers are under/around the buildings calls for an in-depth job safety analysis before performing the work.

In some incident records used for this study, the researchers noted a lack of proper safety procedures or not properly following existing safety procedures at the time of the incident. For example, no cribbing or blocking was used in seven incidents. OSHA 1926.305(d)(1)(i) mandates that "after the load has been raised, it shall be cribbed, blocked or otherwise secured at once." Another example involves an incident in which the jack sank in water-saturated ground. According to OSHA 1926.305, Section C:

> When it is necessary to provide a firm foundation, the base of the jack shall be blocked or cribbed. Where there is a possibility of slippage of the metal cap of the jack, a wood block shall be placed between the cap and the load.

In this regard, the California General Industry Safety Orders §3562 (Jacks) offers the following safety requirement (although it does not specify the material to be used for the block): "in the absence of a firm foundation, the base of the jack shall be blocked. If there is a possibility of slippage of the cap, a block shall be placed in between the cap and the load."

In two other cases, the jack manufacturing instructions in terms of rated capacity were not followed. This violated the California General Industry Safety Orders §3562 (Jacks) that states, "the rated load shall be legibly and permanently marked on a prominent location on the jack by casting, stamping or other suitable means."

Since manufactured homes have a permanent metal chassis, electrocution risk is present during the setup process. For example, in one case, a staple was misfired into a cable, which caused a ground fault and subsequently caused the chassis to become energized during the setup process. Therefore, performing electrical and mechanical activities during setup while workers are under or around the buildings is safety sensitive and, thus, calls for an in-depth job safety analysis before performing the work.

The reports associated with the incidents described were not clear or detailed enough to identify why improper securing/connecting methods were in use or why proper safety procedures or manufacturing instructions were not followed.

Occupations

The types of occupations involved in incidents analyzed were also investigated to determine the most risky occupations in the manufactured building construction sector. In 44.3% of incidents, the report did not identify the occupation of those involved. Among the cases with a known occupation involved, construction laborers and construction trades had the highest risk of incident.

Equipment/Tools

Equipment/tools were involved in 60% of incidents. Jacks had the highest frequency (70.9%). Most jacks involved in incidents were reported as hydraulic jacks. Saws, such as radial, cutoff and table saws, had the sec-

FIGURE 4
Incident Causes & Frequency

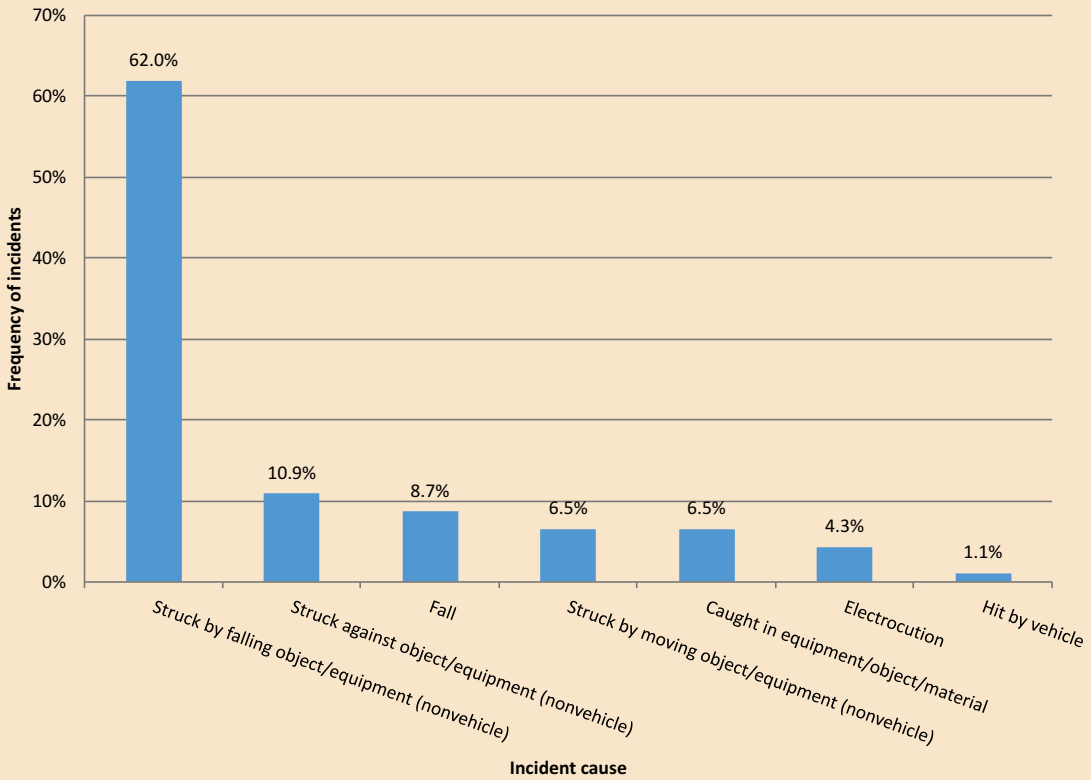


FIGURE 5

Incident Cause of Cause & Frequency

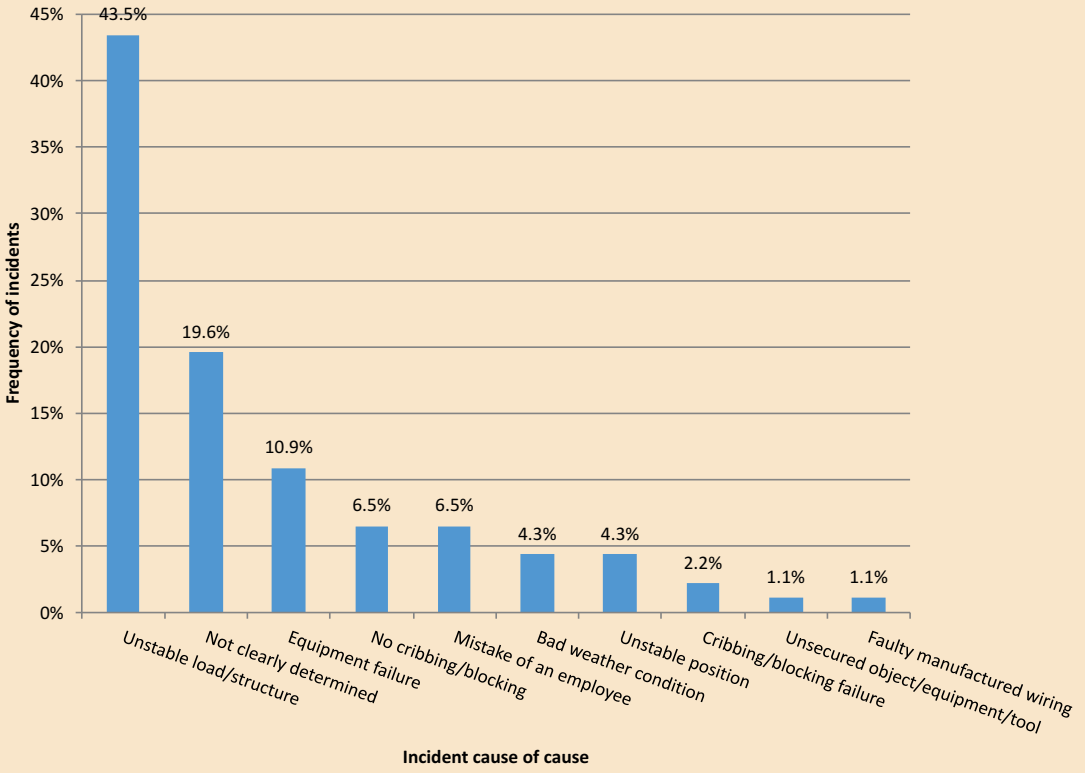
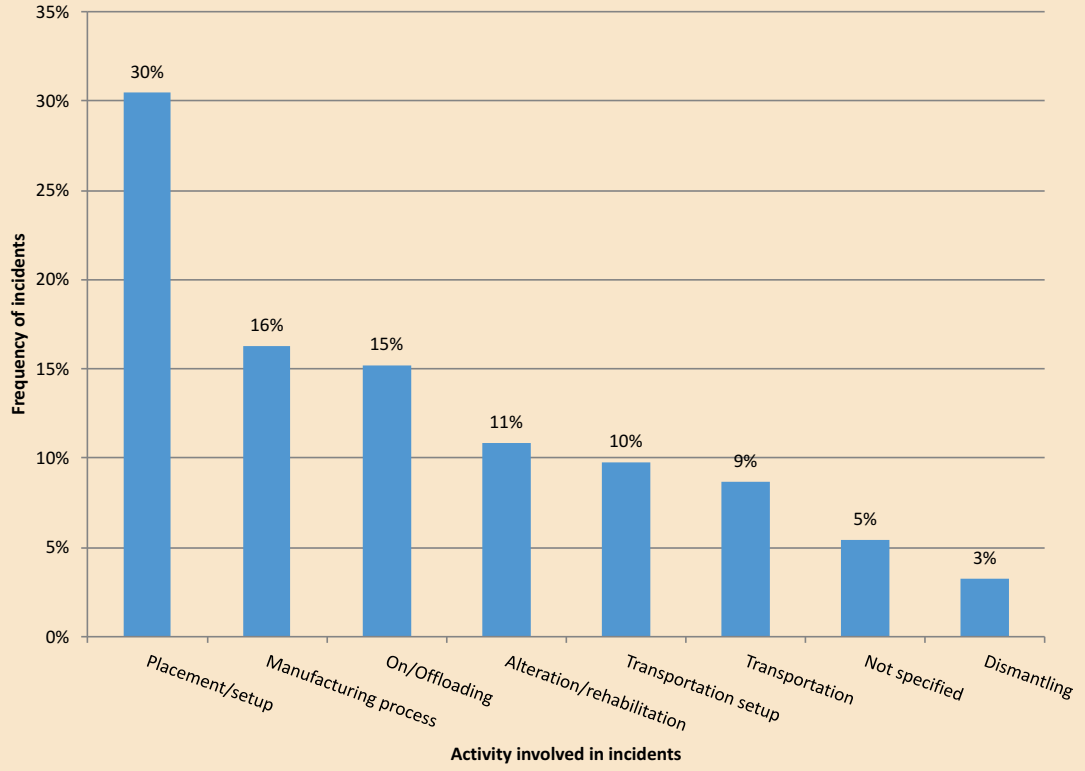


FIGURE 6

Activities Being Performed at Time of Incident



ond-highest incident rate (14.5%). Other types of equipment or tools involved included crane, forklift, mobile home trailer, pickup truck and portable abrasive cutter.

Activity

For pattern recognition purposes, researchers also analyzed activities being performed at the time the incident occurred (Figure 6, p. 39). Based on the findings, the activity with the highest incident rate (30%) was the setting of a manufactured home on its foundation.

Location

Analysis of incident reports by state showed that California (23%), Oregon (12%) and Texas (10%) were associated with 45% of the incidents. However, since the total number of manufactured units assembled in each state is unknown for the study period, results cannot be generalized.

Recommended Practices

Based on the results, the researchers recommend several practices that practitioners can use to improve safety during the manufacture, transport and installation of manufactured homes:

- Devise a comprehensive safety process and involve different responsible individuals and parties.
- Develop a comprehensive safety risk management plan to ensure that safety risks are properly managed (i.e., identified, analyzed, treated, monitored and controlled).
- Effectively use proper tools such as modeling software to detect and reduce hazards during the manufacture, transportation and installation phases.
- Develop safety standards, instructions and training programs directly related to manufactured home construction, and ensure that employees comply with safety rules, standards and requirements.
- Properly plan the sequence of activities while setting up a building.
- Perform an in-depth job safety analysis before performing work.
- Adequately secure manufactured home loads during placement, transportation, lifting and storing, and provide adequate support and stability for structures/equipment during lifting operations.
- Stay clear of jacks during loading and after the load has been raised.

The researchers further recommend that construction practitioners develop and manage manufactured home operations based on safety standards and training programs focused on this specific construction sector.

Conclusion

This research targeted the safety performance of manufactured homes in the manufacturing process and found several patterns in the safety records of manufactured home construction. This study found 92 incidents involving 97 casualties related to this construction sector. A review and analysis of the reports produced the following key findings:

- The majority of the incidents resulted in fatalities (64%). "Struck by falling object/equipment" was the cause of 69% of fatalities and 62% of total incidents. In 86% of incidents with the cause of "struck by falling object/equipment," the falling object was the manufactured home. Close analysis found that the root cause of 43.5% of the incidents was unstable load/structure.
- The study also examined the occupations involved in the incidents. In 44% of the incidents, the occupation was not reported. Among the incidents with a known occupation involved, construction laborers and construction trades were exposed to more work-related hazards.
- Regarding the equipment involved in the incidents, jacks had the highest frequency rate (71%) and saw was the second highest.
- Overall, the incident descriptions provided in the OSHA database had some limitations for the purpose of this study; this limited the researchers' ability to determine the main root cause of the incidents. Based on the reports, securing the manufactured structure on jacks or during the installation process was the most safety-sensitive operation.

In summary, this study provides practitioners in the manufactured home industry with a foundation for improving safety. Effectively addressing safety in this sector requires a comprehensive process that involves all stakeholders during planning, design, manufacture, transportation, installation and dismantling.

To improve the manufactured construction sector's safety record, the researchers recommend that future research focus on stabilizing manufactured structures during placement, lifting, transporting, on-site setup and dismantling. **PS**

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