

Influence of Fall Hazard Warnings on Construction Sites

Chia-Wen Liao¹, Tsung-Lung Chiang²

¹ Department of Civil Engineering and Hazard Mitigation, China University of Technology
No.56, Section 3, Hsinlong Rd., Taipei 11695, Taiwan.
cwliao@cute.edu.tw.

²Occupational Safety and Health Administration under the Ministry of Labor of Taiwan
11F., No.439, Southern Building, Zhongping Rd., Xinzhuang Dist., New Taipei City 24219, Taiwan.
jonman5954@gmail.com.

Abstract - A high proportion of accidents in the manufacturing industry are caused by falls. In particular, the highest number of accidents occur at openings and it has been proven that the main cause of these accidents is inattentive blindness. The safety requirements for site openings vary from country to country. This paper examines the differences in the effectiveness of different warnings for opening covers through an experiment on inattentive blindness. The results of the study show that there is a significant difference between the response to different opening cover warnings in terms of simple warnings about the hazards of openings. The highest response rate for the presence or absence of openings in the floor is obtained when the opening cover warning is written in text. When the position and number of openings are considered, wooden covers without any warning have a higher response rate. It is also found that yellow warning covers help participants to focus on the question being asked. However, it is also found that there is no significant difference in the hazard caused by inattentive blindness between different opening cover warnings for important issues related to fall prevention, such as the presence or absence of a cover and when the cover was removed. It is clear that inattentive blindness cannot be eliminated by changing the warning on the opening cover. Therefore, it is recommended that fall prevention warnings and cautions at openings are targeted at workers who may remove the covers. The results of the study may provide effective recommendations for the future management of site openings.

Keywords: falls; openings; construction industry; occupational injury; inattentive blindness.

1. Introduction

Falls account for more than half of all disaster types on Taiwan construction sites. From 1999 to 2020, there were 1,904 fatal occupational disasters in northern Taiwan. The proportion of fatalities due to falls has been increasing year on year. In 2020, the percentage of falls reached a new high of 75%, as shown in Fig. 1, and falls from openings were the most prevalent. Falls from edges and openings in roofs and floors account for only 5% of falls in the EU [1], but in Taiwan the proportion of falls from openings is significantly higher, as shown in Fig. 2. It is clear that the hazard of falling from openings is not effectively managed and controlled in the construction industry in Taiwan.

Inattentive blindness occurs more often when people are absorbed in an attentionally demanding task [2] [3]. And the individual performing the task simply fails to see what should be obviously visible and thereafter cannot explain his or her error [2] [4] [5]. This human-factors phenomenon is well recognized as a ordinary condition that all people periodically exhibit [5] [6].

In addition, the significant effects of inattentive blindness to fall hazards at construction site openings has been demonstrated [6]. The requirements for site opening safety facilities vary from country to country. In Taiwan's opening protection regulations, there are clear requirements for warnings at opening covers. However, it is worth exploring further why such a requirement is not effective in preventing falls from openings, and whether this is related to the phenomenon of inattentive blindness.

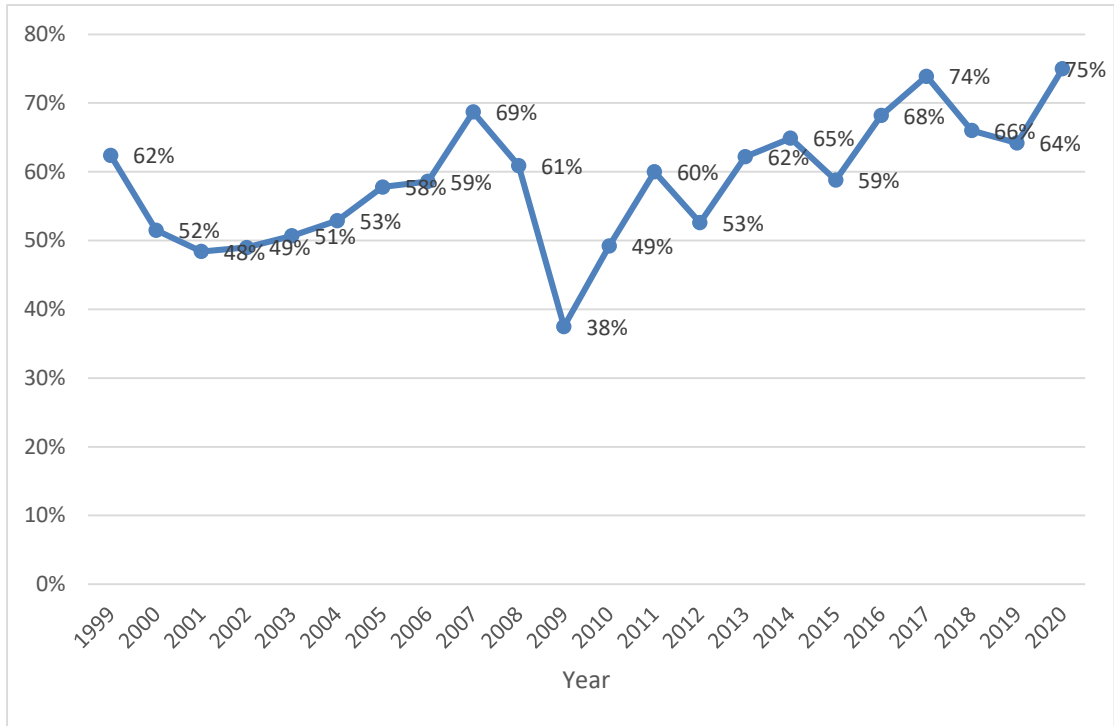


Fig. 1: The proportion of falls in the Taiwan construction industry during 1999-2020.

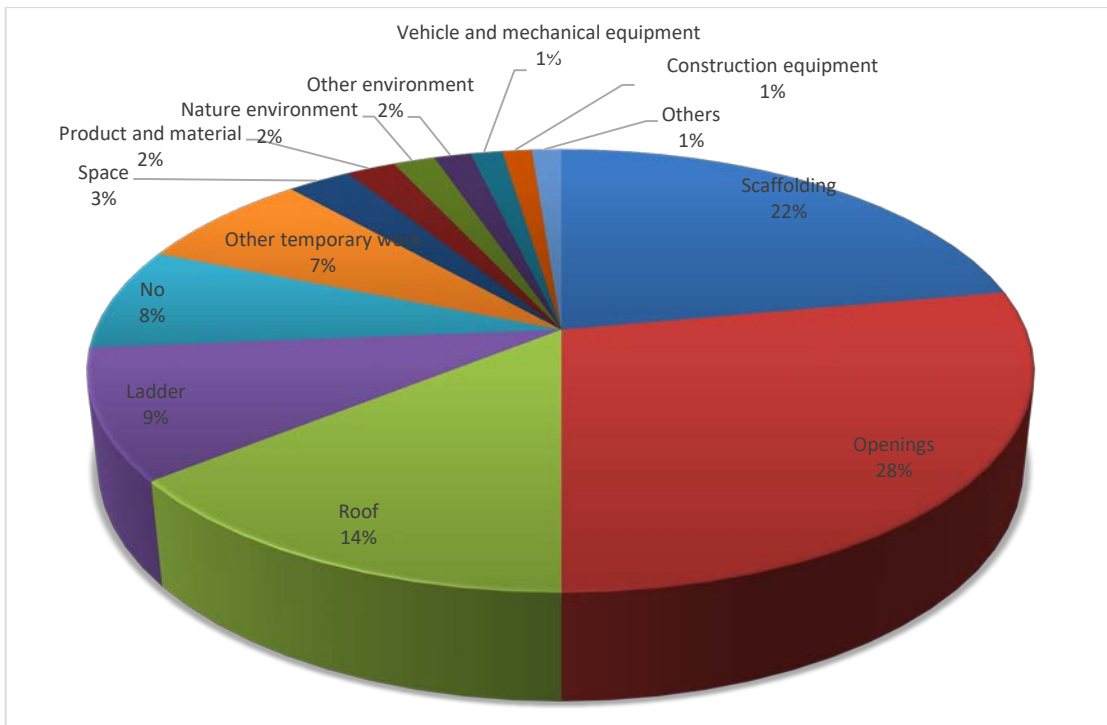


Fig. 2: Source of injury in the Taiwan construction industry during 1999-2020.

2. Requirements for Opening Warnings in Six Different Countries

This study examined the occupational safety regulations of six countries, including the United Kingdom, the United States, Japan, Singapore, China, and Taiwan. The differences in occupational safety regulations in relation to opening warnings were compared, as shown in Table 1. It was found that except for the US, China, and Taiwan, where there were clear requirements for warnings or cautionary statements for opening safety facilities, there were no such regulations in the other three countries.

In the UK, the Work at Height Regulations 2005 do not require warnings for openings. Similarly, in The Health and Safety (Safety Signs and Signals) Regulations 1996, only safety colors or warning signs are required for areas where falls have occurred. There are no clear requirements on warnings for openings. In Japan, the "Ordinance on Industrial Safety and Health (Appended Tables 2, 5 and 9: up to the revision of Ordinance of the Ministry of Health, Labor and Welfare No. 23 of 2009)" only mentions the need for guardrails and covers for openings. However, there are no requirements on warnings. Similarly, in Singapore, the 'Workplace Safety and Health (Work at Heights) Regulations 2013' only requires warnings for fragile surfaces, but not for openings.

In the USA, "1926.502 - Fall protection systems criteria and practices." 1926.502(i)(4) specifies that opening covers must be marked with the word "HOLE" or "COVER". However, there is no provision for color warnings. In China, Article 28 of the 'The Administrative Regulations on the Work Safety of Construction Projects' clearly states that safety warning signs must be clearly displayed at all openings and the safety warning signs must comply with national standards, namely the "General Rules for Safety Warning Signs". In these rules, all safety warning signs are clearly defined in terms of shape, color, and text. In Taiwan, Article 21 of the 'Standards for Construction Safety and Health Installations' states that the opening cover should have a warning message written in yellow. However, there is no explicit provision for the content of warning messages.

In summary, we can see that, with the exception of China, which has detailed regulations on the content and color of warnings, the remaining countries may have no regulations or may have very general text or warnings. It is clear that these countries do not attach much importance to warnings for openings.

Table 1: The requirements for opening warnings in the relevant legislation of six different countries.

Country	Name of Regulation	Terms and Conditions	Remarks
UK	The Health and Safety (Safety Signs and Signals) Regulations 1996	2.1.3. Places where there is a risk of colliding with obstacles or of falling must be permanently marked with a safety color and/or with signboards.	There are only general requirements, with no explicit indication that warnings are required for openings, and no specified color or wording
UK	The Work at Height Regulations 2005		No opening warning requirement
USA	1926.502 - Fall protection systems criteria and practices.	1926.502(i)(4) All covers shall be color coded or they shall be marked with the word "HOLE" or "COVER" to provide warning of the hazard.	Textual content of the warning is clearly specified, but no color is specified.
Japan	Ordinance on Industrial Safety and Health (Appended Tables 2, 5 and 9: up to the revision of Ordinance of the Ministry of Health, Labor and Welfare No. 23 of 2009)	Article 519 (1) The employer shall provide enclosures, handrails, covers, etc., (hereinafter referred to as "enclosures, etc." in this Article), to places having a height of 2 m or more and where it is liable to endanger workers due to a fall, such as at an end of a working floor and an opening.	No opening warning requirement
Singapore	Workplace Safety and Health (Work at Heights) Regulations 2013	17. (3) (a) that prominent warning notices are affixed at the approach to the place where the fragile surface is situated.	There are only requirements for warnings for fragile surfaces, but not for openings.

People's Republic of China	The Administrative Regulations on the Work Safety of Construction Projects	The construction unit shall place obvious safety warning signs at the entrance to the construction site, at the construction cranes, temporary electrical facilities, scaffolding, entrances and exits, staircase entrances, lift shaft entrances, hole entrances, bridge entrances, tunnel entrances, the edges of foundation pits, blasting materials and hazardous gases and liquids storage areas, and other dangerous areas. Safety warning signs must comply with national standards.	A separate national standard (General Rules for the Installation of Safety Warning Signs) is used as the norm, with clear wording and color requirements.
Taiwan	Standards for Construction Safety and Health Installations	Article 21. The covers installed by the employer shall be in accordance with the following provisions: VI. The covers used for temporary openings shall be painted yellow on the surface and have a warning message written on them.	The color of the warning is clearly specified, but there is no specific wording.
Taiwan	Regulations on Occupational Safety and Health Facilities.	Article 232. Employers should place warning signs in places where workers are at risk of falling and should prohibit access by non-work-related personnel.	There are no clear regulations on the content of warning signs.

3. Simulated Scenarios and Questionnaire Design

The simulated scenario design by Liao and Chiang [6] was used in this study. A three-dimensional interior scene for a construction site was produced in the simulation video, as shown in Figure 3. In the video, there are five rooms either side of a central corridor, providing a total of ten rooms. The door for each room is labelled the room number. There are three floor openings in the central corridor. The size of each opening is 1 square meter. When the video starts, each of these openings has wooden cover. However, after the participants have finished viewing the first room, the covers are withdrawn. Each of the five rooms on the left hand side has floor openings. These openings are not covered. A total of twenty-one workers are working inside the corridor and the rooms. Of these, thirteen workers are not wearing helmets. Three workers are standing beside an opening, and one worker is standing at the top of a ladder. Neither of the two ladders in the video is secured with straps. The video is seen from the participants' visual angle, permitting participants to walk down the central corridor from the first room to the ninth room, and then finally turn towards the central corridor [6].

The aim of this study is to discuss whether opening warnings can increase workers' awareness of openings and thus reduce the associated potential hazards. In the simulated scenario of this study, three different types of warnings were installed on the original opening cover. The three types of opening cover warnings were yellow paint on all covers, yellow paint on covers with the text "OPENING HAZARD", and a white skull on the yellow covers. The three types were compared with the open cover with no warning, so that the differences in test results could be observed, as shown in Fig. 4(a)-4(d).

A questionnaire was designed based on the 14 main questions in the literature. The questions relating to openings were retained with slight adjustments, so that 11 questions remained. As the original question "Where are the openings in the floor?" existed, the original two questions "Is the floor opening in the middle aisle?" and "Is the floor opening in the room?" were deleted. In addition, the question "Is there an opening in the floor in the middle aisle?" was added so that respondents could clearly answer the question about the hazards due to openings of interest to the study.

Prior to showing the video we requested participants to "look inside the ten rooms" and find the answers to the questions, "how many workers are there in total?" and "how many workers are not wearing a helmet?" After watching the video, except for answering the two original questions, participants were also asked other questions [6].

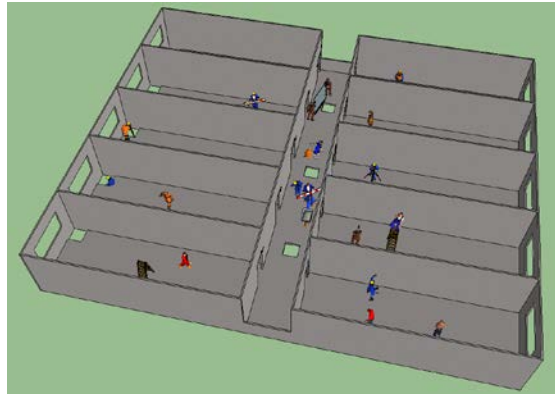


Fig. 3: Interior scene of construction site in simulation video

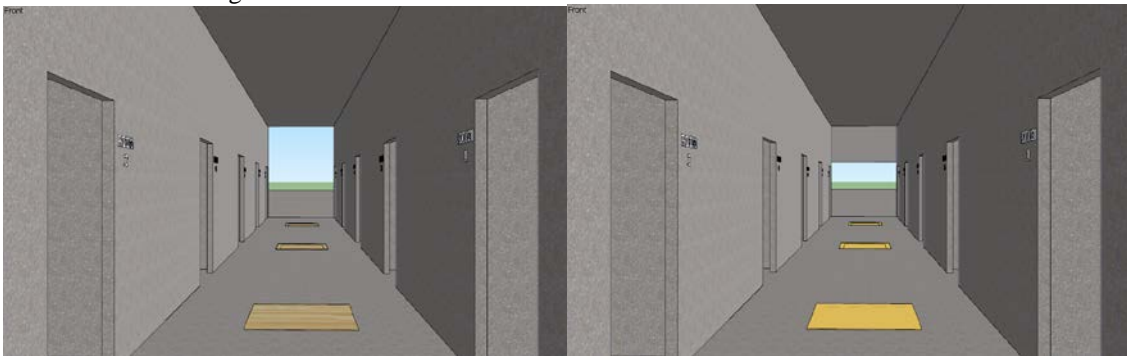


Fig. 4(a): Scene 1 from simulation video (wooden) Fig. 4(b): Scene 1 from simulation video (yellow)

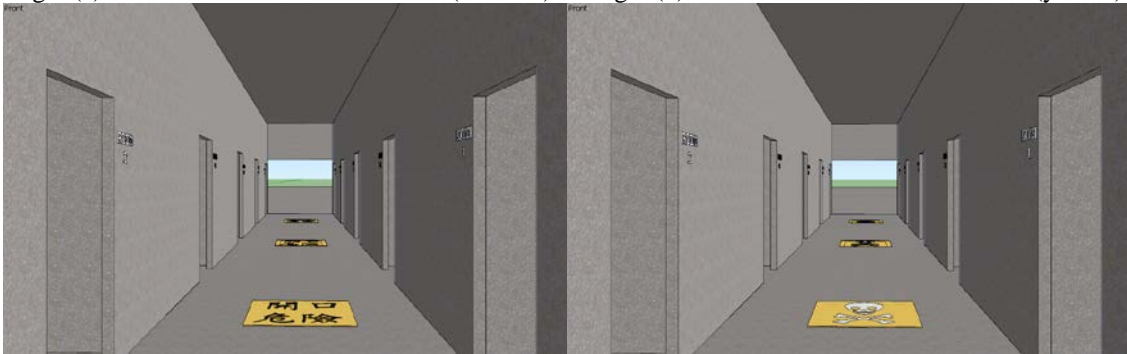


Fig. 4(c): Scene 1 from simulation video (text) Fig. 4(d): Scene 1 from simulation video (skull)

4. Results

The experiment was conducted on 1505 people who were involved in the construction industry. After deducting the invalid questionnaires from those who had seen similar videos and experiments, 1381 valid questionnaires remained. The validity rate of the questionnaire was 91.8%. Reliability analysis was conducted on the questionnaire. The result showed that the Cronbach's alpha was 0.709. This result shows that the results of this questionnaire are consistent.

Table 2: Questionnaire response results.

Cover type	Questionnaire (n)		Valid rate (%)
	Original	Valid	
The wooden cover	355	318	89.6%
The yellow cover	417	393	94.2%
The text cover	340	303	89.1%
The skull cover	393	367	93.4%
Total	1505	1381	91.8%

4. Conclusions

The results of the study showed that there was a significant difference between the different opening cover warnings in terms of warnings about the hazards of openings, as shown in Table 2-3. The highest response rate for the presence or absence of openings in the floor was obtained when the opening cover warning was by text (73.9%). As far as the position and number of openings are considered, the wooden cover without any warning had a higher response rate (26.2%、29%). It was also found that the yellow warning cover helped the test subjects concentrate on the question. However, it was also found that there was no significant difference between the different opening cover warnings for further inattentive blindness, such as whether the opening had a cover or not, or when the cover was removed. Obviously, the inattentive blindness of the general workforce is still difficult to eliminate by changing the warning of the opening cover.

Therefore, the control or warning for openings should be changed to target the person using the opening rather than the general operator. For example, instead of "Danger - Hole Beneath", it is suggested that the opening warning be changed to "This cover must not be opened without permission". The results of the study may provide useful recommendations for the management of openings at construction sites in the future.

In addition, the strength of opening covers is mostly regulated in various countries, but the management measures for opening covers are rarely specified. As the warning of an opening cover does not eliminate the potential hazards caused by the opening, the following management methods are recommended for such hazards:

1. Prior to the opening of an opening cover, an application should be made on-site and the location and time of opening should be made known.
2. In addition to the strength of the opening cover being adequate, when it is necessary to open the cover, warning facilities should be set up around it and a person should be assigned to monitor the opening throughout the removal period to prevent other personnel from approaching.
3. When the necessity for opening the cover is over, the cover should be reinstated immediately, and the warning facilities should be removed only after the site manager has confirmed that it is safe to do so.

Table 3: Results of Pearson's chi-squared test between different types of covers.

Item	Correct (%)					Chi-square Test	P value	
	The cover	wooden cover	The text cover	yellow cover	The skull cover			
Main task	Please answer the following:							
Q1	How many workers did you see?	29.0%	33.7%	44.3%	37.6%	19.089	.000**	
Q2	How many workers are not wearing a helmet?	26.8%	46.5%	53.9%	38.7%	57.221	.000**	
Inattentive blindness task								
Q3	How many rooms did we pass through?	50.5%	42.2%	56.5%	52.6%	14.436	.002**	
Q4	In the videos, are there any openings in the floor?	64.0%	73.9%	63.9%	63.5%	10.860	.013**	
Q5	In the videos, where are the openings in the floor?	26.2%	15.2%	15.3%	18.5%	17.245	.001**	
Q6	Are there any openings in the central corridor?	61.5%	55.1%	44.3%	54.5%	22.067	.000**	
Q7	How many openings are there in the corridor?	29.0%	19.5%	18.3%	20.4%	13.914	.003**	
Q8	Do the openings in the corrido have covers?	35.3%	34.3%	35.6%	33.8%	.353	.950	
Q9	When did you realize that the covers had been moved?	12.3%	14.9%	15.3%	12.8%	1.888	.596	
Q10	Do the openings in the rooms have covers?	15.5%	18.2%	21.1%	21.5%	5.269	.153	
Q11	Are there any people standing by the openings?	61.8%	67.7%	64.1%	62.7%	2.690	.442	

Note: * Indicates a significant significant at the 0.05 level.

** Indicates a significant significant at the 0.01 level

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