2025-1448 IJOI
http://www.ijoi-online.org/

International Journal of
Organizational Innovation

A STUDY OF SAFE, AESTHETIC, AND EASILY DISASSEMBLED DESIGN FOR AN ANTI-FALL DEVICE FOR WINDOWS

Kuo, Tien-Yu
Far Eastern University of Science and Technology
jasonkuo0516@gmail.com

Abstract

The economy is growing rapidly. Along with the increase in population density, more high-rise buildings are being built. However, there are some potential dangers over the windows above second floor of the buildings. The economy is growing rapidly alone with the increase in population density; more high-rise buildings are being built. However, there are some potential dangers over the windows above second floor of the buildings. Windows brought the sunlight and wind into the buildings. However, there are great conflicts between falling prevention and safety evacuation of window designs nowadays.

1. Sometimes children are falling from the window without anti-fall devices.
2. Due to improper design or missing installation, there are windows with anti-fall devices had caused personnel injuries and difficulties of rescue.

The design of this study is based on the core technology of “Automatic return reel” which is applied to architectural and interior window designs of high-rise buildings to set up an easy install and disassemble as well as personnel falling prevention and safety evacuation device. Through on-site experiments we can understand the influences between steel cables in four different diameters and the windows which installed the device of this study.

The results are as follows:
1. There is no absolute difference of steel cables with different diameters in the function of anti-fall devices.
2. The window is automatically closed by the forced-on steel cables which tension is no difference in this experiment.

In addition to the particularity with aesthetic and easily disassembled for personnel and objects of the design by this study as well as the necessity of safe evacuation. Moreover, it can be widely used in all kinds of materials and windows in all buildings.

Keywords: Anti-fall, Safe evacuation, Rescue, Steel cable, Winding device.

Introduction

Prosperous economy caused the increasing density in population of the main cities worldwide. The problem of housing is getting worse due to the usable area of the cities are decreasing. High-rise buildings are the first choice of people which there are limited space of living. The problem of living space were solved by establishing high-rise buildings, yet, there are many potential dangers relatively in high-rise buildings. In spite of the authorities of all nations valued the importance of the safety regulation and protection of high-rise buildings; but, there are still tiny details which can cause great damage have not been noticed that we must not to ignore.

"Windows" are mainly used for ventilation and lighting in buildings. It has the necessity no matter what it is a one-story bungalow or a high-rise building.

Motivation

In the past, the application of architectural design to the lighting of windows was decided according to the common sense and experience of the designer. Although the desired effect is achieved, the potential danger is hard to find. "Window" is an opening in a wall or roof that allows the exchange of

light and sometimes air (Wikipedia Window). It can also reduce oppressiveness as well as psychological stress relief. However, there are extremely rare window designs and research about falling prevention (Figure 1-1) and safe evacuation (Figure 1-2) nowadays. Therefore, how to make windows a low price, aesthetic, easy install, falling prevent and safe evacuation when fire accident to become the motivation of this research and design.

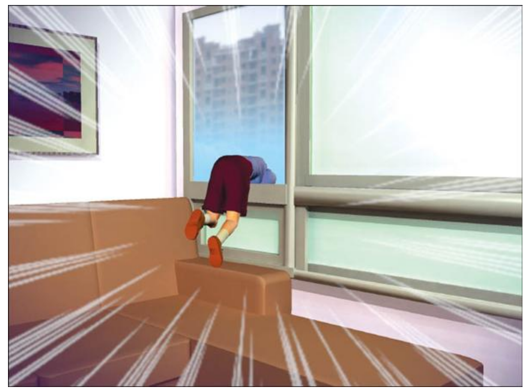


Figure 1-1 Personnel Fall Down (Liberty Times)

Figure 1-2 Fire Evacuation (Apple Daily)

Purpose

The purpose of this study is to design a window of a building with an anti-fall device. (Figure 1-3). Specifically, the study aims to fix the steel rope recovery device on the window frame body and attach the wire rope traction device on the other end on the inner frame body. With the wire rope traction device, the steel rope will retract into the recovery device. When the window is closing, the wire rope traction on the inner frame body of the window can be pulled out from the steel rope recovery device. This device is applicable to all kinds of window materials. In case of emergency, the inner frame body on the other side can also be opened directly or cut with a wire trimmer to prevent falling and achieve safe evacuation.

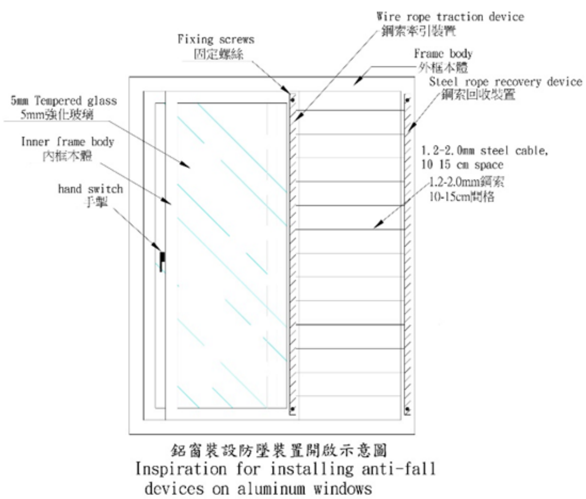


Figure1-3 Inspiration for installing anti-fall devices on aluminum windows)

Based on aluminum windows, this design create anti-fall devices that are low-priced, aesthetic, safe, and can be easily installed. By experimenting with different wires and wiring systems, this study will explore the differences in tensions in differing steel wire diameters and serve as a foundation for future aluminum windows.

According to previous literature on aluminum windows and anti-fall devices, the study explores the following:

(1) Structures of aluminum windows and discussion
(2) Influences on the safety design of aluminum windows
(3) Explorations of aluminum windows and its anti-fall abilities and predictions
(4) Dissemination of aluminum windows and anti-fall steel wires
(5) Effectiveness of aluminum windows and its anti-fall features.

Literature Review

This literature review is divided into four main sections. The first section introduces the overview and definition of "windows." The second section explores the fundamental theory of tension and terminology definitions. The third section examines fall prevention factors, and the fourth section analyzes existing patents related to fall-prevention window designs.

Overview and Definition of Windows

Definition of Windows.

In architectural terms, a window is an opening built into a wall or roof to allow light and air to enter the interior space. In classical Chinese, "chuang" (窗) and "hu" (戶) originally referred to window and door, respectively. In modern Chinese, "chuanghu" (窗戶) refers specifically to windows.

Windows can be categorized by material—such as solid wood, aluminum-wood composite, PVC, and aluminum alloy—or by their opening methods, including casement windows, tilt windows, top-hung, bottom-hung, pivot windows, sliding windows, and skylights. Based on their operation, windows may be manually operated, motorized, or remote-controlled. Additionally, combining windows with latticework or louvers creates architectural styles like traditional Chinese lattice windows, antique floor windows, European-style lattice windows, and louvered windows. (Source: Wikipedia – Windows)

In this study, "windows" refer specifically to aluminum windows installed in buildings (see Figure 2-1), designed for ventilation, visibility, and light transmission. The scope of this study focuses on the fall-prevention function of these windows.

Figure 2-1: 3D Elevation of Building

Types and Characteristics of Windows

Casement Windows (Outward/Inward Swinging Windows):

Casement windows are the most common type (Figure 2-2), where the sash is hinged to the window frame, allowing full 100% opening. They offer excellent airtightness when closed, making them energy-efficient—a growing concern in modern architecture. However, they require clear space for the sash to open, making them unsuitable for narrow areas.

Casement windows can be categorized by hinge location into side-hinged and hung types. Side-hinged windows open horizontally and maintain balance during operation, suitable for larger windows. Hung windows open vertically and are commonly used for kitchens, bathrooms, and bedrooms due to limited opening angles. Modern designs now combine both functions, allowing dual-directional opening.

Figure 2-2: Casement Window

Sliding Windows:

Sliding windows (Figure 2-3) operate by gliding the sash on tracks with rollers. Their advantage lies in saving space whether open or closed and simplicity in design. However, only up to 50% of the sash can be opened, and their airtightness is generally poor. Some modern designs allow multiple sashes to fold to one side or enhance airtightness, but sliding windows still perform worse than casement windows in thermal insulation and are less common in developed countries.

Figure 2-3: Sliding Window

2. Fall Prevention Factors

Windows play a vital role in energy conservation by enabling natural light and ventilation—functioning as conduits for both light and air.

Key design aspects influencing daylight performance include:

Window Aspect Ratio (Length × Width × Depth): This determines light attenuation and visible sky from the window area (Saxon, 1983).

Window-to-Wall Ratio: This affects the extent of daylight penetration.

Larger indoor spatial indexes (calculated as [L×W / (L+W)] × H) increase visible sky and daylight factor but also allow more radiant heat. Conversely, smaller spatial indexes reduce daylight factor and radiant heat. However, larger window openings also increase the risk of accidental falls for people or objects.

Given the complex and variable environments in which windows operate, theoretical models are insufficient to accurately assess fall risks. Therefore, few studies, domestic or international, have focused on fall-prevention design for windows. Key factors include opening area, window type, installation floor, and usage purpose.

To mitigate fall risks, various preventive devices are used, such as anti-fall nets, iron bars, and opening size restrictions.

Patent Analysis of Fall-Prevention Window Design

To analyze related technologies, a search was conducted through the Taiwan Patent Search System, Espacenet, and Prior Art Finder. The search used the following IPC codes:

- E06B 3/28: Removable window panes
- E06B 5/00: Doors/windows for special purposes
- E06B 7/00: Special equipment related to doors/windows
- E06B 9/00 – 9/01: Screens, grilles, protective devices for openings

Search results:

- 28Taiwanese patents (e.g., "Quickly assembled invisible iron window using snap rope")
- 2 Chinese patents (e.g., "New type of window safety device")
- 0 U.S. patents
- 0 European patents

These 28 patents differ from the proposed system in this study.

NO.	Announcement Number	Announcement Date	Patent Name
1	M637582	2023/02/11	Invisible iron window structure with steel cable anti-detachment installation track
2	I823706	2023/11/21	Quickly assembled invisible iron window structure by using snap rope
3	M592027	2020/03/11	Invisible iron window
4	M639403	2023/04/01	Embedded invisible iron window
5	M640216	2023/04/21	Quickly assembled invisible iron window structure by using snap rope
NO..	Announcement Number	Announcement Date	Patent Name
6	M628532	2022/06/21	Invisible iron window
7	M616736	2021/09/11	Embedded invisible iron window
8	M613111	2021/06/11	Window type invisible iron window
9	M604351	2020/11/21	Base body strengthening device of invisible iron window (2)
10	M603912	2020/11/11	Quick release device for concealed iron window steel cable
11	M600340	2020/08/21	Multifunctional invisible iron window

12	M595154	2020/05/11	Invisible window grille and its fixing device
13	M572401	2019/01/01	Invisible iron window
14	M564632	2018/08/01	Invisible iron window
15	M553359	2017/12/21	Invisible iron window
16	M524381	2016/06/21	Removable anti-fall window
17	I518237	2016/01/21	Anti-Theft cable with safe protection and escape method thereof
18	M502718	2015/06/11	Safety guard-ing net struc-ture
19	M501475	2015/05/21	Movable hidden apparatus for fall prevention
20	I379938	2012/12/21	Anti-falling structure

NO.	Announcement Number	Announcement Date	Patent Name
21	M435504	2012/08/11	Anti-falling device
22	M427442	2012/04/21	Security device for window
23	M426652	2012/04/11	Wireless anti-theft system of invisible iron window
24	M423734	2012/03/01	Security, anti-theft steel string net structure
25	M423151	2012/02/21	Anti-falling window screen
26	M418964	2011/12/21	Falling prevention window structure

27	M411464	2011/09/11	Invisible iron window
28	M393567	2010/12/01	Steel cord protection net structure

Table 2-1 Patent search for window anti-fall safety device in the Republic of China (Taiwan)

NO.	Announcement Number	Announcement Date	Patent Name
1	CN 206438875 U	2017/08/25	A new type of window safety device
2	CN 219492152 U	2023/08/08	Use the snap-in rope to quickly assemble the invisible iron window structure

Table 2-2 Patent search of window anti-fall safety device in the People's Republic of China

Description of Relevant Patents

Taiwan Patent No. M418964 – "Anti-Fall Window Screen" (see Figure 2-4)

This anti-fall window screen comprises at least the following elements: a main frame that includes a first frame along the horizontal direction and a second frame along the vertical direction. On the exterior side of the main frame, multiple steel cable fasteners are installed to loop the cables and form a protective cable mesh. On the interior side of the main frame, a front blocking plate is attached to the first frame and a rear blocking plate to the second frame. These blocking plates create a spacing cavity within which a detachable screen can be housed. This configuration allows users to remove the screen from the main frame for cleaning or maintenance. Furthermore, the upper front blocking plate is taller than the lower one, ensuring that the detachable screen remains securely positioned within the cavity without falling out.

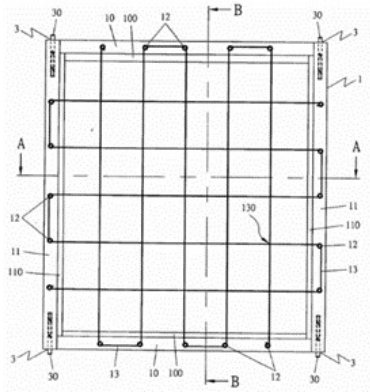


Figure 2-4. Structure of the Anti-Fall Window Screen (Source: Patent Holder)

Taiwan Patent No. M418964 – "Anti-Fall Window Structure" (see Figure 2-5)

This anti-fall window structure incorporates a horizontally slidable bar between the components of the window frame, which can move up and down. The upper frame includes two hooks on the left and right sides. The side frames contain multiple interlinked slides, along with several vertical and horizontal tension cables that intersect to form a protective mesh. The area of the protective mesh can be adjusted by moving the horizontal bar up or down. This design allows the safety net coverage to be modified according to the growth stages of young children, without obstructing window egress during emergencies.

Conclusion

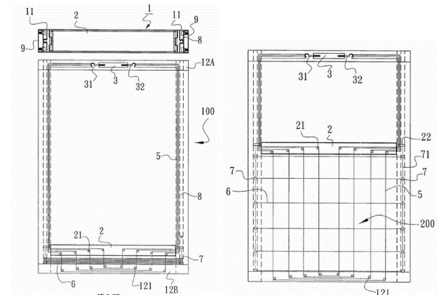


Figure 2-5. Structure of the Anti-Fall Window (Source: Patent Holder)

Taiwan Patent No. M616736 – "Embedded Invisible Iron Window" (see Figure 2-6)

This patent describes an embedded type of invisible iron window system, which consists of a pair of first frame members installed on the top and bottom (or optionally only on top and bottom), and a pair of second frame members installed on the left and right sides. The first frame members are embedded into the designated mounting recesses of the building structure. Fasteners are inserted into the side grooves of the first frame members to secure them to the building for enhanced structural integrity. A covering component is then combined with the first frame member to conceal the fasteners. The upper and lower frame members serve as mounting bases for the upper and lower cable brackets. These brackets are secured into the fastening grooves of the first frame members using second fasteners, ensuring a firm attachment. Steel cables are then mounted through these brackets to complete the construction of the invisible iron window.

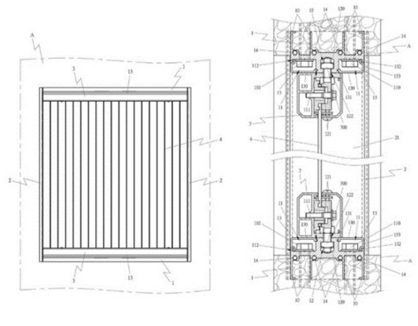


Figure 2-5. Structure of the Anti-Fall Window (Source: Patent Holder)

<u>China Patent No. CN219492152U – "Quick Assembly Invisible Iron Window Using Snap Rope" (see Figure 2-7)</u>

This patent discloses an invisible iron window structure with anti-detachment cable track system, primarily composed of at least one track, an outer cover, multiple fixing bolts, a steel cable, and at least one snap-fit plate. The track is approximately L-shaped and made of extruded aluminum, featuring a flat surface with fixing holes for anchoring it to the wall. Threaded holes are provided along the middle section of the track to receive the fixing bolts.

A slanted sliding slot is located at the bottom end of the track. Fixing bolts are arranged in sequence and secured to the track's flat surface for looping the steel cable. The snap-fit plate is a thin elongated strip designed to slide into the slanted slot. When the steel cable is looped around the bolts and the snap-fit plate is inserted into the slot, the cable is effectively sealed within the space, preventing it from slipping out during packaging or shipping. This design facilitates compact and secure transport of the invisible iron window assembly.

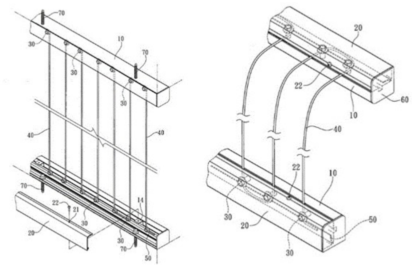


Figure 2-7. Invisible Iron Window with Anti-Detachment Cable Track (Source: Patent Holder)

In summary of the above patent analysis, no similar research or design has been found either domestically or internationally. This study proposes a novel design that integrates a steel cable retraction mechanism, steel cables, and a traction device to achieve significant improvements in fall-prevention safety for various types of windows, including casement, tilt, top-hung, bottom-hung, pivot, and sliding windows.

Research Design

In this study, it is observed that after the completion of a building, windows without fall-prevention protective devices can easily lead to the accidental falling of people or objects. As a foundation for the research, the necessary hardware components—such as U-shaped aluminum brackets, retractors, and steel cables—were installed around the window openings of the building. The study then focused on the application of tensile force principles in physics. Based on the detailed product construction drawings, a physical prototype was fabricated to evaluate whether the fall-prevention function of the window design meets the expected performance.

Research Project

Research Site and Equipment

The test site for this study is located at No. 9, Xinhe Road, South District, Tainan City, Taiwan. The subjects of the investigation are windows on the second floor and above of the building belonging to the Chi-Neng Center.

For this study, one window on the second floor of the center was selected as the primary research site. The testing period lasted 62 days, starting from July 2024, focusing on evaluating both the durability and practicality of the design.

Related diagrams of the research site are shown in Figures 3-1 and 3-2. The red-framed area in the building illustrations indicates the main location of the research.

Figures 3-1 Research site building

Figures 3-2 Research Locations Main Research Window

Equipment Used

Based on the objectives of this study, the following equipment was selected to facilitate the research: a notebook for recording observations, a digital camera, a digital video recorder, a ruler, and a portable tension measuring device (as shown in Table 3-1). These tools were used to support the research process and to accurately document the conditions on site.

Item	Name	Photo	Illustrate
1	Notbook		Record relevant measurement results and information
2	Digital camera		Take and record image and phenomena of the current situa-

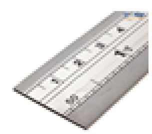
			tion, etc.
3	Camera		Take and record image and phenomena of the current situation, etc.
Item	Name	Photo	Illustrate
4	Iron ruler		Used when measuring small range objects such as material dimensions. For example, a 30cm iron ruler
5	Tape measure		T Used when measuring short to medium distance objects such as dimensions. For example, 5M tape measure
6	Camera		Measuring the tension of a steel cable。 MET-RH50+ digital electronic tension measuring instrument (0.05~50Kg)

Table 3-1 List of tools used in research

Experimental Site: Research Methods and Content

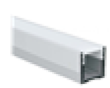
In this study, commercially available aluminum materials, support rods, and retractors (as listed in Table 3-2) were used to construct the test setup. Field measurements, photography, and mapping documentation were then conducted at the experimental site to investigate the current state of the designed fall-prevention window system. Detailed records were kept, including the test date, time, status of the aluminum window when opened or closed, and the tension in the steel cable during window opening. The research methods and content are as follows:

1. *Photographic Documentation*

Photographic records were taken on-site to capture firsthand images and visual data of the window. These serve as a reference for future analysis and visual evidence in support of the research. A digital camera and digital video recorder were used to carry out the documentation.

2. *Measurement and Mapping Records*

On-site measurements were conducted, and a condition inspection checklist was developed based on previously organized fall-prevention window factors. Measurements were taken at 10 cm increments of window opening. Actual data and visual records were collected, including: material dimensions, window opening types and sizes, and variations in cable tension (see Tables 3-3, 3-4, and 3-5). Tools such as paper, pen, ruler, and a digital tension measuring device were used to carry out the recordings.

Item	Name r	Photo	Illustrate
1	Aluminum 1		Aggregate for making anti-fall windows, in which a wire rope reel can be placed.
Item	Name r	Photo	Illustrate
2	Aluminum 2		Aggregate for making anti-fall windows, used as a fixing device when pulling steel cables.

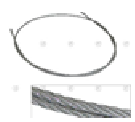
3	rod plug 1		Plug sleeves for both ends of aluminum 1.
4	rod plug 2		Plug sleeves for both ends of aluminum 2.
5.	Automatic return reel		Automatically retractable wire rope.
6	stainless steel wire rope		The main material used to prevent people and objects from falling。
7	wire lrope chuck		For fixing the end of the wire rope.(1.0-2.5mm)
8	Steel cable aluminum sleeve		Used to prevent friction between the steel cable and the aluminum window during movement.
9	Mirror bead screw		For fixing anti-fall device.

Table 3-2 List of Materials Used in Research

Basic building information	building location:			
	The coordinates of the building:			
	Building floors:			
Experimental floor	floor			
Experimental aluminum window dimensions	(L) cm	(T) cm	(H) cm	Material

Table 3-3 Building Checklist

Wire rope size(Diameter)	cable length	Steel cable tension
1.0mm	cm	Kg
1.5mm	cm	Kg
2.0mm	cm	Kg
2.5mm	cm	Kg

Table 3-4 Cable tension checklist

Wire rope size(D)	The window opens 30 cm	All windows open
Steel cable tension	Kg	Kg
Wire cable spacing (10cm is accurate)	Cm	Cm
The pulling force of window panel return	Kg	Kg

Table 3-5 Cable tension and spacing change checklist

Research Plan

Test Subject

The objective of this study is limited to standard aluminum windows, primarily used for natural lighting and ventilation on the exterior walls of buildings. The focus is on window designs installed at heights equivalent to the second floor or above. (See Figures 3-1 and 3-2)

Instrument Description

In this study, to understand the performance of the steel cable in the fall-prevention device when fixed onto a standard aluminum window, we observed how the cable engages when the window sash is opened and interacts with the window frame. The purpose is to determine the amount of tensile force required for the steel cable to effectively prevent the fall of a person or object. Additionally, the study also investigates the tensile force at which the cable causes the window sash to move, resulting in a reduction of the window opening or complete closure.

A digital tension measuring device (see Figure 3-3) was used to perform tensile tests and record the data, minimizing measurement errors.

Figure 3-3 Digital tensile force measuring instrument

Design and Description of the Fall-Prevention Device

This part of the study is divided into four main components: the design phase, prototype fabrication, data recording methods, and experimental procedures, which are explained as follows:

Design Phase

In this study, the advantages and disadvantages of various commercially available fall-prevention devices were analyzed to develop a design that is easy to assemble in real-world environments, aesthetically pleasing, effective in preventing falls, does not hinder emergency egress, is adaptable to various window types, and remains cost-effective.

1. *Prototype Fabrication and Measurement Point Planning*

To meet the requirements of this study, in addition to design drawings, the fall-prevention device was physically installed onto the aluminum windows of the building according to the planned design. Measurement points were established as part of the testing framework. The measurement plan is divided into four parts, described as follows:

(1) Measure the tensile force applied to the steel cable of various diameters when the window sash is fully opened.

(2) Determine the amount of tension required for the window sash to automatically return to the closed position.

(3) Measure the relationship between the closing gap of the sash and window frame, and how the tensile force

affects the spacing between each steel cable.

2. *Recording Method*

The on-site data recording for this study is divided into three stages, based on the tensile force generated by steel cables of different diameters installed in the fall-prevention device. The tests focus on the force exerted under full window opening, partial opening (30 cm), and the force required to trigger window closure. The details are as follows:

(1) Full Window Opening Record: Record the tensile force generated by steel cables of various diameters when the window is fully opened.
(2) 30 cm Window Opening Record: Record the tensile force and spacing between steel cables when the window is opened to 30 cm. Observe whether differences in cable diameter and tension result in changes in spacing between the cables.
(3) Window Closure Force Record: During testing, record the conditions under which the window—when fully opened or opened to 30 cm—automatically returns to a closed state once a certain level of tensile force is reached. Additionally, record any changes in spacing between the steel cables during this process.

Conclusion

With economic prosperity, the amount of usable land in major cities around the world has been decreasing, leading to increasingly severe housing problems. As a result, making efficient use of limited land has become a major challenge for urban areas, and high-rise buildings have emerged as the primary solution to address residential needs.

Windows are essential elements in buildings, serving purposes of ventilation and natural lighting. Whether in single-story houses or high-rise buildings, the installation of windows is necessary. However, the higher the floor level, the greater the potential safety risks associated with windows. This study aims to examine and address these potential dangers. Based on the findings and analysis presented above, this research proposes a window fall prevention device that is practical, aesthetically pleasing, easy to install and remove, does not obstruct emergency escape, and offers a high level of safety.

References

Wikipedia, https://zh.wikipedia.org/zh-tw/Wikipedia

Lin, C.-Y. (1994). Compilation Guidelines for Building Disaster Prevention Plans — The Function of Windows as an Example.

Hu, W.-C. (2011). Complete Practical Compilation of the Latest Building Regulations. Education Friends Publishing.

Liu, Y.-T. (2012). The Meaning of Architecture. Baihua Literary Press.

Taiwan Pediatric Association. (2015). Committee for the Promotion of

Children's Health and Welfare, Taiwan Pediatric Association.

Taiwan Patent Search System.

Global Patent Search System (GPSS) – Patent Application Programming Interface (API).

Beer, F. P., Johnston, E. R. Jr., DeWolf, J. T., & Mazurek, D. F. (2014). Mechanics of Materials (6th ed.).