Design safety for decorated iron stairs used in architecture

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Abstract:

The stairs provide a means of ascent or descent. Stairways need to be protected by a stair rails to prevent the chances of falling. Major cause of stair-related injuries is poor design and construction of stair rails that affect the user's gait and visual attention. The stair rails to a variety of potentially hazardous characteristics, including riser height irregularity. Stair rails must be designed to resist the loads they are likely to experience throughout their lives without collapsing or becoming unstable and without deflecting unacceptably, causing a loss of amenity. The barrier must also be sufficiently durable, without the need for reconstruction. Changed many of the standards previously agreed upon from the industry. While bad design is the most commonly cited reason for stairway fall injuries, other reasons cited include user behavior. ***The problem***, stair rails fall injuries prevention efforts are clearly warranted. So the research role of evaluating design features and identifying potential hazards in contemporary stair rails. ***Therefore, the aim of research*** is that design practices and how this information can be used in research and practice to improve stair safety to identify aspects of stair rails designs. ***This research studied nine axis***: material, kind of stairs, Hazards Along Inadequate Stairs Railing, The decorative iron spiral stairways, Support of stair rails elderly, handicapped and children, Openings in stair rails Supports (For Children), Interactive stairways and stair rails, Stair rails height requirements and Analysis of safe stair railing. ***The main results*** of this study show that, it Should the education and awareness on stair rails safety, designers will take more interest in designing safer stair rails that at the same time are attractive and innovative.

Keywords:

- ***Stair rails***
- ***Handrail***
- ***Decorative wrought iron***
- ***Injuries***
- ***Children***
- ***Elders***
- ***Safety***

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1. Introduction

A stair rails is a safety barrier located along the open side(s) of a stairway with a fixed ladder. It used as the primary access to a dwelling or in public building. A stair rails is installed along one or both sides of an ascending / descending stairway, to provide a safe grasping surface. They help in preventing a loss of balance for users ascending or descending stairs. They provide a means for users to quickly regain balance after a slip or stumble. (1)

If the top of the stair rails is to serve as a handrail along a stairway, here is a typical requirement for stair rails and stair rail stop height if the top is being used as hand railing:

People need adequate space on stair rails to move safely and comfortably. A basic principle of safe stair rails design is that the handrail must be available for the user to grasp on the first step and maintain a grip all the way through the last step. Handrails are most heavily used at the top and bottom of stair runs. (2)

Guidelines for facilitating the user's approach to and exit to ensuring a user's safety, both in terms of physical attributes and appearance characteristics, throughout the entire stairway. (3)

There are several important functions for stair rails:-

1. To slide a hand while monitoring one's progress and stability.
2. To use as a pivot at corners.
3. To provide support for an elderly or infirm user.
4. To grab onto for support in the event of an accident. The need to perform these functions prevails throughout the length of each flight and for all landings.

Scientists noted that relatively few of the people he observed utilized handrails for physical support (1%), or for pulling themselves up (3.5%). People generally used

handrails for balance (9.4%), guidance (23.3%), or not at all (62.9%). (4)

2- The research study the design of stair and handrail, through the following axis:-

1- Materials

For centuries, stair rails have been used for decorative effect. Decorative wrought iron always has been one of the favored materials because of its versatility; durability and potential for good design. Stair rails are one of the most dangerous parts of the architectural environment. Stairway falls are a leading cause of unintentional injuries in buildings that results in human, economic and social losses. (5)

2. Kinds of stairs

1. Private stairs means stairs used by a limited number of people who are generally very familiar with the stairs, e.g. the internal stairs in a dwelling.
2. Semi-public stairs means stairs used by larger numbers of people, some of whom may be unfamiliar with the stairs, e.g. in factories, offices, shops, common stairs serving more than one dwelling or homes.
3. Public stairs means stairs used by large numbers of people at one time, e.g. in places of public assembly.

3- **Hazards Along Inadequate Stairs Railing**

The majority of these falls (90%) occurs in homes Combining risks from two leading factors in stair-related falls. It is proceeding of the International Conference on Fall Injuries Prevention and Protection, Tokyo. The 2013 annual cost to society for these injuries is 100 billion dollars in medical and litigation expenses. (6) Falling in public settings is also part of the problem. (7) A recent survey of problematic activities in public buildings found that using stairways was the top problematic activity out of groups surveyed, making stairway design the top priority of end users in public buildings. (8)

Stairs railing have decorative patterns, for example wrought iron railings for open spaces between balusters that are greater than 3.5 inches (89 mm) are areas where a child's head could slip through or body parts could become caught during a fall injuries. (9) Stairway falls are a public health concern that the profession needs to consider. In the United States, stairways are a leading site of fall-related injuries, accounting for 1,900 deaths and 1.3 million hospitalizations per year. (10)

Large gaps under the bottom rail allow children to slide or roll off the sides of stairways to areas below. Knowledge for design of stairways is limited, however, which has resulted in difficulty identifying best practices and improving design guidelines. (11)

Stair users tend to focus their visual attention on the surrounding environment where views are present, rather than their stepping locations, and use less of the handrail, which are behaviors that increase the risk for slipping, tripping and falling. (12)

Table (1) some example of railway hazards

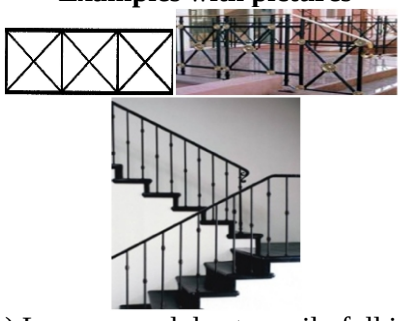
Railways Hazards	Examples with pictures
There are two hazards that ensue: a loose, insecure stairs railing (depending on the number of split baluster ends) and a child hazard (open baluster spacing lets a kid fall injuries off of the stair rails). For example. Bracing is often used to support a stair rails. Another variation on this theme was a railing with stair rails spaced several stair treads apart and large enough for a person to easily fall injuries through.	
Sharp edges of balusters pose risk of bodily injury, especially during a fall or obstruction that can catch clothing or a handbag strap as users pass up or down a staircase. Below, the open hook ends of the stair rail balusters have been seen catching handbag straps.	

Fig.(1) Large spaced due to easily full injuries

Fig. (2) Sharp edges

Horizontal rails and other balustrade attributes that can be climbed also pose risks for children and even adults.

Fig. (3) Risks of Horizontal rails

Stair rails more common, additional evidence of a stylistic preference toward minimalism. In the simplest designs, only a railing was provided with no protective stair rails.

Fig. (4) simplest designs have no protection

Attention to the stairway is important for safety, persistent gaze toward the stairs can also be an indicator of perceived hazards. Handrails were not fully extended non-continuous. Have design features that would be considered hazardous, such as open risers and inadequate handrails. The shifting of visual focus increases perceptual errors.

There are ample and clear guidelines about hand railing size, height, shape, grasp ability, mounting, strength, continuity, smoothness etc. Can be a snag hazard at a hand railing, particularly at the railing ends, which is why hand railing returns are required at those locations.

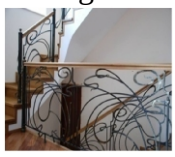


Fig. (5) Handrails were not fully extended non-continuous

Fig.(6) Risks of railing ends

Hand railings, too low, too high, or that are not securely fastened are in some respects more dangerous than no hand railing at all, since the stair user thinks there she can grasp the handrail to prevent a fall. The accidents were caused by stair rails having sharp surfaces for example the lip can so easily catch a toe of someone climbing a stair.

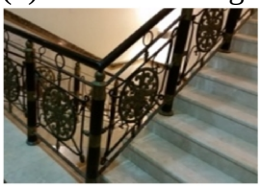


Fig.(7) Grasp the handrail to prevent a fall

4- The decorative iron spiral stairways

Among various stair configurations, spiral stairways are considered more dangerous than straight stairways. Because the treads are tapered, users are twisting their bodies and shifting their weight differently on the left and right foot as they ascend and descend. This pattern of walking puts stair users at a greater risk of losing balance during movements of body rotation compared to the gait patterns associated with straight stairs which typically do not require the user to twist their torso.

The risk of overstepping is increased by treads that are too narrow to accommodate the length of the foot. This condition is often found along the inner radius of winder or "pie-shaped" treads in curved stairways, which should be avoided whenever possible since it is not as safe for foot placement as straight treads, although the outer tread can provide a safer pathway.

The building code requires an 11 inch (280 mm) tread as the minimum effective depth for accessible stairways in public buildings. (13)

Narrow stairways without handrails can create problems in implementing handrail retrofits in the future. For example, adding handrails to the open riser stairway may not be possible without creating discomfort since handrails take up at least 3 inches (76 mm) on each side of the stairs and this would reduce the effective width of the stairs even more. A narrow stairway width in spiral configurations forces the user closer to the inside radius where the tread becomes too small for safe walking.

Winding and spiral stairways shall be equipped with a handrail offset sufficiently to prevent walking on those portions of the stairways where the tread width is less than 6 inches (15 cm).

Although this is the optimum tread dimension for stairs, treads in residential buildings are

currently allowed to be smaller, with a minimum tread of 10 inches (254 mm). Treads within spiral flights can be even smaller with a 7.5 inch (191 mm) minimum depth measured 12 inches (305 mm) from the narrower edge. (14)

The International Building Code (IBC) has exceptions to the requirement for handrails on both sides, notably residential stairs and spiral stairs; stairs on decks and patios are not required to have any handrails; a single elevation change at an entrance or egress door and changes in elevations of three or fewer risers within dwelling units also do not require handrails. (15)

Table (2) some example of decorative iron spiral stairways.

Showing the components of the decorative iron spiral stairways.

Cast Iron Spiral Staircase With Landing 14 Steps.

Fig.(8) Cast Iron Spiral Staircase

The stair rails mistake that you may encounter in a home where a narrow stairwell has made it difficult to move furniture in or out of a room. Someone removes the railing to move large items up or down the stairs.

Fig.(9) narrow stairwell (uncomfortable)

Fig.(10) Interactive stairways

5-Support of stair rails elderly, handicapped and children

Behavior, preliminary analysis at NBS showed that older persons tended to move more slowly on stairs than younger adults (16).

In addition there were more incidents than expected for persons who used the handrail to balance or pull themselves up than for persons who either did not use the handrail or who only used it for guidance. This finding is strongly suggestive of the vulnerability of the user groups who require supplementary support. Ageing causes reductions in strength, gains in mass, decrease in balance and stability when mobile, and onset of arthritis, decrease in bone density, and an increase in falls and the associated fear of falling amongst other things. Confirm their fear of the stair climbing task especially in descent. (17)

Persons with difficulties judging the extent of the treads below may have to hold onto the handrail, almost as if it were a "third leg". By holding onto the handrail in this manner, the person can acquire the support necessary. Accordingly, such supplementary support should be available whenever a visually

impaired user might require it. grab-bar in ascent - persons with diminished strength may require a handrail to pull them up from one tread to the next. Whereas most people can elevate themselves from one tread to the next with their leg muscles, those who do not, may have to use their arms to pull themselves up from step to step. However, this requires a handrail or some other object to pull against at every point where a physically impaired user might require it.

Fulcrum in ascent or descent - in addition to the perception and stamina problems, some stair users who have problems in flexing certain joints may not be able to perform movements typically required for stair use. As a consequence, they may have to improvise unique patterns of stair movement. Since such persons lack the capability to perform the required movements on their own, they may use portions of the stair as prosthetic devices to supplement their own capabilities. In such cases, the user may actually use the handrail as an extent ion of his own skeletal system. Since the specific disabilities associated with this kind of stair movement are so varied, handrails are needed on both sides of each flight. (18)

6- Openings in stair rails Supports (For Children)

A given flight of stairs is frequently used by children up to the age of 6 years provide an intermediate handrail on at least one side of the flight which is mounted 24" above the surface of the nosing edge of each tread.

Young children, even if they cannot walk, can be attracted to stairs as exciting places to play and test their own capabilities. Among the more attractive parts of the stair are the handrail and supporting balusters and spindles. Whether the child is playing with the spindles themselves, or is merely playing on the stair, there is a possibility that he might lose his balance and fall injuries between the handrail supports, onto a surface below. For young children, the waist and chest may slip through an opening, leaving the head lodged between the spindles.

However, from anthropometric data on children, it appears that the 50th percentile 2 year old has a hip depth of 4 in. and a head width of 5-1/4 in. These numbers indicate that the depth at the hip is a critical dimension, since it is smaller. For a 1 year old child, this figure is 3-1/2 in. Since the 1 year old (while too young to actually walk on stairs) is likely to be the most vulnerable to these kinds of incidents while crawling on stairs and pulling himself up on the handrail, the latter figure is proposed as the appropriate design criteria.

Also shopping malls have public areas where children under six years old are expected to be present, and non-public areas unlikely to be frequented by children, for example, in areas used for food preparation or stock handling. The barrier infill in the public areas must be designed to prevent a child falling through the barrier and offer no easy or obvious methods of climbing.

Here's an example building code citation for the 4-inch rule applicable to guardrails: In public educational facilities, any vertical drop of 18 inches or more shall be protected by a wall or guardrail a minimum of 42 inches in height. Guardrails shall have intermediate rails or ornamental pattern such that a 4-inch diameter sphere cannot pass through any opening up to a height of 34 inches. (19) The openings anywhere in the stair rails must be of such size that a 100mm diameter sphere cannot pass through them.

7- Interactive stairways and stair rails

In reducing obesity rates in the U.S.. In 2013, New York City Mayor Michael Bloomberg issued an executive order requiring that all new and renovated City buildings meet active design strategies. (20) It is now recommended that architects design highly visible, easy to access, and attractive stairways to encourage use. (21)

Interactive stairways are one thread of activity related to this new emphasis in design practice. While there has been a great deal of interest in encouraging stair use on both architectural and policy levels, much less emphasis has been placed on stair safety. For example, several studies have examined the effectiveness of signs, artwork, music, and interactive features to promote the use of stairs when elevators or escalators were present. (22)

The higher frequency of stair use, for any reason, increases the exposure to risks of tripping, slipping and falling. But, in interactive stairways specifically, the interventions have the potential to have an unsafe impact by causing distraction from the stair climbing task and altering gait while traversing the stairway. Compared with other interventions, interactive features have shown a significantly higher impact on stair use and thus greater promise for stairway design as an

intervention for promoting health and fitness. This study considers interactive features such as sound effects and other technologies that affect the entire stairway as opposed to individual elements such as interactive art hanging along stairway walls. Interactive stairways can change the purpose of stairways in buildings by allowing users to engage in stair climbing tasks while feeling as though they are having an influence on the built environment. (23)

The features are able to detect movement on stairs through sensor technology which allow users to sense their own movements as feedback is triggered. Perhaps the best known example of this type of stairway was the "Piano Stairs" at the Ode plan subway station in Stockholm, which was part of Volkswagen's "The Fun Theory" campaign in 2009. This subway stairway, located next to an escalator, was modified to look like a piano keyboard and play musical notes when users ascended and descended the steps. The study, aimed at changing sedentary behavior by making the stairway fun to use, reported a 66% increase in stair use over escalator use. (24)

The interactive stairways are use, especially in museums as technology exhibits .There are several potential safety problems with interactive stairways. First, they provide incentive for repeated use of stairways, increasing the exposure to risks. Second, since stair climbing is largely affected by visual attention. (25)

Interactive stairways motivate people to use the stairs in unconventional ways. For example, sounds effects that are triggered by movements often cause people to run, jump, skip, and even dance on the steps. These types of movements may require special consideration for safety features such as handrails, slip resistant treads, and visibility of stair tread edges. The following hypotheses guided the research. Interactive stairways attract the user's gaze to the stairway itself. There will be less diverted gaze to the surroundings. There will be more handrail use on interactive stairways. The interactive stairways can be as safe as any other stairway.

8- Stair rails height requirements

Changed many of the standards previously agreed upon from the industry. For example, a study conducted by the American Academy of Pediatrics prior to the 1991 version of the Life Safety Code, indicated that approximately 950 mm out of 1000 mm children under the age of 10 could pass through a 6 in. wide opening between guards. These statistics have caused the industry to revise past standards to reflect a more stringent approach to protection. (26)

For example from change:

1. Stair rails installed after March 15,1991, must be not less than 36 inches (91.5 cm) in height.
2. Top edges of stair rails used as handrails must not be more than 37 inches (94 cm) high nor less than 36 inches (91.5 cm) from the upper surface of the stair rails system to the surface of the tread. (If installed before March 15, 1991, not less than 30 inches [76 cm]).
3. Building codes and research findings do not completely agree over how to place handrails so they might serve the above functions. Research done by Maki and Fernie (1988) indicates a handrail height of 36 to 40 inches is most effective in preventing falls. (27)
4. Handrails must be placed between thirty-four and thirty-eight inches above the nosing of the stair treads. Handrails are essential elements of staircases that provide support for users and protect them from mishaps designed to furnish persons with a handhold or assist with, the movement of a person. (28)

9- **Analysis of safe stair railing**

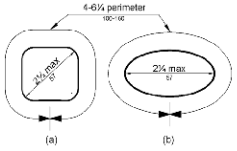
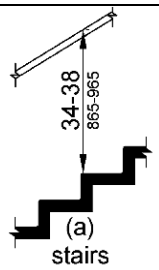
Stair rails should be designed in accordance with the relevant clauses in the appropriate materials .It is important that the design procedure takes account of the relevant aspects of durability, geometry, occupancy, strength and comfortable. The design effort should focus on ensuring that:-

1. The durability requirements of the specific application are met by the proprietary balustrade system, and the supporting structure is capable of accommodating the loads applied to the balustrade system without collapsing or excessive deflection.
2. The supplier of the proprietary balustrade system must provide evidence that the balustrade system meets the requirements of the Building Code.
3. ensure adequate performance and protect users from injury due to failure in testing, selection and performance

In instance, a stair rails is intended to retard

the passage of the whole body. These contrasts to a handrail which is intended to establish a firm and stable handhold. Both a stair rails and a handrail should be provided.
For example when Handrails were too wide or too thin after losing balance on the stairs we search for support in an attempt to arrest a fall by reaching out and grasping a handrail. (29)
Handrail shapes (table 3) that are too wide or too thin are not ergonomically designed to be grasped firmly and thus may not be effective during falls. Facilitate communication about safety in the design of stair rails that influence safe behavior throughout the profession as an essential step toward promoting safe stair rails design practices. The following table show the specify.

Table (3) New kinds of handrail

Handrail Speciation		
Handrail cross section and size :	Railing grip size and shape: (must be able to be grasped) Round rails: between 1.25" and 2" in diameter Metal ogee shaped: <= 2.25" across widest dimension Rectangular shaped: perimeter must be between 4" and 6.25" . Perimeter larger than 6" must have a graspable finger recess (see details at the ASM document link below) (30)	 Fig.(11) Handrail cross section
Handrail shape	Grip force capabilities of the human hand. optimizes grip forces in the hand. Round shaped rails with a diameter of about 1.5 inches maximize grip forces for adults, while a diameter of between 1.125 and 1.25 inches maximizes grip forces for children. Rectangular shaped boards tipped on edge produce a nice decorative effect as a handrail and are often easier to attach than round shaped railings. (31).	
Height.	Top of gripping surfaces of handrails shall be 34 inches (865 mm) minimum and 38 inches (965 mm) maximum vertically above walking surfaces, stair nosing's, and ramp surfaces.	 Fig.(12) Height of hand rails
children elementary schools	When children are the principal users in a building or facility (e.g., elementary schools), a second set of handrails at an appropriate height can assist them and aid in preventing accidents. A maximum height of 28 inches (710 mm) measured to the top of the gripping surface from the ramp surface or stair nosing is recommended for handrails designed for children. (32)	
Additional handrails for children	Additional handrails for children are recommended. It should be provided at	

	600 mm from pitch line vertically to the top of handrails. (33)
Handrail continuity	Handrail continuity: handrails should be continuous - that is a hand can slide along the rail without interruption from above the top riser to above the bottom riser; handrails can be interrupted at a newel post Handrails must be continuous from a point above the top riser to a point above the lowest riser of each flight of stairs. This would allow a newel post to be attached to the face of the bottom riser, with half of its base resting on the bottom tread.
handrail extensions	At landings, handrail extensions can help people identify the start and end of elevation changes, gain stability when mounting and dismounting stair runs, and make a safe transition in gait between landings and steps. (34).
Two handrail s	Requires stairways having two or more risers to have at least one handrail, at a height of between 34 and 38 inches above the nosing. Recommendations include the provision of handrails on both sides of stairways. (35)

Fig.(13) Handrail extensions

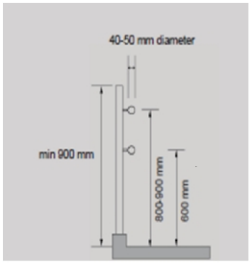


Fig.(14) There are two risers handrails

3- . Results & discussion

After study this research and deduct the results, it is clear that: Handrails, treads and risers must be structurally sound, firmly attached to the structure, and properly maintained to perform their intended function safely as:-

1. **Stair rails shall be install a properly positioned and capable of supporting normally imposed loads and shall be maintained in good condition.**
2. **Stair rails are required to meet the performance criteria described in the Building Code.**
3. **The relevant Building Code clauses for stair rails are:- Structure, Durability, Access routes and Safety from falling.**

And also the research shows that:-

4. stair rails design features and that more assessments of stair rails in use can help identify best practices and additional knowledge gaps. Contemporary practices in stair rails design and the effects of stair rails design features on user safety. New technologies allow the use of unusual materials for stair treads.
5. Elements of the stair rails system should be designed to enhance the perceptual testing process. Features of the environment should force the user. The stair rails and its surroundings should be designed to protect the user from further injury upon impact, should a fall occur. Stair rails and handrails shall be so surfaced as to prevent injury to employees from punctures or lacerations, and to prevent snagging of clothing.
6. The elders and people with disabilities who require additional support to maintain balance, following minimum standards and taking advantage of exceptions like these can pose significant safety risks. spatial these areas, including the landings, are where they are needed most.
7. The secondary handrail is included at a lower level where it is safe to do so. This would reassure and support not just younger students but people of short stature.
8. The handrail should level out at each landing. This will give a clue to visually impaired people that the floor is about to become level. Suitable handrails are important to enable

tactile guidance

9. In architectural which are likely to be used by children under five years old, stair rails should be so design that a 100 mm diameter sphere cannot pass through any openings in the stair rails. Stair rails should not be readily climbable and should be designed in such a way as to discourage young children from climbing it. Features in the guarding that might provide a foothold should be avoided e.g. horizontal rails. (36)
10. Improving the physical characteristics of the environment surrounding the stair rails is as critical to stair safety as maintaining the structural integrity and quality of the stairs themselves.
11. Stair rails safety can be improved through demonstrations of the extent to which favoring aesthetics in stairway design can be dangerous. In addition, evidence supporting the effectiveness of new and innovative design approaches is needed;
12. Designers and building owners have the opportunity to take responsibility for initiating safety in the design process by making intelligent use and avoiding misuses of important stair rails features.
13. Found most common causes of stair falls and injuries such as uneven or damaged steps and stairs, missing or unsafe railings, loose, crooked treads, or lack of visual cues that tell a walker that she is approaching a step.
14. The stair rails edge should not be steep, that risers should be of uniform height and treads should be of uniform width.
15. The handrail should be so constructed and fitted as to be capable of being readily gripped by hand and safely used.
16. Handrails are essential and they need to be a size and shape that makes them easy to grip.
17. There should not be any deceptive visual cues, inadequate lighting levels, glare, or any other sort of visual misinformation present in the stair rails.
18. The ends of stair rails, handrails and mid-rails shall be constructed so as not to constitute a projection hazard.
19. The handrail should be so constructed and fitted as to be capable of being readily gripped by hand and safely used
20. The effectiveness of tactile, auditory, or other sensory cues for warning handicapped users of the presence of a stair rails should be determined.
21. The hand grip portion of handrails shall be limited in cross-sectional dimension as noted and shall have a smooth surface with no sharp corners.
22. Avoid use spiral stairs or winders in residential buildings.
23. Clearance at brackets - the points at which the supporting brackets attach to the stair rails should be positioned so that they will not interfere with the user's fingers, and cause him to lose his grip.
24. The shifting of visual focus increases perceptual errors, thus, stair rails should be designed in a way that draws the user's attention to important features of stairways, rather than to any event or activity within the space. While focusing visual.
25. The stair rails should be available at all points throughout the flight, placed at a height within the user's reach, and structurally capable of supporting the user's weight under impact.

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