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THE USE OF NANO-GLASS IN PASSIVE FIRE SAFETY IN BUILDINGS

Sara Gawdat*, Akram Farouk, Ayman Farid

Architecture department, Faculty of Engineering, Ain Shams University

Correspondence: saragawdat22@gmail.com

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ABSTRACT.

There are many solutions for building materials to act against fire through the use and integration of passive and active technologies inside the building. Nanotechnology (technologies that depend mainly on nanostructured materials) can play an effective role in passive fire safety as the properties of materials can greatly enhance fire resistance quality and fire retardancy; creating more safe environments when exposed to fires. This paper focuses on exploring nanotechnology-based materials that can considerably improve fire protection and prevention strategies in the building and construction sector. The paper examines identified use of combining various chemicals with nanotechnology, which focuses on the use of Nano-Glass, to support design and safety planning in architectural buildings. These plans have a great influence on protecting the occupants' lives and properties during fire situations. Based on the assessment, recommendations are given to further explore and test the advantages of nanotechnology in developing Nano-based finishing materials for the enhancement of life safety in buildings.

KEYWORDS: Flame retardancy, Passive fire safety, Nano-glass.

استخدام زجاج النانو فى الحماية من الحريق فى المبانى

سارة جودت, أكرم فاروق,أيمن فريد

قسم الهندسة المعمارية, كلية الهندسة, جامعة عين شمس

البريد الالكترونى: saragawdat22@gmail.com

الملخص

هناك العديد من الحلول لمواد البناء للتصدي للحريق من خلال استخدام ودمج الاساليب السلبية والميكانيكية داخل المبنى. يمكن لتقنية النانو (التقنيات التي تعتمد بشكل أساسي على المواد ذات البنية النانوية) أن تلعب دورًا فعالاً في الحماية السلبية من الحرائق حيث أن خصائص المواد يمكن أن تعزز بشكل كبير جودة مقاومة وتثبيط الحريق ؛ خلق بيئات أكثر أمانًا عند التعرض للحرائق. تركز هذه الورقة على استكشاف المواد القائمة على تكنولوجيا النانو التي يمكن أن تحسن بشكل كبير استراتيجيات الحماية من الحرائق والوقاية منها في قطاع البناء والتشييد. تفحص الورقة الاستخدام المحدد لمواد كيميائية مختلفة مدمجة مع تقنية النانو ، والتي تركز على استخدام زجاج النانو ، لدعم التصميم

وتخطيط السلامة في المباني المعمارية. هذه الخطط لها تأثير كبير على حماية حياة وممتلكات المستخدمين أثناء حالات الحريق. بناءً على التقييم ، يتم تقديم توصيات لمزيد من استكشاف واختبار مزايا تقنية النانو في تطوير مواد التشطيب القائمة على النانو لتعزيز سلامة الحياة في المباني.

الكلمات المفتاحية : تأخير الحريق, الحماية السلبية من الحريق, الزجاج النانوى

1. INTRODUCTION

As part of the world's recognition of the role of technology in advancing the use of materials in favor of human comfort and safety; nanoscience has enabled revolutionary change in numerous sectors of industries such as furniture, electronics, building materials, fabrics, and others. This manipulation of matter at the nanoscale has revolutionized our contemporary technology in many sectors; especially in material design, building methods, and architectural perceptions.

Nanotechnology has become the cutting-edge technology of the 21st century. Based on the advanced material technology. It is proven that nanostructured materials are capable of breaking down the uncontrolled environment that occurs during a fire.

This study investigates the value of contemporary advanced technologies in using Nano-finished materials for the safety of buildings, specifically during fire situations. For specify, Nano glass is studied as a material example that presents a higher level of interior transparency, flexibility, and better quality security in buildings. The study is divided into the following main parts;

- Literature review which sheds light on a) Fire safety and fire retardant materials from the architecture perspective b) Nanomaterials and their types according to their composition, dimensions, and significant properties.
- The definition of nano glass as a case study material and examples of the use of Nano glass in buildings concerning the design and safety perspectives featuring works of different architects.
- Conclusions and recommendations

2. METHODOLOGY

The study methodology is focused on case study analysis to confirm the positive relationship between the use of nanomaterials (specifically nano glass) and fire safety planning in architectural buildings. This is achieved through a literature review of the concepts and applications of fire safety in architectural buildings, nanotechnology, its applications in architecture, and the most significant features for Nano flame retardants. The study then shifts to analyze the role of Nano flame retardant glass in selected case study buildings and the relation towards enhancing life safety respecting the design and aesthetic aspects to draw conclusions and recommendations.

3. RESULTS AND DISCUSSION

3.1. Literature Review

3.1.1. Fire safety in buildings

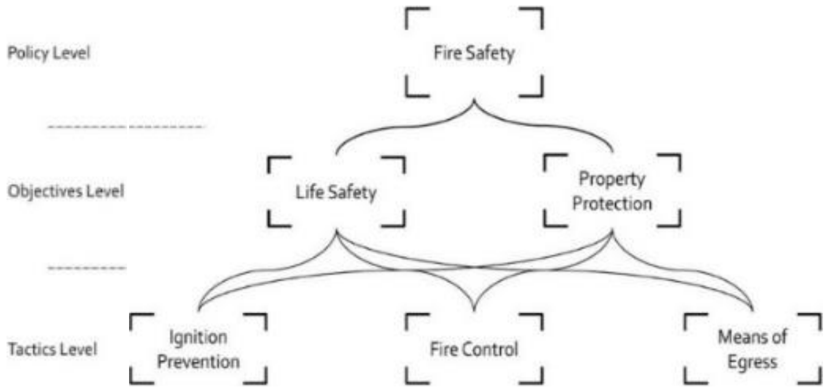

Figure 1. A simple Fire Safety Hierarchy [12].

Fire safety represents one of the most demanding challenges in the design of any project due to the crucial role it plays in the protection of human life and the safety of the property. [1] To maintain the safety of occupants and the preservation of property in the event of a fire in a building, a blend of passive and active techniques is used. A passive fire system is a cohesive component of the design and construction of the building that will be discussed in this paper [2][3][4].

In the passive fire safety approach, preventing fire ignition is the first layer of protection. The second layer, in the event of not being able to prevent the fire, is to minimize its negative effects on occupants, properties, and building structures [1].

One method of limiting the spread of fire is to divide different areas of a building into fire zones and ensure that each fire zone’s external walls are made of fire-retardant materials. This will help prevent the spread of fire from one fire zone to another. Moreover, smoke stop doors - leading to and from the fire cells- and the principal evacuation routes must be remained closed at all times. When these doors are kept open, it puts the occupants at risk. Since smoke is frequently dark and has poor opacity, it is recommended to use self-closing doors [5]. The direct result of ignition is smoke, which is made up of hot, unstable gas. Any path it encounters will enable it to rise and spread. Although its density may vary depending on the type, in most cases the victims suffocate from smoke before they are exposed to the fire's real heat or flame.

3.1.2. Fire retardant materials

Many people are unaware that their television, sofa, mattress, and computer are all made mainly of plastics, which were originally made from oil products. Many of these products could be ignited by a simple short circuit or cigarette and would quickly turn into a burning mass. Such flammable materials are treated with chemicals known as flame retardants to make them less flammable. They are made to reduce the chance that a fire would ignite when they come into contact with a mild heat source, like a cigarette or electrical defect. The flame retardant will slow down the burning process and commonly stop the spread of the fire to other items saving lives, properties, and surroundings.

There are numerous various substances employed for this purpose since "flame retardant" refers to a function instead of a chemical category. Due to the vast diversity in nature and morphology of the objects and materials that must be made fire safe, a wide range of products is required. For instance, the physical, chemical, and combustion characteristics of plastics vary widely. Consequently, to maintain essential material capabilities, they must be paired with the right flame retardants. To assure the fire safety of a variety of materials, such as foams in furniture, foam, mattresses, plastics, mattresses, fiber insulators, and wood items, as well as natural and synthetic textiles, flame retardants are therefore required. These materials, for instance, are utilized in vehicles, aircraft, and building parts [6].

Flame-retardants assist combustible materials and final products achieve strict fire safety standards set forward by regulations and examinations. The use of flame retardant materials frequently satisfies the practical and decorative needs of the client while also providing the most cost-effective solution, even if fire safety can sometimes be achieved by employing non-combustible materials or by design and engineering strategies [6].

Intumescent fireproofing and cementitious fireproofing are the two most widely used passive fireproofing mechanisms. The table below shows the main differences between the two types.

3.1.3. Nanomaterials

Nanotechnology enabled the production of nanomaterials. Some materials contain at least one dimension that is less than 100 nm in length, width, or height. Nanomaterials composites display exceptional chemical, physical, and biological properties at this scale. The typical way to categorize nanomaterials is based on their dimensions, which range from zero to three, depending on the type of material. Examples of zero-dimensional nanomaterials include nanoparticles, one-dimensional Nanorods and nanotubes, two-dimensional Nanocoatings, Nanofilms, and three-dimensional nanocomposites and nanocrystals. The structure of the particles concerning one another, rather than the size of the material, is primarily responsible for the assortment, which is harder to characterize as the level of dimension increases [7].

In this sense, the most significant benefits of nanomaterials are improving existing materials by preventing them from damage, decrease in manufacturing processes, minimizing the need for maintenance (and as a result decreasing CO_2 emissions), in addition to the reduction in raw material use, energy consumption, preserving resources, environmental protection which leads to economic improvement [8].

The primary cause of the highly noticeable attitudes and behaviors that materials demonstrate at the nanoscale is the qualitative diversity in the actions of these materials. Examples of such include: The relative ascend in the surface area; as materials at the nanoscale develop a significant surface area relative to their volume. Furthermore, "Quantum confinement" Nanoscale uniqueness in materials controls "wavelike" quantum mechanical characteristics of electrons. Additionally, materials' arrangement at the nanoscale has a significant impact on their capabilities making them significant from those at the macro and microscales. This includes magnetic properties, freezing, and melting temperatures, and charging potential, without changing their chemical structure [9].

3.1.4. The Possible role of nanomaterials in life safety

In light of the literature review, there are numerous ways to employ nanotechnology in the protection of buildings from the impacts of fire. As explained, the quality of materials can significantly improve fire resistance strength, and flame retardancy, and can produce spaces with enhanced safety when subjected to fires. Accordingly, technologies that rely on nanoscale materials -with their advanced characteristics- can provide effective solutions that improve fire prevention measures. The quality and efficiency of saving occupants' lives and property can be improved by combining numerous chemicals with nanotechnology.

3.1.5. Case study: The use of Nano-Glass as a fire retardant in architectural buildings

In architectural buildings, most heat gain and loss take place on the glass external building skin. Architects also employ glass for special design purposes. Nanotechnology focuses on the enhancement of glass properties [10].

In the Nano field, glass is introduced with fire safety specs equipping it with functional films of thickness 3mm positioned between glass sheets. This customization enables the glass to act as a fire barrier for more than 120 minutes, withstanding flames of more than 1000℃.

A patented Nano technological technique was used in the early 1990s for forming silicate fire-resistant materials in fire safety glazing. The company that produces Nano silicate raw materials developed a sophisticated fabrication process using nanoparticles with a size less than 70 nm, producing slim, stable, and very clear fire-resistant glass providing 120 min.

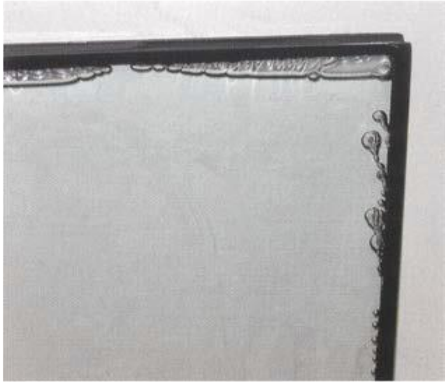

Figure 2. A robust sandwich panel when exposed to fire the product [8].

In case of exposing the product to fire, it turns into a fume and then is extinguished, and the Nano silicate composes a non-transparent shielding coat facing the fire. In addition, the availability of "flush glazing" with single parts attaching without any vertical mullions. Moreover, the fire-resistant lightweight structural panels and sandwich structural elements made of straw and hemp are promising products. In case of fire the material doesn't burn but char [8].

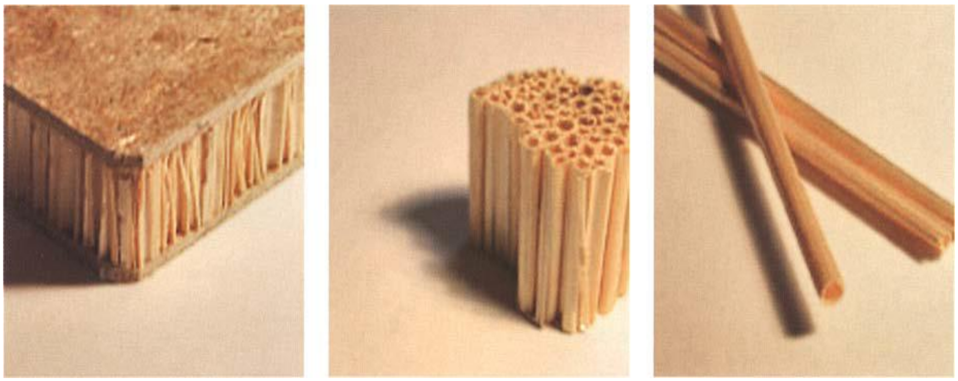

Figure 3. The gel fill material in the glazing cavity (here faulty but clearly visible) foams when exposed to fire for an extended period [8].

3.1.6. Application for the use of Nano-Glass as means to support fire safety in architectural buildings

3.1.6.1 One Central, Dubai World Trade Centre, Dubai, U.A.E

"One Central" is a 38- story commercial complex that has won awards for creating Dubai's Central Business District's unique skyline. The development of the site is strategic. The mixed-use site presented a significant design challenge.

The lift shaft is typically located in the center of mixed-use high-rise skyscrapers, and each floor's lift lobby is divided by glass doors. If the lift lobby is not "compartmentalized" as a fire zone, flames and smoke can travel through these shafts to any floor of the structure. Due to the significant pressure difference, the shafts behave as chimneys, which causes the fire to spread quickly to all floors of the building. As a result, in one central location, the use of a passive fire-resistant glazing solution was implemented in lift lobby sections using the nano-glass solution.

Contraflam 60-3/4, an EI 60 fire-resistant glass from Vetrotech, is used to compartmentalize the lift lobbies [11].

Figure 4. An interior view in central Dubai world trade Centre [11]**.**

Figure 5. An interior view in central Dubai world trade Centre [11]**.**

3.1.6.2. Zugspitze Mountain Station, Eibsee, Germany

With the opening of the Panorama 2962 summit restaurant in July 2018, the modification of the mountain station for the new Bavarian Zugspitze cable car line was finished. The latest addition to the structure on Germany's tallest mountain, designed by Hasenauer Architects, offers breathtaking panoramic vistas because of its wide glazing. Safety is guaranteed at the mountain station with Vetrotech Saint-Gobain fire-resistant glass panes.

Anything but ordinary: The new Bavarian Zugspitze cable car line is an extraordinary project in terms of both structure and general needs. It was ultimately finished in July 2018 with the opening of the restaurant at the mountain station.

The project was faced with numerous difficulties due to the project's altitude, the weather at the Zugspitze peak, geological considerations, and logistics. This held for the installation of the fire-resistant glass panes from Vetrotech Saint-Gobain, which, like all other materials, had to be transported to the mountain station. The 176 square meters of Contraflam glass panes that Vetrotech Saint-Gobain provided for the station's multiple superstructures prioritize safety at the intersections of different areas of use as doors, windows, or fire-protection walls. (Saint Gobain, n.d.).

Figure 6. The Zugspitze Mountain Station designed by Hasenauer Architects [11]**.**

3.1.6.3. Nordea Headquarters, Copenhagen, Denmark

Nordea, a major Nordic financial institution, is relocating to its brand-new Danish headquarters in Copenhagen's up-to-date Orestaden neighborhood.

Over 1'600m^2 of Contraflam Lite Structure EW30 solutions were provided by Vetrotech. The building's gorgeous and light-filled atriums, which are ringed by an amazing installation of fire-resistant glass up to the sixth level, were among the many things made possible by Vetrotech glass [11].

In line with the above examples, it is shown that several important architectural buildings sought the use of Nano-glass material to support design and fire safety objectives. The comparison of the case study buildings is summarized in the table below.

Figure 7.A focused shot for Nordea headquarters [11]**.**

Figure 8. A focused shot for Nordea headquarters [11]**.**

Table 2: Comparison between the Case study examples regarding the building occupancy, the material used and its achievements (By author).

Case			Location	Completion	Client		Occupancy						No. of stories	Area of installed product	Fire retardant material					Projects' achievements								
					Public	Private	Residential	Assembly	Educational	Health care	Mercantile	Business			EW Contraflam 30	EI Contraflam 30	EI Contraflam 60	EI Contraflam 90	EI Contraflam 120	Sound reduction & acoustic comfort	Pressure equalized glass	Aesthetic factor	High clarity demand	Tight timelines for delivery, execution, and hand-over at site	Butt-joint glass partitions	Customized design glass panel	Oversized glass panel	Special site conditions
1		One central, Dubai world trade Centre,	Dubai, U.A.E.	2021				●	●		●	●	38				●			●	●		●	●				
2		Zugspitze mountain station	Eibsee, Germany	2018		●			●			●	3	176m²		●					●		●					●
3		Nordea Headquarters ,	Copenhagen, Denmark	2017		●						●	6	1600m²	●					●		●	●				●	

CONCLUSION AND RECOMMENDATIONS

As glass is one of the most significant non-structural materials that architects use in all buildings. And as shown in the examples displayed, the integration of Nanomaterials with finishing materials in buildings has improved their properties and provided them with higher fire-resistance capabilities. This enables us to place glass wherever the design needs rather that using traditional fire-retardant materials while planning for implemention of fire safety strategy in buildings. Architects would then be able to give the needed attention to the optimum finishing materials that serve the space and design requirements as Nano glass can act as a fire and smoke barrier and guarantee the highest safety levels in buildings.

Therefore, Nano flame retardant glass is highly recommended to be involved in the construction industry due to its capability of preserving the aesthetic factor without affecting the safety factor in buildings.

In recommendation, architects and designers need to involve nano glass in the local market, as it can can introduce high resistance to fire, beside its aesthetic, acoustical and high clarity factors. By employing nanostructured materials, occupants and properties could be protected during a fire and other identified threats.

REFERENCES

[1] canadian wood Council, "Fire safety in residential buildings."

[2] D. D. Evans, "Active fire protection systems," *Nist Ncstar*, pp. 439–446, 2005.

[3] M. Lisa, "Active and passive fire protection system," vol. 1, no. 2010, pp. 1–7, 2010.

[4] S.-H. Wu, "The Fire Safety Design of Apartment Buildings," 2001.

[5] F. N. and J. L. Håkan FRANTZICH, "Risk Concepts in Fire Safety Design," *Engineering*, no. June, pp. 1001–1006, 2001.

[6] J. Troitzsch, "Flame Retardants.," *Kunststoffe - Ger. Plast.*, vol. 77, no. 10, pp. 90–91, 1987.

[7] A. Z. Aljenbaz and Ç. Çağnan, "Evaluation of nanomaterials for building production within the context of sustainability," *Eur. J. Sustain. Dev.*, vol. 9, no. 1, pp. 53–65, 2020.

[8] sylvia leydecker, *Nano materials in architecture, interior architecture and design*. 2008.

[9] R. Tureck, "An introduction to Nanoscience and Nanotechnology," *Music Lett.*, vol. 48, no. 2, pp. 196–198, 2017.

[10] M. Ezel, "Nanotechnology Innovations for the Sustainable Buildings of the Future," vol. 8, no. 8, pp. 886–896, 2014.

[11] Saint Gobain, "Vetrotech Contraflam." [Online]. Available: https://www.vetrotech.com/.

[12] V. Koutsomarkos, D. Rush, G. Jomaas, and A. Law, "Tactics , objectives , and choices : Building a fire risk index," *Fire Saf. J.*, vol. 119, no. April 2020, p. 103241, 2021.