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# ESTABLISHING A NEW RESTORATION STRATEGY TO USE NANOMATERIALS IN REVIVING DAMAGED BUILDINGS POST-DISASTER

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Nanotechnology, Nanomaterial, Restoration, Post disaster, Strategy.

# ESTABLISHING A NEW RESTORATION STRATEGY TO USE NANOMATERIALS IN REVIVING DAMAGED BUILDINGS POST-DISASTER


## Abstract

Nanotechnologies are a new solution of many problems of contemporary society, by creating products and processes for more specific uses with less environmental impact throughout their life cycle. The use of new technology such Nanotechnology in the restoration of damaged buildings post-disaster will be a contemporary solution to achieve sustainable development. After the explosion of Port of Beirut in August 4, 2020, it is necessary to search a new technology that restore and retrofit damaged buildings and in the other hand, to achieve the architectural quality, comfort and energy saving, in addition to its impact on energy consumption rates, its economy feasibility, in order to reduce primary energy consumption and greenhouse gases emission in the residential sector. The aim of this study is to establish a new restoration strategy depending on the use of nanomaterials to revive the damaged buildings due to the disasters. The results shows that the integration of Nanotechnology in the restoration and conservation of damaged buildings, we will achieve more efficient and durable built environment through balancing new technology with sustainability.



## Keywords

Nanotechnology, Nanomaterial, Restoration, Post disaster, Strategy.

## 1. INTRODUCTION

As mentioned by S. Prasad, H.C. Su, N. Altay, J. Tata, 2015, Disasters can cause an intensive disruption to livelihoods by the destruction of infrastructure, assets, by a break-down of lifeline systems like utilities, communication services and financial systems, additionally to a reduction of labor, and disruption of markets and provide chains. Also, the Department of Homeland Security in 2013 divided disasters into three principal categories, (Natural disasters, technological disasters and human-caused incidents).

In Beirut, an enormous explosion on August 4, 2020, at the Port of Beirut has damaged the town and also the population; facing already a socio-economic crisis, additionally to COVID 19 pandemic. More than 8,000 buildings were destroyed in Beirut, 640 buildings are considered historical, and 60 of those are in danger of collapse. A number of the damaged buildings are landmarks, like the Sursock Museum. Additionally to several old areas and edifices like Gemmayze and Mar Mikhael. (Auji H., 2020)

Nanotechnology could be a new approach to research and development, and it helps to manage the structure and fundamental behavior of matter at the atomic and molecular level. As mentioned by Sylvia Bedecked "Nanotechnology refers to the creation, investigation, and application of structures, molecular materials, internal interfaces or surfaces with a minimum of one critical dimension or with manufacturing tolerances of (typically) but 100 nanometers components ends up in new functionalities and properties for improving products or developing new products and applications." (Bedecked S., 2008)

Nanotechnologies are a new solution of many problems of latest society, by creating products and processes for more specific uses with less environmental impact throughout their life cycle. Today, it is needed to style and propose new sustainable nanomaterials and protocols to reduce the environmental impact. The employment of recent technologies such as Nanotechnology within the construction and restoration will be considered among the effective factors in establishing functional features of architecture including providing the sustainability of the country's cultural heritage.

This paper highlights the importance of nanotechnology and also the kind of nanomaterials uses for restoration and conservation of buildings post disasters, then, the research presents different case studies to demonstrate how we will use nanomaterials and nanoscale techniques to restore by taking different types of buildings in Beirut in the area damaged by the explosion of August 4 (restore artwork, restore cultural heritage and restore the all the interiors elements of the building), to realize in final steps the aim of this thesis which seeks to establish a new restoration strategy depending on the use of nanomaterials to revive the damaged buildings after disasters.

## 2. METODOLOGY

This study is based on a literature review and on an analytical, comparative, and qualitative studies.

Literature review on Nanotechnology and Nanomaterials, in addition to the use of nanomaterials in the restoration of damaged buildings after disasters.

An analytical and comparative study, it includes the analyzes to how we can restore buildings damaged by studying 2 practical case studies (SURSOK MUSEUM IN ASHRAFIEH and Saint George Hospital) and applying the using of nanomaterials and techniques needed after disasters to preserve the architectural value and to reduce the energy consumption.

This stage is based on:

- Site visit to the area damaged by the explosion.
- Selection of the data referring to the social media.
- Referring to the report of UN-habitat /NRC and others.
- Basing on the current restoration of damaged buildings, to compare with the restoration by using nanotechnology.

At last, a strategy, recommendations and conclusion in order to evaluate the most efficient materials to preserve the sustainability of different types of buildings and to evaluate the application of such approach on future application and in Lebanon current situation.

# 3. LITERATURE REVIEW

## 3.1. Nanotechnology Definition

Nanotechnologies are a new approach to research and development in order to control the structure and fundamental behavior of matter at the atomic and molecular levels, as mentioned in Figure 1.

Nanotechnology: “Nano” from the Greek word Nanos (Latin nanus) meaning “dwarf”.

The definition is given by the German Federal Ministry of Education and Research (BMBF)

Summarizes nanotechnology as follows: Nanotechnology refers to the creation, investigation and application of structures, molecular materials, internal interfaces or surfaces with a minimum of one critical dimension or with manufacturing tolerances of (typically) but 100nanometers. The determinant is that the very nanoscale of the system components ends up in new functionalities and properties for improving products or developing new products and applications. (Sylvia Bedecked, 2008)

Referring to Mendez (2006), the sector of nanotechnology is predicated on three different aspects: first, is dimension oriented Nano technological interventions, where scientists are working to make smaller and smaller devices and structures, to realize Nano metric-scales; second, is operation oriented Nanotechnological interventions, where scientists also are attempting to find new characteristics of materials by modifying them at atomic or molecular scale; and third, is fabrication oriented Nanotechnological interventions, where bottom-up assembly or molecular self-assembly, in other words, the union of atoms and molecules seek to form a replacement more complex structure. (Mendez 2006, p.22)

Nanotechnologies are a replacement solution of the many problems of latest society, by creating products and processes for more specific uses with less environmental impact throughout their life cycle.

## 3.2. Historical Background

Many people allege that Feynman's 1959 vision launched nanotechnology, but the reality is that nanotechnology has been around for billions of years.

Without having any knowledge about nanotechnology the Romans have changed the elemental structure of the fabric by adding the silver-gold alloys and granting a new character to the existing material, the basis of nanomaterial science.

In addition, as mentioned by Veena SG Rao in 2018, Stained-glass windows found in medieval churches contain different size gold nanoparticles with the specific size of the particles creating orange, purple, red, or greenish colors. Also, Einstein, as part of his doctoral dissertation, calculated the size of a sugar molecule as one nanometer.


Fig.1: The nanoscale. Source: http://futureforall.org/nanotechnology/nanotechnology.htm

In a 1959 lecture, Nobel physicist Richard Feynman suggested that one might manipulate matter at the atomic scale, assembling "Nano machines" by direct manipulation of atoms. John Von Neumann envisioned self-replicating machines, prompting Eric Drexler, of the Foresight Institute, to link the DNA blueprint concept with the Nano machine concept, yielding fantastic sci-fi-like predictions like grey goo, an imagined man-made or accidental life-like self-replicating Nano-organism that devours the globe because it uses almost anything to make more of itself. (Nanopedia. http://nanopedia.case.edu. 2008)

### 3.3. The Advantages of Using Nanotechnology

The application of nanotechnology affords an added value, and additional functionality, in addition to market demand with the product development. Nanotechnology can be a good benefit to the following areas:

- Reducing the load and also the volume of materials.
- Increasing the efficiency of the materials.
- Reducing the upkeep cost and time (easy to clean, longer cleaning intervals).
- Reducing energy consumption and CO2 emissions.
- Conservation of resources, more comfort, and a Greater economy. (Ming Hu, 2015)

### 3.4. Nanotechnology Application in Architecture

Nanotechnology continues to be a fledging science but it is capable to alter the globe around us because it has been forecast a very promising future. (Leydecker.,2008)

Nanotechnology can be used for design and construction processes since nanotechnology products have many unique characteristics.

Nano architecture is that the alteration of architecture within the new Nano revolution within the 21st century. The employment of nanotechnology in architecture depends not only on the materials, the equipment, but also on the shape and style theories, shown in Figure 2.

The main characteristics of nanotechnology used in the architecture utilized in the following:

- Structural composites lighter and stronger
- Coating with low maintenance.
- Better properties of cementitious materials
- Reducing the thermal transfer rate of fireplace retardant and insulation
- Increasing the sound absorption of the acoustic absorber.(Chikute G.,2017)

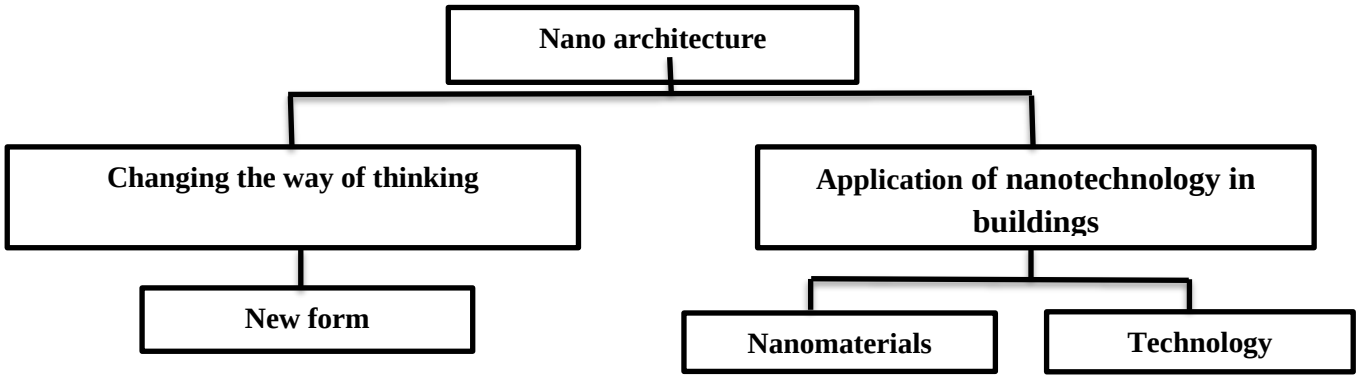



Fig.2: Nanotechnology in architecture. Source: researcher based on: El Samny M.(2008)

**Application of Nanotechnology in Architecture**

1-Project: Nano-House

The Nano House Initiative was conceived in 2002 by the Institute of Nano-scale technology in Australia. Visualized and implemented by architect James Muir. The most objective of this project is to attain more sustainability in our houses models supported nanotechnology materials and techniques, by using Self-cleaning coated glass, electrochromic glass, and photovoltaic cell, additionally to the wide selection of Nano based materials.

Fig.3: A 3D model for the proposed Nano house. Source: Mohamad S., 2014

Material effect:

1. The used electrochromic glass is ready to vary its transparency degree from opaque, semi-transparent to transparent.
2. Self-cleaning glass will reduce maintenance cost and energy and keep buildings' surfaces clean.
3. Cold lighting systems and the photovoltaic solar cell will be used too in order to reduce the building's energy consumption. (Mohamad S.,2014)

## 3.5. Identifying the Nanomaterials Used in Architecture

The nanomaterials are suitable materials for architectural, because of their consolidation and also the protection capacity of damaged building materials. The nanoparticles are able to self-cleaning coatings, preserving the first aspect of treated elements, decreasing the deposition of pollutants and soiling, and reducing the beginning of external degradation processes because of soiling phenomena. The nanoparticles must have the subsequent properties: thermal stability, biologically and chemically inertness, non-toxic, low cost, stability toward visible or near UV light, good adaptability to various environments, and good adsorption in the solar spectrum.

According to current researches and applications that covered nanomaterials, we are able to classify materials that are employed in architecture into structural and non-structural materials, coatings, lightings, and insulations, shown in Table 1.

Table 1: Nanomaterials used in architecture. Source: Researcher based on Sylvia Leydecker, 2008

| Classification | TYPE | PROPERTIES |
|---|---|---|
| Structural materials | Nano-concrete | -Self-healing concrete<br>- Translucent Concrete |
| | Nano-Glass | - more strengthening of glass<br>- reduces the energy consumption<br>- saves energy and naturally provides sunlight<br>- supply electricity to every corner inside our buildings |
| | Nano-Steel | -reduces the cost of reinforcing steel used in the concrete<br>-Flexibility in design,<br>-large spaces without supporting structural elements<br>-reducing Co2 emissions and maintenance costs |
| | Nano-Wood | -flexibility and formability and treated with nanomaterials<br>- to improve its performance and increase the duration of its use |
| Non-structural materials | Thermo, Photo and Electro-chromic nano glass | -reduces the effect on the environment<br>-gives more aesthetic to design<br>-provides internal comfort<br>-change its transparency and its energy production |
| | Nano-Polymers | High hardness, light weight |
| | Nano- Sensors | - more intelligent building<br>- everything could be defined by temperature, and color of wall based on<br>the non- visual signals among Nano- sensors |
| | Nano- textiles | Generating the energy depending on light elements integrated |

| | | |
|---|---|---|
| | | with the textiles. |
| | The Nano-lighting | -improve the internal climate and energy used,<br>-Using wonderful designing methods to reflex a definite thought |
| | The Nano-solar energy | -transform the solar energy to the electric energy |
| Coatings | | -Self-cleaning<br>- De-polluting<br>- Scratch-resistant<br>-Anti-icing and anti-fogging<br>-Antimicrobial<br>-UV protection<br>-Waterproofing |
| Lightings | Nanotech LED Lighting | -affects our perception and adds a visual experience to both exterior and interior spaces. |
| | Organic light emitting diodes (OLEDs) | - high level of flexibility and efficiency in design,<br>-energy saving<br>- Various colors are available and the quality of the emitted light is high. |
| Insulations | Nano gel | -Provides a combination of thermal and sound insulation,<br>- Light transmission and diffusion characteristics. |

### 3.6. Port Beirut Explosion August 4, 2020

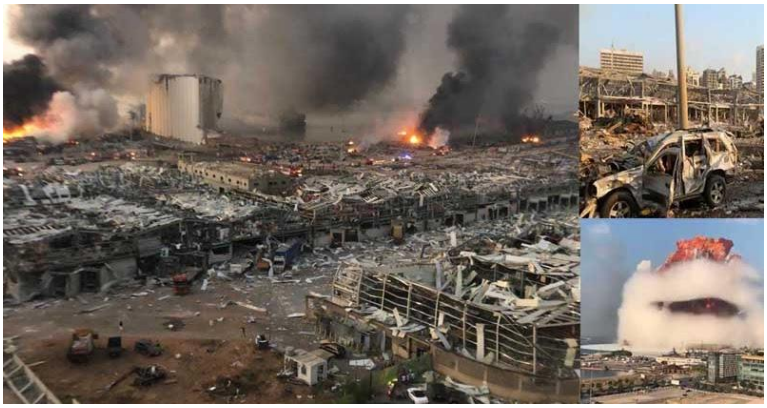


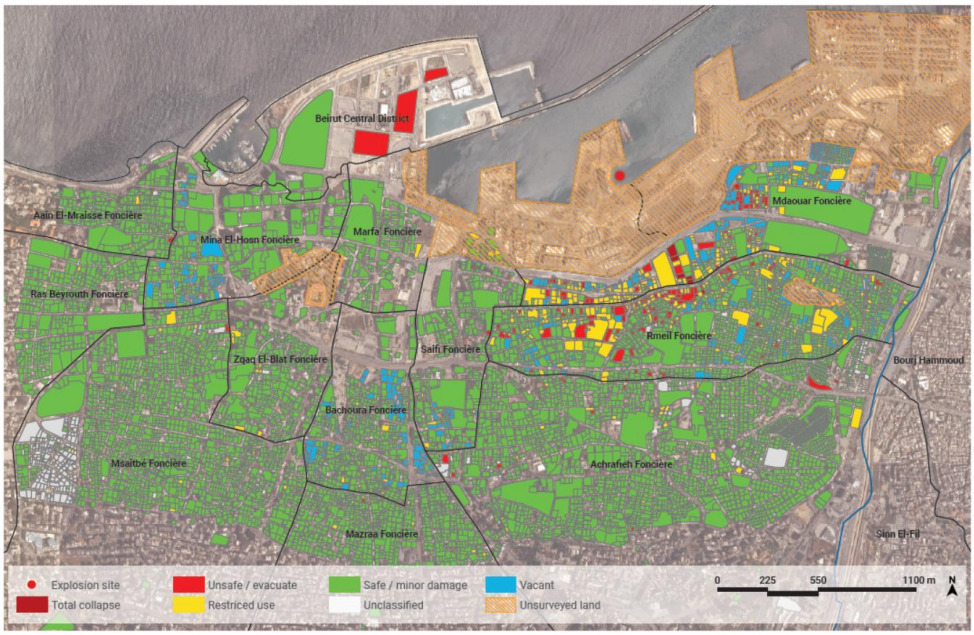
Fig.4: Beirut Explosion August 4, 2020. Source: Wikipedia

The date of August 4, 2020 has special meaning for the people of Beirut and surrounding. An outsized explosion occurred near a port in Beirut, Lebanon, that caused an in-depth suffering to the people of the town and damaged the cultural and physical fabric, additionally, to the death quite of 200 persons.

The 2020 explosion caused a horrific loss of life, extensive destruction to the built and natural environments, and had a serious impact on the livelihoods in Beirut and the surrounding.

This massive explosion on August 4 killed a minimum of 191 people and damaged quite 6,000 buildings include around 350 historical buildings, of which over 90 were in danger of collapse.

According to the third weekly report issued by the Order of Engineers and Architects dated 9/9/2020, 14.1% of heritage buildings within the surveyed area are at high risk of collapse/damage, while 11.3% are at mid-risk of collapse/damage. This means that just about a quarter of the surveyed historic buildings in the port vicinity were damaged by the blast.




Map 1: Detailed map showing damage categories of assessed plots as of 5 September 2020. Source: UNHABITAT, 2020.

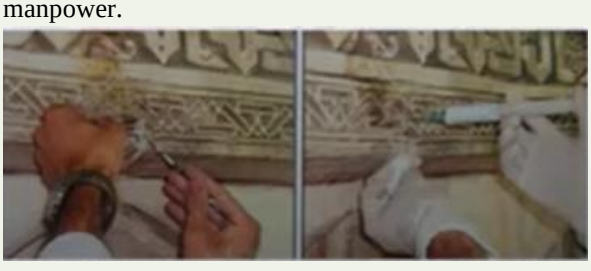
## 3.7. Using of Nanomaterials in The Architectural Restoration

The using of nanomaterials in the architectural restoration is classified as follows:

A- Restoration of cultural heritage (artifact/wall painting)
B- Restoration of buildings damaged by disasters.
C- Restoration of historical buildings.

Table 2 shows that the different method of restoration has many advantages and disadvantages, but the using of Nanomaterials in the restoration process is more sustainable and durable than the other traditional methods.

Table 2: Advantages and disadvantages of new and traditional techniques. Source: Researcher based on الحلو إ.(2020) تقنيات النانو في حفظ ديمومة الابنية الاثرية في العراق

| **New Techniques ( Nanomaterials)** | **Traditional techniques of restoration** |
|---|---|
| **Advantages:**<br>1-Contribute the prolonging the life of the building<br>2- Access to highly environmentally efficient buildings<br>**Disadvantages:**<br>1- Exposure to the dust of this compound during manufacturing and for long periods of time maybe causes cancer.<br>2- The high price of materials additionally to the lack of manpower.<br>  | **Advantages:**<br>**1-**The same original materials<br>2-newly manufactured materials<br>**Disadvantages:**<br>**1-** The buildup of successive reforms that lose archeology their originality<br>2-The traditional material must follow up and maintain periodically looking on the age of the materials utilized in the restoration.<br>  |

**A- Restoration of cultural heritage( artifact/wall painting):**

Restoration of works of art has been a constantly evolving pursuit in which Nano-based techniques play increasingly valuable roles. Nano-dispersions of solids, micelle solutions, gels and micro-emulsions offer new reliable ways to revive, and restore works of art by merging together the main features and properties of soft-matter and hard-matter systems, allowing the synthesis of systems specifically tailored for the works of art to fight the deterioration processes which threaten many priceless masterpieces, as shown in Figure 5.

Fig.5: Brancacci chapel in Florence: painting by Masaccio before and after the removal of wax spots. The left image shows a wax spot under UV light. Source: P. Baglioni, E. Carretti, D. Chelazzi, L. Dei, R. Giorgi, S. Grassi, A. Macherelli, B. Salvadori.

**B- Restoration of Buildings damaged by disasters**

**Case study: Restoration of the main and eastern façade of Al Mahali Mosque in Egypt after the earthquakes and the environmental conditions**

The earthquakes affected an oversized kind of structural systems; Historic brick masonries are exposed to aggressive environmental conditions especially the bottom water rise, as mentioned in Figure 6. The building materials within the heritage buildings during this city are suffered from many damage factors and also the forces of harm and unbalance, which caused the damage. Al-Mahalli mosque is taken into account the biggest central mosque within the city is threatened damaged. (Hemeda S., 2018)

Fig.6: AL Mahali Mosque using Nanoetchnology. Source: Hemeda S.,2018

The restoration process during this building is by using Nano-Silicia to treat the red bricks within the main elevation, additionally to Nano-Titanium with other nanoparticles.

**C- <u>Restoration of historical buildings:</u>**
**Case study: Restoration of Albergo dei Poveri in Genoa:**

The Albergo dei Poveri in Genoa, built between the mid-seventeenths to the mid-nineteenth century, it's owned by a personal institution and located, within the late nineties of last century, to the University of Genoa which has taken charge of the renovation and reuse operations, with a view to establishing the teaching and departmental headquarters of the schools of humanities.

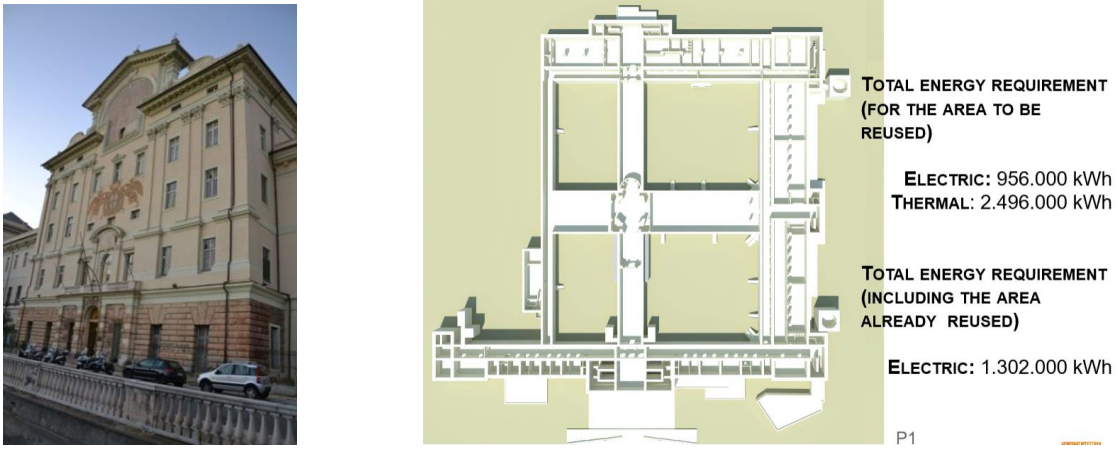



Fig.7: Energy requirement in Albergo dei Poveri. Source: G. Franco , A. Magrini , M. Cartesegna , M. Guerrini ,2015

The restoration process in this building is by employing better insulation, additionally to the restoration of windows. The use of nanotechnology aimed to increase the energy performance of the building envelope, possible interventions considered were insulation of the ground on the bottom, combined with interventions to eliminate rising damp, insulation of roofing systems, and enhancement of the energy performance of external windows. (G. Franco , A. Magrini , M. Cartesegna , M. Guerrini, 2015)

## 4. APPLIED STUDY: BEIRUT-AREA OF EXPLOSION

### 4.1 Parameters (Framework of Analysis)

In general, the interventions in damaged buildings by using nanomaterials should be in many components of these buildings to achieve sustainability and to retrofit the energy consumption in these buildings. These components are windows, furniture, painting, artworks, wood, wall partitions, insulation, and solar protection, as shown in Table 3 below;

Table 3: Nanomaterials proposed to use in the case studies. Source: Researcher, 2021.

| **Parameters (Framework of analysis)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Nano-Coating Paint | Nano-coating for wood | Nano-coating for wall covering | Nanomaterials in Furniture | Nano-coating for tiles | Nanomaterials in Windows | Nano-insulation | nanoparticles to restore works of art | Solar protection (KALWALL/NANOGEL) |

### 4.2 Criteria of selection

The criterions of selection are as the following:

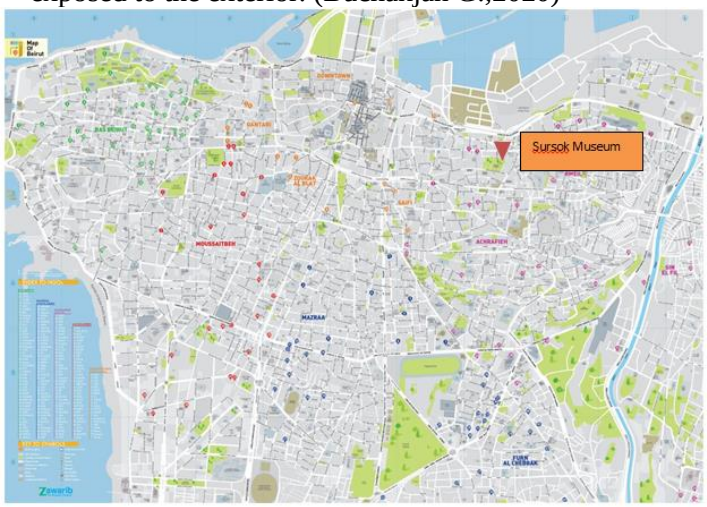
- Buildings of a distinct design nature of architectural importance.
- Diversity of study cases, like residential buildings, historical buildings, hospitals.
- Location within the area damaged by the explosion of August 4.

- Because of the explosion of 4th august in Beirut, we choose 2 case studies to analyze it, the 1st case study is the Sursok museum (historical building includes the restoration of works of art), and therefore, the 2nd case study is Saint George Hospital.

## 4.3 Case Study: Sursok Museum

### 4.3.1 Background of Sursok museum

The Sursock Museum opened its doors in 1961 with the Salon d'Automne, an open call exhibition showcasing new art of the time. The explosion of August 4, 2020, was damaged the Sursok museum which will not damage during the war. At the Sursock Museum, the inside of the museum is nearly completely destroyed," said Elsa Hokayem, the museum's deputy director. "The wood, the lamps, the doors and 25 works of art are damaged." the explosion blew within the windows, ripping drawings, and paintings from the walls because it flung shards of glass and twisted metal around the century-old building. A folded black object manufactured from iron was stuck to the ceiling, as if it had been a contemporary sculpture, but it clothed to be a door. Within the library, the ceiling collapsed on the ground, leaving wooden panels and rare books exposed to the exterior. (Buchakjan G.,2020)




Map 2: Location of Sursok Museum in Beirut. Source: Researcher, 2021.

Fig.8: Damaged in Sursok museum, Source: Brown L.,2020

### 4-3.2 Application of Nanomaterials in the restoration of damaged buildings after disasters.

Nanotechnology is taken into account as the foremost important theoretical and applicative framework of human knowledge for the near future; breakthroughs are restricted to few applications, one being the conservation and restoration of cultural heritage and historical buildings.

The importance of the appliance of nanomaterials within the restoration process of Sursok Museum is to share the positive impact of this application is one of the important buildings in Beirut.

Due to the explosion, many components of the museum are destroyed, windows, ceiling, painting, artworks, wood, wall partitions,… Proceeding from this case, we propose some nanotechnology solutions to convert this special building to a sustainable building used nanotechnology and nanomaterials as mentioned in Table 4 below;

Table 4: Nanomaterials proposed to use in Sursok museum. Source: Researcher, 2021.

| Parameters (Framework of analysis) used in Sursok museum | | | | | | | |
|---|---|---|---|---|---|---|---|
| Nano-Coating Paint | Nano-coating for wood | Nanomaterials in Furniture | Nano-coating for tiles | Nanomaterials in Windows | Nano-insulation | nanoparticles to restore works of art | Solar protection (KALWALL/NANOGEL) |
| ✓ | | | | ✓ | | ✓ | ✓ |

**a. Nano coating paint:**

Nano coatings are used to develop the functions of surfaces and are also used to improve the properties, quality and work to branch the efficiency of the building, also to enhance the self-cleaning properties, insulation materials, fire resistance, bacteria, fog, and are used Nano coatings on materials to avoid wasting cost.

Nano coatings are versatile and might to use almost anywhere: Self-Cleaning, Lotus-Effect, Self-cleaning: Photo catalysis, Easy-to-clean (ETC), Antibacterial….etc

Fig.9: using of Nano coating paint in the interior spaces. Source: Researcher, 2021.

**b. Nanomaterials in Windows:**

The special colored windows in the Sursok museum were destroyed due to the explosion of August 4. We propose that the replacement of those windows is by the sun protection glass with a self-cleaning coating (TiO2) and fire protection. The building will use Nano-treated glass, which allows circulation by entering the sunshine in proportions to fulfill the needs. It reduces the entry of ultraviolet rays, and also distinguishes it with its dual function, it includes the protection feature from sunlight and self-cleaning by stimulation optical, because it saves maintenance costs and cleaning.

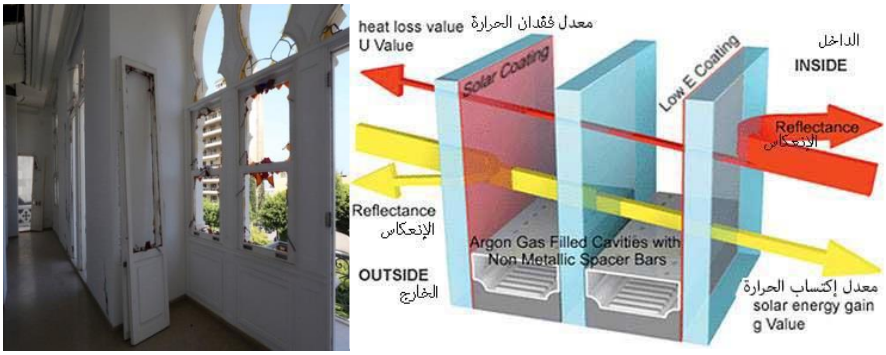



Fig.10: Nanomaterials in windows in Sursok museum. Source: Researcher Figure 11: Solar control glass is multi-layer. Source: Researcher,2021.

**c. Nanoparticles to restore works of art:**

Sursok museum is considered one of the buildings that store a giant number of cultural heritage, murals, artifacts, and others. This cultural heritage is damaged by the explosion of August 4.

Nano dispersions of solids, micelle solutions, gels, and micro emulsions offer new reliable ways to restore and preserve works of art by merging together the most features and properties of soft-matter and hard-matter systems, allowing the synthesis of systems specifically tailored for the works of art to fight the deterioration processes which threaten many priceless masterpieces.

Fig.12: cultural heritage damaged on Sursok museum. Source: Facebook page of Sursok museum.

**d. Solar protection (KALWALL/NANOGEL)**

KALWALL is a unique cladding and roofing system, it can diffuse natural daylight and transmitted it internally as 'museum quality' light. Also, it helps to eliminate shadows, and sharp contrasts, in result no need for external solar control or internal blinds and curtains. In addition, NANOGEL is a light-transmitting aerogel, aims to comprise about 95% air, in Nano-sized pores that prevent heat transfer. Aerogels are the world's lightest, and best insulating solids.

The advantages of KALWALL and NANOGEL are: diffusing natural daylight, changing the ambiance of interiors and is proven to have a fundamental influence on personal well-being, working and learning. These types of solar protection (KALWALL+NANOGEL) achieve a very low 'U' value of 0.28 W/m2K , also to achieve insulation values equivalent to a solid wall, while using large areas of translucent cladding or roofing.

The roof of the Sursok museum is destroyed, as shown in the figure below, for this reason, we choose to use Kalwall and Nanogel as roof system to diffuse the natural light, achieve an internal ambiance, and reduce energy cost.

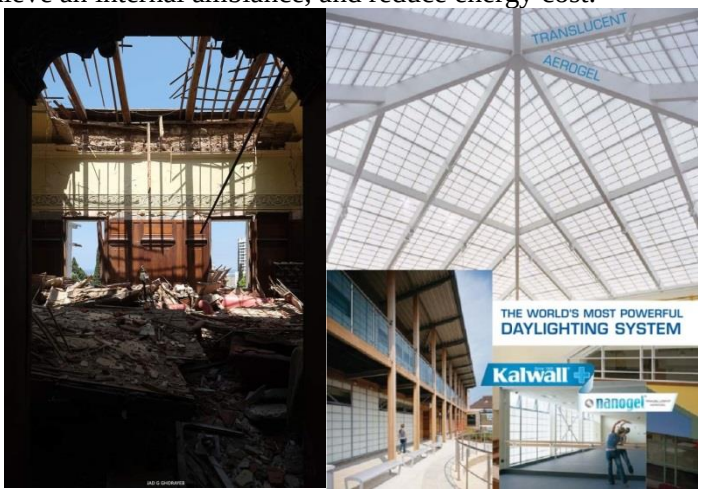
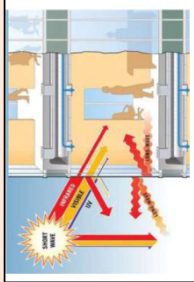
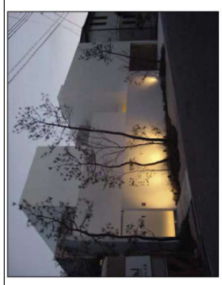
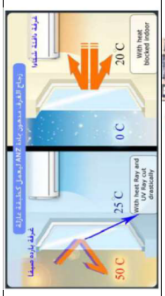



Fig.13: proposal to replace the roof of Sursok museum by Kalwall and nanogel roof system. Source: Researcher based on Manualz.com

## 5. NEW RESTORATION STRATEGY OF USING NANOMATERIALS IN BUILDING DAMAGED AFTER DISASTERS

In conclusion, the proposed nanotechnology material in the Sursok museum, should achieve the best quality of the internal spaces, in addition, to achieve zero carbon architecture.

| Name of material | Function | Properties | Typology of building | Building method | Environmental climate | Nanotechnology impact | Pictures |
|---|---|---|---|---|---|---|---|
| **Nano-glass** | -Self-cleaning coating(TiO2)<br>-Fire protection | - led to the strengthening of glass<br>- it helps in energy consumption<br>- saves energy and naturally provides sunlight<br>- supply electricity to every corner inside the buildings | All type of buildings | Using Carbon Nano tubes in structure of glass to create durable glass | -Hot climate<br>-Cold climate | -Generating energy<br>-Self Cleaning<br>-Zero water absorption and impermeable,<br>- Rich colors & wide applications |  |
| **Nano-coating paint** | -Achieve solutions to damage from nature and extreme weather conditions.<br>- Protection against pollution<br>-Improve the quality of air | -Easy-to-clean coatings (lotus effect),<br>-Anti-painting<br>-Anti graffiti coatings,<br>-Antibacterial<br>-Antimicrobial coatings.<br>-Fire proof | All type of buildings | - The TiO2 Fe 2O3 paint prepared exhibited good corrosion-resistant behavior in acid treatment test.<br>-Preparation of TiO2 Nano paint by embedding the TiO2 nanoparticles in alkyd resin matrix by using ball milling process. | -Hot climate<br>-Cold climate | -Self Cleaning<br>-Energy conservation paint<br>-Decrease in permeability to corrosive environment and hence better corrosion properties.<br>-Thermal and electrical conductivity. |  |
| | ANZ-G uses of liquid paint<br>-It acts as a heat insulating layer when applied to glass surfaces | -Achieve sustainable interior design<br>- Reduce the cost of electricity consumption | | heating the glass to over 1,000 degrees F, then rapidly cooling to lock the glass surfaces in a state of compression and the core in a state of tension | | -Saving 20% of the energy used in internal spaces<br>-More than 80% from the sun's rays over the red close are dispersed |  |
| **Nano-coating wood** | -Flexibility and formability and treated with nanomaterials<br>-Improve its performance and increase the duration of its use | -Improvement of durability<br>-Decrease of water absorption<br>-Improvement of UV absorption<br>-Improvement of mechanical properties<br>-Improvement of fire resistance | All type of buildings | Varnishes, lacquers, and paints are common coatings applied to wood surfaces; their role is both protective and decorative. | -Hot climate<br>-Cold climate | -Self-cleaning surface<br>-The contact area between water and wood is minimized -Surface adhesion reduced.<br>-Water rolls off instead of penetrating the wood.<br>-resistant to extreme environmental conditions such as very cold weather and snow. |  |
| **Nano-coating in tiles** | | - photocatalytic self-cleaning surface coating<br>-Anti-bacterial. | All type of buildings | Four layers consists nano-tiles:<br>1-flexible plastic mattress as supportive layer<br>2-coloured ceramic material application<br>3-printing is optional<br>4-ceramic top coating. | -Hot climate<br>-Cold climate | -Keep down the cost of cleaning.<br>-Photocatalytic self-cleaning surface coating. |  |

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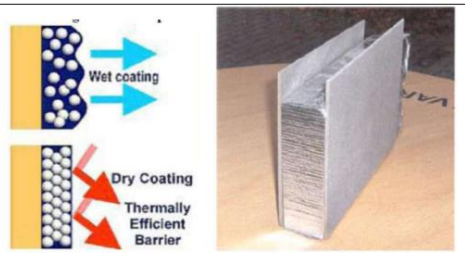
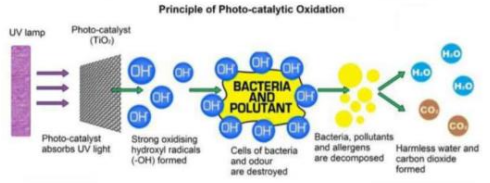
| **Nano-insulation**<br><br>**1-Nano Gel**<br>**2-Thin-Film Insulation** | -Providing industrial lighting, which reduces electrical energy consumption.<br>-Creating comfort in the internal spaces. | -It has high thermal insulation ability<br>-Provides natural lighting<br>- Sound insulator<br>- Improvement of UV absorption | All type of buildings | The panels are constructed as follows: an enveloping skin made of plastic foil (often coated with aluminum) or of stainless steel encloses the fill material in a vacuum. The fill material takes the form of a foam, powder or glass fibers. The hermetically weld-sealed ends protrude on each side and are usually folded back and stuck to the panel. | -Hot climate<br>-Cold climate | -Reducing electrical energy consumption through cooling and heating.<br>-Heat isolation for stability of the internal temperature efficiently isolates 2-8 from the traditional product. |  |
| **Nano-materials in furniture** | -High resistance against the effects of environmental<br>- Increase the rate of stability and hardness and make furniture surfaces anti scratch.<br>- Resistant to biological agents (fungi, bacteria, and insects).<br>- Water proof.<br>- Anti- soiling and self-cleaning.<br>- Resistant to Flame and / fire proof. | -Easy to clean<br>-Anti-bacterial<br>-Anti-fingerprints, scratch proofing<br>-Dirt-repellent | Hospital / hotel/offices / schools/ | Using TiO2 as antimicrobial, that helps it collect the ultraviolet light coming with sunlight or a light source, significantly increases its photoelectric activity. | -Hot climate<br>-Cold climate | -Self- cleaning.<br>-Anti-bacterial (covid 19,…) |  |
| **Nano-particles for art of work** | -Achieve light weight, more strength and durability<br>-Resistance to cracks and corrosion.<br>-Treatment and restoration. | -Maintain the stability of colors and degrees of thermal insulation.<br>-Resistance to UV and moisture resistance and be fog on the glass. | Historical buildings ( museum, cathedral, mosque,..) | A-The treatment of wall paintings is often performed in two steps:<br>1-the classical Ferroni–Dini method to revert chemically the sulfate salts to carbonate, inhibiting their migration, the application of a nanoparticle dispersion, which provides the right content of calcium hydroxide binder.<br><br>B-Nano-dispersions of solids, micelle solutions, gels and microemulsions offer new reliable ways to restore and preserve works of art by merging together the main features and properties of soft-matter and hard-matter systems | -Hot climate<br>-Cold climate | -Protection from wind, rain, and dust from atmosphere.<br>-Preserve the maximum amount of the original substance |  |

Table 5: Restoration Strategy to use nanomaterials to revive the damaged interior spaces due to disasters. Source: Researcher.

## 6. RECOMMENDATIONS

At the end of the research, we recommend a number of recommendations:

A. The necessity of searching for methods of settling nanotechnology in Lebanon.
B. The necessity of fostering this technology and focus on it in Lebanese Scientific Researches and experiences and to realize the economical role that such technology plays, and to establish specialized research centers in this field in the Lebanese universities .
C. Working on knowing and studying architectural uses of nanotechnology that is compatible with the Lebanese environment and local community.
D. Prepare a list of available Nano-materials in the Middle East market and Lebanese market, which can be used in the construction field and in the restoration process in the current situation.
E. Integrating nanomaterials with digital fabrication techniques in the restoration activities in the area of the explosion and in the conservation in building exteriors and interiors.
F. Towards more integration between nanotechnology and structural materials.
G. Using Nano building skin,
H. Integrating nanotechnology in the interior of buildings as anti-bacterial to eliminate the bacteria from the surfaces such COVID19.

## 7. CONCLUSION

A. Nanotechnology works to achieve sustainable interior design by improving the performance efficiency of existing buildings.
B. Nanotechnology contributes greatly to the rationalization of electrical energy consumption.
C. Nanotechnology contributes to working on the restoration of damaged buildings with highly efficient technologies and works to solve the problem of rationalizing electric energy simultaneously.
D. Nanotechnology has contributed to counteracting the complex design process and opening horizons for designing complex projects capable of applying these technologies from concrete to insulation and solar protection and other Nano materials.
E. Nanotechnology has contributed to improving and eliminating environmental pollution and is considered one of the effective solutions in dealing with the Coronavirus, through the ability to self-clean all components of the building interior and exterior and by controlling the process of entering the sun.

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