Semi-alive architecture “from healing to self-healing in architecture”

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Abstract. Buildings are exposed to external factors, time factor, and usage during their operational life that their sustainability, toughness, and shape get affected negatively. Those factors also reduce the reliability of building materials and technologies used in them since buildings are lifeless being and they don’t possess the properties of living beings. For decades, scientists tried to transform the properties of living beings to various science fields such as computing, architecture, and others. One of the most important properties is the ability of living beings to heal from damage and to resist external factors. The concept of healing in architecture refers to developing maintenance and preservation techniques but they remain traditional and don’t evolve to the concept of sustainability. Therefore, more attention has been given to making buildings possess self-healing property and making them sustainable so that they last for the most possible period while reducing maintenance costs and preserving them. Hence, this study is concerned with "the problem of the absence of a complete knowledgeable vision of the self-healing concept in architecture and that of transferring the properties of this concept from living beings to architecture", while the object of the study "is to transform buildings from being dead to being semi-alive those can specify and fix damage by themselves, so they can renew themselves or resist external factors". In order to achieve its objective, this study have taken the concept of healing in general and particularity in architecture form various angles, from the effects of healing on the user or the environment and also the effect on the building itself, to recommending traditional methods of maintenance, renovation, and rehabilitation to achieve healing. Also, the study was concerned with self-healing concept in general and how to achieve it in architecture with the aid of technological advancements via surveillance systems of the structural health, developments in building materials, self-assembly, and renewal and how it affected the designers' design strategy and philosophy. A comparison was also made between healing and self-healing methodologies in order to achieve sustainability in architecture before finishing the study with conclusions.

1. Healing in Architecture
1.1. The Idiomatic And Linguistic Definition of The Word “Healing”

The concept of “healing” is derived from the word “Heal” which in most of its meaning denotes the state of well-being and recovery as follows:
- Healing, (source: heal): wish him a speedy recovery, i.e., being healthy and well. [1]
- Healing is known as recovering from illness, i.e. May Allah heal him, someone recovers if asked for a recovery [2]. Its equivalent in English is “to seek a cure”, i.e., I cured him with a medicine. [3]
Idiomatically: healing is the restoration of health to the body after its imbalance and impairment. It also means adaptation of soul with what removes the harm. It is clear from the above that there are many linguistic meanings for the word healing, some of which indicated the edge of a thing or its end, another to supervise something, as well as sunset, peremptory limit, joy, statement and other meanings. But we find that the most common meaning of the word is treatment and wellness and this is what will be the basic concept that we adopt in this research.

1.1.1. Healing in Architecture

Architecture dealt with the concept of healing broadly but with different meanings, some of which were based on its being linked to the user, considering architecture as the treatment. Others relied on the link of the concept to the building and the human ability to repair it.

1.1.1.1. The concept of healing on the user

In an article for Alyn Griffiths on Architonic’s blog, it was mentioned that good architecture creates in addition to its tasks, fun environments for time spending and practical use. This scenario is more important than providing treatment or support to people who deal with illness or trauma, and it is necessary to study some of the ways where smart design and design help to ensure a positive diagnosis of the future of healthcare by creating healthy buildings for the body and mind [4]. As a carefully designed building can lead to dealing with the natural rhythms of human neuroscience, and thinking about how the human body's tectonics and our physical appearance exist. There are many examples of how the physical form deals with human and harmonizes properly with the natural structure that can constantly evoke the human response in everywhere and from consciousness to unconscious emotion [5]. Living patterns lie in all advanced design solutions successfully. Generations of people have built their surroundings throughout the trial and error, and formations that made them feel physiologically and psychologically healthy have been discovered, as living patterns emerged through the development of the built shape, a long selection process originated from thousands of experiments. Choosing a healthy architectural solution is used on other possibilities. It uses reactions to determine a state of well-being which leads to health in the long run. This process is the same in genetic programming, where "programs" develop after millions of iterations, with choosing variables constantly and re-choosing them until they lead to the typical desired result [6].

Here we find that the concept is associated with the ability of the building’s planning and design to communicate with human psychology to achieve comfort and its ability to interact with the person and change the psychological state and help him in achieving psychological comfort and get rid of environmental stresses of the human being and its ability to prolong the user's life.

Over the past decade, there has been a renewed awareness of the role of natural environments, where the term Buildings that Hell has been used to refer to the possibility of green areas within buildings to assist in achieving recovery for Physical Health patients. Roger Ulrich point out the health benefits of parks inside hospitals which help patients in hospitals to recover faster by reducing physiological indicators of stress, mood improvement and help in recovering. The healthcare community must consider adopting integrated care systems in which outdoor treatment and curative gardens are an essential complement to indoor treatments [7].

We note from the above that recovery here is associated to the physical and psychological treatment of people through the use of green areas and their ability to enable and accelerate treatment for the Physical Health patient.

1.1.1.2. The concept of healing with the environment

One of the concept uses in architecture is the impact of the building on the environment, where many studies have emerged to address the effect of buildings by the amount of toxic emissions in the environment, as well as the ability of those buildings to absorb these emissions, which are called “buildings that
“breathe”. There are a lot of problems related to AQ (Air Quality) and the lack of oxygen needed for human health and activity, which is one of the most important causes of the concept of SBS (Sick Building Syndrome), opposite to the concept of healthy buildings. Sick building syndrome called for the green concept in design to change its path towards paying more attention to the occupants and their health, in addition to the development of other terms, namely the ecology of buildings, as well as the orientation of green design proposals towards the use of less toxic materials and improving the quality of indoor air and employing the values of approved health design proposals in the researches of building biology. SBS has been defined as "a group of nonspecific symptoms which include eye, nose and throat irritation, mental fatigue, headache, nausea, dizziness and skin irritation, which appear to be associated with certain workplaces. In addition, the embodied environmental impacts of the building during its entire life cycle can be in the same order of magnitude as during the use phase as the construction industry consumes 40% of the materials entering the global economy and generates 40-50% of global production of greenhouse gas emissions and acid rain factors [8]. Several studies have stated that the use of building materials can have a major impact on the environment during the life cycle of a building. Physical use with operational capacity is the most important environmental aspect of the building [9].

As a result of the impact of buildings on the environment in the large amount of emissions generated that cause environmental pollution, the designers intentionally produced a building that helps absorb this pollution from the environment and transform it into pure oxygen, and these buildings are called buildings that breathe. It is clear from the above that the application of the concept of healing was through the buildings' ability to purify the air from toxic emissions in the surrounding environment, i.e. the buildings' ability to improve the living environment, whether inside or outside the buildings.

1.1.1.3. The concept of healing in buildings

The concept of building healing is related to the problems and diseases that lead to the occurrence of deformities and defects in the buildings that are caused by climatic causes and natural environmental factors or developments and functional changes. The concept, also, relates to understanding the possibility of repairing the building or restoring it and returning it to work with the same previous ability to perform the job assigned to it taking into consideration the safety of the users of the building [10]. A large number of architects believe that the problems and diseases of the building are identical to any component or system that does not operate as intended [11]. The broader definition in the context of the construction industry will include innumerable performance problems associated with buildings, interfaces, control of mechanical, electrical and plumbing systems, and the ability of building systems, etc. And from this perspective a non-exhaustive list consists of structural and architectural performance failures (structural failures of all types, treating moisture problems, durability, degradation, maintenance, and repair, structures that are improperly designed or built (to be structurally sick) [12]. The main purpose of the repairs is to rehabilitate the architectural form of the building so that all its joints and components begin to work and the building is quickly resumed, but these traditional architectural repairs do not restore the original structural strength of the walls or cracked columns, and may sometimes be very deceptive, as a building skin envelope will hide all weaknesses and will suffer more severe damage if exposed to the same conditions that affected him in the original [13]. As for the restoration process, the strength of the structure is to be restored, as the main goal of the restoration is to make structural reforms and make the structural elements and compounds sufficient to carry the loads on them and transfer them safely. The restoration process may include cutting parts of the elements and rebuilding or strengthening them by adding more construction materials in order to achieve the original strength of the structural structure [14].

It is clear from the above that the inability of the building to perform the required job makes it considered sick and needs recovery, and this functional weakness may be due to external influences on it that cause damage to the building itself, which makes it invalid, whether in terms of construction, formality and even functionality, so there were numerous methods of maintenance, restoration and rehabilitation represented by repair operations to reach the building's recovery and healing, usually through traditional
methods, whether in the detection of damage or its treatment.

1.1.2. Traditional maintenance, restoration and rehabilitation

The term restoration has received the attention of many researchers in the field of building restoration in the modern era, and many of them have agreed on the meaning indicated by it (the term restoration), where it is called the practical work carried out by the restorer in order to protect the building from cracking or collapse as well as finding methods for repairing various damaged artistic holdings. Scientific studies and field experiments carried out by maintenance experts in various international building maintenance centers and institutes became the recruiter who develops the science of maintenance and provides vitality and confirms its personality between the humanities and other experimental sciences [15]. Maintenance is often defined as a series of activities that are undertaken to take care of the structure of the building and services to ensure the intended functions and achieve the optimum performance of the building's life cycle [16]. Building maintenance is also defined as an act to maintain, restore, or improve every part of it, such as maintaining the performance of the fabric construction, its services, and its surroundings, to an acceptable level and to preserve the benefit and value of the building including improvement, renewal, and upgrading, as well as repairing existing facilities [17]. The engineer's act of dealing with a building that has some diseases is very similar to the doctor's treatment of a patient who has symptoms of the disease, so his work can be divided into four phases, which are [18]:

- Examine the situation in all its aspects and describe it accurately.
- Diagnosis and attempt to determine the causes of the disease.
- Evaluating the current situation and judging the safety of the building.
- Choose the appropriate treatment and start it, so that the building can recover and function better.

This was what was done by traditional methods, so visual diagnosis is the basic step in building inspection work and before visual inspection, all information about the building and structural plans, and building and maintenance records for the building should be obtained for the initial study during the visual examination, and therefore special attention should be paid to additions and changes. The inspector should also identify structural components and non-structural components, monitor the presence of cracks and fractures, check the integrity of structural members to detect excessive deviation, check the building's inclination and mark all defects observed on the drawings for a detailed desk study, and the first visual inspection should be under the supervision of a professional expert [19]. After this examination and study, further field investigations are required, including mapping of cracks and fissures, deviation measurements, stability, and inclination, the identification of potential sources of water leakage, and a more accurate survey of the defects identified, after which some test methods are used for a rapid and initial assessment [20].

1.1.2.1. Types of maintenance

Maintenance on the building can be classified into the following [21]:

- Routine maintenance: It is simple maintenance such as cleaning and security works, and it requires extensive unskilled labor and its costs are limited and distributed over the life span of the building.
- Preventive maintenance (preventive backup - exploratory preventive): in which the sources and locations of faults are determined through periodic inspection and inspection of building elements, their removal and treatment, and they need relatively skilled labor and their costs are higher than the costs of routine maintenance, but less than the costs of repair maintenance.
- Repairs maintenance: It is the process of repairing and treating sudden and unexpected malfunctions of one of the building elements, whether it is constructional, architectural, health, electrical, or electromechanical, and it requires specialized labor hands and its costs are very high (the cost of calculating the depreciation of the damaged element and the cost of re-working this element or replacing it with a new element). These costs for maintaining the original building condition are for the purpose of the building performing its job in full efficiency, and the cost represents a large proportion of the total cost of the building over its life span [22].
It is clear from the above that previous operations, despite their dependence on some modern devices, they contain many negatives, so the process of discovering the damage is with the naked eye. This process may be difficult because it cannot monitor the defect in all places, usually the places of damage are covered with packaging materials such as false ceilings and other, and it may be discovered after long periods of the occurrence of the defect. This may affect the safety of the users of the building, while the costs of maintenance and restoration are very high and may not be possible in some cases due to the exacerbation of the problem. Therefore, studies in the world have turned to the possibility of self-detection of faults in the building, as well as self-treatment in early times.

2. Self-healing in architecture

2.1. Self-Healing

One of the great things about living organisms is the ability to heal after an injury, if we are not able to regrow the skin or repair broken bones we will not last long when seriously injured, and in most cases self-healing helps us to restore a fully functional condition. In fact, most natural systems and living organisms are able to heal themselves, which contribute greatly to their durability and resilience, and although the idea of applying such mechanisms to engineering problems has been around for nearly a century, this type of research is, still, in its infancy. The term self-healing is used to describe a piece of equipment or system that has the ability to detect and correct errors without the need for external assistance, and it aims to create self-healing systems, so that the system must diagnose problems and estimate their status and fix them automatically (Cambridge Dictionary), it also means the reference to a system or sub-system that has the ability to feel and diagnose without human intervention (Your Dictionary), self-healing means becoming more complete, and more capable of achieving what you wish to achieve, this perfection may involve healing the physical wound, or behavior that helps to heal (Website Learning center). As for the practical aspect, self-healing is synonymous with self-repair, self-renewal and self-immunity, as these terms describe the system that can perform by itself all the necessary recovery steps to restore its distribution behavior of a specific pattern of operations [23]. But the difference between self-healing and self-repair lies in mechanism. Self-healing is a bottom-up approach, in which the components of the system heal the damage from the inside. For example, if a particular nail is broken, the nail will grow on its own and gradually remove the damaged area of the nail, without needing any conscious decision or control of the brain, the failure component is fixed. As for self-repair, it is a top-down approach, where the system is able to maintain or repair itself. For example, if one of the hand's nails is broken, the other hand would be used to cover and fill the damage location appropriately, based on informed decisions of the mind [24]. Ghosh has defined the self-healing system as a system capable of realizing that it is not working properly, and without human intervention, of making the necessary adjustments to restore the normal state [25]. Ghosh explained in his writing (Self-healing Materials, Fundamentals, Design Strategies, and Applications), self-healing can be of two types [26]:

- Independent (without interference).
- dependent (human intervention / external start up required).

The basis for understanding and implementing self-healing systems is to reveal the damage, which is the starting point from where repairs begin [27].

Through the above general definitions of the concept of self-healing, it turns out that it represents a system that helps to explore and diagnose the defect without external interference to the component, where the object depends on itself and its components in the diagnosis and identification of the defect, and also represents the healing process of that defect on its own depending on specific techniques free from external interference.

2.2. Self-healing in public areas

Self-healing describes any device or system that has the ability to perceive that it is not working properly
It means having the ability or property of healing by itself (Webster Dictionary). In the field of robotics, most of the current methods of self-recovery depend on a kind of repetition and replacement of failed parts, which come at a high cost and may require specific timetables for repair during the life of the robot. In software engineering, implementing self-healing and other subjective features is less challenging and almost automatic when working with multi-factor systems or service-oriented architectures, although much research is still needed in this area [28].

But in most other areas, the strategies for self-healing and self-repair are still the subject of extensive research, and the focus will be on the current progress in self-treatment techniques and the possibility of predicting future developments in the field of architecture.

2.3. Self-Healing in Architecture

All buildings today share a common thing where they are made using traditional techniques, including plans, manufacture and construction, all of these efforts lead to an inactive unsustainable object, and with the increasing demand for more sustainable and long living buildings, researchers focused on self-repair materials, which can withstand minor abuse and return to their original physical condition, says (Carolyn Drive), head of the Department of Natural Process Design (NPD), that such materials will not only be lasting their traditional counterparts, but also need less material in their manufacture [29].

In order to apply the self-healing approach in architecture, we must address it in several ways, including: attention to techniques that can determine the defect and its discovery at its initial stages, as well as relying on techniques that help self-healing of the building in the event of the defect without notifying the specialists and impacting the design strategy.

2.3.1. Self-Healing by Sensors

When buildings and essential systems are exposed to degradation, it is necessary to meet safety requirements, functions, and durability throughout their service period. Until recently, the only ways to increase the life span of the building were either continuous maintenance that is done traditionally, as early detection of this degradation is done by visual inspection, either during routine maintenance visits or when sending the maintenance team to the site to investigate a known or doubtful problem, however these inspections are time consuming and costly and the alternative is to provide the infrastructure with sensors that are permanently connected to report any damage in the mechanism in accordance with a centralized system [30]. One of the main sources for accelerating the deterioration of concrete structures is cracks in them. To evaluate and repair structural problems in the existing effective concrete structures, it is necessary to detect cracks and monitor their expansion and continuity, and this is difficult to make with traditional methods that depend on visual control, therefore, science has moved towards the use of advanced numerical systems for monitoring [27]. These techniques and methods are able to monitor and control cracks in structural structures, but they do not directly contribute to the repair process, but at the same time they are more effective in preventing serious damage to the building as they are an effective tool in repairing cracks in the early stage of deterioration (Figure 1). For this purpose, self-healing systems for concrete structures [31] were developed. It is expected that the use of the "sensor / computing" system will increase significantly in the coming years. Therefore, there is an increased interest in sensor technology for various uses [32].

Through the previous figure, we find that the function of the sensors in the concrete structures is to study the state of the structure and search for possible damages in its initial stages, and then find and measure it and measure the temporal age of the building and enter into an evaluation process, through which either the integrity of the structure is determined to return to work again or specify by necessity treating or removing damage in its early stages.
2.3.1.1. Structural Health Monitoring (SHM)

With the development of new and more reliable construction methods, this culture began to spread more and the functional structure is retained for longer periods of time. Basic building materials such as concrete ushered in a new era of engineering that enabled rapid and low-cost construction of buildings that have now become the backbone of modern societies, many buildings that were constructed in the nineteenth century until the mid-twentieth century continue to work properly until today as evidence of the strength of structural structures provided by appropriate materials and their acceptability in terms of form, however, durability has its limits, as prolonged life span of the structural components leads to a dangerous accumulation of damage to the structure, where time obsolescence is one of the most important problems faced by these structures, whether formally or structurally [33]. Structural health monitoring in architecture (SHM) refers to the process of implementing a damage detection and characterization strategy for structural system. Damage is defined here as changes in the physical or engineering properties of a structural system, which negatively affects system performance. The SHM process includes monitoring the system over time using measurements of the dynamic response of a sample through a set of sensors, detection of sensitive characteristics of damage from these measurements, and statistical analysis of these features to determine the current state of the health of the system where the outcome of this process is updated periodically from information related to the ability of the structure to perform its intended function in light of the aging and the inevitable deterioration resulting from operational environments after extreme events, such as earthquakes, blasts, or the age of the building, among others [34]. Structural Health Monitoring (SHM) aims to give a diagnosis of the condition of the materials that make up the different parts and the complete assembly of these parts that make up the entire structure and at every moment during the life of the structure, the condition of the structure must remain in the specific field of design, although this can be
changed by aging in time due to use, environment action, and accidental events thanks to the time dimension of the observation which makes it possible to look at the complete log database of the structure, and with the help of "use monitoring", it can also provide a prediction of the development of damage and the remaining life etc. [35]. As researchers face a challenge to develop technologies to monitor and update old buildings at the same time to push the boundaries of SHM through creative use of advanced technologies and data processing algorithms, this problem is a snapshot of the latest research in SHM of structures, and includes a range of topics such as data processing algorithms for damage detection, modeling and simulation (36).

![Figure 2. An illustration of the location of the sensors in the concrete column [37].](image)

It is clear from the above that SHM is a breakthrough in engineering by integrating electrical, magnetic, photonic, acoustic, thermal, and other physical variables, chemical variables, information technology, computer science and technology, as well as communications technology into a single system so that the structure has the capabilities of sensing and diagnosing itself, in an attempt to mimic the sensors present in living organisms that can determine the locations of problems at the moment of the imbalance, no matter
how small and early. SHM includes several basic steps to complete the system in general, that are technology Sensing, the mechanism of obtaining data, transferring and managing this data, and then the process of analyzing it to reach the final product, whether negative or positive. The analysis process gives a detailed diagnosis of all parts of the building related to the sensors, and thus defining the defect and the aging of the building and its effects.

2.3.2. Self-healing Using Materials

Biological organisms have an amazing ability to start self-healing and repair themselves automatically, when they are exposed to damage such as scratching in the human skin or damage to most living things by means of a tool that will heal the skin in a few days and on their own, as it can sense the location of the damage and work to stop it preventing it from getting worse, then working to self-repair it with little help from us (and often without that help). Self-repair materials will have a tremendous impact on almost all industries, extend the life of the building, increase safety, and reduce product costs by reducing requirements of maintenance thanks to nanotechnology. These visions come close to the reality that is one of the methods of using nanomaterials that have the ability to release active substances encapsulated in a controlled manner, which leads to the creation of semi-living buildings [38]. The materials generally face damage during their traditional use, so disposal of this damage through the adoption of self-healing mechanisms would provide an improved life span and stable strength and this is especially important in materials that aim to perform in a manner designed for times when repairs are not possible [39]. The materials used in our daily life usually become unusable for one of the following reasons [40]:

- Aging: Most substances gradually wear off over time, sometimes over a long period of time.
- Wear: Most materials wear during continuous use.
- Defect: Some materials experience sudden and unexpected fractures when exposed to certain forces such as stresses or strains that cause cracks or internal fracture breakdowns and the formation of small cracks in the structure of the material quickly spread.

Accordingly, all buildings have a common denominator, as they are made by traditional techniques, whether at the level of design and preparation of plans or industrial production of materials or methods of implementation as well as labor, all of these processes lead to inactive production that is not sustainable and the only way to construct sustainable buildings and cities is to place them in a continuous dialogue with their surroundings. In order to achieve this, we need to find the right language for dialogue, metabolic materials is a technique that works as a chemical interface or a language through which artificial structures in architecture can communicate with natural systems. This technology is currently being developed in cooperation with scientists of synthetic biology and the origins of life sciences that represent their model systems for achieving materials belonging to a new set of technologies that are described as (living technology) that possess some properties of living systems but are not considered (live) [41]. What we need is access to materials that behave similarly to the human body, sensing defects, working to stop them and then starting the repair process as soon as possible and above all subjectively, this is the basic concept of the so-called self-healing materials, which can be defined as synthetic materials, that have the ability to repair themselves automatically without the need for diagnosis or human intervention [42]. Metabolic materials can be considered the next generation of architectural forms that are not only a decorative skin cover but living integrations designed to give biological functions [29]. Often the nature's approach to energy efficiency, sustainability, durability and even beauty is unparalleled, which is why the materials, structures and systems exhibited by living systems provide this approach, as it is aesthetically pleasing and designed to remain and last the longest period of time [43]. Accordingly, the basic concept of the so-called self-healing materials can be defined as synthetic materials that have the ability to repair themselves automatically by themselves without the need to diagnose a defect or human intervention.
2.3.2.1. **Types of self-healing materials**

It was classified into four main types [44]:
- Self-repairing materials containing (healing agents)
- Self-repairing materials including an internal vascular network similar to that of the blood vessels
- Shape-memory materials
- Reversible polymers

2.3.2.2. **Embedded healing agents:**

The most well-known self-repairing materials inside them contain granules or microcapsules filled with glue-like chemical fluids that can repair the damage. Forming some cracks inside the material will in turn lead to breaking the walls of the capsules and thus emptying their content of liquid that soon fills the cracks surrounding them, but this method can be used only once [45]. See (figure 4).

![Figure 4. explains the mechanism for cured embedded materials [46].](image)

2.3.2.3. **Microvascular materials**

The human body has a comprehensive vascular system (a network of blood vessels of different sizes) that transports blood and oxygen to obtain energy and repair damage as more blood is pumped to the affected areas. Material scientists work to design self-repairing materials that work in the same way, some of them have very accurate vessel networks (its thickness is about 100 microns). They deliver healing materials to the damaged places only when it occurs, and the vessels lead to pressurized warehouses (they can be likened to syringe that is slowly pressing), and its content is characterized by moving further distances so it can be used successfully in places such as skyscrapers [27]. See (figure 5).

![Figure 5. An illustration of the mechanism of action of microvascular materials [27].](image)
2.3.2.4. Smart shape-memory materials
These materials often work with shape memory, and this mechanism makes the material remember and able to return to its original shape [47]. (Figure 6).

![Figure 6. Explaining the mechanism of smart materials [47].](image)

2.3.2.5. Reversible polymers
It operates according to the system of reactive ends, as these ends located in the damage area seek to reconnect with their neighbors to form new bonds and repair the damaged area, because the electrically charged ends are attracted to each other [27].

2.4. Effect of self-healing substances on finishings
The architect has always looked for beauty and aspired to its designs. No matter how keen the architect is to do this, there are some things that cause problems that disturb him and may distort this beauty. These things are cracks and scratches, which the building is exposed to with the passage of time and spoils the aesthetic view of the building. So it was the dream of any designer to have self-healing materials that help hide cracks and scratches and restore them back to normal easily [48]. These materials have now become available, but at relatively high prices, and are considered the emerging application of nanotechnology, and designers are not far from the future in which we will have interior design materials and furniture that have the ability to process cracks in buildings on their own, or scratches on furniture and restore their original appearance, by filling them and fixing the links across the damaged surfaces and then hardening them again which leads to repairing them on their own or at least preventing further damage. So knowledge focused on how to use these coatings by incorporating them into the interior design work provides solutions to reduce the cost of damage that happens during its life cycle and maintain its form [49]. Figure below
2.5. Self-assembly and Nanocoatings
The process of using nanomaterials is not limited to the safety of structures only, but goes beyond that to other uses such as self-cleaning or air self-cleaning. The construction industry is increasingly using nanocoatings to build surfaces, such as walls, doors and windows, as it opens up new avenues for sustainable and environmentally friendly structures (providing an organized protective layer to the base materials). It creates a surface of the required protective or functional properties. The concept of the main mechanism of nanocoatings is the capabilities of self-healing through the process of self-assembly (is a phenomenon where the components of the system combine automatically through a reaction to form a larger functional unit) (Figure 8) [50].

(Figure 9) shows a thin self-cleaning glass system based on a thin layer of titanium oxide TiO2 that cleans the glass itself in two stages: the photocatalytic phase of the process shatters the organic dirt on the glass and splits it with ultraviolet light and makes the glass super sensitive, during the next stage the rain washes the dirt without leaving any streaks as the water spreads evenly over the top surfaces [51].

Other uses of nanomaterials for building materials are [52]:
- Flame Resistant Coating: it has excellent anti-pollution property and high flame resistance.
- Scratch Resistant Paint: to maintain the surface appearance and durability of wood floors or window glass.
- Anti-graffiti coating: used on surfaces, especially in historical places.
- Anti-corrosion coatings: improve the wear and oxidation resistance of materials.
Figure 8. The process of self-assembly through a set of specific reactions between nanoparticles [50].

Figure 9. Self-cleaning in the glass [51].

We find from the above that nanotechnology revolutionized many industrial fields through the application of nanotechnology in architecture because it is not limited to sustainability and energy efficiency in buildings, but that the advent of the nanotechnology era provides new possibilities that affect both architectural design and its applications and flexibility and dynamism in shapes and beauty, adapting to external and internal requirements, and quality protection in living conditions. We note that all current developments in building materials are simulations of living organisms, whose aim is to access the features of living organisms such as air purification, self-cleaning, temperature regulation, self-healing and energy production / saving, in addition to fire resistance, sun protection and insulation and their application to high-performance buildings and provide long life cycles. The use of materials that have the ability to self-heal helps to increase the durability of the building as well as preserve the shape, and thus the formal acceptability of it in addition to reducing the maintenance costs and risks.

2.6. Design Strategy

Building methods and building materials have evolved in a way and thinking to make the building significantly sustainable, and this development clearly affected the design strategies and design philosophy of the designer, and also provided new tools and approaches that help him think more broadly. The Delgado study [53] demonstrated the importance of fully utilizing building structural health monitoring data to support building management, due to the lack of effective integration with other data sets. The study fo-
cused on providing a methodology for building information modelling BIM, and this approach directly affected the adoption of contemporary strategies, such as digitalization, in order to extend the life of the building and reduce or avoid damage. Stressing that the increasing amount of data created in the building's life cycle provides a lot of information so that data modelling, visualization and simulation are essential aspects to support the decision-making process of the designer in making the self-healing mechanism an essential part of the design process [54]. These systems are very useful for construction as they reduce repair costs and are more permanent, especially in large projects, but when it comes to adding spaces to old buildings, such as rooms or additional floors or others, they may be expensive and unnecessary. But they are considered a building strategy for large projects [55]. The use of self-healing systems in architecture can reduce 15% of current operating costs in addition to changing the mind of the designer to take advantage of improved predictive tools in the design of new projects, achieving additional savings of 10% in building life cycle costs [56].

3. Conclusion

Given the multiplicity of concepts and studies covered by the research, several conclusions can be reached:

1- Healing in architecture is a traditional and inherited process, while self-healing is unconventional and is inspired by living things in its ability to detect and repair damage.

2- Healing is not sustainable and increases the life cycle costs of the building, but self-healing is sustainable by making the building last as long as possible and exceeding its life span and reducing the cost of the building life cycle.

3- The healing process is not without risks due to its dependence on periodic monitoring, which may be delayed in detecting damages, while the risk of collapse decreases when adopting self-healing mechanisms for buildings due to its early detection of risks.

4 - The healing process is costly due to the large number of workers. As for self-healing, it is low cost at the level of the length of the building's operational period due to its lack of need or need for a small number of workers.

5- Because the dependence of healing on the human being in determining the damage and not the technology, therefore, it is inaccurate in determining the size of the damage, but we find accuracy in detection and treatment in self-healing because of its reliance on technological techniques to discover and assess the damage.

6- Healing depends on the skilled workforce to carry out the repair, and this loses accuracy, while in self-healing, the process of detection and treatment is done in a personal way, and you may need workers who implement the reforms by adopting technological methods to define the treatments.

7- Traditional healing methods are used in places that are easily accessible, while self-healing can be used in places that are difficult to reach and in large and heritage projects.

8- The methods of healing in architecture are not considered a design strategy as they are the result of the need when discovering the damage. As for self-healing, it is a design strategy that the designer aims to use during the design process.

9- Healing is an attempt to return the damaged system to its original state.

10- Living organisms contain systems that help them to continue and resist the conditions that affect them. These organisms are a source of inspiration for all sciences, including architecture, because they contain integrated systems that humans seek to emulate in architecture.

11- Designer thought and design strategies are affected by the development of technology.

12- Through the above, self-healing in architecture can be understood as an artificial system that a person supplies to the building in an attempt to make the building in a continuous dialogue with nature by making it capable of self-sensing the defect early and in the initial stage without human intervention, as well as produce the possibility of self-treatment of these problems to reach a long-term building by achieving three pillars, namely, aesthetic acceptability, high performance and safety.
Figure 10. The foundations of self-healing

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