THE USE OF SMART MATERIALS IN CONTEMPORIZATION OF INDUSTRIAL HERITAGE

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The industrial heritage, as one of the subcategories of contemporary architectural heritage, is an emerging phenomenon and also result in the industrialization of the world in the mid-nineteenth century. And it importantly represents and documents a stage of countries architectural histories and developments.

Today, in many cities, the change of expansion and development process causes the industrial collections, that once located outside the city, to integrate into and within the urban context. The existence of these abandoned and ruined factories within the urban context have created dead and vacant spaces in the surrounding area and cause a decline in social, economic and physical statuses in urban districts. Therefore, dealing with them is important which makes it necessary to take a particular approach for dealing with each of them regarding their specific condition and values.

In other hand, Techniques for preserving the industrial heritage are different from those heritage built over the years in larger sections of the historical environment. Since industrial heritage is a new social and economic phenomenon, solving the existing challenges in preserving them, requires innovative approaches. Therefore, get acquainted with smart materials, innovative manufacturing processes and techniques can lead to better, cost-effective buildings design.

The present research is to study the use of smart materials in contemporization of industrial heritage. At first, it explains the concept of architectural Contemporization as the best approach for the restoration of industrial heritage. It shows that the sci-tech Contemporization of factories can not only recreate the abandoned and insecure areas around them but can also help with economic growth, cultural development and employment. Then after introducing high-performance and smart materials and their application, suggests the best and most suitable materials for use in the process of restoration of the industrial heritage. The results show it is a very important step to find a suitable approach for redesigning any industrial heritage and also it is important to choose the best material in order to achieve an environmentally friendly building.

Keywords: Contemporization, Industrial Heritage, Smart Materials, High-performance Materials, Technologies, Adaptive Reuse.

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Abstract

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1. Introduction

Industrial heritage is a new and challenging entry into the heritage area. Determining the importance of industrial heritage issue is essential for everyone. Today, this heritage and especially factories are abandoned within the cities and they are going to be destroyed, therefore, Adapting and repurposing them are now mainstream strategies for urban planners (Douet, 2012, 1) so that they can be transferred to future generations. There are different approaches to interfere with these historical textures and their changes, but the main question is, which approach is appropriate to preserve this legacy and transfer it to future generations?

On the other hand, with the development of innovative products and smart materials, moving towards more efficient and environmentally compatible buildings is essential; therefore, in the process of contemporization of the industrial heritage, the use of smart materials and products can create more efficient and cost effective buildings.

1.2. Methodology

The research questions are: 1. what is the best approach to interfere with industrial heritage? 2. What is the use of smart materials in architecture? And what kinds of smart materials can be used in the process of contemporizing industrial heritage?

In the first part of the research, various attitudes on how to interfere with historical textures and their characteristics are discussed and, finally, the best approach to interfere with these contexts is suggested. In the second part, due to the importance of using smart materials and new approaches in architecture, the different types of smart materials and their use in architecture and restoration are discussed. The conclusion of the research is the result of the analyzes obtained in each section.

2. Intervention in Historical Textures

The work of alteration is paradoxically a function of the general impulse to conserve, and the purpose is to work the existent and the ideal together through the processes of intervention, to keep the existing occupied and significant (Scott, 2008). The scale of intervention in valuable historical districts must be chosen in such a way that it does not disrupt people‘s life, and with its continuity, the hope and sense of participation in the process of revitalization among residents taking into account the maximum Enhancing people's satisfaction and maintaining their resources (Mahdizade, 2001, 63). The purpose of intervention in urban old districs is to find a solution to create favorable conditions for human life and also to create a harmony between the old and new way of life as the needs and content of urban life have already changed from the past (Mahdavinejad 8 Moradchelle, 2011).

Due to the type of context worn-out, various approaches can be used to cope with urban decay areas. These intervention can be done through a change in use of the building or alternative activities, which on a large scale named "functional regeneration" or "functional variation"; or the existing activities would remain, but they become more efficient and more profitable, which is also referred to as the "functional regeneration" on a large scale (Mahdavinejad, 2014, 135; quoted from Lichfield, 1988, 25).

There are many perspectives on how to interfere with the historical context, which will be discussed further.

2.1. Different Approaches to Intervention

There are a general consensus and agreement on the objectives of intervention in the historical context, but to reach understanding in the form of strategies and methods it requires dialogue because of differences in viewpoints.

Officials and experts have three main approaches to how interfere with historical textures (Mahdavinejad, 2014, 133; quoted from Ablaghi, 2001, 118).

2.1.1. Conservation

This approach denies any interventions but preservation, and also it’s against "renovation" and "contemporization", which consider as a factor in the destruction of the context and its cultural-historical values. This attitude in its extreme form is even against the functional "revival" of the historical buildings (Mahdavinejad, 2014, 133).

Theoreticians of this attitude with an emphasis on preservation of authenticity and cultural values, introduce urban development projects and the construction of new buildings using contemporary architecture as a source of disturbance to the urban landscape and

historical and cultural values of society. The result of such an argument would be a kind of pure preservation (Hanachi, Diba & Mahdavinejad, 2008, 52).
There are some critiques to this attitude as follows:
- Ignoring needs of today urban life
- Ignoring the needs and interests of the owners and residents of the district
- Urban decay, the increasing outflow of residents and the replacement of lower social strata, threating works and values and urban identity (Mahdavinejad, 2014, 133).
Preservation in this view is different from maintenance and restoration although they are very similar to each other (Hanachi, Diba & Mahdavinejad, 2008, 53). Restoration can be defined from two perspectives. First, actions that focus on the physical aspects of the buildings, which called "repairs". It includes a series of actions aimed at improving the physical condition of a building or urban spaces. The second group includes a set of actions that focus on content and use aspects of the buildings, which called "maintenance". This group of interventions is trying to bring the buildings or urban spaces back to a more sustainable condition (Habibi, 2002, 18).

2.1.2. Demolition and Renovation

This attitude considers the whole historical context as a worn-out district and does not believe in cultural-historical values in a structural aspect and also considers only a number of monuments worth keeping. This attitude, which is known as “Bulldozerian”, regardless of the cultural-historical values, consider the whole historical context suitable for renovation and investment. Based on this attitude, there are lots of proposals like the plot of renovation around holy shrine of Imam Reza (with an area of about 280 hectares in 1372-1373) (Mahdavinejad, 2014, 133).
Theorists of this view due to the vacant contexts and valuable empty houses, claims that The result of preservation is to reduce the quality of life. The result of such an argument would be a "hasty development" (Hanachi, Diba & Mahdavinejad, 2008, 52).
There are some critiques to this attitude as follows:
- Ignoring the cultural-historical values created over time
- Ignoring social and ethnological values
- Disregarding the role of people and their participation
- The need for large investments and unilateral government interventions (Mahdavinejad, 2014, 133).

2.1.2.1. Causes of Tendency to Demolition and Renovation

The reasons for the tendency towards demolition and rebuilding of historic textures can be found in the prevalence of economic benefits approaches in the present era. It is obviouse that "conservation and restoration are costly even in its physical dimensions, and it costs usually more than demolition and renovation, so the tendency for renovation is much higher in old textures" (Aminzade, 2004, 86). One of the most important reasons for the tendency to destruct and rebuild the old texture is the desire for modernization. In some developmental approaches, there is a kind of precipitancy with the lack of attention to environmental, cultural, social and human infrastructures, which leads to destruction of cultural heritage and precious urban textures. (Hanachi, Diba & Mahdavinejad, 2008, 53).

2.1.3. Interactive Approach (Contemporization)

According to this view, the totality which we refer to as a historical texture is never a homogeneous complex but it actually covers from a wide range of valuable areas and historical complexes, such as Naghshe Jahan square and surrounding monuments, to the old and decay urban textures (which in some cases are even worthless) (Mahdavinejad, 2014, 133).
As stated above, pure protection and hasty development have both caused a lot of damage, therefore, it is suggested to use integrated methods and interactive approaches between preservation and development in the valuable textures of Iranian historical cities (Hanachi, Diba & Mahdavinejad, 2008, 58).
In this regard, the suggested approach for this issue is "Contemporization".
The idea of this approach is to offer an alternative to preservation or demolition, a more general strategy to keep buildings extant beyond their time. It is like an act of transition or translation, from the past into the present, with logically also a consideration for the future of the host building (Scott, 2008, 11).

Table1- Different approaches to intervention in historical textures

Theorists' Views on Intervention in Historical Textures	
preservation	Denies any intervention except preservation, and not accept actions such as "Renovation" and "Contemporization".
Demolition and Renovation	Theorists of this view consider preservation as revivalism and also development as an improvement factor.
Interactive approach (Contemporization)	Contemporization is mediation between preservation and demolition

3. Industrial Heritage

In 2002 International Committee for the Conservation of the Industrial Heritage, (TICCIH), hammered out a charter, signing it in the great steel-milling and tank-manufacturing town of Nizhny Tagil in the Russian Urals (Douet, 2012, 1). The definition of the industrial heritage was approved by this Charter in 2003 (Sharifi and Talebian, 2018). Industrial heritage consists of the remains of industrial cultures which are of historical, technological, social, architectural or scientific value. These remains consist of buildings and machinery, workshops, mills and factories, mines and sites for processing and refining, warehouses and stores, places where energy is generated, transmitted and used, transportation and all its infrastructure, as well as places used for social activities related to industry such as housing, religious worship or education (The Nizhny Tagil Charter for Industrial Heritage, 2003).

Industrial heritage is a new and challenging entry into the heritage area. Identifying why the industrial heritage issue matters is essential not only for the general public, but also for many organizations and heritage experts. Since industrial heritage is a new social and economic phenomenon, solving the challenges in preserving its remains requires innovative approaches. In the valuation of industrial heritage, the social, economic, environmental, and political context, all must be considered. Also, the skills and interests of those who are beneficiary in the future, such as ordinary people or professionals and developers of the heritage, should also be considered (Douet, 2012, 15).

Industrial Heritage buildings need to be used and to be adapted (Scratton, 2005, 4). These buildings are now being prepared for adaptation to another purpose, perhaps quite different from their initial use and their history (Douet, 2012, 21). But this suggested activities should be in harmony with industrial heritage in order to protect the building. This means in this new use of building, the basic functional patterns of the building are consistent with the previous one, so that they display the image of the previous user (Falser, 2013, 17).

Industrial buildings, represents a sustainable resource from past generations which is capable of being ‘recycled’ for new uses (Scratton, 2005, 3), so adaptive reuse has been featured in recent years and is often seen as the only way to preserve industrial areas (Douet, 2012, 21).

A wide range of methods are used in the context of adaptive reuse of industrial heritage; from maintaining the integrity of the legacy through conservation and preservation (in a way appropriate to the values of the heritage), to searching for the new and innovative ways of interventions (mostly architecturally and artistically), or abusing through demolition and devalue the remaining elements (Douet, 2017, 116). Different from that of other cultural relics, the conservation of industrial heritage should take into consideration the adaptive reuse of structures. We should not only preserve and conserve their industrial features and inherent historical information, but also infuse new spatial elements into them and develop new functions. We should not only preserve these old buildings but also revitalize them and weave them into the fabric of contemporary urban life (Song, 2006, 483).

These approaches on preserving and changing the industrial heritage are very similar to those that were noticed before for ways of intervention in historical textures. As noticed before, contemporizing these valuable legacies based on today's needs is the best way to preserve them. This approach is not about to build a better yesterday but to encourage and welcome appropriate new additions and adaptations to industrial heritage buildings. In fact, contemporization is the mediation between preservation and demolition and it seeks out to prepare this heritage for the future generations.

4. Smart Materials

Smart materials with the age of almost three decades have been laid in the procedure of new materials. They have the ability of changing their properties through external stimuli such as stress, temperature, moisture, electric or magnetic fields. This group of material with their "inherent active behavior" would be considered not just a material but a technology (Addington & Schodek, 2005, 29).

NASA defines smart materials as «materials that ''remember'' configurations and can conform to them when given a specific stimulus» (http://virtualskies.arc.nasa).

Encyclopedia of chemical technology defines that smart materials and structures are those objects that sense environmental events, process that sensory information, and then act on the environment (Kroschwitz, 1992). Smart materials are also known as "flexible" and "adaptable" materials, due to their specific characteristics in adjusting themselves to environmental conditions (Addington & Schodek, 2005, 29).

The five fundamental characteristics distinguishing a smart material from the more traditional materials used in architecture are defined as follows (Addington & Schodek, 2005, p.10):

• **Immediacy:** they respond in real time;
• **Transiency:** they respond to more than one environmental state;
• **Self -actuation:** intelligence is internal to rather than external;
• **Selectivity:** their response is discrete and predictable;
• **Directness:** the response is local to activating event.

4.1. Smart Materials Classification

In general, existing building materials, such as traditional, natural and synthetic materials, are classified according to their characteristics, including appearance, texture, chemical composition, mechanical and physical properties, environmental effects, and so on, but in the classification of smart materials beside these characteristics, other properties that are specifically related to separating smart materials from traditional materials are also considered.

All smart materials can be grouped into three types (Ritter, 2007, pp. 43-46)

1- Property changing materials:

Materials that undergo changes in one or more of their properties (chemical, mechanical, electrical, magnetic or thermal) in direct response to a change in the external stimuli associated with the environment surrounding the material. Changes are direct and reversible – there is no need for an external control system to cause these changes to occur. (Addington & Schodek, 2005, 15). Chromogenic systems like thermochromics and photochromics, Shape-memory alloys are among these materials (Ritter, 2007).

2- Energy exchanging material:

Materials that transform energy from one form to an output energy in another form, and again do so directly and reversibly (Addington & Schodek, 2005, 15), like Photovoltaics materials, Piezoelectric materials, Magnetostrictive materials and ext (Ritter, 2007).

3- Material exchanging.

The first class has a great number of potential applications in architecture while the second class would be applied in building servicing such as actuators and sensors and the third class are acted as insulator. Application of smart materials according to their place can be neatly classified into the following systems: Façade, lighting, energy and structural system (Addington & Schodek, 2005, pp. 165-180). Most application of smart materials is in sensors but the most visible and observable application of them in building regards to façade system (Mahdavinejad & and colleagues, 2011).

TYPE OF SMART MATERIAL	INPUT		OUTPUT
Type 1 Property-changing			
Thermomochromics	Temperature difference		Color change
Photochromics	Radiation (Light)		Color change
Mechanochromics	Deformation		Color change
Chemochromics	Chemical concentration		Color change
Electrochromics	Electric potential difference		Color change
Liquid crystals	Electric potential difference		Color change
Suspended particle	Electric potential difference		Color change
Electrorheological	Electric potential difference		Stiffness/viscosity change
Magnetorheological	Electric potential difference		Stiffness/viscosity change
Type 2 Energy-exchanging			
Electroluminescents	Electric potential difference		Light
Photoluminescents	Radiation		Light
Chemoluminescents	Chemical concentration		Light
Thermoluminescents	Temperature difference		Light
Light-emitting diodes	Electric potential difference		Light
Photovoltaics	Radiation (Light)		Electric potential difference
Type 2 Energy-exchanging (reversible)			
Piezoelectric	Deformation	⟷	Electric potential difference
Pyroelectric	Temperature difference	⟷	Electric potential difference
Thermoelectric	Temperature difference	⟷	Electric potential difference
Electrorestrictive	Electric potential difference	⟷	Deformation
Magnetorestrictive	Magnetic field	⟷	Deformation

Figure 1- Sampling of different Type 1 and Type 2 smart materials in relation to input and output stimuli, (Addington & Schodek, 2005, 82)

4.2. The Use of Smart Materials in Architecture

As mentioned before, one of smart materials of type I is chromogenic material. chromogenic transparent materials allows selective and dynamic control of thermal energy and incident light with the ability to change their optical properties in response to a light, electrical, thermal or chemical stimulus (casini,2015,232).

These smart matrials include, Photochromics, Thermochromics, Mechanocromics,

Chemochromics, Electrocromics. Photochromic materials absorb electromagnetic energy in the ultraviolet region to produce an intrinsic property change. In architecture, they have been used in various window or facade treatments, albeit with varying amounts of success to control solar gain and reduce glare (Adington & Schodek, 2005, 85). Photochromic materials (PC), are very popular among today's architects. These materials react to light (UV), or electromagnetic radiation, with a change in color. Photochromic materials or PCs are now available as Photochromic pigments, Photochromic glasses and plastics or Photochromic polymers (Myer, 2002).
Thermochromic materials have properties that undergo reversible changes when the surrounding temperature is changed. The notion of using thermochromic materials on the exterior of a building has similarly always aroused interest. Unfortunately, a major problem with the use of currently available thermochromic paints on the exterior is that exposure to ultraviolet wavelengths in the sun's light may cause the material to degrade and lose its color-changing capabilities (Adington & Schodek, 2005, 91-93).
They are smart glasses based on Thermochromic materials that blocks the heat without blocking the light (Vaysi, 2016). Electrical energy, which is a relatively minor need, becomes one of the major energy supplies in a building, as it is the only source that can power mechanical equipment. Indeed, electrical energy could, and often does, take over the remaining thermal needs of heating, cooking and water heating. As a result, two- thirds of a building's energy use is due to electricity. One of the ways to supply this energy is to use photovoltaic technology (Adington & Schodek, 2005, 180). In this technology instead of there being an applied voltage there is an incident energy (typically solar) that acts on the junction and provides the external energy input (Adington & Schodek, 2005, 101).

Nano Materials
Nanosciences and nanotechnologies constitute a new approach to research and development that aims to control structure and fundamental behavior of matter at the atomic and molecular level (Casini, 2014, 30). it refers to the creation, investigation, and application of structures, molecular materials, internal interfaces or surfaces with at least one critical dimension or with manufacturing tolerances of (typically) less than 100 nanometres components results in new functionalities and properties for improving products or developing new products and applications." (Hosni & Elghany, 2010, 545).
Using nanostructures is, in fact, possible to process the surfaces of the materials to make them, for example, nonslippery, scratch-resistant, corrosion-resistant, hydrofobic, self-cleaning, oil repellent, sterile, reactive, UV-resistant, insulating or reflective to infrared radiation. Also obtainable are: ceramic materials of greater hardness and toughness; metals of increased hardness, with high tensile yield (Casini, 2014, 30)

Phase Changing Materials
Phase change processes invariably involve the absorbing, storing or releasing of large amounts of energy in the form of latent heat and these materials deliberately seek to take advantage of these absorption/release actions (Adington & Schodek, 2005, 88).
The use of nanotechnological insulation materials and smart materials like phase change materials (PCM) in building refurbishment projects could allow to significantly reduce the energy requirements of existing buildings while maintaining their integrity and architectural quality, in order to achieve the goals of reducing primary energy consumption in the building sector (Casini, 2014, 28).
The use of insulating nanotechnology and smart materials for renovation of historic buildings is an effective solution to improve the hydrothermal performance of the envelope by allowing you to reconcile the objectives of reducing energy consumption with the need to preserve their integrity, authenticity and architecture quality. Nanotechnological insulating products and Phase Change Materials (PCM) are suitable for any type of building, but are ideal for external and/or internal interventions of renovation or building restoration, especially of historic buildings subjected to architectural constraints, and in all cases in which it is necessary to increase energy efficiency and comfort with minimum space loss (Casini, 2014, 37).

Structural Health
Over the years a great many inspection techniques have been developed for detection,

assessment and monitoring of damage and deterioration of structures. The field has a longstanding history and is huge. The recent surge of developments in the smart materials area, however, has significantly added new capabilities. According to the Japanese researchers Fukuda and Kosaka from Osaka City University, four major new damage assessment approaches are particularly interesting. These are based on fiber-optics, piezoelectrics, magnetostrictives and electric resistance technologies. Embedded fiber-optic cables can be used to assess breaks, sharp bends, vibrations, strains (deformations) and other occurrences in the base material.
A second major approach to structural health monitoring is based on piezoelectric technologies. Strains induced by forces in piezoelectric materials generate detectable electric signals; hence their wide use as strain indicators. They can be used for measuring both static and dynamic phenomena.
Various electric resistance techniques are also in wide use. The common strain gage directly affixed to a member allows the measurement of strain via an electric resistance approach (Adington & Schodek, 2005, 187-190).

5. Conclusion

The industrial heritage has a special cultural and social significanc as a legacy for the present and future generation, and as a memory for people's lives, and the emotional expression of history and identity. As a result, today it is an important issue to identify the values of this legacy and to explore how to intervene and preserve this heritage.
As mentiond before, there are different approaches to preserve and intervene with this heritage, but contemporization is the most appropriate approach to preserve these buildings and to adapt them to the needs of today's users. Contemporization is the mediation between preservation and demolition and it seeks out to prepare this heritage for the future generations.
Since the industrial heritage is a new social and economic phenomenon, solving the challenges of preserving its remains requires innovative approaches. Therefore, familiarity with smart materials, innovative products and manufacturing techniques and smart energy consumption can lead to better, cost-effective buildings design. In this regard, smart materials and their use in architecture and restoration have been raised. Table 2 describes the types of smart materials used in the field of architecture and restoration and their charactristics.

Table2- Different Types of smart materials and their use in architecture and restoration

Type of Material	Use in Architecture and Restoration	Description
Chromogenic materials like Photochromic and Thermochromic materials	Facads and windows	In order to control the amount and type of input light
Photovoltaic Technology	Facade, roof, open spaces around the building	Saving energy and producing electricity for various uses in the building
Nano Materials	Insulation	Controlling air temperature fluctuations
Phase Change Materials	Insulation	Controlling air temperature fluctuations
Fiber-optics, Piezoelectrics, Magnetostrictives and Electric Resistance Technologies	Monitoring Structral Health	to assess breaks, sharp bends, vibrations, strains (deformations) and other occurrences in the base material

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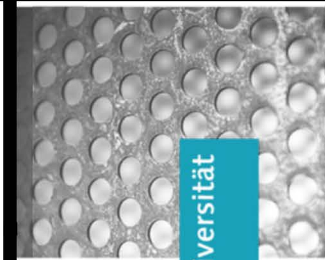

Bauhaus-Universität Weimar

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This certificate is awarded to

Fateme Fanaei Sheikholeslami, Mohammadjavad Mahdavinejad, Hamed Kamelnia

For essay titled

THE USE OF SMART MATERIALS IN CONTEMPORIZATION OF INDUSTRIAL HERITAGE

Was submitted and published at

International workshop and conference on

"Modern Heritage and Future Legacy"

To be held at Bauhaus-Univarsität Weimar, Germany, on 10 th to14th June, 2019

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