Smart Building Technology for Nano-Architecture

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Abstract— **Engineering, Architecture and Medicine are the concepts that exist since the human being has been created in the world, arise regularly in response to human needs health, practice and living. Nevertheless, do we ever consider before the correlation between nano-engineering, nano-architecture and nano-medicine in terms of the nano-structured solutions that scientists discover worldwide in an interdisciplinary platform, getting advance rapidly. Untill 2000s, the most inventive revolution was industrial revolution that hit the headlines during 18., 19.century, based on steel and its innovations. However, today the scienceworld consider and discuss for nanotech as a contemporary intelligence that will be expected to be the world leader forever. So, what are the dreams and what are the limitations for this new nano-world, how efficient are the results, how much repetitive, what is the criteria for the success and what must be the standarts?**

The aim of this research welcomes all the scientists to a new dimension of the nanotech world to discuss for all the affects, critics and drawbacks of nanoscience. What are our concerns, how safe it is, what can be the further risks that we have to face in terms of the health concerns on human and environmental concerns on nature. The size nano has a big question that disorient our minds which is hardly possible to guess all the effects without experiencing the drawbacks. Therefore, the question is; how it could be possible to get precautions against toxicity and how to make a balance to adopt to a new high tech world of nano-architecture?

On the other hand, what makes nano-tech so innovative and what creates the magic? How qantum theory and nano-particle kinetics concepts manage to amaze nanoscientists with its innovations and extraordinary outcomes? Is it possible to create shortcut solutions between the results that has been achieved in nano-medicine to nano-architecture? How the theory and application procedure of nano-tech can be parallel to multiple solution concepts? How sustainable are these solutions? With all the great intelligence of nano-world, how it is possible to enhance the quality standarts of high tech buildings and constructions, how this new findings affects the mechanical strength, structural configuration and construction technology.

Moreover, high tech building technology standarts by using nano – innovation technology go towards to a new dimension that have been called "smart building technology and smart cities". In this concept , "zero energy buildings" theory is a main research area for all the construction scientists coming with a big question to discuss "what cause zero energy? How this could be possible?" Meantime, the construction technology is going towards a century that multifunctional creations and designs has been awarded and worth to discuss for. The recent instance and the most intelligent creation that has been emerged is 'SHED NY Art Center" completed on 5 April 2019, by Diller Scofidio + Renfro Architecture Design Office. Exclusively, all these innovations on the idea of construction and functionality challenge brings the responsibility to find new solutions fort he emerging energy and efficiency needs for these high tech creations. All in all, "Smart Building Technologies" and "Solar Panel Concentrator Systems" for this type funtional creations are new criterias that need to be discuss on to find the source of the energy for the routine management of this type buildings. So, how efficiency standarts could be modified related to advancement of the construction technology and how the new sources of the energy could be provided?

During this research, the answers of all these questions will be criticized with all aspects. So, a standardization methodolgy will be created about the way how we need to adopt the needs, norms and regulations of nanotechnology will be evaluated. Evaluation of efficiency (EE) and success parameters will be examined that will result to understand the limits and the advantages of nano-treatments, with the drawbacks and risks as well. The idea of this research has application to patent for Politecnico di Milano POLIMI IRIS : 05.1. Brevetto & Patent Application: 2018. Nanotechnology In Architectural Restoration: Science & Innovation: Hybrid Nano - Composite Design for Consolidation of the Porous Structures : Limestone & Bone "Transport Phenomena", ID: hdl:11311/1065405

Keywords— ***Nano-architecture, Efficiency, Sustainability, Smart Building Technology, Zero Energy Buildings***

I. INTRODUCTION

Especially, in the last decade, in lots of reseach studies discussed about the innovation that has been carried out with the basics of nano-tech. This raising interest has getting an accelerating attention among scienceworld, starting since 2004, even to get ahead to double the number of the publications in comparison with silica, seeming to be the leader until that moment. [1] Afterwards, roles has been changed, nowadays the question is if silicon valley has been ready to abdicate its throne to nanoscience valley, and moreover if this magic of nanotech is certainly real to follow; how much safe and how much repetitive it is. What could be the health risks on human/environment and how it is possible to get the necessary precautions against to toxicity problems of nano-sized

particles. To be in the safe part, for this concept, it is necessary to understand what the nano-size means, nano-size is an incredible littleness that creates the magic by using the "quantum confinement effects"[2] , 1nm is 1.0*E-9m. This unusual particle size comes with some disadvantages in terms of the inhalation problems for the researchers who are carried out the experimental analysis in laboratory conditions, because the masks that has been used for standart chemical works generally have the adequate protection against powder/dust, and with some extra additive parts they can be useful for chemical vapor protection. However, nano-sized chemicals, having the risk with passing through the mask filters, reaching the lungs and have the potential toxicity risks, especially with the respiratory toxicity that has been shown the effect on mice, with the risk and the possibility, from SWCNT carbon nanotubes to cause lung cancer. [3] On the other hand, another risk factor is spreading these nano chemicals to living atmosphere from their application zones. Little info has been known for long term effects of nanoparticles, so there are inreasing concern among science world if the risk of release could be possible from the building materials and could cause harmful impact not only for human health but also for environment. [4] In contrast, there is a so well known speech that chemistry is not innocent, as a reminder from organic chemistry laboratory studies in undergraduate years of chemical engineering and chemistry departments. All type of chemical compounds have some health risks and there is lots of precautions that researchers need to take into account. To be honest, with the nano-sized criteria of nanoparticles, the respiratory risks of toxicity are further than the standart sized usual chemicals, but to be in a meaningful consideration, this little nano-sized effect have also the positive potency that create the magic of nanoscience with its accelerated limits if penetration depth and adsorption criteria. So, even also having the risks of toxicity, nanotechnology has worth to take necessary precautions, with enhanced high-equipment laboratory conditions and to keep to continue searching on it.

Another discussion point for nanotech is stability criteria, that also has been found resolved, and advised to go further in University of Edinburgh studies. [5] When it comes to stability of the nano-composites, colloid stability and thermodynamic stability is a constant discussion point, needs to be go further. [5], [6]. Colloid stability in nano-particles is a crucial factor that can affect the efficiency of the results, by storage and preparation conditions of nanoparticles, as known before-application procedure, the reactivity performance of the nanostructured particles could able to differ, because of their aim to create agglomeration. Sonication parameter is an efficient way to provide the right colloidal stability and to create effective application in this sense. [7] A study that has been carried out in 2018, at Harvard University Radcliffe Institute for Advanced Study, has been shown that only 6 of 53 cases of the research works could be reproducible and safe with the constant results. [8] This crucial information has been accepted as a crisis on science world and created a huge question mark in our minds that how suffiecient and to what extent it is safe the results of the experimental analysis, while the research has got the proof that only 11% of the outcomes could be repetitive in historical perspective depending on science, technology and medicine. So, the new question is, how we can able to create the standarts of techno-world in order to be more repetitive in terms of the conclusions and to what extend it is possible to be in the safe zone and to avoid the disrupting factors that can even create possible problems for the reliability of the outcomes.

II. Background

A. Factors Affecting the Efficieny of the Outcomes

In the research that has been carried out in the University of Edinburgh, HAP particles that has planned to get applied on archeological human bone structures, has been experienced to analysed in laboratory by researchers themselves. As the result the HAP had been obtained between the range of 20-600 nm particle size in formation even also their chemical composition are the same, surely. This problem has been named "agglomeration" which is known a major huge problem in terms of nanoparticles. [5] Nano-particles have the negative potency to aim to create agglomerates, and this issue directly influence their potential of reactivity, viscosity, penetration capability and efficiency [9]. When nano-sized particles create agglomerates, their size range differs, even also to cause undesirable size-range spectrum. Moreover this phenomena directly have influence on the transport mechanism of the particles into deeper zones of the structures they are applied.

Regarding the problem of whitening and deposition for Ca(OH)2 nanoparticles, lots of studies that has been carried out in literature, focus into what could be done to enhance the quality of the efficiency outcomes of nano-treatment therapy for limestone based structures, regarding especially for the conservation of the cultural heritage buildings CH. Ca(OH)2 nanpoarticles, so called nanolimes, has been widely used lots of studies in heritage preservation literature, but their efficiency potential has not still been adequate as the result of their accumulation, whitening and deposition problems. In some studies, modifying the solvent composition between ethanol to water in different ratios has been discussed [10], also the application procedure has been taken into account by differing the absorption technique from capillary action to nebulization [11] , then experiences has been go deep into to directly modifing the solvent composition with different kinds of alcohols, having different dynamic viscosity properties ranging from 1:2 ratio, from ethanol to butanol, respectively, in order to evaluate the drying rate mechanism, and kinetic stability in response. [12] Drying rate for nano-particles, has been also discussed for 3 different kind of lithotypes (lime mortar, limestone and sandstone) in DRYMASS Research Project that has been carried out in Lisbon National Laboratory for Civil Engineering, with the importance on the influence on back migration and losing from surface for nano-particles. [13] In terms of nanolimes, because of the reason of solvent evaporation from the surface, some of the $Ca(OH)_2$ nano-particles evenly could able to lose from the surface, if adequate carbonation process can not able to performed, so called, named "back migration effect". Back migrated particles also can able to create accumulation on outer surface of the building material that can evenly cause the aesthetics problems in terms of CH buildings, especially. In this case, whitening problem on surface has to be discussed. So, selecting the correct solvent

with suitable drying rate, moreover avoiding the back-migration with after-treatment applications could be good solutions for better penetration and enhancing the quality of the nano-treatment. [9].

B. Stability Concerns: Colloid Stability / Thermodynamic Stability / Kinetic Stability.

"Colloid stability" is a concern that can evenly make difference on particle based systems in dispersion and colloidal phases. In a research study that has been carried out under the support of European Commission, "NANOCATHEDRAL" project, suspension stability in different mediums from water to alcohol has been discussed. Reminding the concerns that has been experienced in Edinburgh University studies on "archeological bone, limestone and autoclaved concrete" substrates which has been described above [5], in NANOCATHEDRAL research work, three different lithotypes (marble, sandstone and limestone) has been evaluated on 6 real site monuments, under the effects of different weather conditions, located in different geographical regions from Pisa/Italy to Oslo/Norway, with various temperature and relative humidity %RH factors of environmental conditions. In consolidation case, "TEOS tetra ethyl orto-silicate " in combination with nano-SiO2 and nano-ZrO2 has been searched, and in protection case nano-TiO2 photocatalitic activity has been discussed. By using "on site monitoring systems" on real site monuments, evaluation process has been performed efficiently for the success of nano-treatment in composite forms. [14] After the research and final critics of Edinburgh University study, Nano-Cathedral Project again focused on the importance of the "colloid and suspension stability" on the serious effect on success potential of the outcomes.

"Thermodynamic stability" is another concern in terms of stability theory that temperature differences can evenly affect the behaviours of nano-composites such as polymer-clay combinations. In a research study that has been performed in Texas State University in USA, "thermodynamic stability" has been accepted as the essential case in order to the nano-composites to be useful in their ongoing analysis. [6] "Kinetic stability", also has been discussed above in DRYMASS research project, is an essential factor that can even affect the efficiency for nanoparticle based treatments, just a similar case with the importance of the stability factor in the pharmaceuticals industry in medicine; "chemical stability, physical stability, microbiological stability and toxicology stability". [15]

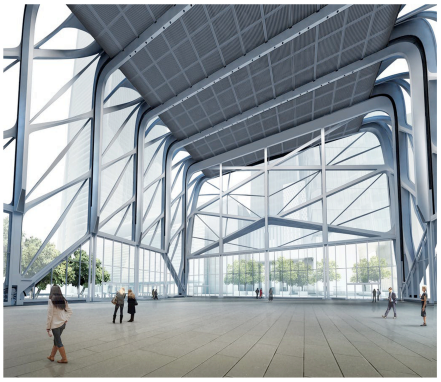
C. Emulsions and Art Works

In Piero Baglioni works, who has been managed to get successful results in terms of preservation of art works for heritage preservation, "microemulsions theory" has been discussed. P. Baglioni also introduced the "Ferroni Method" and the importance of the dispersions of nanoparticles to the scienceworld. For enhanced control of consolidation works Baglioni advised to use alcohol based dispersions on wall paintings and stone consolidation works, also using Japanese paper sheets and adding some $Ba(OH)_2$ barium hydroxide has been offered. Baglioni has also focused on elimination of acidity for paper, canvas and wood, related to heritage art works. [16]

D. Smart Building Technology for Nano-Architecture

"Shed NY Art Center"fun has been recently advanced all the rules of the construction sector and had demonstarted to construction world that a building could be in the top point of the functionality and efficiency with all the outcomes it has. Shed, by using the rail system technology, have movable case structure with steel construction system in its background, and glass facade covers for the enhanced translucidity.

Img 1: Design Concept Image 1 for "Shed NY Art Center – Smart Buildings Technology", by Diller Scofidio + Renfro Architecture Design Office [17]



Img 2: Design Concept Image 2, Steel Case Structure in front, for "Shed NY Art Center – Smart Buildings Technology", by Diller Scofidio + Renfro Architecture Design Office [17]

Research Doctorate has been carried out with the support of the scholarship from Politecnico di Milano, PhD School – Milan/ITALY

Img 3: Design Concept Image 3 for “Shed NY Art Center – Smart Buildings Technology”, “Creation of Functionality”, by Diller Scofidio + Renfro Architecture Design Office [17]

Img 4: Design Concept Image 4 for “Shed NY Art Center – Smart Buildings Technology”, Steel Case Structure in front, by Diller Scofidio + Renfro Architecture Design Office [17]

Img 5: Design Concept Image 5 for “Shed NY Art Center – Smart Buildings Technology”, Detail of the Extraordinary Rail System, by Diller Scofidio + Renfro Architecture Design [17]

Shed NY has completed on 5 April 2019 by Diller Scofidio+Renfro Architecture Office, with the proof of the advanced level functionality on building science and the creation of design. The construction of Shed, also opens to all building construction scienticts a new reseach area that how could e possible to make feasibility assessment for these type building integration systems in terms of their energy needs and efficiency? For this concept, smart building technology seems to be so much connected with the solar panel technology that is also one of the new challange points advanced in Sweden, recently, April 2019 [18]. Using the advanced solar panel technology for the facade of the high- tech buildings can able to create and advance the efficiency levels of this buildings. So, it is obviously seen that “Smart Buildings Technology” concept have great potential to research in accordance with the “Solar Panel Concentrators” systems . With a related connection of “Building Integrated Photovoltaic Modules” system, that has been also discussed in the recent studies of the research group “ESRI Electron Science Research Institute” in February 2019 [19], “transparent and luminescent concentrators , photovoltaic building integration systems and solar windows” could be a potential source of the needs fort he high-tech innovative funtional building technologies.

Img 6: Building Integration Photovoltaic Technologies, recent research by ESRI Electron Science Research Institute, in February 2019. [19]

In an exclusive open-minded consideration with the connection point between the “solar panel concentrators” sytems, “building integration photovoltaics” and “advanced hybrid nano-composite technology” systems, science world could have the potential to discuss on the availability and perfomance criteria of the nano-particles technology and how to adopt the desired nano-particles and advanced nano-coatings systems for the service of the enhanced quality for the smart building technology integrated systems. For the proven cases of the high-resistant and advanced level durability performance properties of the nanomaterials, nano-tech based construction ideas are a open discussion point for all the researchers of construction science that needs to go further for the potential performance enhancements and to understand the limits of the interconnection points between these unique disciplines of building strategies, that can even create the innovation in a

high-tech level of construction world for nano-architecture systems.

III. Methodology

A. Range Spectrum between Nano to Micro and Different Orientation

A so creative solution point in order to overcome the described problems of nanotechnology is to use nano to micro particles together to form more rigid structures and to avoid the back-migration. [9],[20]. To go further with this idea, a research study has been awarded, which has been carried out in Ball State University in USA, with formulating "inconstantly located fibers into concrete" ranging from nano to micro scale in size-length, and in combination with carbon, steel and polymers, for the objective to enhance the mechanical strength of concrete performance. [21]

B. Creating Hybrid Nano-Composite Designs

1) Hybrid Nano-Composites in Architecture

A research study that has been carried out in Berkeley National Laboratories that the secret of the Roman Mortar has the clue of having hybrid composite design structure in itself, by combining the calcium-alumina-silica-hydrates (CASH) together. [22] This discovery announcement from Berkeley Laboratories could be accepted as an *"inherited intelligence",* as the first usage of hybrids and composites in architectural construction, with the proven cases of the secret of Roman Mortar comes from its hybrid designed morphological structures inside.

Recently, another good study has been obtained in European Commission NANOCATHEDRAL research project, that has been carried out to understand the effects of NPs nanoparticles into consolidation and protection cases. The combinations of TEOS (tetra ethyl silicates) in combination with NPs nano-particles has been discussed in NANOCATHEDRAL. Nano-silica and nano-zirconium has been selected as the consolidant role for expecting results to get efficiency on different types lithotypes. Aging factors has been already discussed by using artificial ageing procedures on lab tests. [23], [24], [25]. Photocatalitic activity based on TiO_2 titanium dioxide nanoparticles also has been evaluated. [26]

2) Hybrid Nano-Composites in Medicine

A research study that has been carried out at University of Orleans in France, has been revealed a discovery that there is a so good connection between bone and limestone in terms of their chemical composition (that based on calcium) and morphological structure properties, proven with 2D sections and 3D high resolution tomography images, in terms of porosity criteria, that brings the transport phenomena similarities in these two porous media. [27] This porous media idea has lighten our minds into find similar treatment capabilities between nano-medicine and nano-architecture, meaningfully.

When it comes to making a correlation between nano-architecture and nano-medicine, on a similar way with nano-architecture and nano-composite technology; nano-medicine therapies also based on the essentials of architectural bone tissue scaffolding techniques, creating tissue formation in biomedical tissue engineering applications [28][29]. Using the combinations of NPs such as: SiO_2, CaO, P_2O_5 and Na_2O, in order to form the bioactive glass scaffolds, a model of creating nano-hybrid forms has been evaluating in biomedical applications. In nano-medicine and tissue engineering concept, bone regeneration therapy, creating bone tissue engineering scaffolds based on combinations of different NPs, in a so creative, systematic diagrams algorithm schemes, is a model of finding ways of load bearing defects against osteoporosis [30] and even also in dental applications.

3) Hybrid Nano-Composites in Aerospace Industries

Surface Coating functional coating systems against ice formation for aircraft wings has been an essential issue for safe flights. Regarding this problem, a European Commission Horizon Project PHOBIC2ICE has been studied for optimizing the right nano-hybrid designs for functional surface coatings regarding the aviation technologies. AIRBUS is the partner of this research group and LARFIS Polytecnique Monteral Canada LARFIS Laboratories has been used for the experimental analysis, silica coatings and their potency on hindering the ice formation on aircraft systems has been examined in detail. [31]

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C. Standardization and Evaluating the Efficiency (EE)

Nanocathedral EU Project publications underline that there must be some certain rules regarding to nano-treatment applications such as; aesthestic compatibility, preventing the toxicity of nanomaterials, finding solutions for possible health concerns: regarding the respiratory problems for humans and avoiding the spreading possibility of the NPs to the environment. Also, safety of the results and to what extent the similar outcomes could be provided is an issue needs to be taken into account. In the literature, evaluation criteria of the results has been detected by using monitoring systems for for on site monitoring applications [4], and evaluation of the mechanical durability, compressive strength or flexural strength for laboratory test has been performed on samples. [9],[20]. IR-Photography, UV-Photography, 3-D Structured Light Scanning, and Color Photography also some other techniques has been used on site for the efficieny criteria. [32], [33] In order to evaluate surface morhology, SEM Scanning Electron microscopy, to evaluate interfacial structue TEM transmission electron microscopy and to evaluate phase microstructure XRD X-Ray Powder Diffraction has been used for outcomes of the nano-treatments. [34]

3 point bending test is a destructive testing method, to evaluate the evaluation of the efficiency, in terms of mechanical strength and withstanding time before cracking point of the sample. With th data of withstanding time, it could be useful to go further for this data for the building durability cases against

eartquake deteriorations. [20] On the other hand, in terms of the importance of the on site monitoring applications on historical monuments, Chinese researchers has created a sensor that has highly sensitive performance for on site monitoring applications. [21]

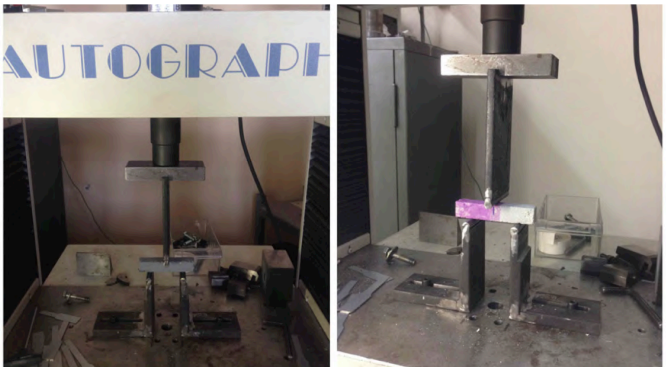

Fig1 : Destructive evaluation test, 3 Point bending test , to evaluate mechanial stregth enhancement, [20]

IV. Conclusion

Stability theory, and colloid stability is the main criteria in terms of the efficiency results in nanoparticle based technologies, having a direct influence on accumulation and deposition problems. Harvard University study that has been shown with the proof that- discussed in introduction part above- only 11% of the experimental analysis research studies in terms of science, technology and medicine has the potency of repetitive outputs. [8] In a meaningful consideration, this coincidental outcomes of the researches, in their backgrounds, must have negative points that can cause the disrupting factors of the reliability of the results. For NPs nano-particles based treatments, taking into account the importance of the viscosity, penetration depth, surface adhesion and adsorption criteria [9], colloid stability affect the efficiency parameter of the results and reliability in nano-science.

Sonication and mixing in high velocity mechanical stirring techniques (such as between the range of 400-600 rpm with a mechanical stirrer) are some of the solutions that researchers are trying to make the nano-dispersions stable before the application on substrate surface [20]. But, on the other hand, this kind of solutions could be possible on pilot size applications that could be carried out in laboratory basis studies, possibly could be so difficult or in some cases, completely impossible with the inadequate technical conditions in the worksite area, such as the difficulty of finding a huge sonicator before an application on site area. As it is clear, some practical solution techniques, that can be evenly possible in laboratory testing analysis could be evenly difficult on real site practice, in a more optimistic way, could be possible, but somehow expensive, on real site practice.

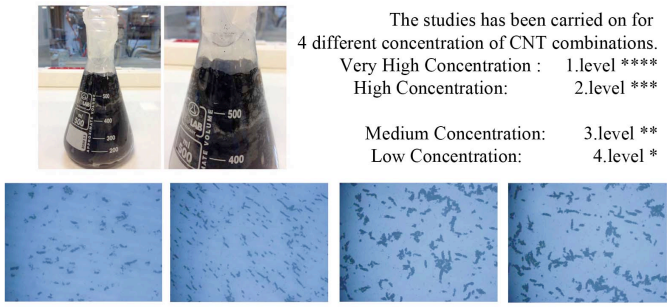

Fig 2: Effect of colloidal stability on CNT dispersions before application to samples of building material, searching the effect of Carbon nanotubes on mechanical strength of construction materials, [20]

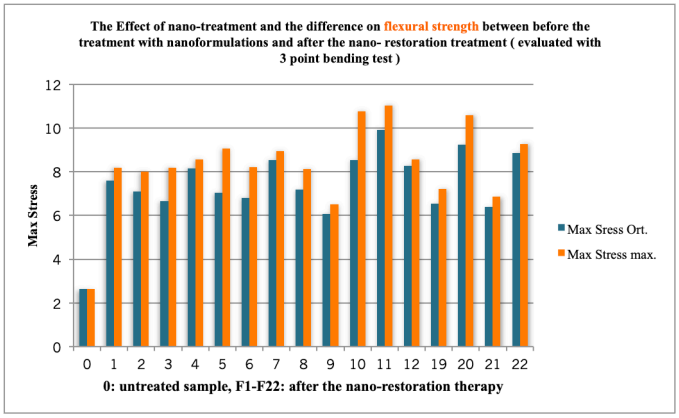

Fig 3: CNT/Ca(OH)$_2$ Nano-composites flexural strength evaluation by 3-point bending test, also effect of colloid stability and dispersion efficiency. [20]

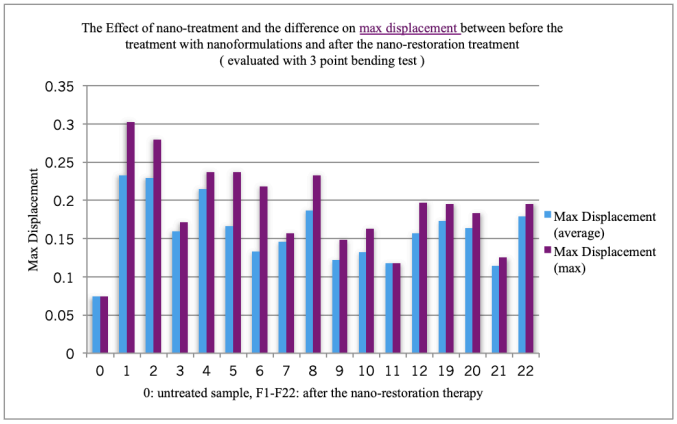

Fig 4: CNT/Ca(OH)2 Nano-composites max-displacement data, evaluation by 3 point bending test, also effects of colloid stability on efficiency [20]

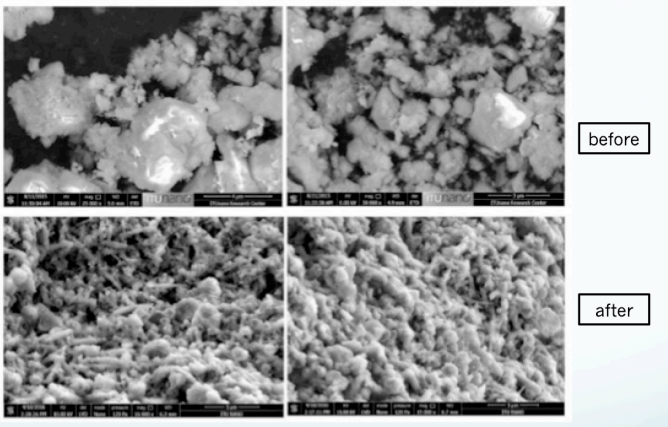

Fig 4: Evaluation of the Efficiency Criteria in nano-tech: SEM analysis of nano-composite treatment, all the defects has been consolidated with the nanoparticles has been shown. (before and after application) [20]

On the other hand, there could be really some certain special cases, especially in architectural restoration applications on real site, that needs extreme safety, and it is evenly worth to spend on it. The fire on Notre Dame Cathedral has been highlighted the issue that the "resistance to fire property" of some construction aimed nanomaterials must be used in some so important cultural heritage CH buildings in order to be sure the safety of the building during restoration works. [35], [36] Otherwise, with the imflammable effect of lots of polymer based construction chemicals, that has been widely used in the restoration works, there is always a risk for an unexpected serious fire while the work on site has been going on. With two other examples of this risk, that has been unfortunately experienced in two historical monuments in Istanbul/Turkey: Galatasaray University's fire and Haydarpasa Train Station's fire. [37], [38]. So, even also nanomaterials and choosing the nano-treatment way especially for construction and restoration works, could be expensive, with huge size application zone and application difficulties [39], somehow, in some cases it is needed and must be obligatory in order for enhanced safety.

ACKNOWLEDGMENT

Regarding the figures and graphical data used in this article, with the experience of my master thesis study has been completed in Istanbul Technical University MEMS Nanotechnology laboratories, special thanks for all the support of my master thesis supervisor Prof Deniz Mazlum and co-supervisor Prof Levent Trabzon.

Dott Eng Arch S.E. SUNGUR (author) master thesis study has carried out with the scholarship of TUBITAK Turkish Scientific and Technological Research Council, and have titled with the innovation patent, by the patent number of 2017/17231.

Finally, I dedicate my study to my dear family; my dear dad, I have missed so much, that I have lost recently, MSc. Electrical Eng. Coskun Sungur, lecturer & academician at ITU Istanbul Technical University, my dear mother Serpil Sungur, the luck of my life, and my dear grandmother that have brought me up with all her big heart and unlimited love.

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