Nano-Structural Innovation for Future Nano-Architecture

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Technology transfer between engineering, architecture and medicine, in solution point of nanotech innovation : porosity and mass transport.

Hybrid Prototype	1st Treatment	2nd Treatment	Compressive Strength (N/mm2)
Prototype 1	$Ca(OH)_2$	SiO_2	evaluation criteria for 1
Prototype 2	$Ca(OH)_2$	HAp (Hydroxyapatite)	evaluation criteria for 2
Prototype 3	SiO_2 nanosilica	HAp (Hydroxyapatite)	evaluation criteria for 3
Prototype 4	SiO_2 nanosilica	$Ca(OH)_2$ nanoparticle	evaluation criteria for 4
Prototype 5	HAp (hydroxyapatite)	SiO_2 nanosilica	evaluation criteria for 5
Prototype 6	HAp (hydroxyapatite)	$Ca(OH)_2$ nanoparticles	evaluation criteria for 6
Prototype 7	SiO_2 nanosilica	SAE	evaluation criteria for 7

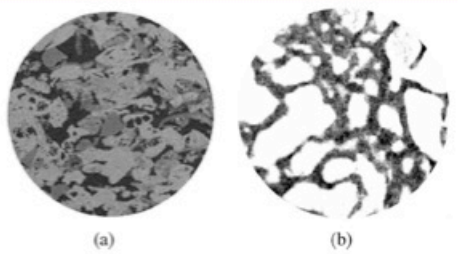
Fill the porosity with new design hybrid-nanoparticles

Functional coating and surface engineering with anti-ice nano-coating technology against freeze thaw cycles

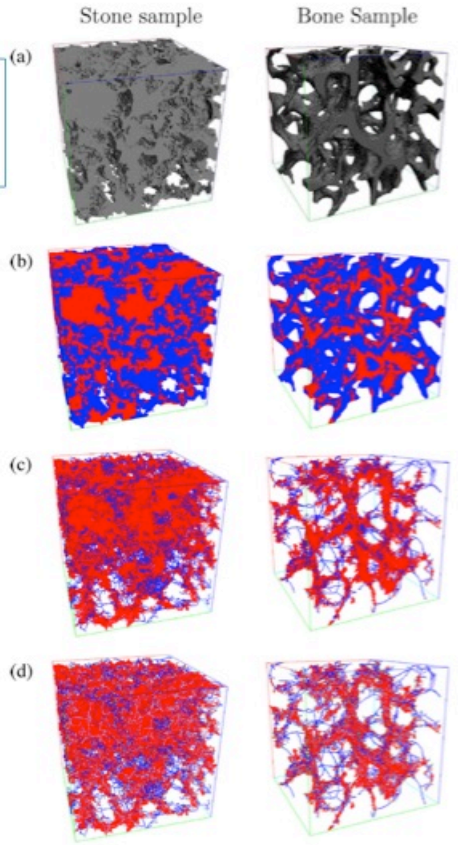
5 Key Rule: Penetration depth, surface adhesion, viscosity, adsorption, subst. porosity.

Bone limestone Publication – Adopting bio-medical techniques to nano-architecture idea

A. Almhdie, O. Rozenbaum, E. Lespessailles, and R. Jennane, "Image processing for the non-destructive characterization of porous media. Application to limestones and trabecular bones," *Math. Comput. Simul.*, vol. 99, pp. 82–94, 2014.



Selected 2D cuts of the stone (a) and bone (b) samples.



3D porous media: one-connected objects
(a), classified volumes,
(b) hybrid skeletons,
(c) and the final individualized skeletons
(d). Rodvoxels are in blue, plate voxels are in red while node and border voxels are in green

3D Characterization of the materials with high resolution X-Ray computed Tomography (XCT)

Abstract

- Aim: Technology treatments and finding innovative solutioons between:
  - treatments in medicine in terms of “bone regeneration”,
  - the treatments in architecture in terms of “nanolime consolidation effects on limestone”
  - and the treatments of aerospace technology in terms of anti-icing nano-coatings.
  - the porosity and mass transport between the correlation of human bone and limestone
- 2 main steps: <u>1ST Step</u>: As reference to Faculty of Medicine: France; University of Orleans [1] on bone regeneration therapy :

- Absorption of compatible nano-chemicals (nano-silica Si02, HAP<200nm particle size, CaO, Ca(OH)2 nano-composite design) treatment to inner porous structure: limestone, in order to have mechanical strength and consolidation.

- <u>2ND Step</u> : As reference to AIRBUS ICEPHOBIC Anti-icing Nano-Coatings Technology European Commission Project – Polytechnique Montreal Canada – Functional Coatings and Surface Engineering Laboratory (LaRFIS): Anti-icing icephobic nano-coatings of the porous structure – limestone.

- Expected result of the 1st step nano-treatment is to gain mechanical strength and consolidation effect inside the building material , regarding as the main treatment. Then, in the 2nd step, regarding as the after treatment therapy with the anti-icing nano-coatings, the expected result will be to prevent the CH buildings against freeze thaw cycles.

Keywords— Nano-architecture, Nano-composite, Hybrid, Design, Sustainability

by using the techniques in aerospace technology, used by AIRBUS, for “anti-icing nano-coatings technology’’; how to find a solution to the well-known problem of freeze-thaw cycles and ice-formation inside the building structure, that finally cause and effects the building material deterioration.

During the study, the discussion will be focus on the solutions for sustainability of nano-treatments in nano-architecture for future.

The discussion points are; hybrid nano-composite design, “a simulation of bone regeneration in medicine”, in which ways and techniques? “HAP hydroxyapatite - SiO2 - Ca(OH)2” hybrid works well to solve the problem?

INTRODUCTION

which nanohybrids and combinations could be more suitable for this sense. Primarily, the research hold in University of Orleans in France [1] shows great correlation between limestone and bone morhology with the proof of the high resolution X-ray computed tomography images that makes obvious the similarity of these two structures in terms of <u>“morphology, texture and topology”</u>. This proof could be a starting point to create the idea of the new nano hybrid design in order to create more compact and more durable structures for architectural concept, not only for preservation but also for consolidation the defects with suitable formulated nano hybrids design parameters. Moreover, with a plus of after treatment, with the experience of Airbus PHOBIC2ICE European Commission Project [6] with LARFIS Functional Coating and Surface Engineering Laboratories in Canada, ice formation that happens above the the aircraft surfaces has been discussed to resolved by using nanoparticles with a surface treatment system.

II. Background

A. Si-HAP Reinforcement

Cambridge University study [7] indicate that silicon substituted hydroxyapatite (HAP) has managed to get successful results for medicine, even if, under 5% silica substitution in combination with HAP crystals, by the technique of the coating, using magnetron sputtering. The focus in the research based on not only hard tissue replacement therapy in medicine but also it is claimed that soft tissue replacement could be possible and effective in this sense.

it is sure that nano science and reinforcement techniques of nanotechnology that has been continuing to work well both in nano medicine [8] and nano engineering during a decade, could be the first and primary saving methodology in terms of the preserving the authenticity in CH monuments. Replacement a pillar, indeed, must be the last case, the last chance to save and preserve.

B. Understanding the Experience on Dental Application Techniques and How to Adopt this Success in Medicine to Architecture

Not only for the fracture resistant on dentin but also the capability of elimination of the bacteries in root dentin by using the idea of calcium hydroxide and calcium oxide nanoparticles. [10] It is obviously clear in the results that nano-sized calcium hydroxide and calcium oxide have been shown great importance to elimimate the bacteries however the standart sized chemicals of the same components have no effect.

C. Understanding the Effect of Particle Size on Success from Medicine to Architecture

In the research study has been completed in the University of Edinburgh [14], it is obviously shown that fine particle sized hydroxyapatite (between the range of nano to fine powder size) can able to create an effect on archeological bone structure. In Edinburgh University research study, it is discussed between the correlation of the success in 3 different type of lithotypes: limestone, portland cement and archeological bone, and the discuss criteria is the transport phenomena and the particle transport effect on these different morphologic media.

Hydroxyapatites has been preferred to synthesised and colloidal stability has been discussed as a research question in the second step. Results have been shown that, the success and the penetration depth of HAP are highly depends on the criteria of agglomeration that hinder the effect of good penetration.
For Edinburgh University study, hydroxyapaptite – ethanol suspensions can able to succeed the penetration until 6mm because of their undesired agglomerates between the spectrum of 20-600 nm size particle size hydroxyapatite colloidal suspensions, whereas 200 nm stable particle size of HAP cystals offers much more success in biomedical applications in literature for human bone systems in terms of osteoporosis treatments. [15]

Also, hydroxyapatite crystals with different percentage of the reinforcement (20%, 40%, 60% and 80%) [16] in process by [SiO_2, CaO, Na_2O and P_2O_5] composition, widely known “45S5 Bioactive Glass” with the official name in the medical literature; performed good results for bone regeneration therapy in medicine, not only with combinations in hydroxyapatites but also by itself as a role of being a scaffold in bone tissue engineering applications. [3],[17],[16]. 20-200nm particle size range spectrum also has been advised in the architecture literature with the experience on limestone applications. [18]

III. METHODOLOGY

A. Interdisciplinary Era Between Medicine to Architecture and How to Adopt the Nano-tech

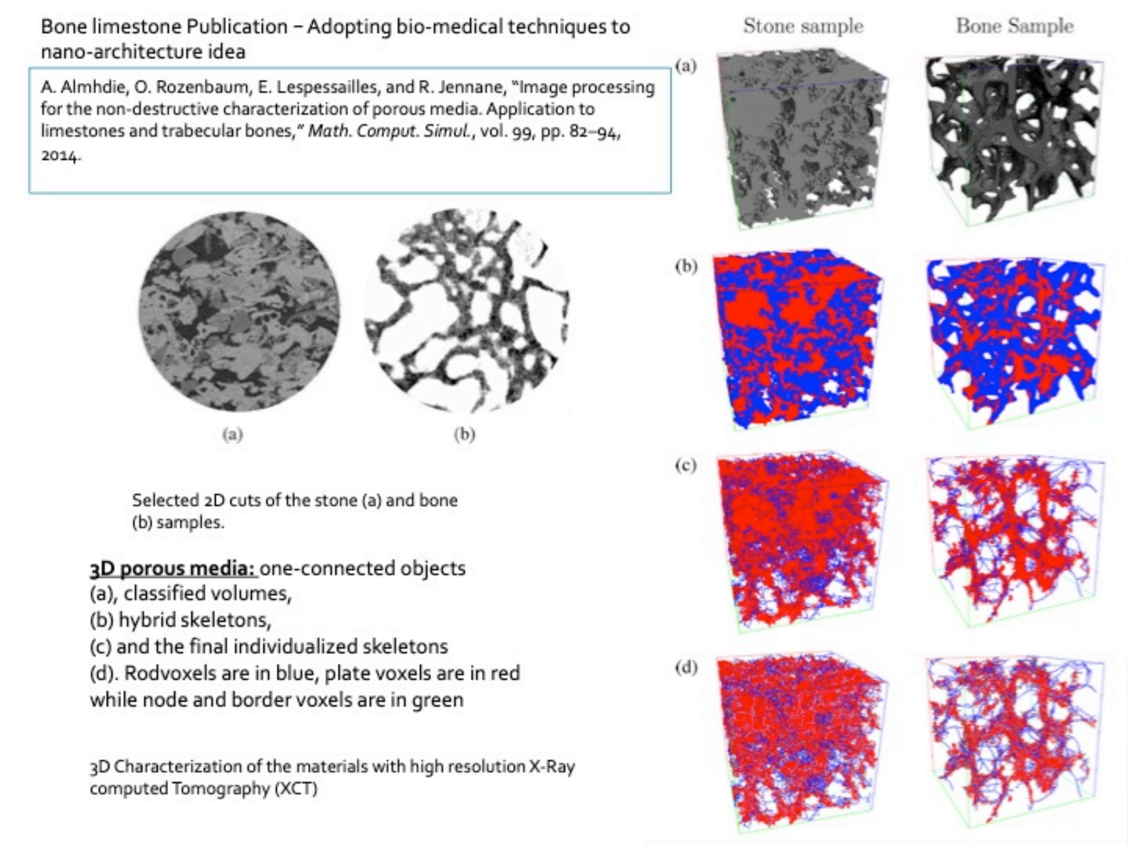
For all the cases of the applications in interdisciplinary area regarding both medicine, architecture and aerospace technologies, the primary rule to understand is there are essential factors that will highly impact on the results on nanotreatment. Dealing with chemicals, even if in nano-size, is much more difficult to overcome the problems that will affect the efficiency and could be a major disturbing factor coming from the environmental conditions such as temperature and relative humidity. [19]

On the other hand for medical applications, in terms of the bone regeneration therapy, and building the bone tissue engineering scaffolds, "silica calcium phosphate composites" find theirselves application area in nano-medicine and they are widely used with the crucial factors of pore size and interconnection layers between Ca-P and Ca-Si, for their success criteria that affects the adsorption, adhesion and formation efficiency. [22]

"45S5 Bioglass" scaffolds have a major impact on nano medical therapies with their capability of interconnections and reaction potential between some other basic chemicals such as SiO_2, MgO and CaO, that creates the different durability performance on compressive strength and tensile strength.[23]

For bone regeneration therapy applications, some optimization of the performance simulation graphics has been evaluated in the literature that could be accepted a proof for the connection between the porosity of the material structure between the compressive strength, under the affect of the application with different chemical composition nanohybrids such as Na_2O, CaO, SiO_2 , P_2O_5 [8], [24]. In order to evaluate the porous scaffold reliability, [CaO, Al_2O_3 , P_2O_5 composition] has been used to detect the flexural strength of the load bearing capabilities [8],

B. 5 Key Point Rule and The Optimal Efficiency List



Considering the efficiency criteria among these different disciplines, there are 5 key points that points out all the attention; penetration depth, surface adhesion, viscosity, adsorption and substrate porosity have the main impact on all disciplines performance criteria regarding the nanotech innovation. [20] Apart from these, as a reference to studies that has been carried out in TU Delft, storing conditions of the nanomaterials, preparation and mixing techniques, finding the most suitable solvent to get homogeneous distribution, density of the colloidal suspension, application process, properties of the substrates or the lithotypes, pre-treatment or after treatment possibilities, environmental conditions (temperature, T and relative humidity, %RH), air velocity (that will affect the criteria of the solvent evaporation rate), techniques such as brushing, full saturation bath, spraying or nebulization in order to get the desired homogeneous distribution among the structure's deeper side and a so crucial factor of sonication that will also affect the colloidal stability are the basics of the optimal efficiency list on nanoscience. [18], [19], [27], [28], [29].

C. Hybrid Nanocomposite Design from Nano-medicine to Nano-architecture

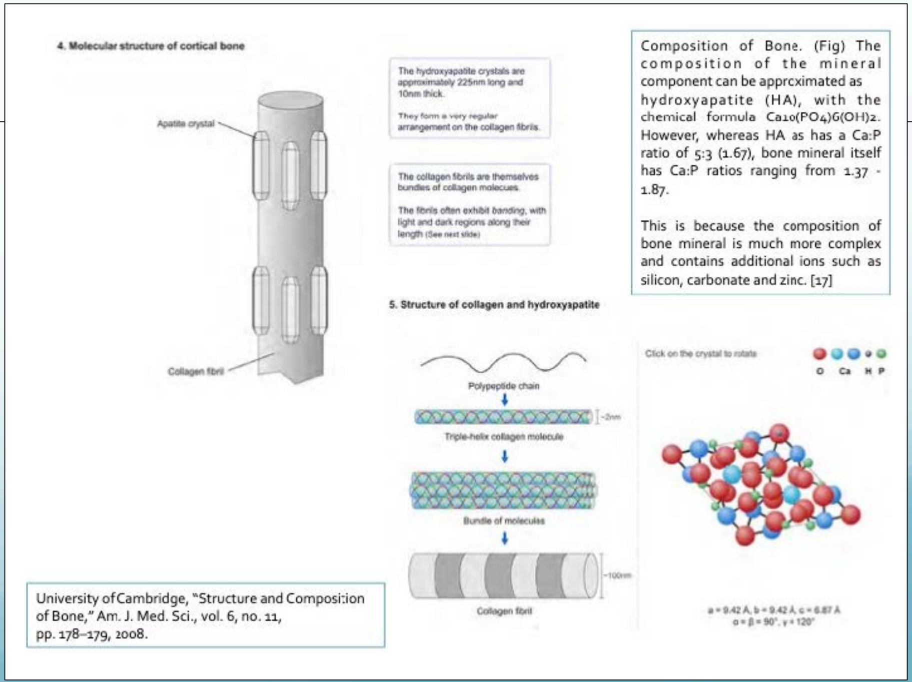
The recent research works that has been carried out especially in Horizon projects focused on creating new design nano-composites with combination of some well known nano-particles such as nanostructured titanium and zirconium particles. [30] Titanium composites in nanosized has been widely used for the stone preservation cases in architectural heritage science thanks to its self cleaning potency. [31],[32],[33]. Also in some studies for preservation again, antibacterial affect of titanium has been discussed. [34]
Apart from titanium, Ca(OH)2 such as known as nanolimes has been evaluated in lots of research studies, and some of them with good results. [18], [20]. Although, effective results has been announced in medical treatments using the HAP hydroxyapatite particles, by using the advantage of the 70% composition similarity depends on the mineralogical part of bone composition [17], a study that has been published in Nature Journal announced that Ca based designed nano-hybrids such as CaSi ceramics (with their official literature names: diopside and akermanite) has better potential effect on bending strength than HAP based treatments, regarding the medical treatments on bone with stem cell therapy. [4]

D. How the Correlation Works Between Bone Regeneration in Medicine and Stone Preservation in Architecture

Bone is a type of natural nano-composite, with Ca, O, H and P components inside the structural configuration, regarding to the study of Cambridge. As it is indicated in the Cambridge University studies regarding to Bone Regeneration therapies,
"Composition of Bone.

The composition of the mineral component can be approximated as hydroxyapatite (HA), with the chemical formula Ca10(PO4)6(OH)2.

However, whereas HA as has a Ca:P ratio of 5:3 (1.67), bone mineral itself has Ca:P ratios ranging from 1.37 - 1.87. This is because the composition of bone mineral is much more complex and contains additional ions such as silicon, carbonate and zinc."



As discussed before in II.A part of this article, Si-HAP reinforcement method is one of the most effective way to gain enhancement to the bone structure regarding to the studies that had been hold in Cambridge University in 2008. [7]

With all these data in the background of the bone regeneration therapy could able to open to a new world of the solutions for stone conservation therapies in architecure by using the intelligence of the porous structures matrix and their relations in terms of porosity, absorption, density, ratios of University of Cambridge, "Structure and Composition of Bone," Am. J. Med. Sci., vol. 6, no. 11, pp. 178–179, 2008.

E. How to Offer Innovative Formulas for Next Generation Solutions

TABLE II. 2 Step Idea (1st step to fill the posority with nanoparticles and 2nd step to create functional surface coating for a solution against a pre-defined problem such as freeze thaw cycles in architecture)

Fill the porosity with new design hybrid-nanoparticles → Functional coating and surface engineering with anti-ice nano-coating technology against freeze thaw cycles

TABLE I. New Formulated Hybrid Nano-composites To Go Further

Hybrid Prototype	1st Treatment	2nd Treatment	Compressive Strength (N/mm2)
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IV. CONCLUSION

Nanotech and innovative design technologies has been created a huge effect on science world with all the reinforcement and enhancement effect criterias in lots of studies has been told above. Now, the question is how to go further and how to adopt these innovations in interdisciplinary area in order to find new solutions for unresolved issues in practice for architecture and engineering applications. In this research topic, regarding to doctorate thesis study that has been carrying out in Politecnico di Milano Department of Architecture and Urban Studies (DASTU), cultural heritage building preservation case is one of the major aims, so, in order to create an innovative solution related to well known problem of freeze thaw cycles in CH buildings, the nw offer of next generation hybrid design is to make a technology transfer between the medicine and architecture, and to adopt the bone regeneration therapy issues to building preservation cases. Under the experience of the successful results that has been carried out on bone scaffold design technology and osteoporosis treatments, with the chemical and morphological composition similarities between bone and limestone [1], it is obvious to sum up that the innovation of nano-medical therapies are also useful for nano-architecture solutions, and this research has been inviting all the architectural science researchers to create new innovative design technologies for all the desired functionalities of engineering and architecture topics. All the innovation starts with to make the correct optimization between the chemical composition of substrate and structural morhology of the lithotype. Taking into account with the criteria of porosity, colloidal stability and transport mechanism; it is possible to make new sustainable interdisciplinary innovations continuously. Moreover, innovation of the nanotechnology comes from the extraordinary structure morphology of the porous matrix substrates and this open minded philosophy brings several correlations such as the effect of the density, mass transport and absorption criteria together. All these parameters will be an open research area for the future researches by theirselves, with their differentiated chemical and physical properties in terms of material science and structural building morphology. As a result, these discussions will be the next generation science world topics, with their innovation in their backgrond.

Thank you , please take a look +36 references on paper