International Workshop on

CONSTRUCTION 3D PRINTING

"Recent Advances and Future Trends"

Date: 17/02/2017 (Friday)

Time: 9:00 AM – 5:40 PM

Fee: Free of charge

Registration

Website: www.construction3dprint.com

Deadline: 13/02/2017 (Monday)

Venue: Centre for Sustainable Asian Cities, School of Design & Environment, NUS, Singapore

Live Broadcast: Available via registration

INTRODUCTION

Join us in the one-day research work on Construction 3D Printing organised by Construction 3D Printing Research Unit under Centre of Project Management and Construction Law (CPMCL), National University of Singapore (NUS). The goals of this workshop, involving researchers from global leading universities, are to share the recent advances in Construction 3D Printing Research around the world and, most importantly, establish a platform for future research collaborations in this fast growing research topic.

TOPICS AND SPEAKERS

3D Printing of Affordable Housing Emerging Ideas, Trends and Software
Assoc. Prof. Lawrence SASS
Associate Professor, Department of Architecture, MIT, US

Ecological Materials for 3D Printing Architecture
Assoc. Prof. Ronald RAEL
Director, print Facility for Architectural Research and Materials (printFARM)
University of California Berkeley, US

Structural Properties of 3D Printed Cementitious Material and Members Reinforced with FRP
Prof. Peng FENG
Deputy Head, Department of Civil Engineering, Tsinghua University, China

Automation in Construction using 3D Printing
Assoc. Prof. Ming-Jen TAN
Associate Professor, School of Mechanical & Aerospace Engineering, NTU, Singapore

The Creation of 3D-Printed SMART Freeform Construction Formwork
Assist. Prof. Jacky K.H. CHUNG
Leader (Construction 3D Printing Research Unit), CPMCL, NUS, Singapore

Groove Light - A quest between Functional Design Flexibility and 3D Printability with Large-scale FDM 3D Printers
Assoc. Prof. Shinya OKUDA
Associate Professor, Department of Architecture, NUS, Singapore

ENQUIRY

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NUS National University of Singapore
CPMCL
Department of Building

Co-organiser
Berkeley UNIVERSITY OF CALIFORNIA
printFARM Laboratory

PROGRAMME

TIME	ACTIVITY	SPEAKER
08:30-09:00	Registration	
09:00-09:10	Opening Speech	Prof. Willie TAN *Head, Department of Building, NUS, Singapore*
09:10-09:15	Welcome Speech	Prof. Sui Pheng LOW *Director, Centre for Project Management and Construction Law, NUS, Singapore*
09:15-09:20	Inauguration Ceremony *Construction 3D Research Unit, CPMCL, NUS, Singapore*	Assist. Prof. Jacky K.H. CHUNG *Leader (Construction 3D Printing Research Unit), CPMCL, NUS, Singapore*
SESSION I – PRESENTATION *Session Chairman: Prof. Sui Pheng LOW (Department of Building, NUS, Singapore)*		
09:20-09:50	3D Printing Of Affordable Housing Emerging Ideas, Trends And Software	Assoc. Prof. Lawrence SASS *Associate Professor, Department of Architecture, MIT, US*
09:50-10:20	Ecological Materials for 3D Printing Architecture*	Assoc. Prof. Ronald RAEL *Director, print Facility for Architectural Research and Materials (printFARM) University of California Berkeley, US*
10:20-10:50	Coffee Break	
SESSION II – PRESENTATION *Session Chairman: To be advised*		
10:50-11:20	Structural Properties of 3D Printed Cementitious Material And Members Reinforced with FRP*	Prof. Peng FENG *Deputy Head, Department of Civil Engineering, Tsinghua University, China*
11:20-11:50	Automation in Construction using 3D Printing	Assoc. Prof. Ming-Jen TAN *Associate Professor, School of Mechanical & Aerospace Engineering, NTU, Singapore*
11:50-13:10	Lunch	
SESSION III – PRESENTATION *Session Chairman: To be advised*		
13:10-13:40	The Creation of 3D-Printed SMART Freeform Construction Formwork	Assist. Prof. Jacky K.H. CHUNG *Leader (Construction 3D Printing Research Unit), CPMCL, NUS, Singapore*
13:40-14:10	Groove Light - A quest between Functional Design Flexibility and 3D Printability with Large-scale FDM 3D Printers	Assoc. Prof. Shinya OKUDA *Associate Professor, Department of Architecture, NUS, Singapore*
SESSION IV – DISCUSSION *Moderator: Prof. Jacky K.H. CHUNG (Department of Building, NUS, Singapore)*		
14:10-15:40	Construction 3D Printing for High-Rise Building – Challenges and Opportunities	All participants
15:40-16:00	Coffee Break	
SESSION V – DISCUSSION *Moderator: Prof. Harn Wei KUA (Department of Building, NUS, Singapore)*		
16:00-17:30	Research Collaboration and Networks	All participants
17:30-17:40	Closing Speech	Assist. Prof. Jacky K.H. CHUNG *Leader (Construction 3D Printing Research Unit), CPMCL, NUS, Singapore*

*Skype Presentation

TOPICS AND SPEAKERS

Assoc. Prof. Lawrence SASS

Associate Professor, Department of Architecture, MIT, US

Topic: 3D PRINTING OF AFFORDABLE HOUSING- EMERGING IDEAS, TRENDS AND SOFTWARE

Synopsis: 3D printing is emerging as one of the fastest growing technologies within this decade. This technology is now capable of producing a wide range of products from medical devices, to furniture and cars. With this method, production time is reduced, and quality of products is increased. With 3D printing becoming more accessible to the masses, the possibility of 3D printing the likes of phones, eyeglasses, and food within our own homes might soon become a reality.

Biography: Associate Professor Larry Sass from the MIT Department of Architecture will present the ongoing and emerging research ideas focused on 3D Printing (digital manufacturing) of affordable housing. The research specifically addresses ways to design, compute and fabricate buildings with digital fabrication technologies. He will also share findings from current research projects related to new software that aids the production of homes through examples. Larry earned his PhD in 2000 and Masters in 1994, both from MIT. He has published widely, and has exhibited his work at the Museum of Modern Art in New York City.

Assoc. Prof. Ronald RAEL
Director, print Facility for Architectural Research and Materials (printFARM), University of California Berkeley, US

Topic ECOLOGICAL MATERIALS FOR 3D PRINTING ARCHITECTURE

Synopsis 3D printed architecture has the ability to transcend the way that buildings are made today. 3D printers allow architects to be material morphologists. They expand our ability to construct because they open the door for us to test material, form and structure simultaneously and instantly. 3D printing is a sustainable method of manufacture and can take advantage of local and ecological material resources. In an era of throw away consumerism and over consumption, excessive energy use, too much waste, and toxic materials, architects have a responsibility to the public, and the planet, to change our mindset about what our buildings are made of, how they function, and to inform the manufacturing processes used to construct architecture. Our research challenges the status quo of rapid prototyping materials by introducing new possibilities for digital materiality. In this scenario it is not solely the computational aspects that have potential for material transformation but also the design of the material itself. Because of the nature of these materials, they can be sourced locally (salt, ceramic, sand), come from recycled sources (paper, rubber), and are by products of industrial manufacturing (wood, coffee flour, grape skins); this would situate them within the realm of "natural building materials". However, the expansive and nascent potential of these traditional materials, when coupled with additive manufacturing, offers unnatural possibilities such as the ability to be formed with no formwork, to have translucency where there was none before, extremely high structural capabilities and the potential for water absorption and storage, the materials that we all know as natural building materials are now unnatural building materials.

Biography Ronald Rael is an applied architectural researcher, design activist, author, and thought leader in the fields of additive manufacturing and earthen architecture. In 2014 his creative practice, Rael San Fratello (with architect Virginia San Fratello), was named an Emerging Voice by The Architectural League of New York—one of the most coveted awards in North American architecture. In 2016 Rael San Fratello was also awarded the Digital Practice Award of Excellence by the The Association for Computer Aided Design in Architecture (ACADIA).
Emerging Objects, a company co-founded by Rael, is an independent, creatively driven, 3D Printing MAKE-tank specializing in innovations in 3D printing architecture, building components, environments and products. At Berkeley, Ronald Rael is the Director of the printFARM Laboratory (print Facility for Architecture, Research and Materials), holds a joint appointment in the Department of Architecture, in the College of Environmental Design, and the Department of Art Practice and is both a Bakar and Hellman Fellow. He often teaches graduate design thesis, undergraduate courses on Design & Activism, and has twice directed the one year post-professional Master of Architecture program, Studio One.

Prof. Peng FENG
Department of Civil Engineering, Tsinghua University, China

Topic STRUCTURAL PROPERTIES OF 3D PRINTED CEMENTITIOUS MATERIAL AND MEMBERS REINFORCED WITH FRP

Synopsis A study of the mechanical behaviour of 3D printed structures using cementitious powder is presented. Microscopic observation reveals that the 3D printed products have a layered orthotropic microstructure, in which each layer consists of parallel strips. The test results confirmed that the 3D printed structures are laminated with apparent orthotropy. Based on the experimental results, a stress-strain relationship and a failure criterion based on maximum stress criterion for orthotropic materials are proposed for the structures of 3D printed material. As 3D-printed elements are weak in their interlayers, FRPs, which are easy-formed, light-weighted and high-strength, are adopted to enhance 3D-printed elements. To investigate the reinforcement effect, FRP reinforced beams and columns were tested. The results indicated that wrapping 3D-printed columns with FRPs changed their failure modes from brittle to ductile, increased the peak loads and the largest deformations obviously. Additionally, finite element analyses were conducted to simulate the failure modes of the 3D-printed elements based on the maximum stress criterion. The results showed that the predicted failure locations corresponded with the experimental failure locations observed. According to this study, 3D-printed elements reinforced with FRP sheets showed potential for future development and applications in construction.

Biography Prof. Peng Feng is the Professor of civil engineering at Tsinghua University. His research field is the high-performance structures with emerging materials and advanced construction techniques for civil engineering, including all-FRP structures and FRP hybrid structures, FRP strengthening of existing structures, integration of structures and functions for sustainable construction, and 3D printing for construction. He has published more than 80 journal papers including 29 SCI journal papers (22 of them in JCR Q1 journals), and has achieved about 1,400 citations by Google Scholar. His several papers were awarded as the Best Paper by ASCE Journal for Composites for Construction, the China Civil Engineering Society (CCES), and the Chinese Ceramic Society (CCS). He was awarded the Excellent Young Scientists by the National Natural Science Foundation of China (NSFC) and the Distinguished Young Scholar Award by the Specialty Committee on Infrastructure Applications of FRP Composites of the China Civil Engineering Society (CCES). He acts as the Chair of three China national standard committees, the Vice-Chair of two national professional committees, the Council Member and the Executive Committee Member of International Institute for FRP in Construction (IIFC), and the Associate Editor of an international journal of Advances in Structural Engineering.

Assoc. Prof. Ming Jen TAN
Associate Professor, School of Mechanical & Aerospace Engineering, NTU, Singapore

Topic AUTOMATION IN CONSTRUCTION USING 3D PRINTING

Synopsis The success of rapid industrialization in various parts of the world may be explained by the automation process which has led to a faster and cheaper ways of production. However, the sector of concrete construction has not been automated to the same extent as other industrial sectors. In the last two decades, the traditional way of mixing and casting of concrete on-site has to a significant degree been replaced by pre-cast or pre-fabrication construction industry in several developed countries. However, the construction sector can still benefit significantly from automation towards reducing labour and construction time, improved quality and reduced environmental impact. In this regard, 3-dimensional (3D) printing was first introduced as a means of rapid prototyping. However, as a new construction method, the information of 3D concrete printing construction is limited. Also, traditional concrete cannot be used directly in 3D printing. In this regard, specially designed concrete is required for 3D printing and to attain the required materials properties. The presentation will attempt to answer whether automation in construction, by 3D printing or otherwise, presents a solution. It will also provide a brief overview of 3D printing research at the Singapore Centre for 3D Printing (SC3DP) over the last year.

Biography Assoc. Prof. Tan Ming Jen received both his B.Sc (Eng.) and Ph.D. from The Royal School of Mines, Imperial College, London. He was Japan Society for the Promotion of Science (JSPS) Fellow at Kyoto University in 1991, Science & Technology Agency (STA) Fellow at the Mechanical Engineering Laboratory (A.I.S.T., M.I.T.I.), Tsukuba, Japan 1992-93, Visiting Scientist at Columbia University (2003) and Fulbright Scholar (2004) at both UCLA and Northwestern University in the U.S. Dr Tan has worked on light metals and metal composites processing over the last 30 years and was appointed Programme Director for Building & Construction at the Singapore Centre for 3D Printing (SC3DP) at Nanyang Technological University, since Dec 2014.

Assist. Prof. Jacky K.H. CHUNG
Leader (Construction 3D Printing Research Unit), CPMCL, NUS, Singapore

Topic THE CREATION OF 3D-PRINTED SMART FREEFORM CONSTRUCTION FORMWORK

Synopsis 3D printing refers to the technology of fabricating objects through the deposition of a material using a print head, nozzle, or similar printing technology. It is a game-changing technology that enables manufacturing goes digital and promotes a third industrial revolution in the Twenty-First Century. Over the past decades, the advancement of materials and techniques enables 3D printing to be widely used in various commercial sectors.
In construction, 3D printing is still in an infant stage. Literature review reveals that most research studies are mainly focusing on cement-based material printing and finally, the formwork-free fabrication approach including concrete printing method and D-shape method have dominated the field. However, this printing approach is subject to some problems such as low productivity, weak mechanical strength and poor surface quality and thus, a new 3D printing fabrication approach is proposed. This presentation aims to introduce a novel concept of fabricating a building using a 3D printed multi-function formwork named SMART Freeform Formwork (SmartForm). This presentation will start with a quick review of construction 3D printing and a critique of the formwork-free 3D printing fabrication approach. Then, it will discuss the concept, principles, advantages, and constraints of the SmartForm and finally, a prototype is presented. This presentation contributes to providing a critical review of recent trends in construction 3D printing and demonstrating the new fabrication approach of using 3D printed formwork.

Biography Dr. Jacky Chung is an Assistant Professor with the Department of Building, School of Design and Environment, National University of Singapore. He started his academic career in the Department of Real Estate of The Hong Kong Polytechnic University (HKPolyU) shortly after obtaining PhD degree from the Department of Civil Engineering of The University of Hong Kong (HKU) in 2010. Dr. Chung is an experienced researcher in the areas of Construction 3D Printing, Building Information Modeling (BIM), Collaborative Team Work, Construction Briefing, Stakeholder Engagement, Public-private Partnership (PPP), and Value Management (VM). Up to 2017, he has been presented 10 research and teaching awards including CIB Guyla Sebestyén Award by the International Council for Research and Innovation in Building and Construction (CIB) in Netherlands, and the Tony Toy Memorial Award by the Hong Kong Institute of Value Management in Hong Kong; and has produced more than 82 research publications in leading academic journals and international conferences. He has been appointed as the Assistant Editor of Built Environment Project and Asset Management published by Emerald and the Editorial Board Member of International Journal of Sustainable Real Estate and Construction Economics, which is a young academic journal published by Inderscience. In addition to research, Dr. Chung is also actively engaged in professional practice and has conducted 22 professionally facilitated VM and partnering workshops for various client organisations in Hong Kong since 1999. He was a founding member of buildingSMART Hong Kong as well as a council member of the Hong Kong Institute of Project Management and Hong Kong Institute of Value Management.

Assoc. Prof. Shinya OKUDA
Associate Professor, Department of Architecture, NUS, Singapore

Topic GROOVE LIGHT - A QUEST BETWEEN FUNCTIONAL DESIGN FLEXIBILITY AND 3D PRINTABILITY WITH LARGE-SCALE FDM 3D PRINTERS

Synopsis Some of current construction 3D printing is based on variation of Fused Deposition Modeling (FDM) 3D printing technology, which is to build up various materials layer by layer fundamentally. Because of that, design flexibility of FDM 3D Printing process is mainly restricted by overhanging geometries, or may require vast amount of scaffolding like supporting materials. Groove Light is one of the early stage pioneer projects in NUS exploring possibilities of large-scale FDM 3D printing, focusing on functional design flexibility and 3D printability. A series of distinctive and complex 3D-printed lanterns is developed, which casts identical geometric shadow patterns, creating the optical illusion that they are floating above continuous geometric shadow carpets. While Groove Light demonstrates possibility of functional complex objects physicalized by the 3D printing process, it also challenges the limitation of overhanging issues by testing various self-supporting geometries, and aims to drastically reduce necessity of supporting materials. This short presentation suggests effectiveness of a selective and custom support strategy for printing overhanging geometries with large-scale FDM 3D printers, as a reference for possible design flexibility for construction 3D printing. It also addresses common 3D printing issues, such as differences between computational models and physical prototypes, in search of ideal 'point' light sources without dimension

Biography Shinya OKUDA is Associate Professor, Department of Architecture, School of Design and Environment, National University of Singapore. He is registered architect in Japan and EU, have practiced with Pritzker prize architects, such as Herzog & de Meuron in Switzerland and Shigeru Ban architects in Japan, prior to joining the NUS in 2008. His other past carriers include, Professional Consultant at CUHK in Hong Kong (2005-2008), a participant at the Berlage Institute in the Netherlands (2000-2001), a graduate with M.Eng in Architecture degree from Kyoto Institute of Technology, Japan (1995). His is one of the founding leaders of Advanced Architectonics Design Lab (AADL) to explore fundamental architectural languages, space and programs, and materialize them as innovative architectural designs by advanced architectonics: art of constructions. The AADL often applies both computational and hands-on approaches, designing with sophisticated materiality, making prototypes as their core of design processes. Those analyses of material, process and holistic integrations in design and construction enable AADL to develop consistently unique yet sophisticated architectural research works. A/P Okuda's past projects include publicly acclaimed Groove Light project at i Light Marina Bay in Singapore (2016), award-winning Cloud Arch (Ultra Light-weight long-span sustainable structure, 2014) and internationally patented Bio Shell (Biodegradable Shelter, 2012). A/P Okuda is also recently appointed as Principal Investigator to develop one of the first Tropical Mass Timber Construction systems by Ministry of National Development, Singapore (Sky Timber project, 2016). Honor received by A/P Okuda includes being the winner of Archifest Pavilion, Singapore (2014), a finalist of President's Design Award for architecture, Singapore (2010), Excellence Award, Asian Design Awards, Hong Kong Designers Association, Hong Kong (2009), the 3rd prize at the International Advanced Architecture Competition, Barcelona, Spain (2007) among many others.

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