ICCER 2020
International Conference on Civil Engineering Research

4TH ICCER 2020

BOOK OF PROGRAM

TOWARDS A SAFE AND SUSTAINABLE CONSTRUCTION USING ADVANCED MATERIALS TECHNOLOGY FOR STRUCTURAL FAILURE PREVENTION, REHABILITATION AND RETROFITTING



Organized by :

INSTITUT TEKNOLOGI SEPULUH NOPEMBER
ICCER Organizing Committee Office
Laboratory of Concrete and Building Materials - Civil Engineering Department
ITS Campus, Keputih, Sukolilo, Surabaya, East Java, Indonesia 60111

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Conference at Glance

The Fourth International Conference on Civil Engineering Research (ICCER) will be hosted by Civil Engineering Department of Institut Teknologi Sepuluh Nopember (ITS) on July 22-24, 2020. The 4th ICCER is an annual event and it is mainly for scientist, researchers and industry with specialties in Civil Engineering or related area. The previous conference had been successfully held in Surabaya, August 2017 in coincide with The 2017 AUN/SEED-Net Regional Conference in Civil Engineering (RCCE).

Population growth in recent years demands an increase in infrastructure development. Safety and sustainability becoming the most important aspects in the construction. Sharing efforts to improve safety and sustainability in the construction continue to be developed by all stakeholders ranging from practitioners to academics. Therefore, the main theme for The 4th ICCER is **"Towards a safe and sustainable construction using advanced materials and technology for structural failures prevention, rehabilitation and retrofitting".**

In accordance with the theme of this year, a variety of topics related to safe and sustainable construction, material technology, structural failure prevention, rehabilitation and retrofitting are expected to be presented at this conference. Through this conference, it is also expected that participants may perform research collaborations and define the platforms for their future research directions.

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Harun Alrasyid, PhD

Scientific Committee Member:

Material and Structural Engineering

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Data Iranata, Ph.D

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Ervina Ahyudhanari, Ph.D. (ITS)
Dr. Catur Arif P. (ITS)
Dr. Hitapriya Suprayitno (ITS)

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Putu Artama Wiguna, Ph.D. (ITS)
Tri Joko Wahyu Adi, Ph.D (ITS)
Farida Rachmawati, Ph.D (ITS)
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Welcoming Speech from Rector of ITS

Assalamualaikum Warahmatullahi Wabarakatuh.

Ladies and Gentlemen,

Allow me in this opportunity to welcome all of you to this conference by praying to the Almighty God for all His blessings, His grace, and His mercies that have made us possible to gather here in excellent condition and good health.

Dear keynote speakers, distinguished guests and all participants,

Institut Teknologi Sepuluh Nopember (ITS) is delighted to host this annual conference. This year, the Fourth International Conference on Civil Engineering Research (ICCER) is hosted by Civil Engineering Department of Institut Teknologi Sepuluh Nopember (ITS) in the virtual format due to recent corona virus outbreak. The main theme of this conference is "towards a safe and sustainable construction using advanced materials and technology for structural failures prevention, rehabilitation and retrofitting".

The world today is facing many challenges, especially in safety and sustainable development issues. We must address the sustainability agenda to deliver improvements in efficiency and resource productivity. Together with the public and private sectors, non-governmental and intergovernmental organizations, scientists and engineers, we are responsible to build a better life and safety for society through the application of knowledge to transform resources into products and services without compromising the ability of future generations to cope with their needs.

In accordance with the vision and mission of ITS, which is to become a world - class research university, this international conference is one among many efforts to make these vision and mission come true. It is part of our concern on the contribution of science and technology for enhancing nation productivity and competitiveness in international level. Hopefully, we all can significantly give more contributions to the nation advancement in the near future. To all of our distinguished guests and participants, thank you for being here, welcome, and enjoy the conference!

Wassalamualaikum Warahmatullahi Wabarakatuh.

Prof. Dr. Ir. Mochamad Ashari, M.Eng.

Rector of ITS, Surabaya, Indonesia

Welcoming Speech from Chair of Organizing Committee

Assalamualaikum Warahmatulahi Wabarakatuh!

Good morning to all distinguished delegates, presenters, participants, and colleagues!

On behalf of the committee, please allow me to welcome you through this wonderful virtual conference.

First and foremost, let me express our sincere gratitude to almighty God who has granted us with blessings, health and grace that we are now able to gather here and participate in this conference.

I would like to thank our esteemed Rector of Sepuluh Nopember Institute of Technology – Professor Mochamad Ashari – for his countless support and unconditional policy that we are able to organise this event at University.
I would also like to thank our honourable keynote speakers coming from three different continents, five countries, for taking part to share their expertise and knowledge to us – I am a hundred per cent sure that we will have something to discuss along the way. Please allow me to introduce them.

1. Prof. Yu Chen Ou – from National Taiwan University – in Taiwan
2. Prof. Mario Attard – from University of New South Wales – in Australia
3. Prof. Tetsuya Ishida – from the University of Tokyo – in Japan
4. Dr. Radomir Pukl – from Cervenka Consulting – in the Czech Republic
5. and lastly – Prof. I Gusti Putu Raka – our dearest professor at Sepuluh Nopember Institute of Technology

Special thanks also to our honourable Scientific Committee and International Board of Reviewers who have helped us tremendously in the journey of this conference.

Ladies and Gentlemen!
This year, the Fourth International Conference on Civil Engineering Research – or you may know as ICCER 2020 – is organised in a unique virtual format due to recent Coronavirus outbreak ramping up globally – which, of course, has been the major cause of cancellation of our face-to-face conference as originally planned in Bali.
In this year, the conference theme is "*towards a safe and sustainable construction using advanced materials and technology for structural failures prevention, rehabilitation and*

retrofitting" which is preferred to resurface our insights into modern and safer infrastructure development – making us more concern about technological advancement in our surroundings.

A variety of topic from different viewpoints will be presented by our keynote speakers in this two-day event and we do hope that this conference is not only a tool to mediate knowledge sharing and transfer but also supports new ideas in creating resilient and sustainable infrastructure in the future.

Ladies and Gentlemen!
We would like to inform you that this conference is organised in two days and is mainly divided into three parts: the first part is the opening ceremony, the second one is keynote speakers presentations; and the third one is, of course, a series of parallel sessions which are provided for authors presenting their research to a group of researchers in separated Zoom invitation links.
We do hope that this conference will not only become a platform for researchers to disseminate their research but also – bigger than that – it could be a medium to facilitate interests among researchers and thus collaborative research in the future is in hand.

Ladies and Gentlemen!
Before I end up my welcoming speech, I would like to express my deepest gratitude to all of our sponsors for their generous financial and moral support – thanks to them that we are able to hold this event amid this global pandemic.
Last but not least, very special thanks also to our organizing committee for dedication, continual support, and hard work in preparing all the materials and ensure that everything is taken care of.
Finally, please allow me to wish you a meaningful and rewarding concrete – thank you for your participation and we do hope to see you again in our next ICCER conference.

Wassalamualaikum Warahmatullahi Wabarakatuh!

Prof. Ir. Priyo Suprobo., MS., Ph.D

Chair of The 4th ICCER

Meet Our Keynote Speakers

Prof. Yu-Chen Ou
Professor
Department of Civil Engineering,
National Taiwan University-Taiwan

Prof. Yu Chen Ou currently works at the Department of Civil Engineering. He received his doctoral degree from The University at Buffallo in 2007. He is a full Professor with research interest in Reinforced Concrete Structure, Prestressed Concrete, Earthquake Engineering and Bridge Engineering. He also serves as President of American Concrete Institute (ACI) Taiwan Chapter and Chair of Concrete Engineering Committee, Chinese Institute of Civil and Hydraulic Engineering, Taiwan.

Prof. Tetsuya Ishida
Professor
Department of Civil Engineering
Tokyo University Japan

Prof. Tetsuya Ishida currently works at the Department of Civil Engineering, The University of Tokyo. He received his doctoral degree from The University of Tokyo in 1999. He received several awards including JSCE Research Paper Awarc (with Yamazaki) in 2017, JSCE Technology Development award in 2017 and JCI Technology Award (with Watanabe, Sakai and Sakata. His research focused on Thermodynamics of cementitious materials, Nonlinear mechanics of aging concrete, Modeling of durability performance and Multi-scale and Multi-chemo-physics modeling of Structural Concrete.

Prof. I Gusti Putu Raka,
Professor
Civil Engineering Department
Institut Teknologi Sepuluh Nopember Indonesia

Professor I Gusti Putu Raka is an Emeritus Professor from Department of Civil Engineering Institut Teknologi Sepuluh Nopember Indonesia. He received his doctoral degree from Institute National des Sciences Appliquees de Toulouse France in 1995. His research mainly focused on Reinforced Concrete and Precast Concrete Structure.

Prof. Mario M. Attard
Associate Professor
School of Civil and Environmental Engineering
The University of New South Wales Australia

Professor Mario M. Attard is an Associate Professor from School of Civil and Environmental Engineering The University of New South Wales Australia. His research is focused on Finite Strain Isotropic and Anisotropic Hyperelastic Modeling, Plasticity Modelling of Confined Concrete and Fracture in Concrete and Masonry. He is also serve as Associate Head (Academic) in the School of Civil and Environmental Engineering

Ing. Radomír Pukl CSc.
Project manager
Červenka Consulting

Ing. Radomír Pukl CSc. is a project manager at Červenka Consulting. He is an expert on fracture mechanics, finite element method, numerical simulation of concrete structures, computer graphics. He graduated in 1980 at the Faculty of Civil Engineering at the Czech Technical University (CTU) in Prague an received his doctor degree at the Klokner Institute CTU in 1985. In 1988-97 he was a research associate at the Institute of Construction Materials, Stuttgart University by prof. Eligehausen where he worked in the field of numerical methods and fastening technology. Together with V. Červenka he is the co-author of the program system SBETA. Author of many of scientific publications, member of FraMCOS.

Conference Schedule at Glance

Wednesday, July 22, 2020	
Time (Surabaya Local Time (GMT+7))	**Event**
Keynote Session	
07:30-08:00	Registration
08:00-08:10	Opening (MC)
08:10-08:20	Welcoming Speech from Organizing Committee
08:20-08:30	Welcoming Speech from Rector
08:30-09:45	Keynote Session I - Yu Chen Ou (incld Q&A)
09:45-10:00	Sponsor Session (PT. WIKA BETON)
10:00-10:15	Morning Break
10:15-11:25	Keynote Session II - IGP Raka (incld Q&A)
11:30-11:45	Sponsor Session (PT. ADHI PERSADA BETON)
11:45-12:45	Closing and Lunch Break
Parallel Session	
12:45 - 13:00	Parallel Session 1 Registration
13.00 – 15.00	Parallel Session 1
15.00 – 15:30	Parallel Session 2 Registration
15.30 - 17.00	Parallel Session 2
Thursday, July 23, 2020	
Time (Surabaya Local Time (UTC+7))	**Event**
Keynote Session	
07:30-08:00	Registration
08:00-08:10	Opening (MC)
08:10-09:10	Keynote Session III - Tetsuya Ishida (Incl Q&A)
09:15-09:30	Sponsor Session (PT. WASKITA KARYA)
09:30-10:00	Morning Break
10:00-11:00	Keynote Session IV - Mario Attard (Incl Q&A)
11:00-11:15	Sponsor Session (CERVENKA CONSULTING)
11:15-12:30	Lunch Break
12:30-13:30	Afternoon Registration
13:00-14:00	Keynote Session V- Radomir Pukl (Incl Q&A)
14:00-15:00	Closing (Best paper awards announcement)

Parallel Session Schedule

No	Session	Time	Meeting ID	Meeting Password	Moderator
1	Structure 1	12:45-15:00	936 7044 5515	016017	Data Iranata, Ph.D
2	Structure 2	12:45-15:00	955 6512 8594	418615	Faimun, Ph.D
3	Structure 3	15:00-17:00	956 6524 7567	78466	Data Iranata, Ph.D
4	Disaster Management	15:00-17:00	917 8722 5680	542584	Faimun, Ph.D
5	Construction Management 1	12:45-15:00	933 1671 9655	726917	Farida Rachmawati, Ph.D
6	Construction Management 2	12:45-15:00	996 0955 6818	795542	Arif Rohman, Ph.D
7	Construction Management 3	15:00-17:00	982 7552 6404	659532	Farida Rachmawati, Ph.D
8	Construction Management 4	15:00-17:00	944 5601 0624	116073	Arif Rohman, Ph.D
9	Geotechnics 1	12:45-15:00	963 5802 8383	766471	Dr. Yudhi Lastiasih
10	Geotechnics 2	15:00-17:00	942 3361 2360	447806	Dr. Yudhi Lastiasih
11	Transportation 1	12:45-15:00	962 7935 9001	324673	Hera Widyastuti, Ph.D
12	Transportation 2	15:00-17:00	963 7085 0418	684167	Hera Widyastuti, Ph.D
13	Water Resource 1	12:45-15:00	938 5457 5256	343076	Dr. Mahendra Andiek M.
14	Water Resource 2	15:00-17:00	953 4802 6285	053501	Dr. Mahendra Andiek M.
15	Construction Material and Environment	12:45-15:00	925 3312 3278	896725	Dr. Candra Irawan

Detail of Parallel Session

Session Name : Structure 1

No	Paper ID	Author	Paper Title
1	107	Paramashanti | Larasati Devi Adani	Determination of LRFD Environmental Load Factor in Java Sea for Unbraced Monopod Structures using Reliability Analysis
2	112	Pamuda Pudjisuryadi	Review on 3D printed concrete as structural beam members
3	118	Djoko Irawan | Budi Suswanto | Aniendhita Rizki Amalia | Data Iranata	Rapid Visual Assessment of Building Vulnerability Due to Earthquake Potential Hazard in Surabaya
4	121	Wahyuniarsih Sutrisno | Harun Alrasyid	Structural Performance Investigation of Ship Lift Hoist Pile Structure Exposed to Tropical Marine Environment
5	129	Angga Bayu Christianto | Bambang Piscesa | Faimun | Pujo Aji	3D Finite Element Modelling of Circular Reinforced Concrete Column Confined with CFRP Under Different Eccentric Loads
6	172	Yehezkiel Septian Yoganata | Budi Suswanto | Data Iranata | Djoko Irawan	Analysis Study of Extended End-Plate Connection Due to Cyclic Load Using Finite Element Method
7	159	Adjib Karjanto	Connection System Design Between Beams and Prefabricated Columns on Short Span Bridge Structures With Reinforcement Joint Method
8	215	Indra Komara	Chloride Penetration in Relation to the Microcracking State into Reinforced Ordinary and Engineering Cementitious Composite

Session Name : Structure 2

No	Paper ID	Author	Paper Title
1	105	Leonardus Setia Budi Wibowo	Effect of Reinforced Concrete Beam Confinement under Cyclic Loading on Ultimate Drift Ratio
2	125	Doni Priambodo	Experimental studies of wind flow inside a street canyon between high-rise buildings with angle of attack modifications
3	110	Yongky Sanjaya	The Effect of Street Canyon Width Towards Wind Flow in between High-Rise Buildings
4	92	Indra Sidik Permadi | Redrik Irawan	Structural behavior of open truss FRP bridge without side support
5	93	Jimmy Chandra | Pamuda Pudjisuryadi | Antoni Antoni | Hartanto Wibowo	Analytical modeling of 3D-printed reinforced concrete beams

6	209	Warren Don | Karen Chong | Martin Aitken | Asdam Tambusay | Benny Suryanto | Priyo Suprobo	Influence of link spacing on concrete shear capacity: experimental investigations and finite element studies
7	211	Benny Suryanto | Danah Saraireh | Asdam Tambusay	Temperature dependence and activation energy of electrical conduction in an engineered cementitious composite

Session Name : Structure 3

No	Paper ID	Author	Paper Title
1	161	Hidajat Sugihardjo, Ahmad Basshofi Habieb	A Simplified Method to Estimate The Fundamental Frequency of Simple Span Bridges Supported on Lead Rubber Bearings
2	162	Prof Sofia W Alisjahbana, Ph.D. | Ade Asmi, Ph.D. | Safrilah | Jouvan Chandra Pratama | Prof Buntara S Gan, Ph.D. | Irene Alisjahbana	Numerical Analysis of a Friedlander Localized Blast Load on a Rigid Roadway Pavement Using Levy's Problem
3	174	Vicky Wildan Yustisia | Budi Suswanto | Djoko Irawan | Data Iranata	The Structural Behavior Of Castellated Beam With Shape Variation Using Finite Element Methods
4	182	Candra Irawan | Faimun | Rudy Djamaluddin | I Gusti Putu Raka | Priyo Suprobo | Gambiro Soeprapto	The Increasing of Displacement Ductility and Moment Capacity of Spun Pile usingConcrete Infill
5	200	Sivaek Loomba	A Review on Strengthening Concrete Column Via Ferrocement Jacketing
6	205	Chanachai Thongchom | Suraparb Keawsawasvong | Sayan Sirimontri	Experimental Investigation on Reinforced Concrete Columns Confined with Prestressed Steel Straps
7	212	Danah Saraireh | Benny Suryanto | Asdam Tambusay	Effect of micro-cracking on the electrical and self-sensing properties of an engineered cementitious composite under tensile straining
8	2013	Asdam Tambusay | Benny Suryanto | Priyo Suprobo	Nonlinear finite element analysis of reinforced concrete beam-column joints under reversed cyclic loading

Session Name : Disaster Management

No	Paper ID	Author	Paper Title
1	147	Diah Sarasanty	Safety Hazards Identification of Construction Site Layout Based On Geographic Information System (GIS)
2	165	Emil Wahyudianto	Updating the slope movement data on the Batu-Kediri road network using digital information
3	133	Andriani Okta Fara Dita | Mohammad Arif Rohman | Cahyono Bintang Nurcahyo	Risks of Public Procurement for Construction Works
4	139	Aditya Nugroho	Evaluation of an Occupational Health and Safety Management System in Universitas Indonesia
5	152	Giovianne Friensty Marantika	Identification of Fire Safety Indicators for Shopping Centre Buildings in Surabaya
6	156	Zafira Nadida	Numerical model for flood inundation due to way sekampung dam breach
7	158	Apriadi Simon Harianja	Structural Equation Model (SEM) Relationship Between Risk and Safety Control System of Risk and OHS Program on OHS Costs in Rusunawa Projects
8	210	N.Retno Setiati	The inspection and evaluation of bridge structures for earthquake risk

Session Name : Construction Management 1

No	Paper ID	Author	Paper Title
1	103	Retno Apriyati	Information System Development of Knowledge Base Integration Management System Quality, Safety and Environmental to Improve Organizational Performance in Construction Company [103]
2	191	yusroniya eka putri	Cost Significant Model Comparasion Based on Standard Construction Cost Analysis and Unit Cost of State Building Formula
3	192	yusroniya eka putri	Construction Cost Change Ratio and Index Development of The Standard Construction Cost Analysis for Building State
4	111	Lia	The Influence of Transactional Leadership and Soft Skill on Project Manager for Project Success Factor
5	113	Indra Yanastyapricena	Factor Analysis of Construction Productivity and Developer's Sales at Bekasi Regency Subsidized Housing
6	120	I.P.A. Wiguna, F. Rachmawati, L.B.Setyaning	Green Design, Green Purchasing and Green Transportation As Part of GSCM In Construction Sector
7	140	Feisal Rajab Rivai | Mohammad Arif Rohman | Supani	A Framework for Mapping Stakeholders Interests Related Social Sustainability in Residential Building

Session Name : Construction Management 2

No	Paper ID	Author	Paper Title
1	141	Freedy Kristiawan | Mohammad Arif Rohman | Machsus	A Framework To Assess Success Criteria Performance Of Public Private Partnership (PPP) Projects In Indonesia
2	144	Junita Taskia Amin	Work Breakdown Structure (WBS) Dictionary And Checklist Development Of Stadium Architectural And Interior Works For Safety Planning
3	146	Alifa Amalia Ilmi, Leni Sagita Riantini Supriadi, Yusuf Latief, Dan Fadhilah Muslim	Development Of Dictionary And Checklist Based On Work Breakdown Structure (WBS) At Seaport Project Construction For Cost Estimation Planning
4	148	Fikca Ayu Safitri | Mohammad Arif Rohman | Retno Indryani	Critical Factor That Influence The Success Of Construction Projects Procurement In Surabaya
5	151	Riezka Hadwiansyah	Structural Equation Model (SEM) Correlation Between Work Breakdown Structure (WBS), Work Method,And Risk On Towards Cost Of Safety On Low-Cost Apartment Project

6	89	Kartika Puspa Negara | Fiona Lamari | Connie Susilawati | Bambang Trigunarsyah	Is Technical Competency Necessary For Client Project Manager? An Empirical Study Of Commitmen-Making Officers (PPK) In Indonesian Public Construction
7	160	A Okviana | Y Latief	Method For Develop Performance Indicator Based On Performance Criteria At Indonesia National Competency Standard (SKKNI) For Construction OHS Young Expert Competency

Session Name : Construction Management 3

No	Paper ID	Author	Paper Title
1	142	Patrisius Valdoni Sandi | Mohammad Arif Rohman | Christiono Utomo	Evaluation Of The Procurement Principles Implementations In Public Construction Project
2	163	Maretha Piselia	4D BIM implementation to improve EPC project performance from contractor's perspective. A case study
3	178	Sesde Asrul Stani	The Role Funding Based Non Cash Loan in The Form of Supply Chain Financing on Elevated Road Project Performance (Case Study Joint Operation Project PT. X)
4	179	Rezi Berliana Yasinta | Christiono Utomo | Yani Rahmawati	A Review of Research Methods in Green Building Implementation on Operation and Maintenance Cost
5	181	Ayu Fatimah Sari | Christiono Utomo | Yani Rahmawati	Real Estate Investment Trust (REIT) As Real Estate Financing for Developers in Indonesia: Literature Review of Previous Study
6	100	Fikry Eswara Adi | Ayomi Dita Rarasati	Modelling of Operational Costs (Tipping Fees) and Incentives to Improve Solid Waste Management Services in Indonesia
7	185	Ade Widya Septari | Yusuf Latief	Evaluation of Maturity Level and Critical Success Factors of Knowledge Management Implementation at State-Owned Construction Company in Indonesia

Session Name : Construction Management 4

No	Paper ID	Author	Paper Title
1	168	Guntur Pinandhita	Implementation strategy of total quality management and quality culture to increase the competitiveness of contractor companies in Indonesia
2	127	Ario Cahya Gemilang	Optimization of the project selection process using analytic hierarchy prosess method: a study of application of project portfolio management in pt.x
3	196	Lisda Nita Suryani Simbolon | I Putu Artama Wiguna | Tri Joko Wahyu Adi	Weighting Variables for Building Performance Evaluation

4	197	Bimo Yudha Prawiro	Study of Partnership Form to Improve Idle Land Based in Risk Management
5	201	Mahendra Perdana Sopaheluwakan | Tri Joko Wahyu Adi	Adoption and Implementation of Building Information Modeling (BIM) by the Government in the Indonesian Construction Industry
6	203	Akhbar Ariefianto Suprapto | I Putu Artama Wiguna	Analysis of the Category of Variation Order in X Project at XYZ Ltd.
7	204	Elok Dewi Widowati | Farida Rachmawati	Identifying Factors Affecting Schedule and Cost Performance on Building Project
8	207	Wahyudi P Utama	Risk allocation of PPP waste to energy projects in Indonesia: A research framework

Session Name : Geotechnics 1

No	Paper ID	Author	Paper Title
1	157	Amelia Yuwono | Widjojo Adi Prakoso | Yuskar Lase	Preliminary 3D numerical pushover analysis of laterally loaded pile groups
2	167	Hanif Audina Rahmawati | Widjojo A Prakoso | Astri Rahayu	Vs and CPT Based Evaluation of Location with High Liquefaction Damage During 2018 Palu Earthquake
3	169	Suyuti	Compared Methods of Empirical and FEM to Evaluate Soil Foundation Capacities for Coastal Dike
4	183	Putu tantri kumala sari | Yusroniya Eka Putri | Yang Ratri Savitri | Anienditha R. Amalia | Nastasia F. Margini | Danayanti A.D. Nusantara	The Comparison of 2-D and 3-D slope stability analysis results based on reinforcement requirements
5	184	Yudhi Lastiasih | Putu Tantri Kumala Sari	Comparison of Ultimate Bearing Capacity Based On Empirical Method, Interpretation of Loading Pile Tes and Finite Element

Session Name : Geotechnics 2

No	Paper ID	Author	Paper Title
1	186	Fathurrizal Muhammad	Circular Lining Behaviour due to Earthquake Load In MRT Jakarta Underground Tunnel Area CP-106
2	187	Muhammad Afief Ma\'ruf | Rusliansyah | Friski Irma Damayanti Ritonga | Balqis Azizah	Stabilization Of Soft Soil Using Admixture Of Palm Oil Boiler Ash And MATOS
3	190	Suraparb Keawsawasvong | Teerapong Senjuntichai	Pullout capacity of cylindrical caissons in anisotropic clays based on AUS failure criterion
4	193	Danar Ariangga Windra Gautama | Bambang Soesilo Supanji | Wiwik Rahayu	The effect of skirt footings for road settlement on peat soil

Session Name : Transportation Management and Engineering 1

No	Paper ID	Author	Paper Title
1	130	Hera Widyastuti | Wahyu Satyaning Budhi	Railway Capacity Analysis Using Indonesian Method And UIC Code 405 Method
2	149	Christian Gerald Daniel	Assessing The Mechanical Properties Of Modified Hot-Recycled And Warm Mix Asphalt Using Aramid-Polyethylene By Wet And Dry Process: A Review
3	206	Anak Agung Gde Kartika | Indrasurya B. Mochtar | Hera Widyastut	The modelling of volume and duration of vehicle parking for shopping stores in Surabaya, Indonesia
4	88	Romaynoor Ismy | Husaini | Sofyan M. Saleh | M. Isya	Flexural Resistance Analysis On The Modeling Of Wire Mesh Layer Placement As Reinforcement In Hot Asphalt Mixtures
5	136	Puspita Dewi | Hera Widyastuti	Intercity Dwell Time Estimation By Using Robust Regression Method
6	137	Sutoyo	Design Of The Strong And Durable Of Flexible Pavement On Road Segment With The Heavy Traffic And Overloads
7	170	Akbar Bayu Kresno Suharso | Ervina Ahyudanari	Demand Analysis At Tanah Grogot Airport East Kalimantan
8	173	Michel Kasaf | Catur Arif Prastyanto	Analysis the use of steel slag as a replacement of natural aggregate on flexible pavement

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Review on 3D printed concrete as structural beam members

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Review on 3D printed concrete as structural beam members

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Abstract. Recently, Three-Dimensional Concrete Printing (3DCP) has gained its popularity as construction material. It offers several advantages over conventionally casted concrete such as absence of formwork, reduction of construction equipment transportation, greater safety, reduction of labour cost, and many others. However, the technology also comes with many challenges. Researches in this area can be classified into two issues which are fresh and hardened states of the printed concrete. Investigation of fresh concrete focuses on the optimal design of rheological properties which determines the pumpability, extrudability, and buildability. While mechanical properties of hardened 3DCP are usually investigated by adopting standard tests for conventionally casted concrete. However, due to the complexity of printing process, it is often that 3DCP behaviours cannot be predicted by its mechanical properties obtained from the tests. This paper reviews some studies done by others to highlight potential manufacturing process related weak points of 3DCP as structural beam members.

1. Introduction

In this rapidly growing technology era, one concrete construction method has been relatively favoured to be researched and developed, namely the Three-Dimensional Concrete Printing (3DCP) [1]. 3DCP is a technology to build concrete by extruding plastic mortar against a casting bed through a nozzle opening which movement is controlled by a robotic arm system [2]. The extruded mortar filaments will shape certain desired 3D body of concrete by adding subsequent layers on top of previous ones, without the use of any formwork. Aside from freedom of formwork, 3DCP has many other advantages, some of them are reduction of construction equipment transportation, reduction of construction time and expenses, greater safety, and saving labour cost [3]. However, to fully utilize those benefits, complexity of 3DCP process rises many challenges. Characteristic of both fresh and hardened states of the concrete should be well investigated.

Fresh concrete for 3DCP should possesses good rheological properties such as pumpability, extrudability, and buildability [4]. Those can be achieved if the mix design of the fresh concrete is well collaborated with the chosen printing process. In other words, different printing process may require different mix concrete design for a successful 3DCP. Consideration of the fresh concrete itself may include the initial yield strength and its development, and the setting time. The yield stress should be low enough that the concrete can be pumped and extruded, but its strength development should be quick enough that the extruded layer could sustain the load from the subsequent layers above. Setting time should be designed that the fresh concrete remains workable during printing process. Logically, in the design process of those properties, the printing process should already be included. Planar path of each layer, relative height of subsequent concrete layer, and speed of printing head (deposition rate) should be balanced that the extruded material could remain stacked, bonded in layers and sustain the weight of other layers that are deposited on top. This challenging relationship between fresh concrete and the manufacturing process of 3DCP has attracted many researchers [5-6].

The next thing that becomes the concern of engineers after successfully constructs 3DCP without collapse, is the quality of the resulting hardened concrete. Commonly, researchers adopt standard tests of conventionally casted concrete to measure the quality of hardened 3DCP. Le et al. [7] conducted experiments that can give some idea about 3DCP hardened properties. Due to gently vibrated hopper and small pressure during extrusion, good 3DCP tends to have higher density than that of conventional concrete. However, it should be noted that the higher density observed were measured from specimens which were cut from 3DCP slab which was relatively easy to print. Compressive strength showed variations (72 MPa to 102 MPa) if the test samples were cut from different printing specimen, even with the same fresh concrete. Specimens which were cut from printed slab showed higher strength (and lower anisothropic behaviour) than that which were cut from curvy printed shapes (more difficult printing process). From flexural strength test, it was observed that lower layers tended to have higher strength since they had higher density and lower w/c ratio. Inter-layer tensile bond strength highly depended on the gap time between layers. Gap time is the time interval of printing process between two subsequent layers at the same position. It can be concluded that due to the nature of printing process, it is logical that the hardened 3DCP properties is highly anisotrophic. Bonding strengths between adjacent layers and filaments play very important role in determining the quality hardened concrete because they are potential weak points of 3DCP. Horizontally, the mechanical properties in the direction of filament path is different to its perpendicular direction. Vertically, the mechanical properties of different layers are also different since lower layers have higher density due to the pressing weights of layers above them.

Furthermore, applicability of 3DCP as structural members raises challenges for engineers even more. There are many things should be considered for assessing the hardened 3DCP quality, which may not be necessary for conventionally casted concrete. Adopting standard assessment for conventionally casted concrete is not enough to give accurate information of how good a 3DCP is. Structural member can show highly non-linear behaviour from the very beginning, which cannot be predicted by standard tests of concrete material. Some reviews of this concern are presented in this paper.

2. Research significance

This paper raises awareness that if 3DCP is to be used as structural members, investigation of 3DCP hardened mechanical properties alone may not be enough to accurately predict the structural performance. Once 3DCP is used to construct certain structural member, the behaviour of the member is not as simple as conventionally casted concrete. Premature non-linear behaviour may arise which is not the case in conventionally casted concrete structural member.

3. Research on 3DCP as structural beam member

The main advantage of 3DCP that complex body forms can be made, has opened opportunities for concrete industry. With 3DCP technology, final weight of structural beam member can be reduced by manufacturing complex shape (introducing hollows) with proper analysis to guarantee the adequacy of the intended application (topology optimization). For example, a beam member can be printed to form a truss like shape (Figure 1), instead of classical prismatic shape. However, to fully utilize this advantage, some manufacturing challenges have to be overcome. Efforts done by others are presented in the following subsections.

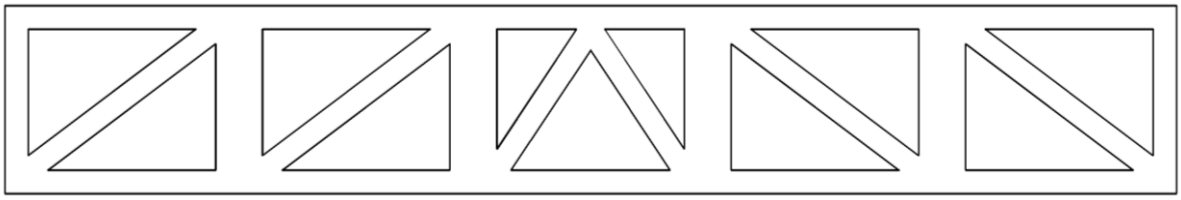

Figure 1. Truss like shape structural beam.

3.1 Non-Segmented 3DCP structural beam

Al-Chaar et al. [8] conducted experiment on truss like 3DCP beams. The beam was 3D printed as one body at one time. Tension reinforcement bars were embedded inside the bottom horizontal chord. A cyclic flexural test was conducted on the beams. It can be seen from the force-displacement relationship (Figure 2), that the beam stiffness started very low and then slightly increased. This behaviour is not normal. It cannot be explained by the material properties alone. There are potential weakening points in 3DCP members in its filament to filament and layer to layer bonding. A numerical modelling by using SAP2000 was done by authors to predict the behaviour of the beams tested by Al-Chaar et al. [8] if treated as conventional homogeneous concrete without considering the weakening of bonding strength. The resulting load-displacement curve is presented in Figure 3. It can be observed that the analytical model possesses stiffness much higher than that of the tested 3DCP beam (Figure 2). This shows that, one should be aware of the potential degradation of 3DCP structural beams due to the potential weakening of the bonding. More complex printing paths will introduce more variation of age differences and qualities between connections.

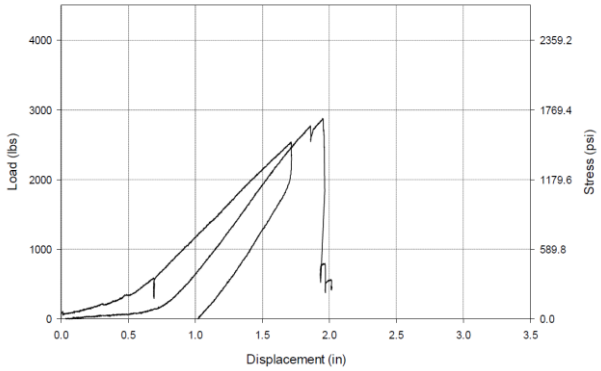

Figure 2. Load-displacement curve of specimen 1SR-S-0: experiment

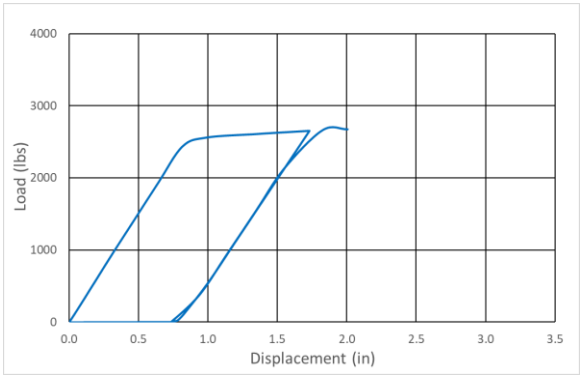

Figure 3. Load-displacement curve of specimen 1SR-S-0: analytical

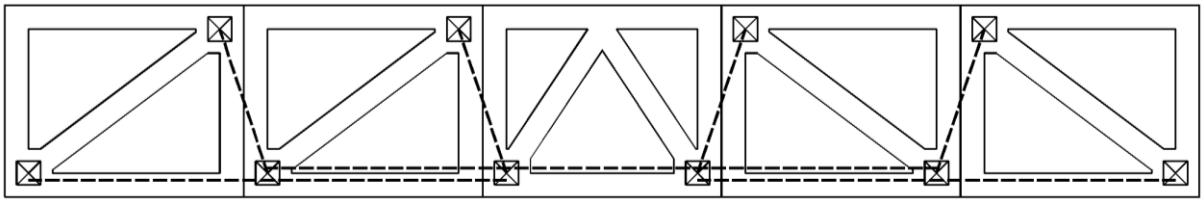

Figure 4. Segmented 3DCP structural beam (adopted from [9]).

3.2 Segmented 3DCP structural beam (non-prestressed connection)

One approach to avoid the weakening problem of the bonding strength, is by printing 3DCP structural members in segments. Making smaller segments reduces the complexity of printing process that consistency of the quality is easier to maintain. Asprone et al. [9] constructed concrete beam from 3DCP segments and conducted bending test. However, the connections needed to assemble the segments raises other challenges. In this case, some hollows in the segments should be made for this connection purpose (see figure 4). Dashed lines in figure 4 represent tension steel bars used to connect the segments. Tension bars mechanically connected and secured with wet joint were used for the connection system. Result of the bending test is presented in figure 5. It was reported that the beam behaved linearly at initial stage (when everything was still intact, with no cracks). But this state was only observed in the very start of the test that it rapidly entered non-linear stage (start of cracking stage, progression of cracking stage, final failure stage). The linear stage (line OA) is comparable with conventionally casted RC beams. But the non-linear stage (line ABC), stiffness reduced quite significantly, not because of degradation of material or wrong optimization but mainly because of the non-effective interface/connection system (the

connected segmental system is prone to local damages). This shows that the printed concrete quality may be improved, but the connection system introduces different kind of weakening.

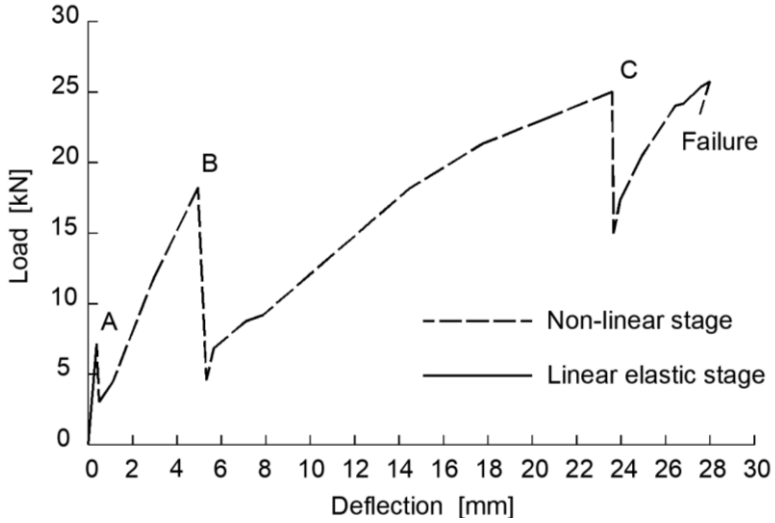

Figure 5. Linear elastic and non-linear stages of load-deflection curve of the beam (adopted from [9]).

3.3 Segmented 3DCP structural beam (prestressed connection)

For segmented 3DCP structural beam to work, the connection system may be improved by using post-tensioning approach. Vantyghem et al. [10] presented prestressed concrete beam design based on topology optimization and manufacturing process with concrete extrusion technology. The illustration of the beam segments and its reinforcement as well as post tensioning tendons is presented in figure 6. Due to the symmetric geometry, only half span of the beam is drawn. Bending test was performed on the manufactured beam to record the load-displacement relationship of upper and bottom chords of the beam. The goal was to verify the service load performance of the optimized shape. A finite element analysis of the beam was also conducted and compared to experimental results.

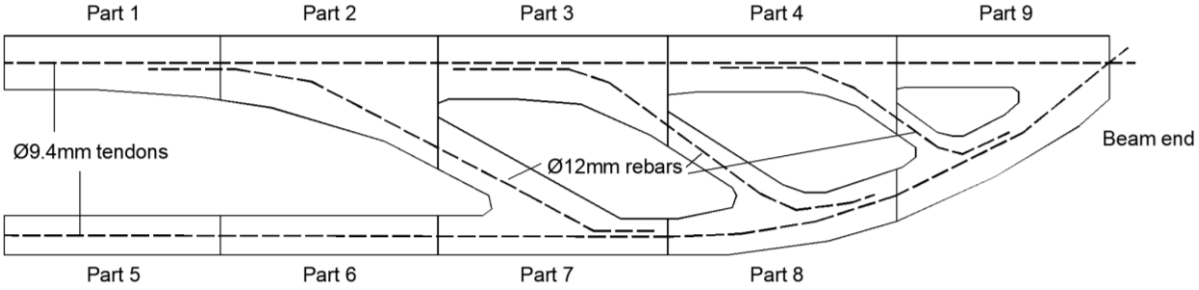

Figure 6. Illustration of the segmented 3DCP structural post tensioned beam (adopted from [10])

Results of the bending test is presented in figure 7. The upper chord showed a good fit (Figure 7a) between the experimental and numerical results. On the other hand, the lower chord shows a much higher deviation (Figure 7b) from the numerical result. Vantyghem et al. stated that this can be attributed to tolerances in the position of the post-tensioning strand within the lower chord, as well as to the sectional assembly. In larger structures, the positioning of the post-tension strand should be easier to control and eliminate this problem. Another factor of uncertainty is the determination of the equivalent material characteristics of the hybrid structure (3DCP segments and grout infill).

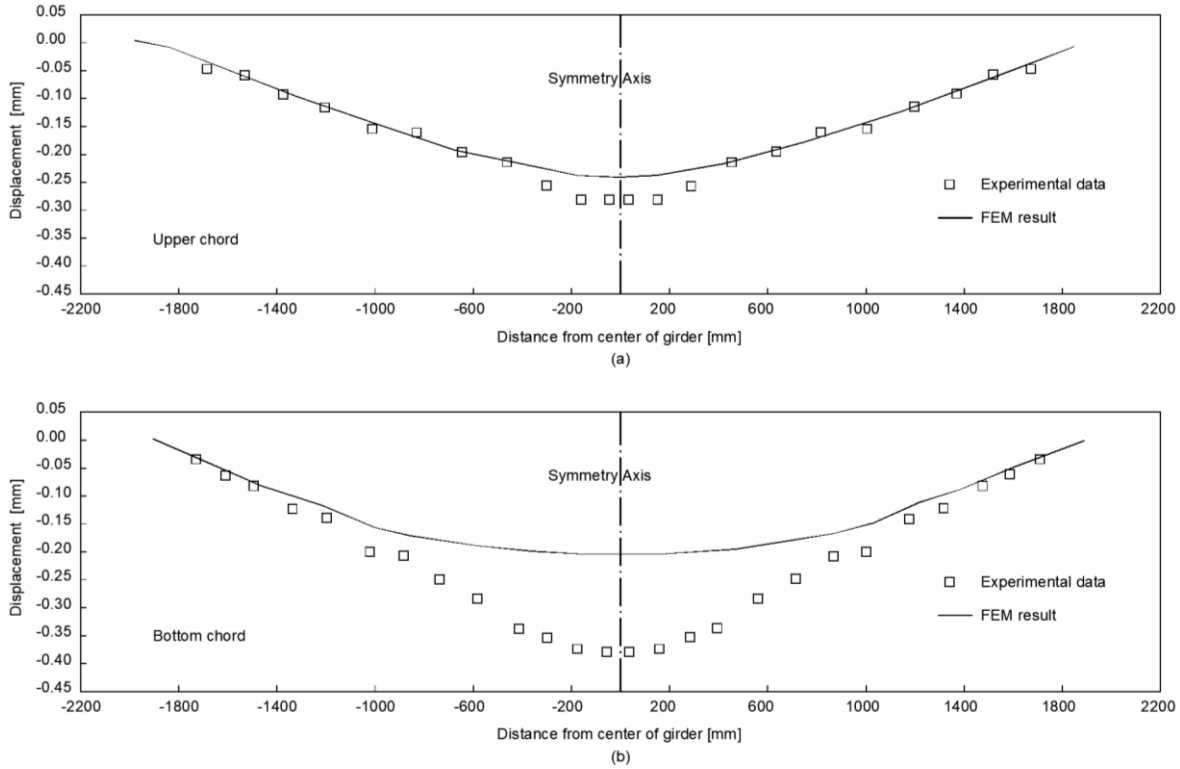

Figure 7. Force-Displacement of upper and bottom chord (adopted from [10]).

4. Discussions and concluding remarks

Reviewing some works by others as well as conducting numerical analysis regarding the use of 3DCP as structural beam members, some discussions and conclusions can be drawn:

- Due to its manufacturing complexity, hardened properties of 3DCP which is commonly assessed by using small specimens, may not be enough for predicting 3DCP structural member behaviour. As a structural member, 3DCP possesses many things to be considered beside of the material hardened properties, that can contribute to its overall behaviour, mainly due to non-homogenous condition introduced by the printing process.
- To overcome weak points introduced by printing large complex shapes, assemblage approach of smaller 3DCP segments are usually taken. Post-tensioning approach to connect the segments is proven to be quite successful. However, in other point of view, assemblage approach is a little bit contradictory to the initial concept of 3D printing which gain its popularity from its one step manufacturing process.

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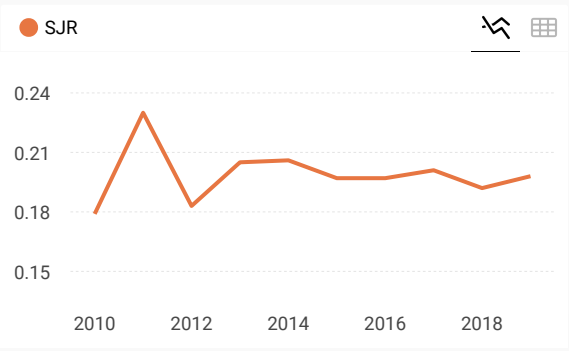

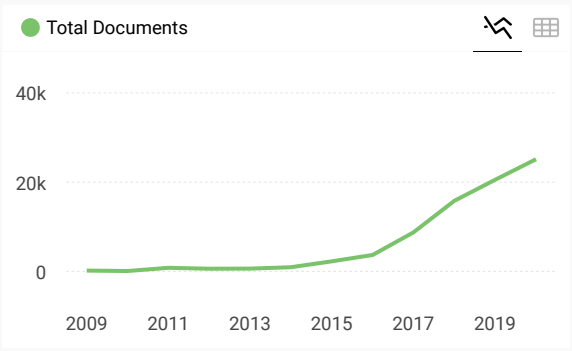

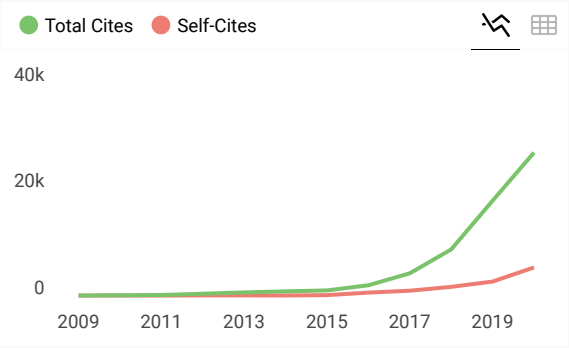

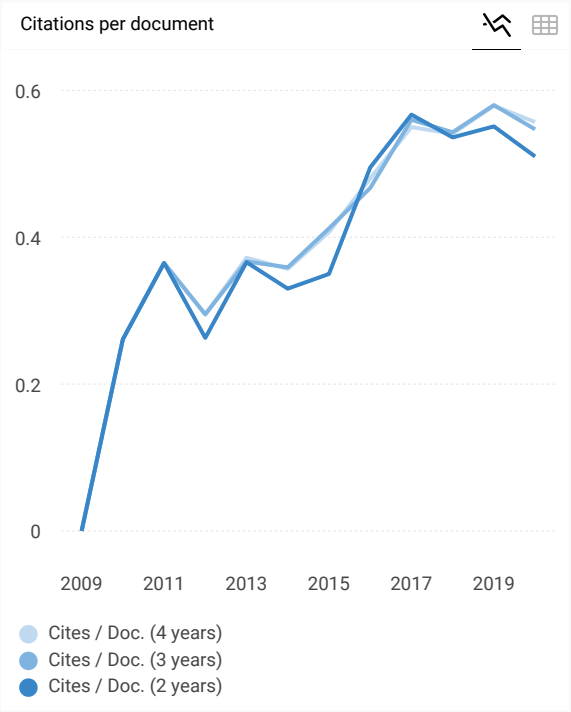

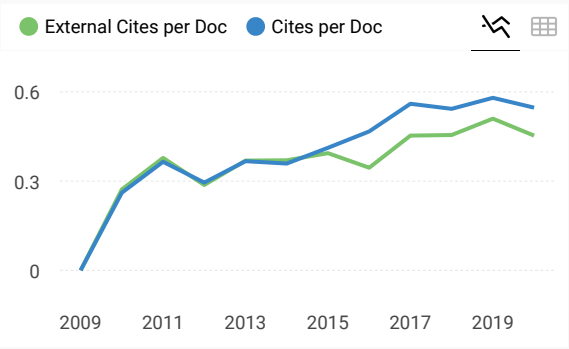

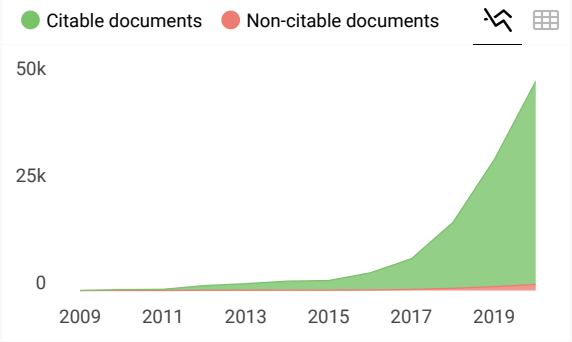

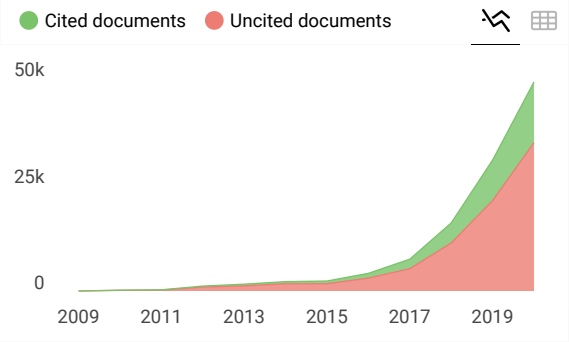

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