

This site uses cookies. By continuing to use this site you agree to our use of cookies. To find out more, see our Privacy and Cookies policy.



With the ability to publish proceedings from events of any size, MSE provides a comprehensive solution for materials science and engineering conferences

Latest published conferences

Vol 930




Conference archive

2020




View forthcoming volumes accepted for publication.

If you would like more information regarding *IOP Conference Series: Materials Science and Engineering* please visit [conferenceseries.iop.org](https://conferenceseries.iop.org), and if you are interested in publishing a proceedings with IOP Conference Series please visit our page for conference organizers.

- **Conference organizers** can use our online form and we will get in touch with a quote and further details.
- **Researchers** will enjoy the conference-based search system to quickly find and browse proceedings of interest. Search through all proceedings by conference title, subject area and conference date / location.

Most read

Most cited

Latest articles

Open all abstracts

#### OPEN ACCESS

Corrigendum: Effect of adding nano-calcined clay and nano-lime on the geotechnical properties of expansive clayey soil (*IOP Conf. Ser.: Mater. Sci. Eng.* 615 012058)

A M al-Swaidani *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **615** 012133

+ Open abstract



View article



PDF

#### OPEN ACCESS

Preface

2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **928** 011001

+ Open abstract



View article



PDF

#### OPEN ACCESS

Peer review declaration

2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **928** 011002

+ Open abstract



View article



PDF

---

**OPEN ACCESS**

Numerical Investigation of the nanofluid mixed convection on two layers enclosure with rotating cylinder: High Darcy Number Effects

Ahmed Dhafer Abdulsahib and Khaled Al-Farhany 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **928** 022001

[+ Open abstract](#)



[View article](#)



[PDF](#)

---

**OPEN ACCESS**

Investigation of Cartesian Routing for Unmanned Aerial Vehicle Networks

Karam mheidy Al-sofy and Sahar Abdulaziz Al-Talib 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **928** 022002

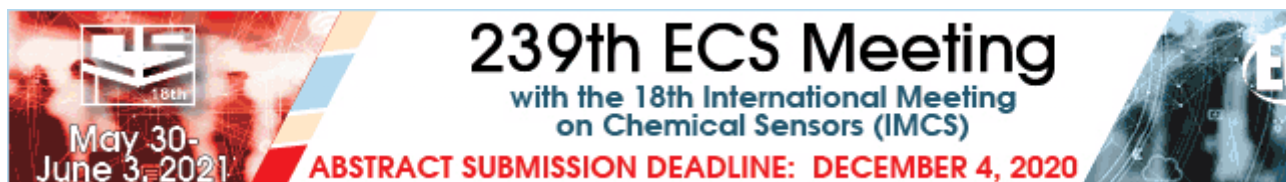
[+ Open abstract](#)



[View article](#)



[PDF](#)



---

**JOURNAL LINKS**

[Journal home](#)

[Information for organizers](#)

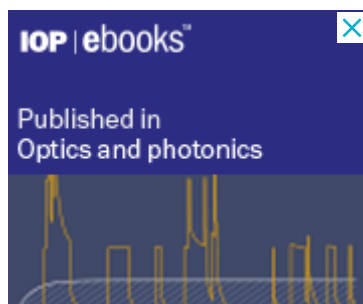
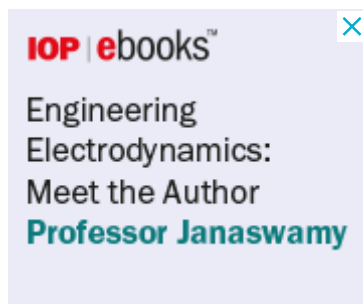
[Information for authors](#)

[Search for published proceedings](#)

[Contact us](#)

[Reprint services from Curran Associates](#)





## JOURNAL HISTORY

---

2009-present IOP Conference Series: Materials Science and Engineering

doi:10.1088/issn.1757-899X

Online ISSN: 1757-899X

Print ISSN: 1757-8981

# Table of contents

Volume 930

2020

◀ Previous issue      Next issue ▶

**4th International Conference on Civil Engineering Research (ICCER 2020), 22-23 July 2020, Surabaya, Indonesia**

Accepted papers received: 03 September 2020

Published online: 03 November 2020

[Open all abstracts](#)

---

## Preface

---

**OPEN ACCESS** 011001

PREFACE

[+ Open abstract](#)      [View article](#)      [PDF](#)

---

**OPEN ACCESS** 011002

Peer review declaration

[+ Open abstract](#)      [View article](#)      [PDF](#)

---

## Construction Project Management

---

**OPEN ACCESS** 012001

Developing activities of green design, green purchasing, and green transportation as the part of green supply chain management in construction sector

L B Setyaning, I P A Wiguna and F Rachmawati

[+ Open abstract](#)      [View article](#)      [PDF](#)

---

**OPEN ACCESS** 012002

Risks of Public Procurement for Construction Works

A O F Dita, M A Rohman and C B Nurcahyo

[+ Open abstract](#)      [View article](#)      [PDF](#)



## A framework for mapping stakeholders interests related social sustainability in residential building

F R Rivai, M A Rohman and Supani

[+ Open abstract](#) [View article](#) [PDF](#)

---

### OPEN ACCESS

012004

## A framework to assess success criteria performance of public private partnership (PPP) toll road projects in Indonesia

F Kristiawan, M A Rohman and Machsus

[+ Open abstract](#) [View article](#) [PDF](#)

---

### OPEN ACCESS

012005

## A concept to evaluate procurement principles implementation of public construction project in Surabaya

P V Sandi, M A Rohman and C Utomo

[+ Open abstract](#) [View article](#) [PDF](#)

---

### OPEN ACCESS

012006

## Work breakdown structure (WBS) dictionary and checklist development of stadium architectural and interior works for safety planning

J T Amin, L Sagita and Y Latief

[+ Open abstract](#) [View article](#) [PDF](#)

---

### OPEN ACCESS

012007

## Development of dictionary and checklist based on Work Breakdown Structure (WBS) at seaport project construction for cost estimation planning

A A Ilmi, L S R Supriadi, Y Latief and F Muslim

[+ Open abstract](#) [View article](#) [PDF](#)

---

### OPEN ACCESS

012008

## Critical factors that influence the success of construction projects procurement in Surabaya

F A Safitri, M A Rohman and R Indryani

[+ Open abstract](#) [View article](#) [PDF](#)

---

### OPEN ACCESS

012009

## Identification of fire safety indicators for shopping centre buildings in Surabaya

G F Marantika, M A Rohman, F Rachmawati and I P A Wiguna

[+ Open abstract](#) [View article](#) [PDF](#)

# A method to develop performance indicators based on performance criteria of Indonesian National Occupational Competency Standards (SKKNI) for construction safety technician competency

A Okviana and Y Latief

[+ Open abstract](#) [View article](#) [PDF](#)

---

## OPEN ACCESS

012011

4D BIM implementation to improve EPC project performance from contractor's perspective.  
A case study

M Piselia

[+ Open abstract](#) [View article](#) [PDF](#)

---

## OPEN ACCESS

012012

Implementation strategy of total quality management and quality culture to increase the competitiveness of contractor companies in Indonesia

G Pinandhita and Y Latief

[+ Open abstract](#) [View article](#) [PDF](#)

---

## OPEN ACCESS

012013

The role funding based non cash loan in the form of supply chain financing on elevated road project performance (case study join operation project PT.X)

S A Stani

[+ Open abstract](#) [View article](#) [PDF](#)

---

## OPEN ACCESS

012014

A Literature Review of Methods in Research on Green Building Cost Analysis

R B Yasinta, C Utomo and Y Rahmawati

[+ Open abstract](#) [View article](#) [PDF](#)

---

## OPEN ACCESS

012015

Research on real estate investment trust (REIT) as real estate financing for developers: a methodology review of previous study

A F Sari, C Utomo and Y Rahmawati

[+ Open abstract](#) [View article](#) [PDF](#)

---

## OPEN ACCESS

012016

Evaluation of the maturity level and critical success factors of the knowledge management implemented in state-owned construction company in Indonesia

A W Septari and Y Latief

[+ Open abstract](#) [View article](#) [PDF](#)

This site uses cookies. By continuing to use this site, you agree to our use of cookies. To find out more, see our Privacy and Cookies policy.



---

**OPEN ACCESS**

012017

The ratio of changes in construction costs and development index of the standard analysis of construction costs for state buildings

Yusroniya Eka Putri Rachman Waliulu

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012018

Weighting variables for building performance evaluation

L N S Simbolon, I P A Wiguna and T J W Adi

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012019

Study of partnership form to improve idle land based on risk management

B Y Prawiro

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012020

Adoption and implementation of building information modeling (BIM) by the government in the Indonesian construction industry

M P Sopaheluwakan and T J W Adi

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012021

Analysis of the category of variation order in x project at XYZ ltd

A A Suprpto and I P A Wiguna

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012022

Identifying factors affecting schedule and cost performance on building project

E D Widowati and F Rachmawati

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012023

Risk allocation of PPP waste to energy projects in Indonesia: A research framework

W P Utama, A Wibowo, D Y Jumas, E Rita, M Peli and Yulcherlina

[+ Open abstract](#) [View article](#) [PDF](#)



---

**OPEN ACCESS**

012024

## The effect of m-sand and waste marble for strength of concrete

R Hidayawanti, Yuhanah, D Mayasari and B Wicaksono

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012025

Compressive strength of geopolymer concrete with fly-ash from Paiton Steam Power Plant and variations of substitution sodium silicate ( $\text{Na}_2\text{SiO}_3$ ) with natural zeolite

I N Amini, Krisnamurti and W T Wahyuningtyas

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012026

## The effect of parsial granulated blast furnace slag (GBFS) substitution and ashes of the boiler crust of the palm oil shells on paving block

T Yuhanah, R Hidayawanti, D Mayasari and B Wicaksono

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012027

The effect of curing in soil and compound on compressive strength of concrete quality  $f_c' 25$  MPa

A Karjanto, B Djatmika, WH Yoh and PB Susanto

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012028

## Factors that influence intention in processing organic waste using biopore hole

A Mardiyani and C Utomo

[+ Open abstract](#) [View article](#) [PDF](#)

---

**Disaster Management**

---

**OPEN ACCESS**

012029

## Flood inundation numerical modelling due to dam break of Way Sekampung Dam

Z. Nadida and U Lasminto

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012030

## Structural Equation Model (SEM) between risk, safety control systems of risk, and OHS programs on OHS costs in rusunawa projects

This site uses cookies. By continuing to use this site you agree to our use of cookies. To find out more, see our Privacy and Cookies policy.



OPEN ACCESS

012031

Updating the slope-movement data on the Batu-Kediri road network using digital information

E Wahyudianto

OPEN ACCESS

012032

Inspection and evaluation of bridge structures for earthquakes risk

R Setiati

## Geotechnics

OPEN ACCESS

012033

Preliminary 3D numerical pushover analysis of laterally loaded pile groups

A Yuwono, W A Prakoso and Y Lase

OPEN ACCESS

012034

Vs and CPT based evaluation of location with high liquefaction damage during 2018 Palu earthquake

H A Rahmawati, W A Prakoso and A Rahayu

OPEN ACCESS

012035

The comparison of empirical and finite element methods to evaluate soil foundation capacities for coastal dike

Suyuti, Zulkarnain K. Misbah and Zhafirah M. Ardhana

OPEN ACCESS

012036

Comparison of ultimate bearing capacity based on empirical method, interpretation of loading pile test and finite element

Y Lastiasih and P T K Sari

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012038

The stabilization of soft soil using admixture of palm oil boiler ash and *MATOS*

M. A. Ma'ruf, Rusliansyah, F. I. D. Ritonga and B. Azizah

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012039

The effect of skirt footings for road settlement on peat soil

D A W Gautama, B S Supanji and W Rahayu

[+ Open abstract](#) [View article](#) [PDF](#)

---

## Structures

---

**OPEN ACCESS**

012040

Structural behavior of open truss FRP bridge without side support

I Sidik and R Irawan

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012041

Analytical modeling of 3D-printed reinforced concrete beams

J Chandra, P Pudjisuryadi, A Antoni and H Wibowo

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012042

Effect of reinforced concrete beam confinement under cyclic loading on ultimate drift ratio

L S B Wibowo and M S D Cahyono

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012043

Determination of LRFD environmental load factor in the java sea for unbraced monopod structures using reliability analysis

Paramashanti and D A Larasati

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012045

Review on 3D printed concrete as structural beam members

P Pudjisuryadi, A Antoni and J Chandra

---

**OPEN ACCESS**

012046

Rapid visual assessment of building vulnerability due to earthquake potential hazard in Surabaya

D Irawan, B Suswanto, A R Amalia and D Iranata

---

**OPEN ACCESS**

012047

3D Finite element modeling of circular reinforced concrete column confined with CFRP under different eccentric loads

A B Christianto, B Piscesa, M M Attard, Faimun and P Aji

---

**OPEN ACCESS**

012048

Connection system of precast beam and column with wet joint for short span bridge

A Karjanto, Nindyawati and P B Susanto

---

**OPEN ACCESS**

012049

A simplified method to estimate the fundamental frequency of simple span bridges supported on lead rubber bearing

H Sugihardjo and A B Habieb

---

**OPEN ACCESS**

012050

Analysis study of extended end plate connection due to cyclic load using finite element method

Y S Yoganata, B Suswanto, D Iranata and D Irawan

---

**OPEN ACCESS**

012051



## The structural behavior of castellated beam with shape variation using finite element methods

V W Yustisia, B Suswanto, D Irawan and D Iranata

[+ Open abstract](#) [View article](#) [PDF](#)

---

### OPEN ACCESS

012052

#### Influence of link spacing on concrete shear capacity: experimental investigations and finite element studies

W Don, K Chong, M Aitken, A Tambusay, B Suryanto and P Suprobo

[+ Open abstract](#) [View article](#) [PDF](#)

---

### OPEN ACCESS

012053

#### Temperature dependence and activation energy of electrical conduction in an engineered cementitious composite

B Suryanto, D Sarairoh and A Tambusay

[+ Open abstract](#) [View article](#) [PDF](#)

---

### OPEN ACCESS

012054

#### Effect of micro-cracking on the electrical and self-sensing properties of an engineered cementitious composite under tensile straining

D Sarairoh, B Suryanto and A Tambusay

[+ Open abstract](#) [View article](#) [PDF](#)

---

### OPEN ACCESS

012055

#### Nonlinear finite element analysis of reinforced concrete beam-column joints under reversed cyclic loading

A Tambusay, B Suryanto and P Suprobo

[+ Open abstract](#) [View article](#) [PDF](#)

---

### OPEN ACCESS

012056

#### Experimental investigations on the durability performance of normal concrete and engineered cementitious composite

I Komara, P Suprobo, D Iranata, A Tambusay and W Sutrisno

[+ Open abstract](#) [View article](#) [PDF](#)

---

### OPEN ACCESS

012057

#### Numerical investigation of HSC column under axial and flexural loading using 3D-NLFEA

P Pradnyanita, B Piscesa, M M Attard, Faimun and A K Samani

[+ Open abstract](#) [View article](#) [PDF](#)

This site uses cookies. By continuing to use this site you agree to our use of cookies. To find out more, see our Privacy and Cookies policy.





## Effect of steel fiber volume fraction to the tensile splitting strength of concrete cylinder

M Maksum, H Alrasyid, M Irmawan and B Piscesa

[+ Open abstract](#) [View article](#) [PDF](#)

---

**Transportation Management and Engineering**

---

## Railway capacity analysis using Indonesian method and UIC code 405 method

H Widyastuti and W S Budhi

[+ Open abstract](#) [View article](#) [PDF](#)

## Intercity train dwell time estimation by using robust regression method: a study case on Surabaya-Yogyakarta line

P Dewi and H Widyastuti

[+ Open abstract](#) [View article](#) [PDF](#)

## Design of the strong and durable of flexible pavement on road segment with the heavy traffic and overloads

Sutoyo

[+ Open abstract](#) [View article](#) [PDF](#)

## Assessing the impact of the incorporation of aramid and polyolefin to hot and warm asphaltic mixture using dry and wet process: A Review

G Daniel

[+ Open abstract](#) [View article](#) [PDF](#)

## Demand analysis at Tanah Grogot Airport East Kalimantan

A B K Suharso and E Ahyudanari

[+ Open abstract](#) [View article](#) [PDF](#)

## Analysis the use of steel slag as a replacement of natural aggregate in the asphalt concrete binder course (AC-BC) mixture

This site uses cookies. By continuing to use this site you agree to our use of cookies. To find out more, see our Privacy and Cookies policy.



[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012065

Development of risk-based standardized Work Breakdown Structure (WBS) to improve time performance on high-speed railway construction project

D B Jati and Y Latief

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012066

Competition measures of TOD point to Central Business Districts in Surabaya using travel time approach (a case study: Joyoboyo Terminal)

A A Zahra and E Ahyudanari

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012067

Valuing subjective cost of motorcyclists used willingness-to-pay in Surabaya

H Widyastuti and A Utanaka

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012068

Student satisfaction with the performance of Surabaya school buses

M C P Lincoln and H Widyastuti

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012069

Public transportation in Jabodetabek: performance satisfaction analysis

E N Jannah, A N H Ibrahim and M N Borhan

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012070

The selection of the International Port Design Standards applicable for Indonesia

I W Dyah and Fuddoly

[+ Open abstract](#) [View article](#) [PDF](#)

---

## Water Resource Management and Engineering

---

**OPEN ACCESS**

012071

2D numerical modeling of the Jeneberang River Flood due to the overflow of the Bili-Bili Dam  
This site uses cookies. By continuing to use this site you agree to our use of cookies. To find out more, see our Privacy and Cookies policy.



[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012072

Numerical rainfall-runoff model of Cimanuk Watershed before and after the operation of Jatigede Reservoir

R M Widayati and U Lasminto

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012073

Diversion canal to decrease flooding at Kemuning river, Sampang district

G Idfi, T Rahayuningsih and N Suryoputro

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012074

The real operational cost for managing Semarang river polder drainage system

F Hartawan and S I Wahyudi

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012075

The comparative study of peak discharge at Ngotok watershed by using the method of SCS, Snyder and Nakayasu for flood control needs

G Idfi, A Yulistyorini and N Suryoputro

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012076

Numerical simulation of the water level of the channel and the Kalidami boezem by pump operation

B Setiawan and U Lasminto

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012077

The benefits of river normalization of Guntur weir upstream to irrigation area service in Demak Regency Central Java Indonesia

A Y Imawan, S I Wahyudi and N R Wahyudi

[+ Open abstract](#) [View article](#) [PDF](#)

---

**OPEN ACCESS**

012078

This site uses cookies. By continuing to use this site you agree to our use of cookies. To find out more, see our Privacy and Cookies policy.



# Hydrological analysis of moveable weir planning for tidal flood handling in Cilacap, Central Java

M Taufiq, H P Adi and S I Wahyudi

[+ Open abstract](#) [View article](#) [PDF](#)

---

## OPEN ACCESS

012079

### Analysis of water surface profile and flood discharge of Cijangkelok river

A W P Sjarief and U Lasminto

[+ Open abstract](#) [View article](#) [PDF](#)

---

## OPEN ACCESS

012080

### The flood prediction model using Artificial Neural Network (ANN) and weather Application Programming Interface (API) as an alternative effort to flood mitigation in the Jenelata Sub-watershed

O M Gessang and U Lasminto

[+ Open abstract](#) [View article](#) [PDF](#)

---

## OPEN ACCESS

012081

### The analysis of water balanced in Bendo Reservoir using Dynamic System

N F Margini, N Anwar and W Wardoyo

[+ Open abstract](#) [View article](#) [PDF](#)

---

## OPEN ACCESS

012082

### Numerical modeling of sub-surface drainage systems in Citraland, West Surabaya

S Dwiuntoroadi and U Lasminto

[+ Open abstract](#) [View article](#) [PDF](#)

## JOURNAL LINKS

---

[Journal home](#)

---

[Journal scope](#)

---

[Information for organizers](#)

---

[Information for authors](#)

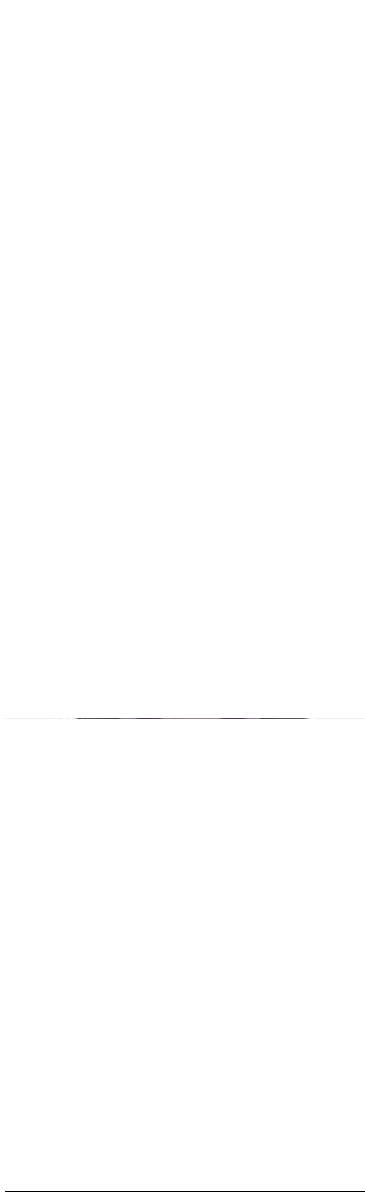
---

[Contact us](#)

---

[Reprint services from Curran Associates](#)







# Source details

## IOP Conference Series: Materials Science and Engineering

Scopus coverage years: from 2009 to Present

ISSN: 1757-8981 E-ISSN: 1757-899X

Subject area: Engineering: General Engineering Materials Science: General Materials Science

Source type: Conference Proceeding

[View all documents >](#)

[Set document alert](#)

[Save to source list](#) [Source Homepage](#)

CiteScore 2020

0.7



SJR 2019

0.198



SNIP 2020

0.484



[CiteScore](#) [CiteScore rank & trend](#) [Scopus content coverage](#)

### Improved CiteScore methodology



CiteScore 2020 counts the citations received in 2017-2020 to articles, reviews, conference papers, book chapters and data papers published in 2017-2020, and divides this by the number of publications published in 2017-2020. [Learn more >](#)

CiteScore 2020

$$0.7 = \frac{49,696 \text{ Citations 2017 - 2020}}{68,224 \text{ Documents 2017 - 2020}}$$

Calculated on 05 May, 2021

CiteScoreTracker 2021

$$0.9 = \frac{55,859 \text{ Citations to date}}{62,145 \text{ Documents to date}}$$

Last updated on 05 October, 2021 • Updated monthly

## CiteScore rank 2020

Category	Rank	Percentile
Engineering		
General Engineering	#228/297	23rd
Materials Science		
General Materials Science	#381/455	16th

[View CiteScore methodology >](#) [CiteScore FAQ >](#) [Add CiteScore to your site](#)

## About Scopus

[What is Scopus](#)  
[Content coverage](#)  
[Scopus blog](#)

## Language

[日本語に切り替える](#)  
[切换到简体中文](#)  
[切换到繁體中文](#)

## Customer Service

[Help](#)  
[Contact us](#)

---

ELSEVIER

[Terms and conditions ↗](#) [Privacy policy ↗](#)

Copyright © Elsevier B.V. ↗. All rights reserved. Scopus® is a registered trademark of Elsevier B.V.

We use cookies to help provide and enhance our service and tailor content. By continuing, you agree to the use of cookies.

 RELX



**Submit Your  
Manuscript With  
Us**

Open

Hindawi

## IOP Conference Series: Materials Science and Engineering

Discontinued in Scopus as of 2021

### COUNTRY

[United Kingdom](#)



Universities and research  
institutions in United Kingdom

### SUBJECT AREA AND CATEGORY

[Engineering](#)  
[Engineering \(miscellaneous\)](#)

[Materials Science](#)  
[Materials Science \(miscellaneous\)](#)

### PUBLISHER

[IOP Publishing  
Ltd.](#)

### H-INDEX

**44**



## Available On Curiosity Stream

Combat Videographer  
Miles Lagoze Presents  
Footage Of U.S.  
Marines In The A  
War Zone.

Curiosity Stream

[Visit Site](#)

PUBLICATION TYPE	ISSN	COVERAGE	INFORMATION
Conferences and Proceedings	17578981, 1757899X	2009-2020	<a href="#">Homepage</a> <a href="#">How to publish in this journal</a> <a href="mailto:mse@iop.org">mse@iop.org</a>

S&P Capital IQ Pro  
Expert insights  
S&P Global

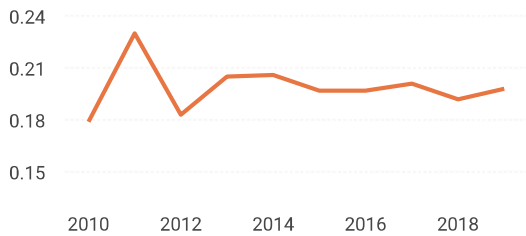
L

### SCOPE

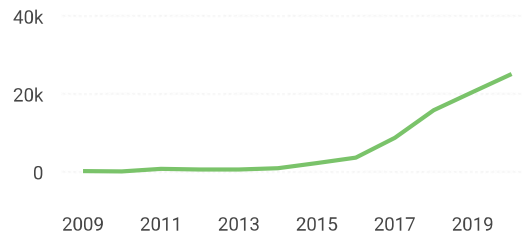
✓ The open access IOP Conference Series provides a fast, versatile and cost-effective proceedings publication service for your conference. Key publishing subject areas include: physics, materials science, environmental science, bioscience, engineering

## Submit Your Manuscript With Us

SJR

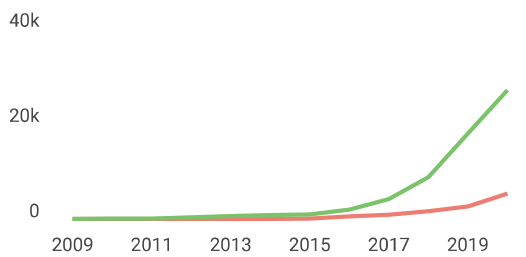


Total Documents

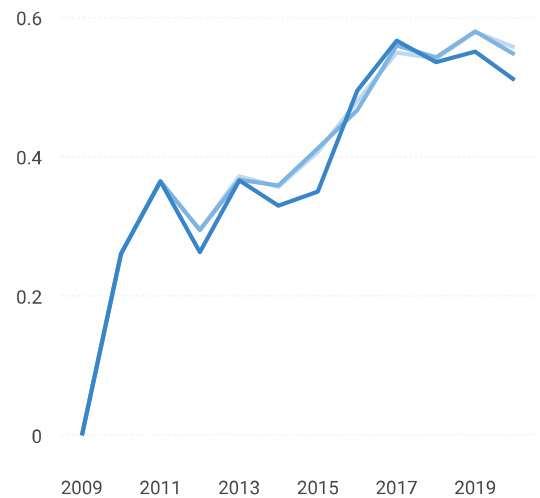


Total Cites

Self-Cites

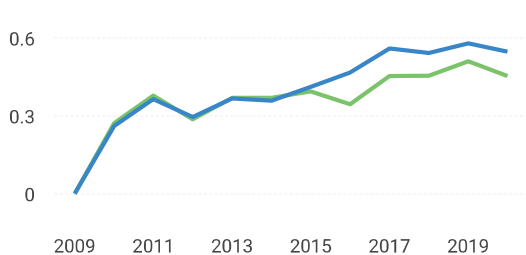


Citations per document

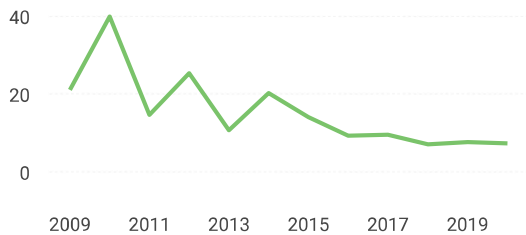


External Cites per Doc

Cites per Doc

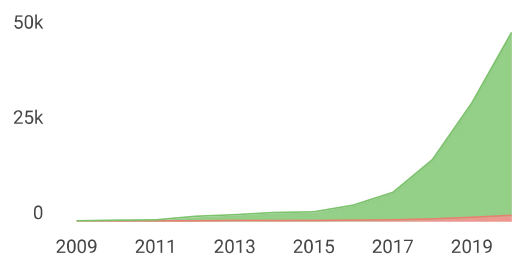


% International Collaboration



Citable documents

Non-citable documents



50k

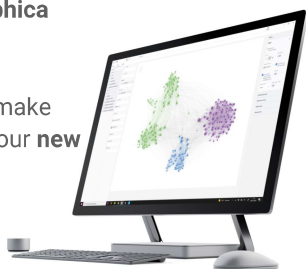
25k



## Scimago Graphica

Explore, visually  
communicate and make  
sense of data with our **new**  
**free tool.**

Get it



IOP Conference Series:  
Materials Science and...

Not yet assigned  
quartile

SJR 2020

0

powered by scimagojr.com

← <https://www.scimag>

Metrics based on Scopus® data as of April 2021

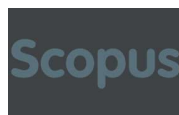
( )

Loading comments...

Developed by:



Powered by:



Follow us on @ScimagoJR

Scimago Lab, Copyright 2007-2020. Data Source: Scopus®

EST MODUS IN REBUS

Horatio (Satire 1,1,106)





# CERTIFICATE

No.112 /ICCERIV/22/07/2020

THIS TO CERTIFY THAT

*Pamuda Pudjisuryadi*

**As**  
**Presenter**

of The 4th International Conference on Civil Engineering Research (ICCER) 2020

22 - 23 July 2020



**ICCER 2020**  
International Conference on  
Civil Engineering Research

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

Chair of ICCER 2020

PAPER • OPEN ACCESS

## Review on 3D printed concrete as structural beam members

To cite this article: P Pudjisuryadi *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **930** 012045

View the [article online](#) for updates and enhancements.

# 239th ECS Meeting

with the 18th International Meeting on Chemical Sensors (IMCS)

**ABSTRACT DEADLINE: DECEMBER 4, 2020**



May 30-June 3, 2021

**SUBMIT NOW →**

# Review on 3D printed concrete as structural beam members

P Pudjisuryadi<sup>1</sup>, A Antoni<sup>1</sup> and J Chandra<sup>1</sup>

<sup>1</sup> Civil Engineering Department, Petra Christian University, Siwalankerto 121-131, Surabaya, Indonesia

**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 possess 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 anisotropic 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 anisotropic. 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.

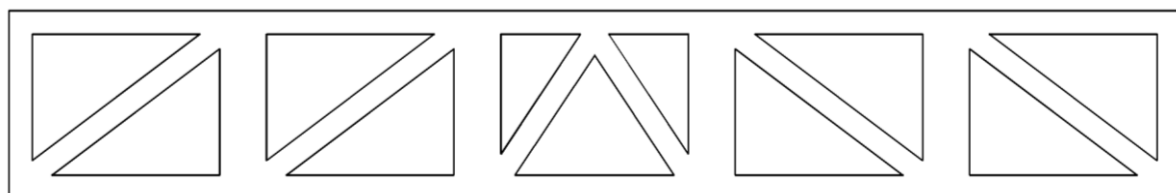
Furthermore, applicability of 3DCP as structural members raises challenges for engineers even more. There are many things should be considered for assessing the hardened 3DCP quality, which may not be necessary for conventionally casted concrete. Adopting standard assessment for conventionally casted 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

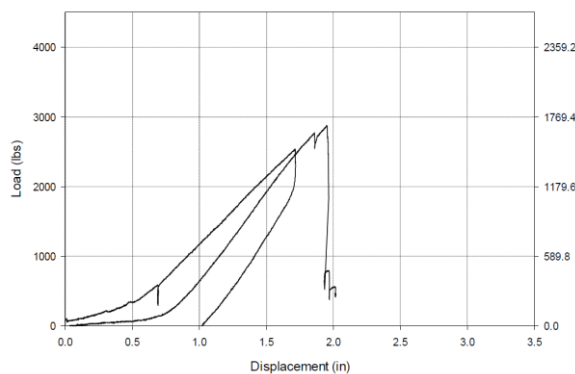
The main advantage of 3DCP that complex body forms can be made, has opened opportunities for concrete industry. With 3DCP technology, final weight of structural beam member can be reduced by manufacturing complex shape (introducing hollows) with proper analysis to guarantee the adequacy of the intended 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.



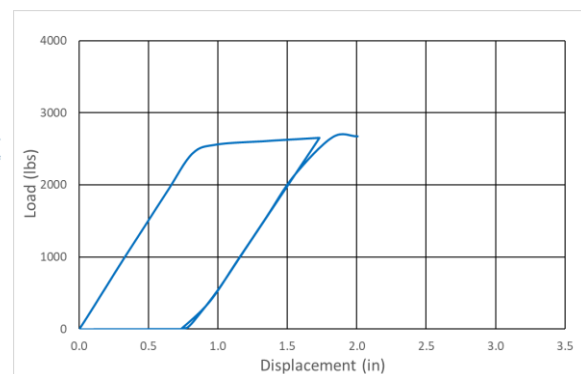
**Figure 1.** Truss like shape structural beam.

### 3.1 Non-Segmented 3DCP structural beam

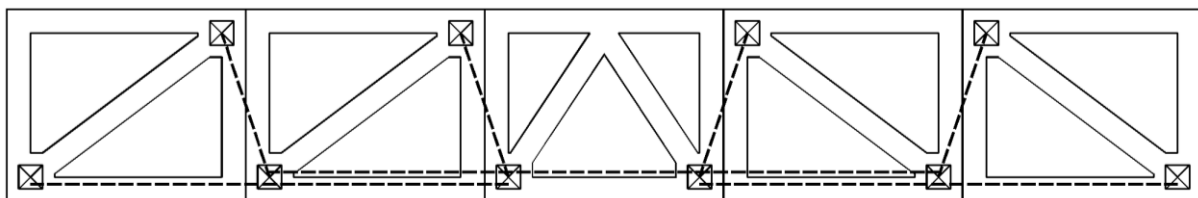
Al-Chaar et al. [8] conducted experiment on truss like 3DCP beams. The beam was 3D printed as one body at one time. Tension reinforcement bars were embedded inside the bottom horizontal chord. A cyclic flexural test was conducted on the beams. It can be seen from the force-displacement relationship (Figure 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



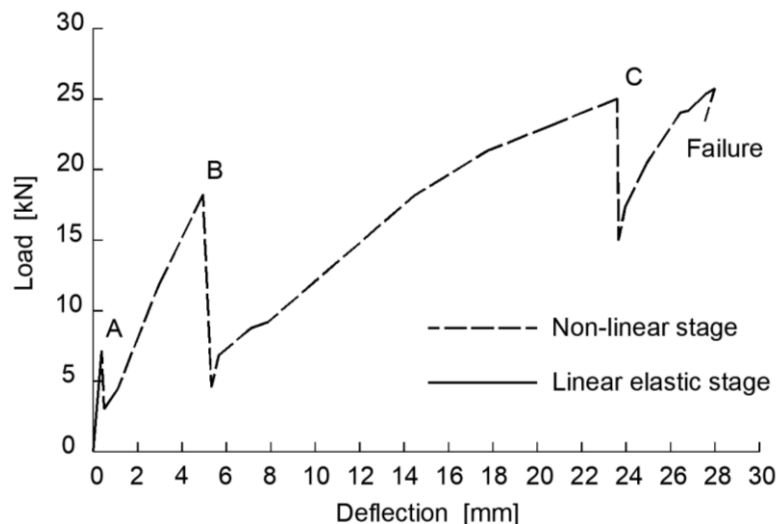
**Figure 4.** Segmented 3DCP structural beam (adopted from [9]).

### 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



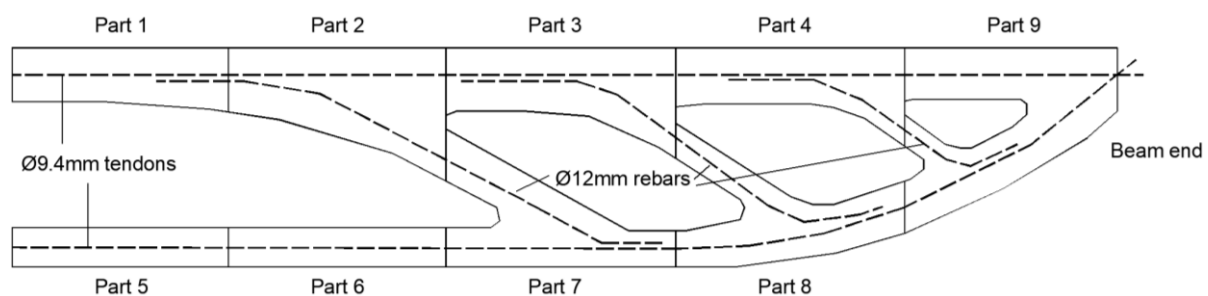
connected segmental system is prone to local damages). This shows that the printed concrete quality may be improved, but the connection system introduces different kind of weakening.



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

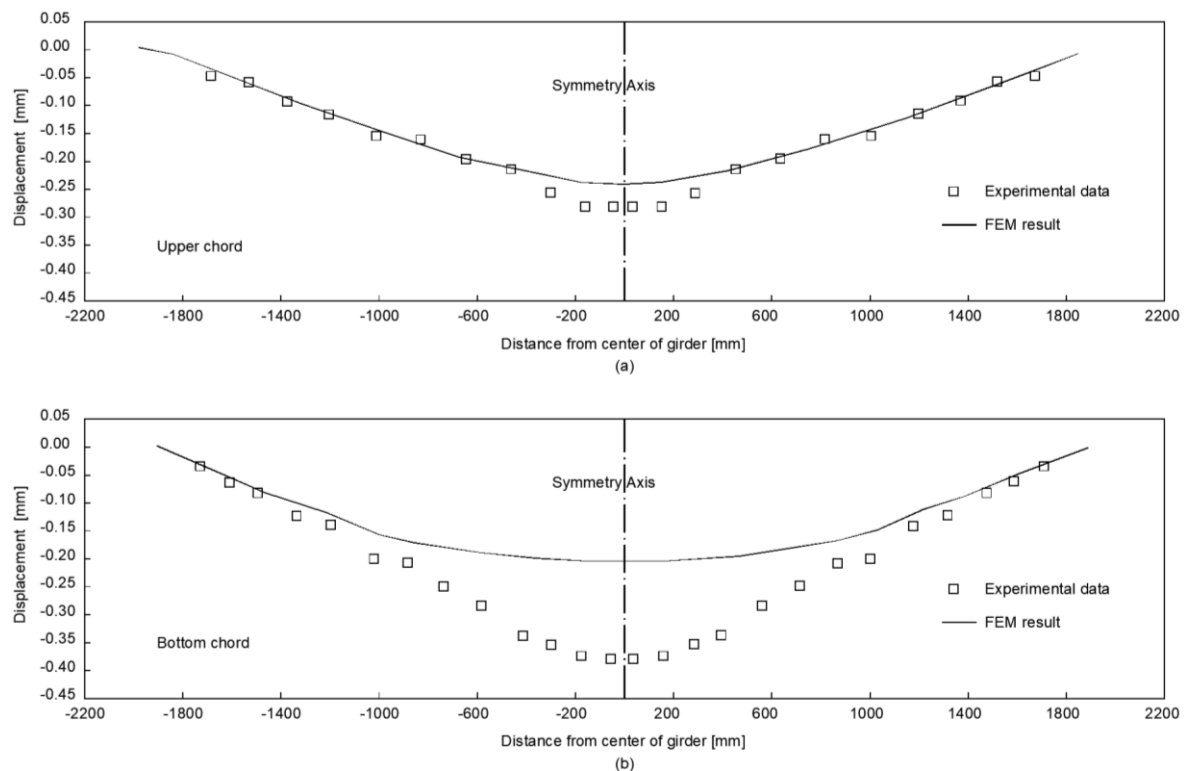
### 3.3 Segmented 3DCP structural beam (prestressed connection)

For segmented 3DCP structural beam to work, the connection system may be improved by using post-tensioning approach. Vantighem 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. Vantighem 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.

#### Acknowledgments

The authors are grateful for the funding provided by the Deputy for Research Empowerment and Development, Ministry of Research and Technology/National Research and Innovation Centre, Republic of Indonesia under PDUPT scheme no. 002/SP2H/LT-MULTI/LL7/2020.

#### References

- [1] Schutter G D, Lesage K Mechtcherine V Nerella V N Habert G and Agusti-Juan I 2018 Vision of 3D printing with concrete — technical, economic and environmental potentials *Cem. Concr. Res.* **112** 25–36

- [2] Gosselin C, Duballet R Roux P Gaudillière N Dirrenberger J and Morel P 2016 Large-scale 3D printing of ultra-high performance concrete - a new processing route for architects and builders *Mater. Des.* **100** 102–9
- [3] Wrangler T et al 2016 Digital concrete: opportunities and challenges *RILEM Tech. Lett.* **1** 67-75
- [4] Valkenaers H, Jansen D Voet A Gysel A V and Ferraris E 2014 Additive manufacturing for concrete: a 3d printing principle *Proceedings of the 14<sup>th</sup> euspen international conference* **1** 139-42
- [5] Ma G, Li Z and Wang L 2018 Printable properties of cementitious material containing copper tailings for extrusion based 3D printing *Constr. Build. Mater.* **162** 613–27
- [6] Kazemian A, Yuan X Cochran E and Khoshnevis B 2017 Cementitious materials for construction-scale 3D printing: laboratory testing of fresh printing mixture *Constr. Build. Mater.* **145** 639–47
- [7] Le T T, Austin S A Lim S Buswell R A Law R Gibb A G F and Thorpe T 2012 Hardened properties of high-performance printing concrete *Cem. and Conc. Res.* **42** 558-66
- [8] Al-Chaar G K, Stynoski P B and Banko M L 2018 Structural behavior of layer-printed reinforced concrete beams *The Op. Const. and Build. Tech. J.* **12** 375-88
- [9] Asprone D, Auricchio F Menna C and Mercuri V 2018 3D printing of reinforced concrete elements: technology and design approach *Const. and Build. Mat.* **165** 218-31
- [10] Vantighem G, Corte W D Shakour E and Amir O 2020 3D printing of a post-tensioned concrete girder designed by topology optimization *Auto. in Const.* **112** 1-11