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Lecture Notes in Civil Engineering

Han Ay Lie · Monty Sutrisna ·
Joewono Prasetijo ·
Bonaventura H.W. Hadikusumo ·
Leksmono Suryo Putranto *Editors*

Proceedings of the Second International Conference of Construction, Infrastructure, and Materials

ICCIM 2021, 26 July 2021, Jakarta, Indonesia

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Preface

This new volume of Lecture Notes in Civil Engineering contains the proceedings of the Second International Conference of Construction, Infrastructure, and Materials (ICCIM 2021). This book presents the latest development in civil engineering on a global scale. It highlights the conference scopes, such as Structural Engineering, Construction Materials, Geotechnical Engineering, Transportation System and Engineering, Constructions Management, Water Resources Engineering, and Infrastructure Development. The 55 articles published in this book went through peer-review processes double-blindly and plagiarism check. Manuscript assessments by the expert reviewers were based on the organizer's technical criteria, including technical criteria, quality criteria, and presentation criteria.

The Second International Conference of Construction, Infrastructure, and Materials (ICCIM 2021) was hosted by the Civil Engineering Undergraduate Study Program of Universitas Tarumanagara, Indonesia, on 26 July 2021. The conference brought together national and international experts to share their researches, knowledge, and experiences. ICCIM 2021 carried the theme "Research and Technology in Civil Engineering to Enhance the Sustainability of the Built Environment".

Due to the global COVID-19 pandemic, which has impacted all activities globally, ICCIM 2021 was held as an online conference. ICCIM 2021 online conference aimed to capture a broader range of participants. The Conference was also expected to facilitate researchers, practitioners, and students in their respective fields of expertise to share information and exchange ideas about the current state of civil engineering development.

ICCIM 2021 was supported by Massey University, New Zealand; Universiti Tun Hussein Onn Malaysia, Malaysia; Nihon University, Japan; fib Indonesia; Diponegoro University, Indonesia; Soegijapranata Catholic University, Indonesia; Universitas Sebelas Maret, Indonesia; and Universitas Atma Jaya Yogyakarta, Indonesia.

ICCIM 2021 has received papers from various countries, such as Indonesia, Japan, Thailand, the United Kingdom, the United States of America, the

Philippines, India, Nigeria, and Bangladesh. More than 600 researchers, practitioners, and students from all over the world registered to attend the Conference.

We are likewise grateful to the keynote speakers for bringing the exciting topics to ICCIM 2021: Prof. Roesdiman Soegiarso (Universitas Tarumanagara, Indonesia); Prof. Monty Sutrisna (Massey University, New Zealand); Dr.-Ing. Joewono Prasetijo (Universiti Tun Hussein Onn Malaysia, Malaysia); and Dr. Tam Chat Tim (National University of Singapore, Singapore).

We would also like to extend our appreciation to the supporting institutions. Secondly, thank you to the sponsors for the utmost support and kind contribution: PT. Waskita Karya (Persero) Tbk, PT. Pamapersada Nusantara, and PT. Bank Negara Indonesia Tbk.

Many people have worked very hard for the organization of this Conference. Special thanks are needed to the Organizing Committee, Steering Committee, Editorial Board, and Scientific Committee. All of whom have generously worked to make this Conference rich in content and pleasant for the attendees. We would also like to thank all the authors who have contributed to the success of this Conference.

Semarang, Indonesia — Han Ay Lie
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Panchor, Malaysia — Joewono Prasetijo
Klong Luang, Thailand — Bonaventura H. W. Hadikusumo
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Concrete Damage Risk Rating Examination to Existing Buildings

Henny Wiyanto, Reagen Yocom, and Glen Thenaka

Abstract Building assessment is a measure that has to be taken by building management to the existing building or operational building because it is very critical to the safety and comfort of the building's users. One of the commonly used building assessment methods is visual assessment. Visual assessment is a non-destructive concrete assessment that is done to identify and define different concrete conditions, which can be seen during its' lifetime. Concrete damage assessment is done to estimate the risk rating of concrete damage against the existing building structures. The risk assessment process is done in three steps: risk identification, risk analysis, and risk evaluation. There are three risk ratings: low, medium, and high. Risk rating examination of the existing building is determined based on the concrete damage type and condition rating value on the building structure element, concrete damage frequency on the building, and critical weight of the building structure element. Risk rating examination results of concrete damage are used to determine priorities building structure element repair.

Keywords Concrete damage · Risk rating · Visual assessment · An existing building

1 Introduction

Concrete damage on reinforced concrete structures cannot be avoided. This is caused by a lot of factors, one of which is poor construction implementation and low material quality. As time goes on, existing building usage also predominantly affects

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the building's condition. Improper building usage will cause physical damage to the building itself. Building usage is the act of using a building according to its' intended function [1, 2]. Oftentimes, building management or owners neglect the building's condition and do not perform proper building assessments because of cost factors. Even though building condition assessment can lower the risk of further building damage, which severely endangers the building's users, that is very risky towards the safety and comfort of building users. Building condition assessment is done with assessment towards concrete damage condition, which is done to estimate the risk of structural and non-structural damage in order to perform building reparation. According to ISO 31000:2009 [3], the risk assessment process is done with three steps: risk identification, risk analysis, and risk evaluation. The search for references about building condition rating has been performed from multiple sources, which are [4–21]. Based on that problem, the risk assessment needs to be done towards concrete damage to the existing building structure.

2 Method

Concrete damage risk rating examination to the existing building is performed in the following steps.

2.1 Risk Identification

Concrete damage risk identification is a step to identify the amount and location of concrete damage on a building structure that can lower a building's functionality. Concrete damage location is divided into four structure elements: shear wall, column, beam, and slab. Concrete damage identification is made using visual assessment.

2.2 Risk Analysis

Concrete damage risk analysis is a step done to assess risk towards the concrete damage types that have already been identified according to the damage amount and location. Damage location affects the structure element critical weight. The amount of concrete damage describes the damage frequency of a damage type on the building.

Concrete damage risk assessment is done with the following steps:

Determining Concrete Damage Type and Condition Rating Based on concrete damage type and condition rating search results for building from multiple

Table 1 Concrete damage type and condition rating [20]

No.	Damage type	Condition rating
1	Craze crack	2.54
2	Mapping crack	3.00
3	Random cracks	3.36
4	Delamination	3.25
5	Pop-outs (small)	2.75
6	Pop-outs (medium)	2.93
7	Pop-outs (large)	3.36
8	Scaling (light)	2.53
9	Scaling (medium)	2.88
10	Scaling (severe)	3.13
11	Scaling (very severe)	3.47
12	Spall (small)	2.86
13	Spall (large)	3.40

references, namely [4–18, 22–24], concrete damage type and condition rating are determined for existing buildings in Indonesia by Wiyanto et al. in [19, 20] as in Table 1.

Criteria and measures for each concrete damage condition rating are as shown in Table 2.

Determining Concrete Damage Frequency Concrete damage frequency is determined based on the amount of damage done to the building. Damage frequency is determined using three criteria based on Table 3.

Determining Concrete Damage Risk Rating The concrete damage risk rating is determined based on concrete damage condition rating and concrete damage frequency using Eq. 1.

Table 2 Criteria and measure for each concrete damage condition rating [19, 20]

Condition rating	Description	Criteria	Measure
1	Very good	No damage	No repairs are needed, but still needs maintenance
2	Good	Light damage	Needs reparation in the field of routine maintenance
3	Medium	Medium damage	Immediately needs further assessment or testing and or reparation
4	Bad	Heavy damage	Needs structure strengthening or weight reduction
5	Very bad	Very heavy/ critical damage	It cannot be maintained or demolished

Table 3 Damage concrete frequency

Rating	Frequency
1	Rare (R)
2	Moderate (M)
3	Common (C)

$$RR_{se} = \frac{\sum CI \times f_{cd}}{n_{cd}} \quad (1)$$

RRse is the concrete damage risk level of each structure element, CI is the concrete damage condition rating, fcd is the concrete damage frequency, and ncd is the amount of damage done.

Determining Building Damage Risk Rating Building damage risk rating is determined based on concrete damage risk rating and damage location. Concrete damage location is divided into four structure elements, each with its own critical weight. Based on structure element critical weight search results for buildings from multiple references, namely [9–13, 21], structure element critical weight for existing buildings is determined by Wiyanto et al. in [19, 20], such as in Table 4.

Building damage risk rating is determined using Eq. 2.

$$SR = \frac{\sum RR_{se} \times w_{se}}{\sum w_{se}} \quad (2)$$

SR is the building's damage risk rating, and wse is the structure element critical weight, as shown in Table 4. Based on the building's damage risk rating value, concrete damage risk rating can be described by referring to Table 5.

2.3 *Risk Evaluation*

Concrete damage risk evaluation is a step used to determine priority towards risk on a building so that further measures can be taken according to the risk rating. This is done in order to maintain and repair a building to increase safety and comfort for the building's users.

Table 4 Structure element critical weight [19, 20]

Structure element	Critical weight
Shear wall (SW)	1
Column (C)	1
Beam (B)	0.7
Slab (S)	0.5

Table 5 Concrete damage risk rating

Rating	Risk	Criteria
1	Low	$S < 5$
2	Medium	$5 \leq S < 10$
3	High	$10 \leq S \leq 15$

3 Results and Discussion

Assessment is applied to an existing high-rise building. Concrete damage risk rating assessment is done based on visual assessment on a 13-year-old 13-story parking building. Assessment is initiated with damage type examination, which is done on each building structure element, and condition rating of each damage. The results of concrete damage examination and condition rating assessment can be seen in Table 6.

Table 6 Parking building concrete damage type and condition rating

No.	Damage type	Element	Condition rating
1	Craze crack	C	2.54
2	Mapping crack	S	3.00
3	Scaling (very severe)	B	3.47
4	Spall (small)	B	2.86
5	Spall (small)	SW	2.86
6	Random Cracks	S	3.36
7	Scaling (light)	S	2.53
8	Scaling (severe)	S	3.13
9	Scaling (light)	S	2.53
10	Random cracks	C	3.36
11	Spall (large)	C	3.40
12	Pop-outs (medium)	B	2.93
13	Scaling (medium)	B	2.88
14	Spall (small)	C	2.86
15	Spall (small)	S	2.86
16	Spall (small)	B	2.86
17	Spall (small)	B	2.86
18	Scaling (very severe)	B	3.47
19	Scaling (light)	C	2.53
20	Spall (small)	C	2.86
21	Spall (small)	B	2.86
22	Scaling (severe)	B	3.13
23	Random cracks	S	3.36
24	Spall (small)	B	2.86
25	Spall (small)	B	2.86
26	Delamination	C	3.25
27	Scaling (very severe)	C	3.47
28	Random cracks	B	3.36

Table 7 Parking building concrete damage frequency

No.	Damage type	Frequency	Rating
1	Craze crack	R	1
2	Mapping crack	R	1
3	Scaling (very severe)	R	1
4	Spall (small)	C	3
5	Random cracks	R	1
6	Scaling (severe)	R	1
7	Scaling (light)	R	1
8	Spall (large)	R	1
9	Pop-outs (medium)	R	1
10	Scaling (medium)	R	1
11	Delamination	R	1

Based on the damage types that are identified in the visual assessment, concrete damage frequency on that building is determined. Damage frequency from each damage can be seen in Table 7.

Concrete damage risk rating of each structural element is determined based on concrete condition rating assessment results and the concrete damage frequency on the building. The risk rating assessment of each structural element can be seen in Table 8.

The parking building's structural damage risk rating is determined based on the concrete damage risk rating of each structure element, with the structure element's critical weight. Parking building structure damage risk rating assessment can be seen in Table 9.

Building damage risk rating is determined referring to Table 5. A risk rating of 5.95 shows that the parking building's concrete damage risk rating is 2, which is the medium rating. Medium risk means that further examination and reparation measures need to be done on the building. From the risk rating, it can be shown that the shear wall and beam elements are the highest priority for examination and reparation measures.

Table 8 Parking building concrete damage risk rating

No.	Damage type	Condition rating	Frequency rating	Risk rating
Shear wall				
1	Spall (small)	2.86	3	8.58
			RR_{sw}	8.58
Column				
1	Craze crack	2.54	1	2.54
2	Random cracks	3.36	1	3.36
3	Spall (large)	3.40	1	3.40
4	Spall (small)	2.86	3	8.58
5	Scaling (light)	2.53	1	2.53
6	Spall (small)	2.86	3	8.58
7	Delamination	3.25	1	3.25
8	Scaling (very severe)	3.47	1	3.47
			RR_{cl}	4.46
Beam				
1	Scaling (very severe)	3.47	1	3.47
2	Spall (small)	2.86	3	8.58
3	Pop-outs (medium)	2.93	1	2.93
4	Scaling (medium)	2.88	1	2.88
5	Spall (small)	2.86	3	8.58
6	Spall (small)	2.86	3	8.58
7	Scaling (very severe)	3.47	1	3.47
8	Spall (small)	2.86	3	8.58
9	Scaling (severe)	3.13	1	3.13
10	Spall (small)	2.86	3	8.58
11	Spall (small)	2.86	3	8.58
12	Random cracks	3.36	1	3.36
			RR_{bm}	5.89
Slab				
1	Mapping crack	3.00	1	3.00
2	Random cracks	3.36	1	3.36
3	Scaling (light)	2.53	1	2.53
4	Scaling (severe)	3.13	1	3.13
5	Scaling (light)	2.53	1	2.53
6	Spall (small)	2.86	3	8.58
7	Random cracks	3.36	1	3.36
			RR_{sl}	3.78

Table 9 Parking building damage risk rating

No.	Structure element	Risk rating	Critical weight	$RR_{se} \times w_{se}$
1	Shear Wall	8.58	1	8.58
2	Column	4.46	1	4.46
3	Beam	5.89	0.7	4.12
4	Slab	3.78	0.5	1.89
		$\sum$	3.2	19.05
		SR	5.95	

4 Conclusion

The building damage risk rating resulted from damage type assessment based on visual to existing buildings can be used to describe risk criteria. The risk rating value can describe concrete damage risk towards building structure, so it can be used to determine priorities for the measures that will be done to the building. These measures can be in the form of building maintenance, destructive testing, and building reparation. This risk rating assessment method can be applied to existing buildings in order to determine building structure element reparation priority.

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