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Concrete Structure Condition Rating in Buildings with Non-Destructive Testing

Concrete Structure Condition Rating in Buildings with Non-Destructive Testing

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Abstract. Concrete damage on building is translated as a condition change from concrete quality. The damage that is referred to can be in the form of physical change or concrete quality downgrade on a building. This change can be caused by several reasons, such as implementation error, building overload, building function change, inadequate building maintenance, natural condition, and natural disaster. Concrete damage condition on buildings can be identified by performing a condition rating assessment. Condition rating assessment Is determined based on non-destructive examination. Assessment analysis results show the concrete structure condition and the action that must be done.

Keywords: Condition rating, Non-destructive test, Concrete structure, Building.

1. Introduction

Concrete is a construction material that has a distinct compressive strength, where if it's assessed with a large number of test objects, the value will spread around certain average values. How high or low the value is depends on the field implementation perfection rating (PBI N.I.-2, 1971) [1]. Concrete is the main material for building a structure that is usually used on highrise buildings. Concrete has basic characteristics it's strong against compression, but weak against tensile load. Concrete must have certain compressive strengths according to the load-bearing function on each structure element. Terms regarding concrete compressive strength refers to SNI 2847-2013 [2] and PBI N.I.-2 [1]. Concrete is one of the main components of building structure that consists of shearwall, columns, beams, and slab.

Quality deviation in the form of concrete quality degradation can happen during the implementation of building structure construction. Concrete quality degradation is the downgrade of concrete's compressive strength, which means the installed concrete's compressive strength is lower than the planned concrete compressive strength. This is caused by many possible factors, among which are incorrect implementation process, inadequate concrete maintenance and compaction, installation or material errors, incorrect formwork removal, incorrect casting height, weather, and less skilled manpower. To identify the installed concrete's quality condition, it's needed to perform concrete structure assessment using the testing method. Testing can be done on new or existing buildings. Building material condition assessment is done with the visual assessment method, non-destructive testing evaluation, and destructive testing including field and laboratorium procedure (SEI/ASCE 11-99) [3].

Based on that issue, a concrete structure condition assessment method that can be applied on building assessment practices in Indonesia needs to be determined.

2. Method

Building Structure Condition Assessment Determination is done with the following steps:

2.1. Identification of Examination Type and Condition Rating Characteristics Determination
Concrete examination type identification is determined based on literature study and field practices. Literature consists of national and international codes, and existing similar research results that are publicized on national and international levels [4-7].

2.2. Concrete Structure Condition Assessment
Concrete structure condition determination is done with the following steps:
2.2.1. Data Collection
Data collection is done with field concrete examination on buildings using identified examination types. Concrete examination is done to all types of structure elements.

2.2.2. Data Processing
The goal of data processing is to determine the concrete structure condition rating that is determined using the non-destructive method. Data processing is done in two steps; determining the concrete compressive strength, and determining the concrete structure condition rating.

1. Determining Concrete Compressive Strength
   Concrete compressive strength on each testing point is determined by combining the concrete compressive strength value from field examination results by using the following formula [4]:

$$F = -24{,}674 + 0{,}653 * R + 5{,}752 * V$$

   Information:
   F : Concrete compressive strength (MPa)
   R : Rebound value
   V : Wave velocity (km/s)

2. Determining Concrete Structure Condition Rating
   Concrete structure condition rating is determined by categorizing concrete compressive strength rating that is resulted from the first step based on the identified condition rating characteristics [8].

   Concrete condition rating for the building structure as a whole is determined by using the weighted-average method formula as follows:

$$SCI = \frac{\sum_{se=1}^{n} w_{se}.CI_c}{\sum_{se=1}^{n} w_{se}}$$

   Information:
   SCI : Structure Condition Index
   w_{se} : Structure element critical weight
   CI_c : Combined condition index that occurs on each structure element
   n : Number of investigated structure element

   Critical weight for each structure element is determined accordingly to Table 1.

Table 1. Structure element critical weight

Structural Elements	**Ctitical Weight**
Shearwall (Sh)	1
Column (C)	1
Beam (B)	0,7
Slab (S)	0,5

3. Results and Discussion

This research is applied to buildings with reinforced concrete constructions. The identified testing type is the non-destructive testing type in the form of Rebound Hammer and Ultrasonic Pulse Velocity (UPV).

The characteristics used in concrete condition rating assessment can be seen in Table 2. Assessment is done by using values between 1 and 3. 1 indicates very good concrete condition, 2 indicates concrete condition that doesn't fulfill criteria and needs repair, and 3 indicates concrete condition that doesn't fulfill minimum criteria and requires direct weight testing. For concrete condition that's included in 3, concrete repair or reinforcement is needed as soon as possible.

Table 2. Concrete Structure Condition Rating Characteristics

Condition Index	Description	Definition	Category
1	Normal	Very good condition Requires maintenance	$F \geq 100\%$
2	Ctitical	Unacceptable conditions Needs repair	$80\% \leq F < 100\%$
3	Very Critical	Unacceptable conditions Requires direct weight testing	$F < 80\%$

Data collection is done on highrise buildings that are existing buildings with dormant construction. Condition index from each concrete compressive strength testing result on each structure element can be seen on Table 3. Condition index is determind based on concrete structure condition index characteristics.

Concrete structure condition index as a whole is determined based on condition index calculation results on each element. The resulted structure condition index values as a whole equal to 3 – this indicates that concrete structure condition is unacceptable and requires direct weight testing.

Tabel 3. Table 3. Concrete Compressive Strength Testing Results

Structure Element	Testing Result		Compressive Strength (MPa)	Condition Index
	Rebound Hammer	UPV (kg/s)		
Column	44.8	0.88	9.62	3
	48.4	0.88	11.97	3
	41.4	0.88	7.43	3
	35.8	0.87	3.71	3
	32	0.88	1.26	3
	51	0.88	13.67	3
	30.6	0.87	0.33	3
	30.2	0.87	0.05	3
	39.8	0.89	6.42	3
	32.6	0.88	1.65	3
	32.4	0.86	1.43	3
Beam	47.2	0.28	7.76	3
	38	2.81	16.32	3
	42.6	3.07	20.78	3
	43.8	2.65	19.17	3
	36	3.02	16.22	3
	31.4	3.06	13.42	3

Structure Element	Testing Result		Compressive Strength (MPa)	Condition Index
	Rebound Hammer	UPV (kg/s)		
	31.8	2.73	11.78	3
	29.2	2.88	10.97	3
	29.80	2.76	10.67	3
	28.60	2.88	10.55	3
	29.00	2.79	10.32	3
	34.6	2.86	14.36	3
	33.6	2.70	12.78	3
	32.4	2.98	13.60	3
	34.6	2.75	13.72	3
	36.4	3.05	16.66	3
	34.6	2.85	14.32	3
	30.6	2.70	10.83	3
	32.8	2.94	13.63	3
	32.2	2.76	12.24	3
	30.4	2.87	11.67	3
	28.8	2.68	9.53	3
	34.6	2.85	14.34	3
Slab	34.6	0.85	2.81	3
	33.4	0.86	2.08	3
	36	0.86	3.76	3
	41.6	0.86	7.46	3
	44.2	0.82	8.91	3
	32.4	0.86	1.42	3

4. Conclusion

Based on analysis results, it's concluded that concrete quality degradation has been done towards the building structure elements. Condition index on each testing result indicates a very critical condition. This means that concrete structure condition on that building is in a condition that can't be taken advantage of. If that building's construction is to be continued, direct weight testing needs to be done first. If the concrete compressive strength assessment results don't fulfill the terms, concrete structure reinforcement or dismantlement needs to be done. Cost efficiency must be considered in making this decision.

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