# CONDITION INDEX BASED MAINTENANCE AND REHABILITATION MANAGEMENT

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**ABSTRACT**

Fires and earthquakes are frequent events that falled buildings. Fires affect the strength of reinforced concrete structural components when going for a long time and the intensity of the high temperature, although the actual concrete is fire-resistant materials because of the nature of non-flammability and thermal insulation of buildings and structures made of reinforced concrete has been designed to withstand the fire for several hours. This is due to the changing nature of the material forming the concrete. Likewise earthquake would cause structural and non structural damage to buildings. For that, in connection with an assessment of the structural integrity of the building, bearing in mind the residual strength. Assessment methods of the Puslitbang Permukiman Dep. PU has been used in Indonesia tend to be qualitative although based on a variety of tests performed.

This paper develops the management model of maintenance and rehabilitation based on assessment of the condition of the building by using the method adoptedconditions index from the U.S. Army Construction Engineering Laboratories (USACERL) so that the level of damage to the building can be represented quantitatively. The results of this study are also expected to be used as historical data for periodic inspection in order to keep the building in an attempt to prolong service life of the building so that the sustainability of buildings can be realized

**KEY WORDS :** Maintenance, Rehabilitation, Management, Buildings, Condition Index

## 1. INTRODUCTION

Infrastructure is the physical building or facility that supports sustainability and economic and social growth. According to Hudson et al., 1997 there are seven categories of infrastructure building, and the building is one of them.

Due to aging, overuse, environmental influences, and mismanagement led to the decline in the condition of the building causing the building to be prone to failure. In this regard encourages the assessment of the performance of a building is determined through a process called the condition assessment. This assessment is done with regards to checking whether the building has been satisfactory in terms of usage, with regard to the information obtained from the physical condition of the building.

Activity assessment bridge between operational and maintenance. If the condition becomes worse, the operation will be affected and thus require assessment of the condition. This makes the operation and maintenance are the two activities are interrelated [NS Crigg, 1988].

According to ACI Committee 437 1985 as quoted by Ted Kay (1992), assessment of the condition of the building will be done if the structures were damaged by the occurrence of incidents such as earthquakes, fires, bombing of the building. The first two incidents are potential cases occurred in West Sumatra.

Generally, the fire would destroy most of the components of reinforced concrete building structures are characterized by declining strength of the concrete component. At temperatures above 100 ° C, the bond between the cement paste aggregate with reinforcement will become dehydrated and aggregate particles will undergo development, resulting in the disintegration of the concrete itself (Chana& Price, 2003). For the structure of the building after the earthquake, there are three conditions that damage may occur, due to the total collapse of the whole structure can not bear the brunt of the earthquake, the collapse of soft story on the ground floor columns caused by inadequate reinforcement details such as the dimensions of reinforcement, reinforcement spacing and the seismic hooks, as well as damage to the third is non-structural damage.

After the earthquake and fire occurred, commercial building owners generally take action to rehabilitate the building and the cost for rehabilitation is a trade off of the economic value of the building. And rehabilitationand maintenance management within the scope of infrastructure management systems (Crigg, 1988).

So that rehabilitation can be done effectively, it is necessary assessment of the performance indicators of the building which is a prerequisite before the action is performed (Hudson et al., 1997). Structural integrity is an indicator of the feasibility of reusing a building after suffering damage. Assessment of the structural integrity of buildings after fires and earthquakes in principle based on the residual strength that plays an important role in determining the form of rehabilitation of damaged structural components (Kumar, 2003).

Assessment model of the condition of the building after the earthquake and fire, has so far been implemented better investigation techniques through visual observation and testing. Although examination techniques can be quite complete, but the assessment of the condition of the building is still highly descriptive and qualitative and tend to describe the condition of the building that have not integrated that can be used directly as a basis for estimating the condition of the building in the future in order to determine the activities and priorities of maintenance.

In this study the building condition assessment models were developed using the method adopted conditions index from the U.S. Army Construction Engineering Laboratories (USACERL) so that the overall level of damage to the building can be represented quantitatively. Assessment limited to only the building structure system. The results of this study are also expected to contribute in determining the framework for assessing and monitoring the condition of the building and assist the parties in making decisions on measures of rehabilitation and reuse of the building after the earthquake and fire.

## 2. CONDITION ASSESSMENT FOR POST FIRE REINFORCED CONCRETE BUILDING STRUCTURE

Assessment ofthe condition ofthe post fire structure buildings in Indonesia is generally done by Agency For Research and Development – Research Institute For Human Settlement Ministry of Public Works. The result of the overall condition of the building accommodate the results offield and laboratory testing and visual inspection so it can be quite comprehensive. However, assessment of the conditions stated in descriptive or qualitative. Decisions about the feasibility of reusing the building is based on the opinion sand competence of assessors caused by the absence of clear guide lines linking eligibility decisions to the level of damage. In contrast to appraisal using index condition, condition assessment of reinforced concrete buildings after the fire by the Agency For Research and Development – Research Institute For Human Settlement Ministry of Public Works was only able to meet the need sat the time of assessment, due to the use of descriptive models, data about the condition of the building can not be used to predict future condition considering resume presented a qualitative assessment of the condition so that can not be entered into the data base as historical data.

## 3. CONDITION INDEX BASED MAINTENANCE AND REHABILITATION MANAGEMENT

The model was developed to make improvements to the method applied by the Agency For Research and Development – Research Institute For Human Settlement Ministry of Public Worksin the assessment of the condition ofthe building structure after fire and earthquake, and combine with the method REMR conditions index in the use of a numerical scale to indicate the condition of the building as a whole. Completion of the method was done by the Agency For Research and Development – Research Institute For Human Settlement Ministry of Public Works refers to the infrastructure management process chain from Guillaumot (2003). Schematic model developed is presented in Figure 1. The assessment process consisted of phase measurement conditions damage, condition assessment phase by using an index of conditions and decision-making stage for the re-use of buildings.

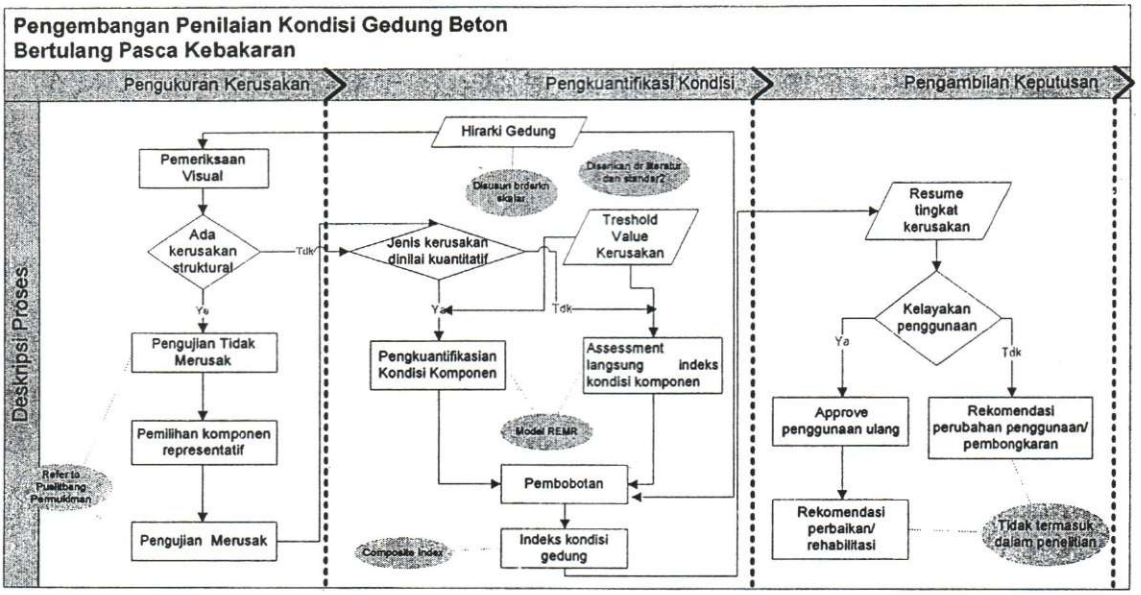


**Figure 1.** The Developed Model

### 3.1 Phase of Measurement of Damage

Refinements were made to the Agency For Research and Development – Research Institute For Human Settlement Ministry of Public Worksof methods for the measurement of damage mainly lies in the selection of structural components to be tested further after visual inspection. Only the components of the structure being damaged and severe damage to betested. Tests carried out on representative components, each of the lightly damaged and destroyed.

### 3.2 Phase of Quantification of Conditions

a. Methods of Quantification of Conditions

Quantificationing to get the index of each condition on the damage done REMR modeled, through the following equation [Foltz et al. (2001) and McKay et al. (1999)]:

$$CII = 100\ (0.4)^{xi/ximaks} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

CII = component condition index
xi = the value of the measurement of component damage
ximaks = max limit value of the component damage (threshold value)

To damage expressed using qualitative criteria, such as discoloration of concrete due to fire, the above mathematical model can not be used. In accordance with the model REMR, direct assessment is used to determine the index condition.

b. Composite Condition Index

By applying a model that embraces the concept composite condition index, then the index value conditions due to the presence of some types of damage (multiple distress) in accordance with the assessment and measurement of structural damage to the building is the combined condition index value of various types of damage. Composite Conditions index calculation performed using the following equation [Foltz et al. (2001) and MsKay et al. (1999)]:

$$Total\ CI = \Sigma\ (Wi)\ (CII) \quad \ldots\ldots\ldots\ldots\ldots (2)$$

c. The Things Needed In Quantification of Conditions

• Threshold value

Conditions of damage reaches the poor category rated the condition index is less than 40 so the value of the damage limit (Xmaks) are 40. Limit values of worst damage (Xmaks) expressed as threshold value of each type of damage. Determining the type of damage and maximum damage limit value for examination and measurement of damage with both qualitative and quantitative measures, derived from several standard classification of fire damage. Threshold value of each damage reinforced concrete structure after fire are shown Table 1.

**Table 1.** Treshold Value For Post Fire Damage

| Test Type | Sub Component | Type of Damages | The worst damage ($X_{maks}$) | | | Explanation |
|---|---|---|---|---|---|---|
| Visual Inspection | 1)Steel | 1. Buckling | All reinforcing bars are bent from the heat categorized heavy damage | | | Expert Judgement |
| | | 2. Rusty | Baik sedikit maupun banyak karat pada tulangan dikategorikan berat | | | Expert Judgement |
| | | 3. Reinforcement Exposure | 50 % dari tulangan kolom atau balok maupun 25 % tulangan pelat maupun dinding terekspos akibat panas | | | Standar The Concrete Society (GBG,2001) |
| | 2) Concrete | 1. Spalling | Kedalaman pengelupasan > 75 % tebal selimut atau tulangan terlihat. Untuk kategori explosive spalling juga termasuk spalling kerusakan berat. | | | Standar Concrete Society &expert judgement |
| | | 2. Cracking | ***Ringan*** Retak yang terjadi hanya pada selimut beton luar. ( lebar 0.5 – 1 mm) | ***Sedang*** Selimut beton retak struktural sampai ke dalam inti beton | ***Berat*** Selimut beton retak sampai tembus ke bagian belakang | Standar Puslitbang Kimpraswil (Dep.Kimpraswil, 2003) |
| | | 3.Crazing | ***Ringan*** Retak crazing masih berupa retak rambut dan jarak hexagonal retakan agak longgar | ***Sedang*** Retak crazing sudah besar, jarak hexagonal retakan menjadi rapat tetapi masih kurang dari 50 mm | ***Berat*** Retak crazing mulai mengelupas (slouging off) | ACI 302.1R dan Standar The Concrete Society |
| | | 4. Pop-outs | ***Ringan*** Diameter lubang sampai 10 mm | ***Sedang*** Diameter lubang 10 – 50 mm | ***Berat*** Diameter lubang besar 50 mm | ACI 202.1 |
| | | 5. Scaling | ***Ringan*** Permukaan beton mengelupas tipis | ***Sedang*** Permukaan mengelupas 5 – 10 mm | ***Berat*** Pengelupasan agregat kasar | Newman, 2001 |
| | | 6. Coloring | ***Ringan*** Beton berwarna | ***Sedang*** Permukaan beton | ***Berat*** Permukaan beton | Standar Puslitbang Kimpraswil & |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | normal hitam/jelaga sampai abu-abu | berwarna pink | berwarna putih keabu-abuan atau putih keriput | The Concrete Society |
| | | 7. Deformation inbeams, columns, plates | Terjadi perubahan bentuk pada balok, kolom atau pelat maupun pergeseran pada joint balok-kolom atau kolom-sloof. | | | Standar Puslitbang Kimpraswil |
| Non Destructive Test | 1) Concrete | 1. Penetrasi Panas | ***Ringan*** Ketebalan penetrasi panas 0 – 15 mm, warna violet beton (dr Phenolphtalene) hilang | ***Sedang*** Ketebalan penetrasi panas 16 – 30 mm, warna violet memudar | ***Berat*** Warna violet tetap pada ketebalan penetrasi besar dari 30 mm | Resume lap kebakaran Puslitbang Kimpraswil |
| | | 2.Homogenitas | Kecepatan rambat gelombang ultra melewati beton ≤ 3 km/dt | | | Neville, AM, 1977 (Holland, R, 1997) |
| | | 3.Kekuatan Beton Scmidht Hammer | fc' aktual ≤ 65 % fc' rencana | | | Standar Puslitbang Kimpraswil |
| Destructive Test | 1) Steel | Tegangan Leleh Baja | $\sigma_y / (\sigma_y)^o$ = 0.8 untuk jenis hot rolled steel atau 0.6 untuk jenis cold worked steel | | | A.K Tovey, 1986 |
| | 2) Concrete | 1. Kekuatan Beton Core Drill | fc' aktual ≤ 65 % fc' rencana | | | Standar Puslitbang Kimpraswil |
| | | 2. Lendutan thd respon beban uji | δ aktual > δ izin dan derajat pemulihan < 75 % | | | SNI |

*Lendutan izin yang terjadi* = $l^2_t/20000\ h$

- Hierarchy

Assessment of the condition of the building after the fire started with the assessment of structural components, and then the system structure that functions supported by these components, and finally the building as a whole. So to assess the overall condition of the building required the elaboration of existing components through a hierarchy that forms the building system. At level 1 is the object of the building assessment. For level 2 or the system is just the structure of the system in accordance with the scope of the study. For level 3 or components are the columns, beams, plates, and foundation walls. For level 5 or subcomponents are steel, concrete, brick, and cement and sand.

- Weight Assessment

Accuracy in assessing the importance weights depend on the experience and competence. Uzarsky (1997) developed the underlying factors giving the scale of interest is as follows:

♣The functions factor.

The scale of interest will indicate the dominance of the function of a component to other components in bearing the burden of the building after the fire.

♣The cost factor.

The cost of repairs to components of a reinforced concrete structure after fire will be declared as the cost of repair of construction methods that include the cost of repair materials, wages and the cost of support tools. The scale of interest is taken will show the dominance of a component of the cost of repairing other components.

♣The maintenance and repairs factors.

Factors closely related to the maintenance and repair of the support function factors. The scale of interest is taken will show dominance given effect maintenance and repair of the structural integrity of a component to other components.

The weight of interest is obtained by a direct comparison above only shows the interest factor between components in terms of functionality, cost and maintenance without considering the condition index values obtained by each of these components. If the index value is lower component condition, the relative weights of these components in determining the value of the combined condition index will be higher than the weight of component condition index value higher. Because of the weight of the early interest will be normalized by the condition index values obtained. Normalization is done by multiplying the weight of initial weight derived from direct comparison with an adjustment factor of each individual depends on the condition index values obtained by each component.

### 3.3 Phase of Decision Making

To translate the meaning of the quantification condition, in McKay et al. (1999) and Greimann et al. (1997) USACERL has developed a relationship between the condition index category handling conditions and recommendations for action based on the decline in the physical condition of the damage. Condition index values are divided into three categories namely scale range good condition in zone 1, the category of intermediate conditions in zone 2 and category of adverse conditions in zone 3. Condition index value 40 is the tolerance of a condition the infrastructure so as to condition the index value 40 will immediately receive maintenance priority.Eligibility criteria for reuse of the building after the fire is determined as follows:

- building condition index between 70-100 are in zone 1, it means building viable for reuse. The structure of the building is relatively good, there are only a few of damage or deterioration that is not significant so that only require structural repairs.
- building condition index between 40-69 are in zone 2, meaning that the building fit for use but must be made immediately rehabilitation and retrofitting of components with a low condition index (zone 2 and zone 3). The structure of the building on the range is not

very good and the level of damage was so disturbed enough structure function.

- building condition index less than 40 are in zone 3, which means the building unfit for reuse. Reusing is possible if there is a change in the function of the structure of the activities in the building. The structure of the building is in poor range with the power that is no longer enough to carry the load.

## 4. IMPLEMENTATION OFCONDITION INDEX BASED MAINTENANCE AND REHABILITATION MANAGEMENT FOR POST FIRE BUILDING STRUCTURE

The developed model was used to assess Pangrango Internusa Plaza Bogor that had been fired for 14 hour.The part that burned is mostly ground floor, first floor and the entire second floor in the main building. Inspection and testing of Agency For Research and Development – Research Institute For Human Settlement Ministry of Public Worksgave the following results (Research Center for Resettlement, 1996):

- 16% of the structure of the ground floor suffered minor damage
- The structure of the ground floor and second floor of mild to severe damage
- The loading test shows the response of the plate component still meets the technical requirements, the degree of recovery is greater than 75% despite of the compressive strength test results of all structural components is smaller than the initial design.
- Concluded overall Pangrango Internusa Plaza building structure can still be used in accordance with the original function,but it should be repaired the cracks and cover the entire visible steel bars in beams and plates.

Application of the assessment of the condition index for post fire building structure is done by selecting the representative component that will represent the other components. Representative component is a component with the worst damage on each floor inspection. Representative component that moderate and severe levels of damage will require further testing in order to quantify the condition.

Because in this study the structural condition index reflex building system condition index, so the index of the condition of the building is 55.84 that in zone2 is categorized as moderate conditions. The conclutionis the building Pangrango Internusa Plaza deserves to be re-used with some strengthening / improvements to be made immediately to the component beams and joists holding of the ground floor and first floor columns.

To assess the effectiveness of the application of the developed method, Table 2 displays the comparison between Old Model from Agency For Research and Development – Research Institute For Human Settlement Ministry of Public Worksand Model-Based Assessment Condition Index in various parameters.

**Table 2.** Comparison of The Two Model

| Parameter | Aspect of Assessment | Old Model | Index Condition Based Assessment Model |
|---|---|---|---|
| Work Process | Phase of assessment | Consists of two stages which is damage measurement and decision-making | Consists of three stages which is damage measurement, quantification of condition and decision-making |
| | Duration of damage measurement | Longer due tothe method ofthe sample in the measurement of damages. | Shorter because only representative components results from the visual inspection was measured. |
| | Eligibility criteria | There is noclear guidance one ligibility criteria correlation with the level of damage of the test results | Defined by the range of indices specified condition |
| | Determining of feasibility of use | It's not easy and subjective opinion based on the interpretation of measurement results so that required a lot of experience engineers | Easy because it refers to the eligibility criteriaset |
| | Final Decision | Descriptive results | Condition index |
| Information Generated | Use formonitoringand maintenance | Hard to be a reference for condition monitoring and maintenance plan due to the descriptive results. | Can be used as a reference for monitoring and maintenance planning caused there is deterioration models |
| | The report designated | Intended for technical and engineering level. | Intended for management level. |
| | Database system | The management can not make the data base given the descriptive results. | The management can make the database |
| Resource Needed | Funds needed | Funds are more needed ing7 types of inspection/ and sampling carried toneach of the damage rement process | Fewer funds needed. -Reduction of the type of testing, itdoes not need Hammer Test and UPVTest. -Reduction the number of penetration samples tested by 67% -Reduction the number of drill core samples tested by 22% -Reduction the loading test site by 2 locations |
| | Resource competency | Resource takes a lot more technician than the engineer for decision makers | The number of technicians and engineers are needed are the same |
| | Information and Technology using | Only for the calculation of the damage measurements | IT is also used as a tool that assists in the monitoring process conditions. |

## 5. CONCLUSION

Condition Index based maintenance and rehabilitation management has several advantages over other methods of assessment of the condition of the building after the fire in Indonesia. Clearly assessmentssimplifying the implementation of condition assessment itself. In addition the program will be shorter because the focus is onrepresentative component testing who suffered the worst damage thereby potentially lowering the costs for building condition assessment. Other advantages are very obvious is the reduction of subjectivity because the assessment is done by a numerical scale with the eligibility criteria for reuse of the building has been determined. The application of this model should be accompanied by documentation or database setup so that the results can be used as an assessment of historical data to determine the model of building damage.

Although this new assessment model applied to the post fire building structure, but the model can also be applied to the assessment of the condition of the building after the earthquake. Adjustments are made to the value of threshold value for each type of damage, while there is no difference to the phase of the measurement.

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