CHAPTER V
CONCLUSSIONS

The result of study on developing performance-based design code in Indonesia has been presented. The research was started with data collection from several construction sites, then statistical analysis of the collected data, and reliability analysis have been carried out. This chapter conclude and present the most valuable finding from the research.

5.1 Material and Fabrication

The result of study on developing performance-based design code in Indonesia has been presented. The research was started with data collection from several construction sites, then statistical analysis of the collected data, and reliability analysis have been carried out.

Five construction sites as source of data have been chosen in the consideration to representing the real condition of construction industry in Indonesia. The sites were three in Jakarta and two in Yogyakarta, two cities which are representing the conditions of many other situations in Indonesia. The owners of the facilities under construction in 2006 were both government and private, on effort to balancing the presumption that the private-owned constructions have better management than those government-owned. Data from all the sites also involved several testing laboratories related to the location of the project.

Some question may arise related to the material used in those constructions sites, whether representing all material in Indonesia or not. This following explanation might answer some. All concrete companies in Indonesia belong to private or private/holding company, and some of them belong to multinational company. All those company controlled by head office in main Island, Java. Indonesian Concrete Association joining nine concrete companies covers all demands in Indonesia and even some part of production exported to other countries. Concrete produced manually usually for minor or special works excluded from this research. The similar case also found in reinforcing steel material.

Statistical examination result for concrete compressive strength involving several ready-mix concrete suppliers show the value of coefficient of variation V between 0.133 and 0.045. The coefficient of variation V of f_c' for all analyzed concrete is V=0.102. Therefore, in the next analysis, V=0.10 was proposed for all considered class of concrete. This value is similar with those proposed by Nowak and Sezersen (2003) [16] for new material data bases in the United States.

Research found that the data involving several batching plant from several suppliers are resulting higher inconsistency (bigger V value) of concrete production than data came from particular company. Statistical examinations also found that the coefficient of variation V decrease together with the increment of concrete grade. These facts are suitable for several cases not only from Indonesia. This data also having similar trend with the information of concrete compressive strength in Japan.

The bias factor, λ, which is ratio between mean to nominal value, explained as follows. For data involving several concrete sources, the bias factor λ in Indonesia is increase along with the increasing the concrete grade. Data of concrete from two particular companies in Indonesia are resulting different trend. Data from one company show the value of λ around 1.13 for all concrete grades, while data from another company show the value of λ decrease along with increasing of concrete grades.

Result of statistical examination for reinforcing steel also presented. For bar diameter, the coefficients of variation V are between 0.007 and 0.016 while the values of bias factor λ are 0.99 and 0.98. This means that the average nominal diameters are slightly less than, but very close to the nominal value. For yield strength of reinforcing bars, the coefficients of variation, V, vary from 0.017 to 0.192 and bias factor λ vary from 1.097 to 1.388. Relating these data of diameter and yield strength, it could be understand that the producer tend to reduce the weight of steel by reducing the volume and compensate with higher yield strength. This approach believed to be one effort to reduce the construction cost.

Comparing the value of yield strength with the similar information from the United States by Nowak and Szersen (2003) [16], it can be seen that the bias factor λ in

United States are vary from $\lambda = 1.125$ to $\lambda = 1.20$, while the coefficient of variations V = 0.035 to V = 0.065. For the United States, recommended value for coefficient of variation V = 0.05 and bias factor $\lambda = 1.145$. For yield strength in Indonesia, the recommended value of coefficient of variation V = 0.10 and bias factor $\lambda = 1.20$, which close to the old values of coefficient of variation V and bias factor λ in United States.

For the aspect of fabrication, result of statistical examinations for data from Indonesia, for width and effective depth of beams show the value close to those from United States. For the width and breadth of column, all data from Indonesia and the United States are in the similar condition showed by the close value of coefficient of variation V and bias factor, λ.

It might be concluded that Material characteristics in Indonesia are not far different with those from Japan and United States based on the research by Nowak and Szrensen [16]. This conclusion showed that for ordinary concrete (normal concrete, exclude high performance concrete, special purpose and using special admixture and fiber concrete) Indonesia apply the similar level on the production. This also occurs on the production of reinforcing steel bar.

The data of fabrication show that the condition of workmanship in Indonesia could be similar with those in Japan but slightly poorer than those from Europe and United States, based on the research by Nowak and Szerensen [16].

5.2 Performance Index for Strength

Analysis on predicting the performance of concrete structures involving many variables both from resistance aspects and combined loadings (or actions). This research stressed the analysis on the aspect of resistance, while the aspect of loading were follow the application from established code and literatures. In the aspect of resistance stressed in this research, two aspects were assessed, i.e. deviations on material production and fabrication of structural member. For both aspects in Indonesia showed that deviations resulted from material production and fabrication of structural member were mostly within the normal limit.

Some question may arise related to the material used in five construction sites, whether representing all material in Indonesia or not. This following explanation might answer some. All concrete companies in Indonesia belong to private or private/holding company, and some of them belong to multinational company. All those company controlled by head office in main Island, Java. Indonesian Concrete Association joining nine concrete companies covers all demands in Indonesia and even some part of production exported to other countries. Concrete produced manually usually for minor or special works excluded from this research. The similar case also found in reinforcing steel material.

The research found that quality control of material productions in Indonesia are not far different with those from Japan and United States. This conclusion showed that for ordinary concrete (normal concrete, exclude high performance concrete, special purpose and using special admixture and fiber concrete) Indonesia apply the similar level on the production. This also occurs on the production of reinforcing steel bar.

The data of fabrication show that the condition of workmanship in Indonesia could be similar with those in Japan but slightly poorer than those from Europe and United States, based on the research by Nowak and Szerensen [16].

On the LRFD as part of verification on performance of concrete structures, there are many format on implementing the partial factors or resistance factors. European practices use global partial safety factor, American practices use strength reduction factor on the aspect of resistance, while the Japanese practices apply more safety factor for each uncertainties. The calculation to determine those factor following European practice was carried out. The analysis result for safety showed that the global partial factor γ_M for concrete γ_c = 1.50 to 1.70 and for steel γ_s = 1.10 to 1.15 incorporating the load factor for permanent load γ_G = 1.35 and variable load γ_Q = 1.5. The safety index used as reference on the analysis following the recommendation from ISO 2394 [10], i.e. the value of performance index for safety is between β = 3.0 to β = 4.0. The recommended global partial factor for safety performances in Indonesia is presented in Table 4.6 and Table 4.15.

The value of γ_M determined for Indonesia are bigger than those from Europe. This fact is resulted by higher deviations in material production and dimensioning of member. It means that the workmanship level in Indonesia need to be improved in order to reach the better performance of concrete structures is Indonesia.

5.3 Performance Index for Serviceability

Similar with the performance of safety, the analysis on performance of serviceability also carried out using the performance index recommended by the ISO 2394 [10], and the value use in this analysis was ran between $\beta = 0.0$ to $\beta = 2.0$. Based on the analysis result for serviceability aspect, the partial factor γ_M might take to be 1.00-1.10 for concrete compressive strength and γ_M = 1.00-1.05 for reinforcing steel tension. On this aspect of serviceability, the load factor for permanent and variable load $\gamma_G = \gamma_Q = 1.0$.

Various codes in the world use the partial factor for the serviceability performances to be taken equal to 1.00 for the variable of strength (resistance) and the load factor. For the case of Indonesia, when using the recommended performance index and load factor equal to 1.00, the value of global partial safety factor for serviceability were little bit larger than 1.00. This might be resulted form the condition of quality control of material production and fabrication of structural member that still having high deviations and need to be improved.

Serviceability performance of concrete structures usually includes the crack widths, deformations, and vibrations into discussion. Since the performance index was determined by adopting the recommendation of ISO 2394 [10], the analysis was run in determining the global partial factor. The values of global partial safety index for serviceability should be applied to the analysis of determinations the design strength of these aspects.

5.4 Some Aspects on Durability

The aspects of durability were not deeply take into the analysis in this research because analysis of durability performance need more complete data and resources. Different with the safety aspect, the serviceability and durability incorporate the conditions of local perceptions and environmental conditions of such region.

However, there is a little chance to relate the obtained data in Indonesia with the durability performance of concrete structures. The discussion on durability performance will involve three conditions affecting the structures. The first is mechanical conditions of the structural concrete. This includes stress or strain level, and crack. Similarly to discussion on serviceability performance, the variables affecting the crack were stress level of concrete and reinforcing steel, dimensioning, concrete cover and tension strength of concrete.

The second was physical conditions. This condition includes the abrasion resistance and the thermal expansion. This two aspects are related to the concrete compression strength f_c'. In this regard, good quality of concrete production and selection method of concrete compression strength become important on determination of good performance of concrete durability. The third conditions is the chemical conditions represented by appearance of aggressive ions in the environmental of the structure. Those include the hydracids, chloride, carbon dioxide, silicate, and also alkali-aggregate reaction. Effect of the appearance of these substance brings the high probability of the damage on concrete matrix and also results in the corrosion of reinforcing steel. The variable on concrete structure dealing with the risk is the air tightness and water tightness which is related to the concrete compressive strength and also the thickness of the concrete cover. Then, the good quality control of production, method on selection of concrete compressive strength and determination the proper thickness of concrete cover affecting the durability performance of concrete structures. For the case of Indonesia, the quality control of material production and the deviations of the dimensioning especially on concrete cover should need to be improved to get better durability performance.

5.5 Steps for Development of Performance-based Design Code for Concrete Structures in Indonesia

Chapter II of this report presented recent development and discussion on performance-based design code. Performance-based design, which is incorporate the probability of failure and also probability of risk, will be match the specific conditions of a country or region. Referring the knowledge from the discussion in Chapter II, several aspects become important on development of performance-based design code for concrete structures in Indonesia.

For the aspect safety performance, study on risk for specific conditions of Indonesia, such as the earthquake, flood, typhoon and other risk shall be performed. Those risk will become important variable on determination of safety performance index for Indonesia. The verification procedures for safety could be applied using the method in the recent code as a recommended method or by adopting another method of verification which is more appropriate and more accurate.

For aspect of serviceability and durability, the specific conditions of Indonesia that affecting the performance of concrete structures should be known well. The humidity, perspective of appearance, sensitivity to vibration and noisy, alkalinity and chloride ion content should be put on the clear description. Those value will provide the correct input for some parameters such as, maximum allowable crack width, concrete cover, water and air tightness which proper for the specific condition of Indonesia.