CHAPTER III

CHARACTERISTICS OF MATERIAL PRODUCTION AND FABRICATION FOR STRUCTURAL RELIABILITY ANALYSIS

This chapter presents the statistical characteristics of material and fabrication of structural member for reinforced concrete ordinary buildings in Indonesia. The statistical data were taken form five construction sites with contract of different construction companies in 2006. The concrete and reinforcing steel of the construction sites came from several production batches and companies. The data collection was limited to normal concrete and excludes prestressed concrete structure. In order to obtain complete figure, data of concrete compressive strength also collected from two different concrete companies to investigate the effect of batching plant to the consistency of productions.

3.1 Concrete Compression Strength

The test data for ordinary concrete were obtained from several batches of ready-mix concrete company supplying different construction projects in Indonesia. The projects are economically middle-upper and middle-lower apartment buildings, a governmental office building, a hospital, and a sport facility for public. All those construction sites were situated in either Jakarta or Yogyakarta. Additional data were also taken from two different ready mix concrete companies to investigate the effect of number of batches. All data of concrete compressive strength were taken based on the regulations in which samples of concrete cylinders have to be taken from each 120 m^3 of concrete production or volume of concrete equal to that to cast 500 m^2 of floor. Due to some aspects, for certain grade contractors commonly use concrete from several companies to supply their construction sites.

The statistical parameters of concrete strength f_c' were calculated and presented together with the cumulative distribution function (CDFs). The CDF curves include all the available samples obtained from different sources and also from two different ready-mix concrete companies. The shape of CDF representing test data can be used for interpretation of the type of distribution. The straight line on normal probability scale represents a normal CDF. The slope of CDF can be used to determine the standard deviation. The CDFs curves of $f_c^{'}$ for all investigated concrete strength taken from several construction sites and sources are shown in Figure 3.1, while the statistical parameters i.e., mean values, bias λ (ratio between mean and nominal value), and coefficient of variation V are listed together with nominal strength and number of sample in Table 3.1.

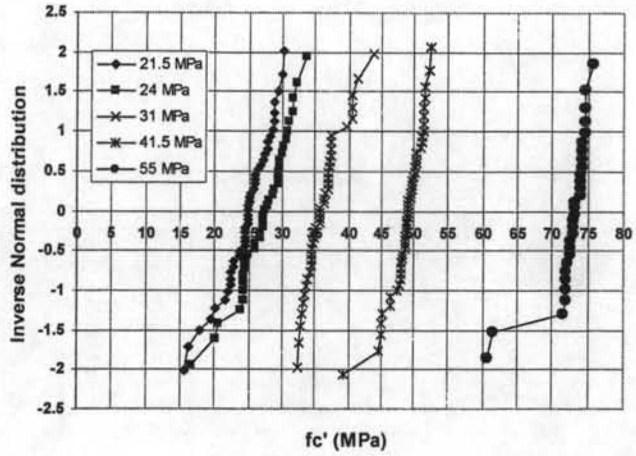
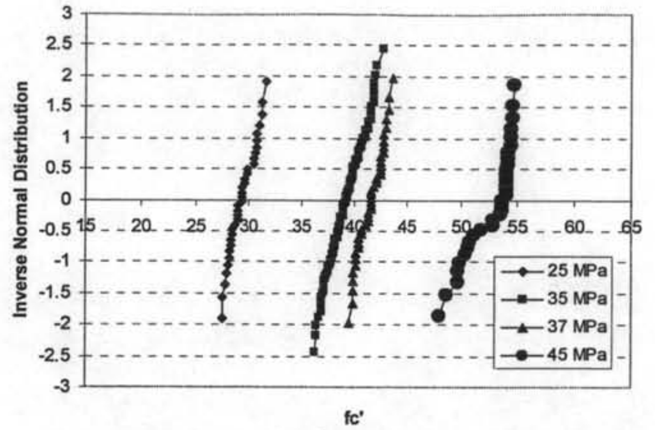


Figure 3.1 CDFs of ordinary ready-mixed concrete from several construction projects in Indonesia.

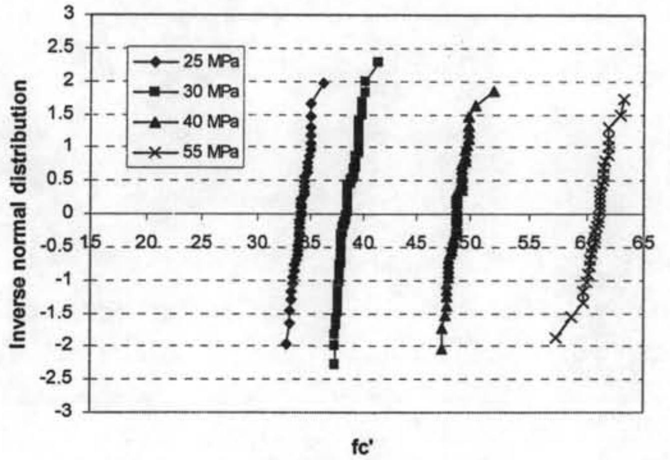
Table 3.1 Statistical parameter for $f_c^{'}$ from several sites and companies in Indonesia

No.	Class MPa	Number n	Mean MPa	Standard Deviation, σ MPa	Coef. of variation V	Bias factor, λ
1.	21.5	45	24.78	3.355	0.135	1.15
2.	24.0	37	27.29	3.627	0.133	1.14
3.	31.0	42	36.23	2.584	0.071	1.17
4.	41.5	50	49.00	2.316	0.047	1.18
5.	55.0	30	72.60	3.329	0.045	1.32

The CDFs of concrete compressive strength specifically taken from two different ready-mix concrete companies in Indonesia are presented in Figure 3.2, while their statistical parameters are presented in Table 3.2.



(a) Company A



(b) Company B

Figure 3.2 CDFs of ordinary ready-mix concrete from two different concrete companies in Indonesia.

Table 3.2 Statistical parameter for f_c' from two different companies in Indonesia

Company	No.	Class MPa	Number n	Mean MPa	Standard Deviation, σ MPa	Coef. of Variation, V	Bias factor λ
A	1.	25	35	29.33	1.181	0.040	1.17
	2.	35	136	39.27	1.439	0.037	1.12
	3.	37	40	41.25	1.159	0.028	1.12
	4.	45	31	52.76	1.977	0.037	1.17
B	1.	25	40	34.20	0.711	0.021	1.37
	2.	30	86	38.52	0.813	0.021	1.28
	3.	40	47	48.81	0.829	0.017	1.22
	4.	55	32	60.95	1.108	0.018	1.11

The bias factors (mean-to-nominal ratios) obtained from the test data from construction sites are shown in Figure 3.3. Based on the presented figure, it is recommended to use the bias factor for concrete strength f_c' shown by the curve in

Figure 3.3. The equation for bias factor recommended for concrete can be calculated from the following formula

$$\lambda = 0.0002f_c'^2 - 0.0124f_c' + 1.3142 \tag{3.1}$$

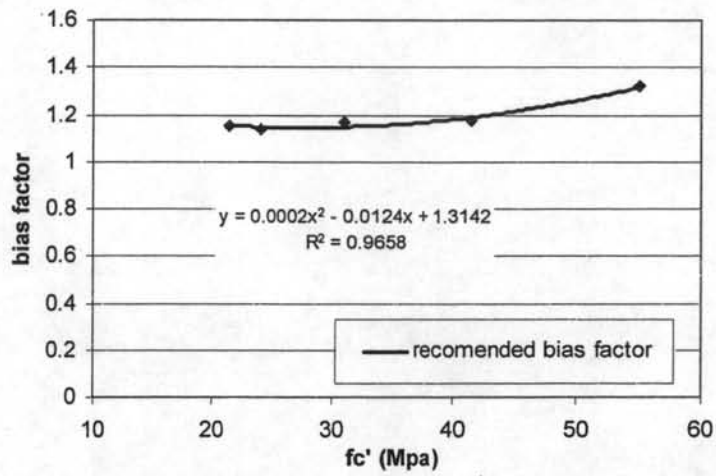


Figure 3.3 Recommended bias factor for compressive strength of concrete f_c'.

Data of concrete compressive strength taken from constructions sites in Indonesia were centered at uneven value. By applying statistical analysis, the data could be represent the even value with the parameter of convenient of variations and bias factors as shown in Table 3.3

Table 3.3 Representation of statistical parameter for f_c' from several sites in Indonesia

No.	Class MPa	Coef. of variation V	Bias factor λ
1.	20.0	0.135	1.15
2.	25.0	0.130	1.15
3.	30.0	0.070	1.17
4.	40.0	0.050	1.18
5.	55.0	0.045	1.30

The determination of average required concrete strength f_{cr}' are based on the statistical calculations. There will always be a certain probability of a test fall below specified compressive strength f_c'. To satisfy statistically based strength performance requirements. The average strength of the concrete should be in excess of the specified compressive strength f_c' which is the strength used in mixture proportioning, depends on the expected variability of test result as measured by the coefficient of variations or standard deviation, and on the allowable proportion of tests below the appropriate, specified acceptance criteria.

The basis of these requirements is illustrated in Figure 3.4, which show three normal frequency curves giving the distribution of strength test results. The curves correspond to three different degrees of quality control, curves A representing the best control, i.e. the least scatter, and curve C the worst control, with the most scatter. The degree of control is measured statistically by the standard deviation (or coefficient of variation), which is relatively small for producer A and relatively large for producer C. All three distributions have the same probability of strength less than the specified value of f_c', i.e., each has the same fractional part of the total area under the curve to the left of f_c'. It is seen from Figure 3.4 that, to satisfy the requirement that, say, 1 test in 100 will fall below f_c', for producer A with the best quality control the mean strength f_{cr}' can be much closer to the specified f_c' than producer C with the most poorly controlled operation [39].

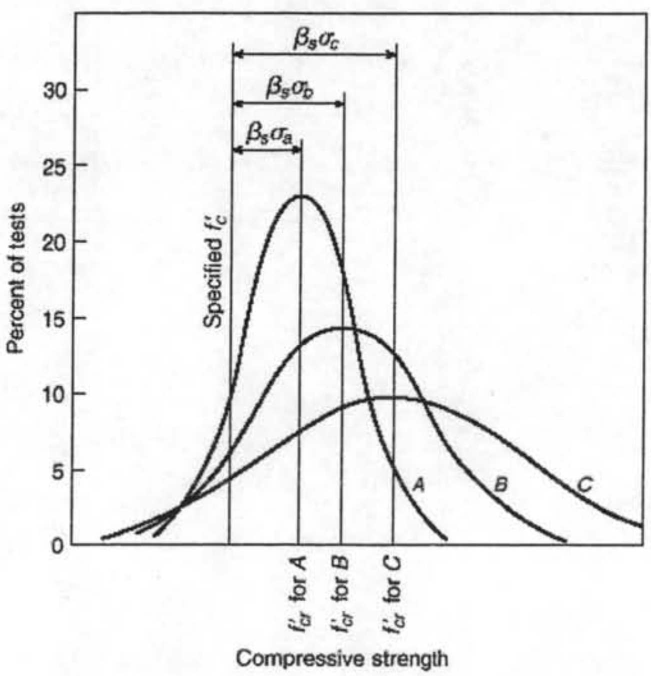


Figure 3.4 Frequency curves and average strength for various degree of control [39]

When a specification requires computation of the average of some number of tests, such as the average of three constitutive tests like in ACI 318, the standard deviations or coefficient of variations will be lower than that computed using all individual test result. The equation to compute the average required compressive strength f'_{cr} for certain specified required strength f_c' will be;

$$f'_{cr} = f'_c + \frac{z\sigma}{\sqrt{n}} \tag{3.2}$$

where z is selected to provide a sufficiently high probability of meeting the specified strength, assuming a normal distribution of strength test results, σ, is standard deviation and n is the value typically specified and should not to be confused with the number of strength test result used to estimate the mean or standard deviation of the record. ACI uses 1% probability that the average of three consecutives test may be below the specified compressive strength f_c'. Using the normal distributions, the z value for 1% probability will lead to 2.33, and the Equation (3.2) will be

$$f'_{cr} = f'_c + \frac{2.33s}{\sqrt{3}} = f'_c + 1.34\sigma \tag{3.3}$$

which same with those specified in ACI code.

Following similar way, the analysis of data from Indonesia for the class of concrete of 20 MPa and 25 MPa will not match the requirement. That resulted from the high standard deviation of that two classes. The computation result for concrete from Indonesia following the statistical requirements shown in Table 3.4.

Table 3.4 Calculation of required average compressive strength in Indonesia

Specified f_c', MPa	Coef. Of Variation V	Bias factor λ	Standard Deviation, σ MPa	Required f'_{cr}, MPa	Obtained MPa	Mark
20.0	0.135	1.15	3.11	24.17	23.00	fail/poor
25.0	0.130	1.15	3.74	30.01	28.75	fail/poor
30.0	0.070	1.17	2.46	33.30	35.10	pass/medium
40.0	0.050	1.18	2.36	43.16	47.20	pass/medium
55.0	0.045	1.32	3.22	59.31	71.50	pass/well

It might be concluded from Table 3.4 that concrete production in Indonesia for specified compressive strength equal or less than 25 MPa were showing poor quality control, while for class of 30 MPa to 40 MPa were medium quality control and more than 55 MPa were well controlled. Then it might be specified the classification of quality control for concrete in Indonesia based on the value of coefficient of variations as shown in Table 3.5.

Table 3.5 Classification of quality control production for $f_c^{'}$ in Indonesia

Quality control	Coefficient Of Variation, V
poor	$V > 0.10$
medium	$0.10 \geq V \geq 0.05$
well	$V < 0.05$

As for the poor quality control, for the case of Indonesia means the class of less than or equal to 25 MPa, it might be proposed to use smaller fractile rather than 1% fractile used in the ACI. When it use 0.5% probability that the average of three consecutives test may be below the specified compressive strength $f_c^{'}$. Using the normal distributions, the z value for 0.5% probability will lead to 2.60, Equation (3.3) will be

$$f_{cr}^{'} = f_c^{'} + \frac{2.60s}{\sqrt{3}} = f_c^{'} + 1.50\sigma \tag{3.4}$$

and

$$f_{cr}^{'} = f_c^{'} + 2.6s - 2.5 \tag{3.5}$$

The value of 2.5 in Equation (3.5) represent the 10% of specified compressive strength of 25 MPa as the limit strength should applied those equation. The Equation (3.5) means that 0.5% probability of the average of all test may be below the $0.9f_c^{'}$. The Equation (3.4) and Equation (3.5) might be proposed to compute the average requirement compressive strength $f_{cr}^{'}$ for class of concrete less than 25 MPa in Indonesia. Recommendation on calculation the average requirement compressive strength $f_{cr}^{'}$ for Indonesia are shown in Table 3.6. The recommendations were provided for the case of the producer of concrete have sufficient number of sample test (more than 30 samples)

Table 3.6 Recommendation on calculating the average requirement compressive strength f'_{cr} for Indonesia

Specified compressive strength, MPa	Required average compressive strength, MPa
$f'_c < 25$	$f'_{cr} = f'_c + 1.50s$ (3.4)
	$f'_{cr} = f'_c + 2.6s - 2.5$ (3.5)
$f'_c \geq 25$	$f'_{cr} = f'_c + 1.34s$ (3.6)
	$f'_{cr} = 0.9f'_c + 2.33s$ (3.7)

3.2 Reinforcing Steel Bar

3.2.1 Bar Diameter

Steel reinforcing bars were investigated with bar diameters from 10 mm to 25 mm. Data was taken from the result of tension tests of reinforcing steel used at construction sites which are the same as those for the data of concrete compressive strength have taken. Statistical parameter of bar diameters is summarized in Table 3.7.

The coefficients of variations V of bar diameter were in the range of 0.004 to 0.016. The trend of V is decrease with the higher diameter, and for the diameter of 12 and up show small value of V. The bias factor λ for all observed diameter was close to value of 0.98. It means that the diameter of reinforcing steel bars is slightly less then the nominal.

Table 3.7 Statistical parameters of reinforcing steel diameter in Indonesia

No.	Diameter mm	Number n	Mean mm	Standard deviation, σ mm	Coef. of Variation, V	Bias factor, λ
1.	8	12	7.63	0.12	0.016	0.98
2.	10	15	9.84	0.11	0.011	0.98
3.	12	11	11.77	0.10	0.009	0.98
4.	13	14	12.68	0.10	0.008	0.98
5.	16	18	15.74	0.10	0.006	0.98
6.	19	18	18.79	0.08	0.004	0.99
7.	22	22	21.88	0.09	0.004	0.99
8.	25	10	24.58	0.23	0.009	0.98

Statistical parameter for reinforcing steel from Indonesia shows the conditions that generally the measured diameter will slightly less than the nominal value. This finding is believed due to the fact that reducing material volume can save material production cost. The bias factor λ, which is the mean-to-nominal ratio is around 0.98. The coefficients of variation V are between 0.016 and 0.004.

3.2.2 Yield Strength

The yield stresses of steel reinforcing bars of class BJTP 30 (f_y = 295 MPa), BJTS 35 (f_y = 345 MPa), and BJTS 40 (f_y = 390 MPa) were investigated and their statistical parameters are summarized in Table 3.8. Classification on the standard mechanical properties are based on National Standard of Indonesia SNI 07-2052-2002 [40]. The coefficient of variation varies from 0.017 to 0.192. Those values do not have certain relationship with the nominal grade or the diameter of reinforcing steel bar. The bias factors for strength of reinforcing steel bars vary from 1.097 to 1.388. This facts show that the manufacturer is try to compensate the slightly reduction in diameter with the higher yield strength.

Table 3.8 Statistical parameters of f_y of reinforcing steel in Indonesia

No.	Grade MPa	Diameter mm	Number n	Mean MPa	Standard deviation, σ MPa	Coef. of Variation, V	Bias factor λ
1	BJTP 30 f_y=295	8	12	376.93	40.75	0.108	1.278
2		10	6	407.25	6.76	0.017	1.381
3		12	11	374.29	44.57	0.119	1.269
4	BJTS 35	16	18	378.38	72.54	0.192	1.097
5	f_y=345	19	18	391.87	69.86	0.178	1.136
6	BJTS 40 f_y=390	13	14	541.24	53.85	0.099	1.388
7		22	22	433.22	46.39	0.107	1.111
8		25	9	433.56	9.99	0.023	1.112

Steel production shall follow standard production of industry for certain country. Since that material produced by machine and follow the certain high quality control, its variability relatively small both for dimensioning and the strength. Based on the specification [40], the tolerance for dimensioning are related to diameter of the bar. For the smallest diameter, 6 mm, the tolerance limit is ± 0.3 mm. From Table 3.7 it can be seen that the production of reinforcing steel in Indonesia for the dimension are within the limit.

The strength of reinforcing steel bar were higher than specified value with the trend the lower bias factor along with the higher grade of steel. This condition might shows that the producer tend to maintain the high strength even the specified were not as that high. That policy seem give higher economic value than to change the mixture of steel so often.

3.3 Fabrication of Structural Member

Fabrication factor of reinforced concrete structural members play important role on their performances. The preciseness of each detailed dimension and position of reinforcement affect the dead load, moment of inertia and moment arm. It also reflects the level of workmanship and is also affected by the appropriateness of equipment. Data were taken from five building construction sites for data collection of concrete ant reinforcing steel

Table 3.9 Statistical parameters for concrete cover and member dimension in Indonesia

Parameter	Nominal mm	Mean mm	Standard deviation, σ mm	Coef. of variation, V	Bias factor, λ
Beam concrete cover	30	27.39	2.43	0.089	0.913
Column concrete cover	40	49.00	6.85	0.140	1.225
Width of Beam	250	250.96	0.87	0.035	1.004
Height of Beam	500	496.14	1.31	0.026	0.992
Column (square)	580	580.85	0.33	0.005	1.001
	700	700.52	0.34	0.005	1.001
depth of slab	120	123.25	1.16	0.094	1.027

Table 3.9 shows statistical parameter of concrete cover for beam and column. For the case of Indonesia, the concrete cover for beam seems to be less than nominal value. The coefficient of variation V is 0.089 and the bias factor λ is 0.913. Even less than nominal value, both V and λ still have good consistency and agreement with the nominal. The concrete cover for column are more than the specified value with the coefficient of variation V = 0.14 and the bias factor 1.225. This fact might resulted from the lack of spacer and stiffer during the casting of concrete column.

The possible deviations in geometry of the concrete elements and of the cover, or the of the position of steel shall not alter significantly the SLS nor the ULS performance of the relevant elements. For most of the quantities, their deviations within the specified tolerances should be considered as statistically covered by partial safety factors. The tolerance for concrete sectional dimension and tolerance for the position of reinforcement can be seen in Table 3.10 and Table 3.11.

Table 3.10 Tolerances for concrete sectional dimension [12]

Elements and dimension (mm)	Tolerances (mm) $\Delta a = (a_{nom} - a_{act})$
Beams; columns; walls	
$a \leq 200$	$\lvert\Delta a\rvert < 5$
$200 < a \leq 2000$	$\lvert\Delta a\rvert < 3.5+0.008a$
$2000 < a$	$\lvert\Delta a\rvert < 17.5+0.001a$
slabs	
$a \leq 200$	$-10 < \Delta a < 6$
$200 < a \leq 2000$	$-20 < \Delta a < 4+0.010a$
$2000 < a$	$-30 < \Delta a < 20+0.002a$

Table 3.11 Tolerances for the position of reinforcement [12]

Structural depth (mm)	Tolerances (mm) $\Delta a = (d_{nom} - d_{act})$
$d < 1000$	$\Delta d < 10$
$1000 < d < 2000$	$\Delta d < 0.010d$
$2000 < d$	$\Delta d < 20$
Tolerance of cover $(a_{nom} - a_{act}) < 10$ mm	

The fabrications of concrete structural member in Indonesia as shown in Table 3.9 are within the tolerance limit as specified in Table 3.10 and Table 3.11. Therefore, the deviations arose in the fabrication process will be covered on the partial safety factor both for serviceability and ultimate limit states.

3.4 Comparison of Material Production and Fabrication between Indonesia and Japan

3.4.1 Concrete Compressive Strength in Japan

For comparison of concrete compressive strength data from Indonesia, the similar data from Japan have been analyzed and presented. Those data are two different sets, which were chosen for the comparison of two different sets of the Indonesian data respectively. The first was taken from data base collected by Public Work Research Institute (PWRI) [25] of Japan during 1992-1994 and limited on classes of 21 MPa and 24 MPa. Samples were taken and tested by government officer at many construction sites of bridges piers, culverts and slabs. The data were originally taken for the purpose of surveying quality of concrete at actual sites.

The second set of data came from two ready-mixed concrete companies in Hokkaido and Fukuoka, which are northern and southern parts of Japan. This kind of data was taken to control the concrete production quality in order to maintain the certification of ready-mixed concrete company. Sample tests were made one for every 150 m^3 of concrete production no matter purposes for the concrete will be.

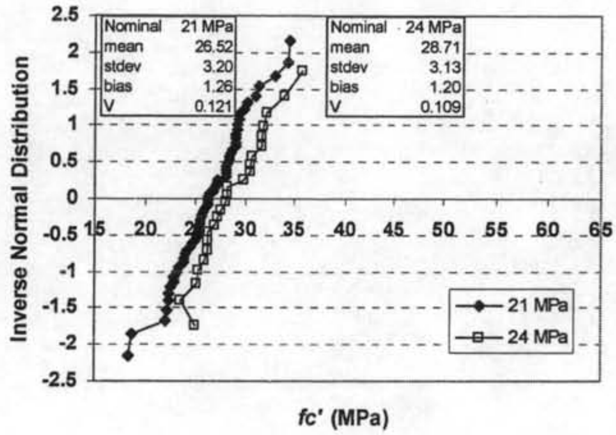


Figure 3.5 CDF of ordinary ready-mixed concrete for classes 21 Mpa and 24 Mpa in 1992 in Japan.

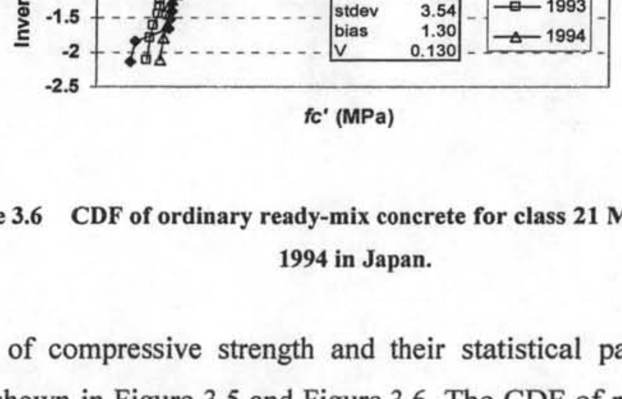
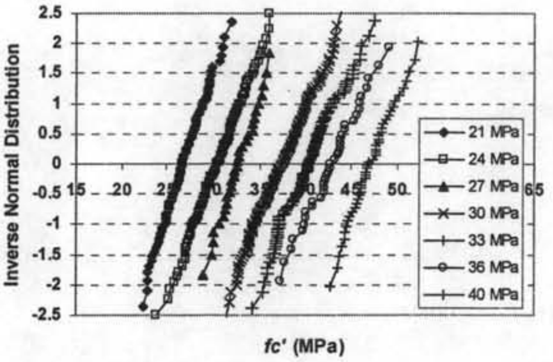
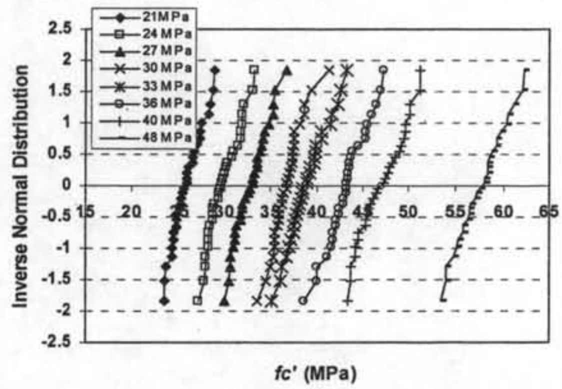


Figure 3.6 CDF of ordinary ready-mix concrete for class 21 Mpa in 1992 to 1994 in Japan.

The CDF of compressive strength and their statistical parameters from the PWRI's data are shown in Figure 3.5 and Figure 3.6. The CDF of ready-mixed normal concrete for concrete strength taken from two companies in Japan are shown in Figure 3.7(a) and 3.7(b), while the statistical parameters are listed in Table 3.12



(a) Hokkaido area



(b) Fukuoka area

Figure 3.7 CDF of compressive strength of ordinary ready-mixed concrete from two companies in Japan.

Table 3.12 Statistical parameter for compressive strength of ready-mixed concrete from companies in Hokkaido and Fukuoka

Company	No.	Class Mpa	Number n	Mean Mpa	Standard deviation, σ MPa	Coef. of variation V	Bias factor λ
Hokkaido	1	21	30	25.84	1.56	0.060	1.23
	2	24	30	29.88	1.67	0.056	1.24
	3	27	30	32.84	1.72	0.052	1.22
	4	30	30	36.76	1.56	0.042	1.22
	5	33	30	38.97	1.98	0.051	1.18
	6	36	30	43.31	2.02	0.047	1.20
	7	40	30	47.09	2.38	0.050	1.18
	8	48	30	57.59	2.37	0.041	1.20
Fukuoka	1	21	111	26.80	2.05	0.077	1.28
	2	24	159	30.55	2.36	0.077	1.27
	3	27	30	32.75	1.82	0.056	1.21
	4	30	176	37.41	2.71	0.072	1.25
	5	33	115	40.35	2.75	0.068	1.22
	6	36	37	42.93	2.82	0.067	1.19
	7	40	51	47.16	2.30	0.049	1.18

As shown in Figure 3.5, the CDFs and statistical parameters of concrete for classes of 21 MPa and 24 MPa, which were taken from various construction sites in Japan, are quite similar to those for similar grades taken from various construction sites in Indonesia. This fact shows that the statistical characteristics of compressive strength of ready-mixed concrete produced by various companies are similar in Indonesia and Japan. It should be noted that the CDF and statistical parameters in 1992, 1993 and 1994 are similar to each other.

As shown in Table 3.12, the data of compressive strength of ready-mixed concrete of produced by the company in Hokkaido show the coefficients of variation between 0.0605 for grade of 21 MPa and 0.0412 for grade of 48 MPa. The coefficient of variation for the data from the company in Fukuoka ranges from 0.0765 for grade of 21 MPa to 0.0487 for grade of 40 MPa. The ready-mixed concrete in Hokkaido gives better consistency in quality. It is interesting to say that those values of the coefficient of variation are bigger than the corresponding values in Indonesia, which are between 0.017 and 0.040 (see Table 3.2), but it support the fact that the concrete produced on single producers plant will have better consistency fort both case of Indonesia and Japan.

3.4.2 Concrete Cover and Member Dimension

Level or workmanship also play important role on the reliability analysis. In order to get the condition of workmanship in Indonesia, several indicator of workmanship are compared with the data from Japan.

Table 3.13 shows statistical parameter of concrete cover for beam and column from Indonesia and Japan. For the case of Indonesia, the concrete cover for beam seems to be less than nominal value. The coefficient of variation V is 0.089 and the bias factor λ is 0.913. Even less than nominal value, both V and λ still have good consistency and agreement with the nominal. The statistical parameters of concrete cover for beam from Japan show the value of V higher than those from Indonesia. This might be related to the formwork, spacer and support system, and difficulties on project site, which is not covered on this research.

Table 3.13 Comparison of statistical parameters for concrete cover

Country	Member	Nominal mm	Mean mm	Standard deviation, σ mm	Coef. of variation, V	Bias factor, λ
Indonesia	beam	30	27.388	2.43	0.089	0.913
	column	40	49.000	6.85	0.140	1.225
Japan	beam	30	35.977	5.84	0.299	1.199
	beam	40	41.791	5.20	0.227	1.045
	column	40	56.906	10.05	0.327	1.423
	column	50	55.863	6.41	0.206	1.117

Bias factor of concrete cover for column from Indonesia and Japan show the value bigger than the nominal. The concrete cover of column is affected by difficulties arose from reinforcement arrangement, horizontal pressure from fresh concrete and total size of cross sectional and height of column. Data of concrete cover for column from Indonesia and Japan show the similarities.

Table 3.14 Comparison of statistical parameters for member dimension

Country	Item	Nominal mm	Mean mm	Standard deviation, σ mm	Coef. of variation, V	Bias factor, λ
Indonesia	beam width	250	250.955	0.87	0.035	1.004
	beam height	500	496.136	1.31	0.026	0.992
	column (square)	580	580.850	0.33	0.005	1.001
	column (square)	700	700.524	0.34	0.005	1.001
Japan	beam width	700	709.679	5.21	0.007	1.014
	beam height	600	609.312	8.11	0.013	1.016
	column (square)	700	701.176	6.29	0.009	1.002
	column (square)	800	807.797	4.42	0.005	1.010

Table 3.14 shows comparison of the statistical parameter of measured member dimension. All sets of data have relatively small value of coefficient of variation V which means shows good consistency. The values of bias factor λ are also close to 1 which means the dimension of member close to the nominal size. Comparing the statistical parameter of beam dimension from Indonesia and Japan in Table 3.14, coefficient of variation of data from Indonesia is higher than those from Japan. It is means that the fabrication of beam in Japan more consistent than fabrication of beam in Indonesia. Meanwhile, the statistical parameters of measured column dimension are similar for the data from Japan and Indonesia. Regarding to the tolerances for concrete sectional dimension as shown in Table 3.10, all set of data were within the tolerance limit

3.5 Conclusion of the Chapter

Statistical characteristics for material and fabrication for concrete structures in Indonesia have been presented. Data from Indonesia were taken from five construction sites including apartments, office, hospital and public facilities. Those constructions involve several constructions industries with different level and quality control systems. The data include concrete compressive strength, diameter of reinforcing bars, and preciseness of fabrication of members. Data then partially compared with similar information from Japan.

The statistical characteristics in Indonesia and Japan are similar. The statistical characteristics of compressive strength of ready-mixed concrete produced by a single company in both Indonesia and Japan show lower coefficient of variations than those of the concrete produced by several companies. This fact is quite reasonable, considering the situation, which was found in this study, that mean value and standard deviation of compressive strength for the same grade are likely to be different among different ready-mixed concrete companies (or factories). It should be understood that the data of PWRI in Japan are taken during construction in 1992 to 1994, while data from construction sites in Indonesia was taken in 2006.

Overall comparison between the Indonesian and Japanese data clearly implies that the quality control of ready-mixed concrete in Indonesia, which is a developing country, is quite comparable to or could be better than that in Japan. This finding is understandable since practically the same level of technology for producing normal concrete in major ready-mixed concrete factory is applied in both Indonesia and Japan.

Fabrications of reinforced concrete structural members in Indonesia attract more attentions since it involves skill of worker, appropriateness of equipment and quality control system. The measurement related to fabrication focused on concrete cover and member size precision. The measured concrete cover for beam in Indonesia is less than the nominal with the value of bias factor is 0.913. This is different from the similar case in Japan in which values of λ are 1.229 and 1.08. The value of V and λ of concrete cover for column shows the similar trend between data from Indonesia and Japan. Table 3.9 shows that coefficient of variation for beam concrete cover in Indonesia is smaller than those for column, while the bias factor for beam also lower than for column. It might lead to conclusion that for case of Indonesia concrete cover for beam were more consistence than those for column but less than nominal, while for column were bigger than nominal. For case of Japan, the coefficient of variation and bias factor does not show clear difference between beam and column.

The most important factor in order to obtain consistence concrete cover and good preciseness are fitting the spacer appropriately and the stiffness of formwork.

Measured column and beam sizes are in good precision with the nominal value and good consistency in production. Both sets of data from Indonesia and Japan show the value of V between 0.005 and 0.009, indicating good consistency. Those values also indicate that for ordinary conditions Indonesia and Japan use the same method on casting reinforced concrete column.