CHAPTER IV

PARTIAL SAFETY FACTORS FOR STRUCTURAL CONCRETE MEMBERS IN INDONESIA

As mentioned in Chapter II, for the performance-based design, each aspect of performance need to be verified using the most accurate and appropriate method. This chapter presented the determination of partial factor for concrete structural members in Indonesia in order to provide several partial factor for verification procedures for the aspects of safety and serviceability.

4.1 Concept of Global Partial Safety Factor

The global partial safety factor, γ_M, following European practices can be written as [38];

$$\gamma_M = \eta \cdot \gamma_m \cdot \gamma_{Rd} \qquad (4.1)$$

The η is a conversion factor which transform the strength of control test specimens to the strength in the structure. In the European practice, the values included in the γ_M i.e., 1.10 for concrete and 1.00 for steels are mean values, roughly assessed as valid for any structural shape. The η is not a safety factor and there is no basis at all to modify it in order to modify the reliability degree or to keep it constant. In very particular cases however (for some mass-productions) it is not excluded that tests made on products make it possible to demonstrate statistically the ratio of strengths between products and standard specimens of concrete be greater than generally expected.

The γ_m part mainly concerns the strength of the material. For European practices, its value is about 1.25 for concrete and 1.05 for steels. It shall be emphasized that these values shall be considered as practically independent of the real quality of the material (characterized by it standard deviation). The reason of this is that this factor shall be applied not to the mean value of the strength but to a specified 5% fractile. Physically this means for example that the reliability degree remains practically unchanged if the quality of a concrete is made more constant (resulting into a smaller standard deviation of the strength – favorable modification) but the cement content is reduced (resulting into a smaller mean strength – unfavorable modification), so that both modifications combined together result in an unchanged characteristic strength

The γ_{Rd} part, mainly takes into account the geometrical uncertainty, especially on the reinforcement. The uncertainty on the models of the resistance, which conceptually might be included in γ_{Rd} is at present mainly included the models themselves. The value of γ_{Rd} for European practices included in γ_M are about 1.10 for concrete and 1.05 for steel. If it were statistically demonstrated that in some well defined cases the geometrical uncertainty is significantly reduced by comparison with the most common cases, this partial factor might be reduced.

4.2 Calculation of Global Partial Safety Factor γ_M for Case of Indonesia

Procedure on calculating γ-values based on FIB Bulletin No. 202 "Reliability of Concrete Structures" [33] presented on Chapter 2.3.3. This section provide the values of each variable on those calculation procedures, especially with the data from Indonesia.

4.2.1 Action Parameters

Variable of permanent loadings $V_G = 0.05$ and $V_Q = 0.40$ are taken following the variability suggested by CEB [33] since the variability of loadings from Indonesia is not covered in this study. The V_G don't affect the final result very much with exception for the case when G is totally dominating the variability on the resistance side is very small. The value V_Q is approximately valid for the yearly maximum of floor loads is buildings, snow load and wind load. Investigation have shown the calculation result for γ_M do not change very much if V_Q is chosen to 0.20 or 0.60. Ratio of characteristic to mean of permanent load is take to be $\lambda'_G = 1.05$. This value were including the variability from the fabrication of the structural member. For the variable action Q the characteristic value is assumed to be the 0.98-fractile of the statistical distribution function for the yearly maximum resulted to $\lambda'_Q = 1 + 2.06V_Q = 1.824$

For the ratio of variable load to permanent load, ν, the calculations are performed for two values $\nu = 0.2$ and $\nu = 2$, which is assumed to be the most common ratio of variable to permanent load. For partial factor for loading according to CEB FIP model code, it were taken to be $\gamma_G = 1.35$ for permanent load and $\gamma_Q = 1.5$ for variable load.

4.2.2 Resistance Parameters

The probability distribution functions for all parameters ζ_S, ζ_R, a, η and f are assumed to be lognormal. In some cases, for f, it has been possible to verify that this assumption is in agreement with observations.

Concrete Compression Strength

Data of concrete compressive strength from Indonesia can be seen on Table 3.3. In the calculation, three concrete grades are used which are shown in Table 4.1

Table 4.1 Value of V_{fcc} and λ'_{fcc}

Grade	V_{fcc}	λ'_{fcc}
20 MPa	0.135	0.87
30 MPa	0.071	0.86
40 MPa	0.05	0.85

In the conversion factor η, the temporal variability of strength is not taken into account in the calculations as it is not covered by γ-factors but by a special coefficient 0.85 introduced into the model code. Thus, the characteristic value was taken to be η_k = 1.0 and the ratio is $\lambda'_\eta = 1.0/\mu_\eta$. The values related to η are shown in Table 4.2.

Table 4.2 Variability representing the η value

Grade	μ_η	V_η	λ'_η
20 MPa	0.90	0.075	1.11
30 MPa	0.875	0.088	1.14
40 MPa	0.85	0.10	1.18

Concrete Tension

For concrete tension, the value from Indonesia are not taken directly from the result of laboratory testing, but obtained from the concrete compressive strength using certain formula as follow;

$$f_{ct} = C \cdot f_{cc}^{\ 0.7} \tag{4.2}$$

$$\mu_{fct} = 0.17\mu_{fcc}^{\ 0.7} = 0.17\left(\frac{f_{cck}}{\lambda_{fcc}}\right)^{0.7} \tag{4.3}$$

$$V_{fct}^2 = V_c^2 + 0.7^2 V_{fcc}^2 \tag{4.4}$$

The value of f_{ctk} are given in CEB Model Code 1990 [12], and the parameters given in Table 4.3 are obtained. The conversion factor η is assumed to have the same values as for the concrete compression.

Table 4.3 Values of μ_{fct}, V_{fct} and λ'_{fct}

Grade	μ_{fct}	V_{fct}	λ'_{fct}
20 MPa	1.60	0.177	0.94
30 MPa	210	0.152	0.95
40 MPa	2.60	0.154	0.96

Tension Reinforcement

Data of reinforcing steel from Indonesia can be seen in Table 3.7 and Table 3.8. As an average value of V_f = 0.07 may be chosen. It should be pointed out that, depending on the way of treating the results this value of the coefficient of variation includes the combined effect of the variability of the strength of the steel and the variability of the area of the cross section of the reinforcement bar. If the characteristic value is assumed to be a 0.05-fractile the value of λ'_f will be $\lambda'_f = \exp(-1.65\ V_f) = 0.89$. The value of λ'_f could be reduced to 0.85 to reduce the fractile to be less than 0.005-fractile. No conversion factor is needed which means $V_\eta = 0$ and $\lambda'_\eta = 1$.

Cross Section Dimension

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 deviations of member dimensioning and concrete cover from Indonesia can be seen in Table 3.9. For a rectangular cross section, the geometrical quantity a, which is determining for the load bearing capacity of the cross section, can be written in many ways depending on the problem considered. The value of V_a for the case of Indonesia can be determined based on the values shown in Table 3.9 and the result of V_a for each aspect of calculation of strength can be seen on Table 4.4. Those value are taken from the variability on dimension of beam which have the high variability on dimensioning.

Table 4.4 Value of V_a for case of Indonesia

Aspects of dimension	Value of V_a
a = const. b.d	0.059
a = const. b.d2	0.100
a = const. b.h	0.044
a = const. b.h2	0.063
a = const. d	0.047

The Model Variability Coefficient

The coefficient of variation of load action $V_{\zeta S}$ and for resistance $V_{\zeta R}$, for the model variability coefficients ζ_S and ζ_R can be regarded as measures if uncertainties. There are great differences between the values of them for different models. In some cases they are close to zero. In other cases they may have fairly great values, 0.2 or more. In those case when the conditions of equilibrium are included in a calculation model there should be no model uncertainties associated with these conditions [33].

A global coefficient ζ can be introduced for the consideration of the model uncertainties as well on the load effect side, ζ_S, as on the resistance side, ζ_R. Then in the probabilistic method the mean, μ_ζ, and the coefficient of variation V_ζ will be

$$\mu_\zeta = \frac{\mu_{R\zeta}}{\mu_{R\zeta}} \tag{4.5}$$

$$V_\zeta = \sqrt{V_{R\zeta}^2 + V_{S\zeta}^2} \tag{4.6}$$

When the method of partial coefficient is used, it is a general assumption that the calculation models shall be chosen so that they are on the safe side. That means the value of model variability of action should be sufficient large compared with the mean value. In the same way the value for model variability of resistance should be sufficient small compared the mean value. The value of model variability can be regarded as characteristic values corresponding to certain fractiles of the probability distribution function for ζ_S, and ζ_R [33].

Concerning the assumption of the variability of the coefficient ζ it may be assumed that the model uncertainties are [33]

- small ($V_\zeta \leq 0.10$) for models used if the reinforcement is determining, for bending moment capacity
- medium ($V_\zeta \cong 0.2$) for model used if the concrete is determining for bending moment capacity (perhaps something between small and medium), shear capacity, anchorage of reinforcement, etc.
- great ($V_\zeta \cong 0.27$) only in some special cases, for example, shear capacity in combination with fatigue.

On this calculation, model variability are taken to be $V_\zeta = 0.2$ for concrete strength, for models used if the concrete is determining (maximum value); and $V_\zeta = 0.1$ for reinforcement strength, for model used if the reinforcement is determining for bending moment capacity.

The Safety Index

The value of safety index used in the calculation are to be taken $\beta = 3.0$, 3.5, and 4.0 which is close to the recommendation from IS0 2394 [10] and are covered the range of safety index target proposed by American practices as shown in Chapter 2.4. These values are provided for normal concrete building. These number have been derived with assumption with the assumptions of lognormal or Weibull model for resistance, and Gaussian model for permanent load. It should be stressed that a-β value and the corresponding failure probability intended primarily as a tool for developing consistent design rules, rather that giving a description of the structural failure frequency [10].

4.3 Global Partial Safety Factor γ_M for Performance of Strength

The calculation result of calculation on estimating the γ_M for safety can be seen in Table 4.5.

Table 4.5 Global partial safety factor γ_M for strength for case of Indonesia

Aspect on resistance	Material Control MPa		ν = 0.2			ν = 2		
			β = 3	β = 3.5	β = 4	β = 3	β = 3.5	β = 4
V_a = Const · b· d	Concrete Compression	f_{cc} = 20	1.136	1.244	1.359	1.206	1.411	1.646
		f_{cc} = 30	1.052	1.136	1.224	1.142	1.323	1.529
		f_{cc} = 40	1.050	1.134	1.220	1.159	1.345	1.558
	Concrete Tension	f_{ct} = 20	1.233	1.369	1.550	1.281	1.514	1.787
		f_{ct} = 30	1.188	1.311	1.474	1.246	1.466	1.721
		f_{ct} = 40	1.179	1.315	1.468	1.263	1.301	1.499
	Steel Tension	f_y	0.692	0.693	0.690	0.890	0.981	1.079
V_a = Const · b· d^2	Concrete Compression	f_{cc} = 20	1.184	1.306	1.436	1.243	1.461	1.715
		f_{cc} = 30	1.101	1.199	1.302	1.180	1.374	1.597
		f_{cc} = 40	1.099	1.197	1.299	1.196	1.396	1.627
	Concrete Tension	f_{ct} = 20	1.280	1.431	1.631	1.317	1.565	1.856
		f_{ct} = 30	1.235	1.373	1.554	1.283	1.516	1.792
		f_{ct} = 40	1.179	1.315	1.468	1.299	1.352	1.567
	Steel Tension	f_y	0.692	0.693	0.690	0.890	0.981	1.079
V_a = Const · b· h	Concrete Compression	f_{cc} = 20	1.119	1.223	1.332	1.193	1.393	1.622
		f_{cc} = 30	1.035	1.114	1.197	1.113	1.282	1.476
		f_{cc} = 40	1.032	1.112	1.193	1.146	1.327	1.535
	Concrete Tension	f_{ct} = 20	1.216	1.348	1.522	1.268	1.496	1.763
		f_{ct} = 30	1.171	1.290	1.446	1.233	1.448	1.698
		f_{ct} = 40	1.179	1.315	1.468	1.249	1.283	1.475
	Steel Tension	f_y	0.694	0.695	0.692	0.891	0.983	1.082
V_a = Const · b· h^2	Concrete Compression	f_{cc} = 20	1.123	1.227	1.338	1.196	1.397	1.628
		f_{cc} = 30	1.039	1.119	1.203	1.133	1.309	1.509
		f_{cc} = 40	1.036	1.116	1.199	1.149	1.332	1.540
	Concrete Tension	f_{ct} = 20	1.220	1.353	1.529	1.271	1.500	1.768
		f_{ct} = 30	1.175	1.295	1.452	1.236	1.452	1.703
		f_{ct} = 40	1.179	1.315	1.468	1.253	1.287	1.481
	Steel Tension	f_y	0.700	0.702	0.700	0.894	0.987	1.086
V_a = Const · d	Concrete Compression	f_{cc} = 20	1.132	1.239	1.353	1.203	1.407	1.641
		f_{cc} = 30	1.048	1.131	1.217	1.140	1.319	1.523
		f_{cc} = 40	1.046	1.129	1.214	1.156	1.342	1.554
	Concrete Tension	f_{ct} = 20	1.229	1.365	1.544	1.278	1.510	1.782
		f_{ct} = 30	1.185	1.306	1.467	1.243	1.462	1.716
		f_{ct} = 40	1.179	1.315	1.468	1.260	1.296	1.493
	Steel Tension	f_y	0.714	0.718	0.719	0.902	0.998	1.106

The value of V_a from the aspect of a = const·b·d^2 seem resulted the highest value of γ_M for concrete compressive strength, while for steel reinforcement, the V_a value from a = const·d resulted the highest value. From the three value obtained by incorporating three concrete grades, the average value of γ_M for concrete compressive strength is about 1.646, while for the steel tension strength, the value of 1.10 could be the proper value.

The value of global partial safety factor γ_M as shown in Table 4.5 is provided for determining the design strength of material, i.e. concrete and steel. As these values were determined incorporating the specified dimensional aspect which is similar to the calculation of strength, the values in Table 4.5 might lead to the partial factor on determining the resistance of structural member. Table 4.6 show the partial factor for strength using the data of concrete compression strength $f_c' = 30$ MPa.

Table 4.6 Reduction factor for member strength

Strength condition	Factor for member strength		
	ν = 2		
	β = 3.0	β = 3.5	β = 4.0
Tension-controlled section	1.06	**1.17**	1.28
Compression controlled section			
▪ member with spiral reinforcement	1.19	1.32	**1.46**
▪ other reinforced member	1.21	1.42	**1.66**
Shear and torsion	1.12	**1.24**	1.37

Table 4.6 show the reduction factor for member strength. The bold values were the values might proper for the recommendation. Those recommended values were considering the most common ratio of variable-to-permanent load, $\nu = 2$ and the safety index β close to the recommendation from ISO 2398. The value of β for compression is chosen to be higher than the other in term of avoiding the brittle failure in compression members.

4.4 Global Partial Safety Factor γ_M for Performance of Serviceability

The calculation on estimating the global partial factor γ_M for serviceability using the similar variable as for safety, except for load factor for both permanent and variable load, γ_G and γ_Q taken to be 1.0, and also for model variability taken to be $V_\zeta = 0.1$ for concrete and $V_\zeta = 0.05$ for steel. The result of calculation on estimating the γ_M for serviceability are shown in Table 4.7.

Similar with those for safety aspects, the value of γ_M for concrete compressive strength is still determined by the value of V_a from the aspect of a = const·b·d^2, which resulted the average value from three class of concrete is γ_M = 1.162, while the value of γ_M for steel is 1.0.

Table 4.7 Global partial factor γ_M for serviceability for case of Indonesia

Aspect on resistance	Material Control MPa		v = 0.2			v = 2		
			β = 1	β = 1.5	β = 2	β = 1	β = 1.5	β = 2
V_a = Const · b· d	Concrete Compression	f_{cc} = 20	0.997	1.058	1.120	0.878	1.012	1.162
		f_{cc} = 30	0.960	0.999	1.037	0.861	0.981	1.113
		f_{cc} = 40	0.959	0.997	1.035	0.865	0.989	1.126
	Concrete Tension	f_{ct} = 20	1.034	1.118	1.217	0.897	1.047	1.216
		f_{ct} = 30	1.017	1.091	1.176	0.888	1.031	1.191
		f_{ct} = 40	1.025	1.104	1.186	0.892	1.038	1.203
	Steel Tension	f_y	0.714	0.718	0.719	0.845	0.954	1.006
V_a = Const · b· d^2	Concrete Compression	f_{cc} = 20	1.014	1.086	1.161	0.887	1.030	1.189
		f_{cc} = 30	0.983	1.035	1.089	0.871	1.000	1.142
		f_{cc} = 40	0.979	1.030	1.080	0.875	1.008	1.155
	Concrete Tension	f_{ct} = 20	1.049	1.144	1.254	0.906	1.063	1.244
		f_{ct} = 30	1.035	1.120	1.220	0.897	1.048	1.218
		f_{ct} = 40	1.041	1.130	1.224	0.902	1.055	1.230
	Steel Tension	f_y	0.714	0.718	0.719	0.845	0.954	1.006
V_a = Const · b· h	Concrete Compression	f_{cc} = 20	0.990	1.048	1.106	0.874	1.007	1.153
		f_{cc} = 30	0.952	0.987	1.021	0.857	0.976	1.104
		f_{cc} = 40	0.951	0.985	1.018	0.862	0.984	1.117
	Concrete Tension	f_{ct} = 20	1.028	1.109	1.203	0.894	1.042	1.208
		f_{ct} = 30	1.011	1.082	1.162	0.885	1.026	1.183
		f_{ct} = 40	1.019	1.095	1.173	0.889	1.033	1.195
	Steel Tension	f_y	0.714	0.718	0.719	0.845	0.954	1.006
V_a = Const · b· h^2	Concrete Compression	f_{cc} = 20	0.992	1.050	1.109	0.875	1.008	1.155
		f_{cc} = 30	0.954	0.990	1.025	0.859	0.978	1.108
		f_{cc} = 40	0.953	0.988	1.022	0.863	0.985	1.119
	Concrete Tension	f_{ct} = 20	1.030	1.111	1.207	0.895	1.043	1.210
		f_{ct} = 30	1.013	1.084	1.166	0.886	1.027	1.185
		f_{ct} = 40	1.021	1.097	1.176	0.890	1.034	1.197
	Steel Tension	f_y	0.714	0.718	0.719	0.845	0.954	1.006
V_a = Const · d	Concrete Compression	f_{cc} = 20	0.997	1.058	1.120	0.878	1.012	1.162
		f_{cc} = 30	0.958	0.997	1.035	0.860	0.981	1.112
		f_{cc} = 40	0.959	0.997	1.035	0.865	0.989	1.126
	Concrete Tension	f_{ct} = 20	1.034	1.118	1.217	0.897	1.047	1.216
		f_{ct} = 30	1.016	1.090	1.174	0.888	1.030	1.190
		f_{ct} = 40	1.025	1.104	1.186	0.892	1.038	1.203
	Steel Tension	f_y	0.884	0.884	0.880	0.823	0.915	1.009

Result of calculations of global partial safety factors for serviceability as shown in Table 4.7 also incorporate the aspect of cross sectional dimensioning of structural member which are also incorporated in the calculation of several aspect of serviceability.

Serviceability performances includes the aspects of crack width, deformation and vibration. The application of these values in Table 4.7 might be explained as follow.

There are many formulations on predicting the crack width such as the approach of ACI, CEB-FIP, JSCE, Chinese, and many others. All those formulation on predicting the crack width involve the stress (or strain) level of the concrete and reinforcing steel. For the deformation, the calculation pass through the determination of sectional inertia which is involving the strength of material, i.e. concrete compressive strength and strength of reinforcing steel. Similar with the deformation, calculation of vibration include the stiffness of member which is also involving the strength of material. For the case of Indonesia, implicating the value on Table 4.7, whenever involving the concrete tension strength, concrete compression strength, and tensile or compressive strength of reinforcement, the characteristic strength value might be divided by the factor of 1.10, 1.05, and 1.00 respectively. Application of partial safety factor for some aspects of serviceability based on the value on Table 4.7 showed in Table 4.8. The values on Table 4.8 should be applied as multiplier factor on the calculating the predicting value of certain aspect. As an example, after the maximum crack width obtained by certain predicting formulas, the result multiplied by the partial safety factor before the final result should be compared with the limiting value.

Table 4.8 Application of partial safety factor for the aspect of serviceability

Aspect of serviceability	Partial safety factor as multiplier of calculation
Stress limitation	
- concrete compressive stress (0.40 – 0.60 f_{ck})	1.00
- concrete tensile stress (depend on the condition of action	1.00
- tensile stress of reinforcement (0.80 – 1.00 f_{yk})	1.00
Crack width	1.05
Displacement and deformation	1.10
Vibration (the natural frequency)	0.95

4.5 Observation on the Aspect of Durability

The durability performance of concrete structure is dependent on the quality of the concrete. Where deterioration is resulted from steel corrosion, the quantity or thickness of the concrete cover (sometimes referred to as Covercrete) is also of extreme important. Greater concrete cover usually means longer time it takes for aggressive agent to reach the steel causing corrosion. Too much a cover, on the other hand, could result in larger and more cracks allowing direct access of aggressive agent to the steel reinforcement [14].

On these regard, the concrete cover as an important variable on determining the durability of concrete structure should suite the limiting value of minimum and maximum thickness. The minimum thickness of concrete cover was needed in accordance with the determined time travel of chloride ion or other corrosive substance. On the other hand, the maximum concrete cover was limited by the fact that too much cover could result in larger and more cracks.

Quality of concrete material as cover also play important role on the durability aspect. This is determined by concrete compressive strength f_c', water and air tightness, which both related very much with the application of water-to-cement ratio. Since the aspect of water-to-cement ratio related to water and air tightness was not covered in this research, only the aspect of quantity of concrete cover observed related to characteristic compressive strength and the environmental condition.

The basic of the thickness of concrete cover to deal with the environmental condition for structural members specified clearly in the Japanese code [15] and showed in Table 4.9. It may be noted that the values in Table 4.9 are for cast in place concrete and shall apply to case when inspection is easy and repair can be carried out with relative ease.

Table 4.9 Basic concrete cover (c_o) [15]

Environmental conditions	Slab (mm)	Beam (mm)	Column (mm)
Normal condition	25	30	35
Corrosive condition	40	50	60
Severely condition	50	60	70

Minimum concrete cover for a structure in 'normal' environment or in 'corrosive' environment that causes reinforcement corrosion, other than due to chloride attack should be in accordance with Equation (4.7), and, should not be less than diameter of the bar.

$$c_{min} = \alpha \cdot c_o \tag{4.7}$$

where c_{min} is minimum concrete cover; α is cove factor, which may be taken as given depending upon the characteristic compressive strength of concrete f'_{ck}; and c_o is basic cover, which may be taken as given in Table 4.9 depending upon the type of the member and environmental conditions. The vale of α for the case of concrete cover of Indonesia can be found in Table 4.10. Those values of α is based on the conditions of quality control of concrete production in Indonesia as explained in Chapter 3.

Table 4.10 Cover factor α for case of Indonesia

Characteristic compressive strength f'_{ck} (MPa)	Cover factor α
Not greater than 25	1.2
From 25 to 40	1.0
Not less than 40	0.8

An appropriate concrete cover is required to prevent corrosion of reinforcement, and to protect the reinforcement against fire. There fore, the concrete cover need to be determined considering such factors as quality of concrete, diameter of reinforcing bars, environmental conditions in the neighborhood of the structures, effect of harmful substances on concrete surfaces, size of the member, error in construction, and importance of structure. The value of α showed in Table 4.10 was one aspect incorporating all those values for the conditions of Indonesia.

4.6 Global Partial Safety Factor for Concrete Structural Member in Indonesia

The partial safety factor for Indonesia should base on the condition of Indonesia. In Chapter 4.3 to 4.5 the calculation result have been presented for certain condition and dimension aspect that can be related to the determination of load bearing capacity for certain member.

Using the format from European practices, the global partial safety factor for Indonesia with load factor for the permanent load γ_G = 1.35 and for variable load γ_Q = 1.5 lead to the value of global partial factor γ_M = 1.5 to 1.7 for concrete compressive strength and γ_M = 1.15 for reinforcing steel tension. The value of partial factor for concrete tension strength was about γ_M = 1.6 to 1.8, but it should be understand that the basis for the calculations concerning the tensile strength of concrete is not very comprehensive and well documented [33]. As 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. The curve of γ_M-value for concrete compressive strength with $\nu = 2$ and $\beta = 4.0$ which become the most critical value are shown in Figure 4.1. The value of calculated partial safety factor for the case of Indonesia can be seen on Table 4.15. For comparison, safety factors and their presentation format can be found in Chapter 2.4.

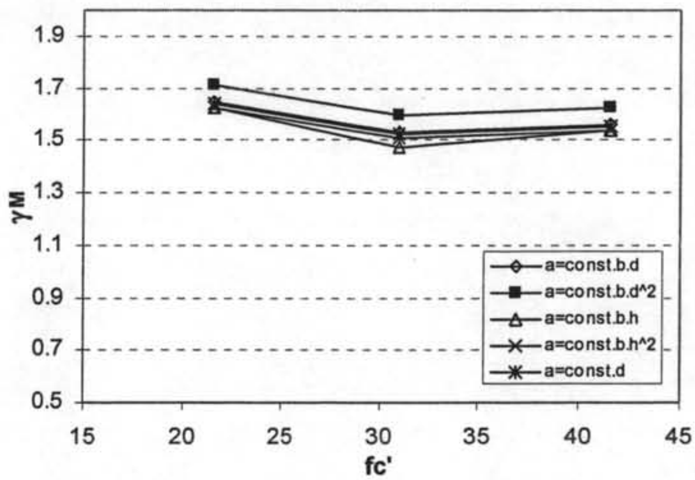

Figure 4.1 Value of γ_M for concrete compressive strength with $\nu = 2$ and $\beta = 4.0$

Table 4.11 Determined partial safety factor for case of Indonesia

Partial factor γ_M of fundamental basic variable	with design situation: Persistent/transient	Accidental	Action, γ_F	Unfavorable effect, γ_{sup}	Favorable effect, γ_{inf}
concrete			Permanent γ_G (exclude P)	1.35	1.0
Compressive strength, γ_c	1.50 to 1.70	1.2			
Tensile strength, γ_{ct}	see relevant clause	see relevant clause	Prestress γ_P	1.1	1.0
Reinforcing steel					
Tensile strength γ_s	1.10 to 1.15	1.0	Variable, γ_Q	1.5	Usually neglected
Compressive strength, γs_c	1.10 to 1.15	1.0			
Note: for serviceability verification the value of γ_{M}, = 10.0-1.10 for concrete and γ_{M}, = 10.0-1.05 for reinforcing steel, while γ_G, and γ_Q are taken to be 1.0					

It should be clarified that the values in Table 4.6 and Table 4.11 not to be applied together. These values on both table were replaceable. One the values of global partial safety factor determined from Table 4.11 is used, the reduction factor for strength in Table 4.6 no need to be involved in the same time.

4.7 Conclusions of the Chapter

The result of calculation on estimating the global partial factor γ_M-value have been presented. The value of partial factors are needed on the verification of performance of structures, and in this case was for safety and serviceability. There are many ways on representing the partial value, but all came from the basic theorem to make sure the structures will act on the safe condition during expected service live.

On this chapter, the result of calculation on estimating the γ_M-value for concrete structures in Indonesia have been presented. The global partial factor, $\gamma_{M,}$ as part of expression of LRFD needed on verification of performance following the presentation of the European practices, for the case of Indonesia were presented. The calculation to determine global partial factor involved the η, conversion factor which transforms the strength of control test specimens to the strength in the structure, the γ_m part mainly concerns the strength of the material for concrete γ_c and for steel γ_s, and γ_{Rd} part, mainly takes into account the geometrical uncertainty, especially on the reinforcement. From the analysis, it might be suggested the global partial factor γ_M for concrete compressive strength γ_c = 1.50 to 1.70 and γ_s = 1.10 to 1.15. The value of γ_c seems higher than those value from CEB FIP Model Code which use the value γ_c = 1.5. This higher value in Indonesia was affected mainly from high variation in fabrication that worse than European case. On this aspect of safety, the safety indexes use in the calculation are β = 3.0, 3.5, and 4.0, which close to the recommendation of safety index for building from ISO 2394 and cover the range of safety indexes recommended from the American practice. The load factor incorporated on the calculation were for the permanent load γ_G = 1.35 and for variable load γ_Q = 1.5, following the value used in the CEB-FIP Model Code 1990.

As 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, the load factor for permanent and variable load $\gamma_G = \gamma_Q = 1.0$.