4 LOAD FACTORS AND MATERIAL FACTORS

4.1 PARTIAL SAFETY FACTORS

In limit state design, both cross section capacity and member resistance should be checked against material yielding and structural instability respectively, and various load and material partial safety factors are incorporated for different modes of failure and limit states.

Ultimate design loads or factored loads Q_{ult} are obtained by multiplying characteristic loads Q_{char} by a partial load factor γ_f :

$Q_{ult} = \gamma_f \ Q_{char}$

Design load effects S_{ult}, for example bending moments, are obtained from design loads by the appropriate design calculation:

$S_{ult} = f$ (effects of Q_{ult})

The partial load factor γ_f allows for variation of loads from their characteristic (i.e. assumed working) values, for the reduced probability that various loads acting together will reach their characteristic values and for inaccuracies in calculation and variations in structural behaviour.

Ultimate design resistance R_{ult} is calculated from dividing characteristic or specified material strengths by a partial material factor γ_{m1} to allow for manufacturing tolerances and variations of material strengths from their characteristic values.

$R_{ult} = f\left(Y_s / \gamma_{m1} \text{ but } \leq U_s / \gamma_{m2}\right)$

For satisfactory design of an element at ultimate limit states, the design resistance R_{ult} must be greater than or equal to the design load effects S_{ult}:

$R_{ult} > S_{ult}$

For satisfactory design of an element at serviceability limit states, the same rationale applies with changed values for the load factors, typically values of load factors for serviceability calculations are 1.0. The material factor on properties such as Young's modulus is 1.0.

4.2 MATERIAL FACTORS

4.2.1 Steel plates and sections

For strength design of normal strength **Class 1** steel plates, sections and weldable castings supplied in accordance with the essential requirements or reference standards given in Annex A1.1 of the Code, the recommended minimum partial material factor γ_{m1} shall be 1.0.

Normal strength **Class 2** steel from a known source which does not comply with the specification requirements in Annex A1.1 of the Code shall be tested and if found to comply should also be used with a material factor γ_{m1} of 1.1

Strength design of **Class 3** steel plates, sections and weldable castings from an unknown source shall comply with clause 3.1.4. Such materials shall only be used for minor structural elements where the consequences of failure are limited.

For high strength **Class 1H** steel plates and sections with a yield stress greater than 460 N/mm^2 but less than or equal to 690 N/mm^2 and complying with one of the reference material standards in Annex A1.1, the partial material factors are given in Table 4.1.

For ultra high strength **Class UH** steel plates and sections with a yield stress greater than 690 N/mm^2 and complying with one of the reference material standards in Annex 1.1, the partial material factor should refer to manufacturer's recommendations.

Table 4.1 - Material factors γ_{m1} and γ_{m2} for various classes of steels

Class	$Y_s \leq 460$ N/mm^2		$460 < Y_s \leq 690$ N/mm^2	
	γ_{m1}	γ_{m2}	γ_{m1}	γ_{m2}
1	1.0	1.1	-	-
2	1.1	1.2	-	-
3	*	*	-	-
1H	-	-	1.0	1.05

Notes: These factors for γ_{m1} and γ_{m2} are minimum values to be used and the design strength for particular steel shall not be greater than that of the relevant national material standard as given in clauses 3.1.2. & 3.1.3 or reference published data.

* For Class 3 steel p_y is limited to 170 N/mm^2 and ultimate tensile strength to 300 N/mm^2

4.2.2 Bolts

Design strengths for bolts, which implicitly include partial materials factors in different design situations, are given in clause 9.3.

4.2.3 Reinforcement and concrete in composite design

For strength design of composite sections, the partial materials factors for reinforcing steel and concrete shall comply with clause 2.4.3 of the HKCC.

4.2.4 Grout for base plates and wall plates

Material factors for cement grout for base plate connections, for steel plate to concrete wall connections and for grouting in holding down bolts and anchors shall comply with clause 4.2.3 above, i.e. the ultimate design values for bearing, bond and shear stresses for grout should be the same as for concrete of equivalent cube strength f_{cu} .

4.3 LOAD FACTORS AND COMBINATIONS

The various types of load to which a structure may be subjected are given in clause 2.5. The following principal combinations of loads should be taken into account:

Load combination 1: Dead load, imposed load (and notional horizontal forces)

Load combination 2: Dead load and lateral load

Load combination 3: Dead load, imposed load and lateral load

4.3.1 Load combinations for normal ultimate limit state

The load factors and combinations given in Table 4.2 apply to strength and stability for normal design situations.

Table 4.2 - Partial load factors and combinations for normal condition design

Load combination (including earth, water and temperature loading where present)	Load Type						
	Dead G_k		**Imposed** Q_k		**Earth and water** S_n	**Wind** W_k	**Temperature** T_k
	Adverse	Beneficial	Adverse	Beneficial			
1. dead and imposed	1.4	1.0	1.6	0	1.4	-	1.2
2. dead and lateral	1.4	1.0	-	-	1.4	1.4	1.2
3. dead, lateral and imposed	1.2	1.0	1.2	0	1.2	1.2	1.2

Where the action of earth or water loads can act beneficially, the partial load factor should not exceed 1.0. (The value of the partial load factor γ_f should be taken such that $\gamma_f \times$ the design earth or water load equals the actual earth or water loads)

Where differential settlement is required to be considered, a partial load factor of 1.4 shall be used in combinations 1 and 2 and a partial load factor of 1.2 shall be used in combination 3.

Where collision loads are required to be considered as part of normal design, they shall be treated as imposed loads with the appropriate safety factor.

4.3.2 Load combinations for overhead traveling cranes

Overhead traveling cranes exert vertical and horizontal loads which should be considered with other loads. Details of load factors and loads arising from overhead cranes are given in clause 13.7.

4.3.3 Load combinations for building assessment

Refer to section 17 of the Code. The values of partial load factor given in Table 4.2 shall be used unless lower values can be justified. The minimum value of any load factor acting adversely should be 1.2.

4.3.4 Load combinations for temporary works in construction

The values in Table 4.2 should be used if it is considered that the consequence of failure of a particular element are not serious enough to warrant a higher load factor. In no circumstances should any adverse load factor be less than 1.2. This includes load factors for wind loads.

4.3.5 Load combinations for exceptional events

Exceptional load cases can arise either from an exceptional load such as a vehicle collision or explosion or from consideration of the remaining structure after removal of a key element.

Table 4.3 contains the load factors to be used in these situations and take account of the probability of other loads acting in combination with the exceptional event.

For fire resistant design, separate partial factors should be applied, see clause 12.1.5.

Table 4.3 - Partial load factors and combinations for extreme events

Load combination (including earth, water loading where present)	Load Type						
	Dead G_k		**Imposed** Q_k		**Earth and water** S_n	**Wind** W_k	**Extreme Event** A_k
	Adverse	Beneficial	Adverse	Beneficial			
1. dead, imposed and extreme event	1.05	1.0	0.35	0	1.05	-	1.0
2. dead, lateral and extreme event	1.05	1.0	-	-	1.05	0.35	1.0
3. dead, lateral, imposed and extreme event	1.05	1.0	0.35	0	1.05	0.35	1.0

Where the action of earth or water loads can act beneficially, the partial load factor should not exceed 1.0. (The value of the partial load factor γ_f should be taken such that $\gamma_f \times$ the design earth or water load equals the actual earth or water load). Where differential settlement or temperature effects are required to be considered, a partial load factor of 1.05 shall be used in combinations 1, 2 and 3.

For buildings used for storage or industrial purposes or where the imposed loads are permanent, the adverse partial load factors for imposed load for extreme events shall be taken as 1.0.

4.3.6 Summary of partial load factors

The following Table 4.4 summarises the various partial load factors used in the preceding sections.

Table 4.4 - Summary of partial load factors for ultimate limit state

Type of load and load combination	Factor γ_f
Dead load, except as the following.	1.4
Dead load acting together with lateral load and imposed load combined.	1.2
Dead load acting together with crane loads and imposed load combined.	1.2
Dead load acting together with crane loads and lateral load combined.	1.2
Dead load acting together with extreme event load.	1.05
Dead load whenever it counteracts the effects of other normal loads.	1.0
Dead load when it counteracts extreme event load.	1.0
Dead load when restraining sliding, overturning or uplift.	1.0
Imposed load except as the following.	1.6
Imposed load acting together with wind load.	1.2
Imposed load acting together with extreme event load.	0.35
Wind load.	1.4
Extreme event load.	1.0
Wind load acting together with imposed load.	1.2
Storage tanks, including contents.	1.4
Storage tanks, empty, when restraining sliding, overturning or uplift.	1.0
Earth and ground water load, nominal values.	1.4
Earth and ground water load, acting beneficially.	≤ 1.0
Exceptional snow load, for cold regions, caused by local drifting on roofs.	1.05
Forces caused by temperature change.	1.2
Forces caused by differential settlement.	1.4
Forces caused by differential settlement together with imposed and wind loads.	1.2
Vertical crane loads.	1.6
Vertical crane loads acting together with horizontal crane loads.	1.4
Horizontal crane loads from surge or crabbing, see clause 13.7.	1.6
Horizontal crane loads acting together with vertical crane loads.	1.4
Vertical crane loads acting together with imposed load.	1.4
Horizontal crane loads acting together with imposed load.	1.2
Imposed load acting together with vertical crane loads.	1.4
Imposed load acting together with horizontal crane loads.	1.2
Crane loads acting together with wind load.	1.2
Wind load acting together with crane loads.	1.2
Vertical crane loads acting beneficially to counteract other loads.	1.0

Notes: (a) "Wind" load includes minimum lateral load of 1.0% of dead load.

(b) Extreme event loads are treated as ultimate loads.

4.3.7 Load combinations for serviceability limit states

For the serviceability limit state it is generally sufficient to use a load factor of 1.0 for dead, live and wind loads, i.e. to use the working or characteristic values of the loads.

A load factor of 1.0 should also be used when it is necessary to consider other effects causing movement such as differential settlement and temperature change.