CHAPTER FIVE
EARTHQUAKE FORCES

5/1 GENERAL

Every building or structure and every portion thereof shall be designed to resist the static horizontal and vertical loads equivalent to those produced by an earthquake in accordance with the provisions stated in this chapter. As an alternative, special theories supported by published research that take into consideration the spectral line of structural response, its ductility and its capability to absorb and dissipate energy produced by earthquakes, may be used subject to the approval of the responsible authorities. The structure shall be designed to resist the stresses produced by earthquakes and wind loads, whichever is the greater.

5/2 SCOPE

This code deals with the following :-

(1) Evaluation of equivalent static horizontal forces for buildings not exceeding (50) m, in height.

(2) Evaluation of horizontal forces for slender and special buildings, and structures exeeding (50) m in height.

(3) The values of the factors considered in evaluation of the horizontal and vertical forces acting on the structure.

(4) The requirements and technical provisions that should be followed in evaluation of the forces and in design and construction.

(5) Definition of the earthquake intensity for each geographic zone in Jordan.

5/3 LOAD BEARING WALL TYPE BUILDINGS LESS THAN (12) m IN HEIGHT

Provided the following conditions are met, load-bearing wall type buildings possessing load bearing walls on the full periphery, that do not exceed (12) m in height and that are constructed from concrete or stone with concrete backing, do not need to be designed to resist the horizontal and vertical forces specified in this chapter.

(1) Storey height shall not exceed (3.5) m.

(2) The bearing walls shall not be less than (200) mm in thickness.

(3) The area of openings in any bearing wall (like doors, windows and similar openings) shall be not exceed (1/3) of its total area.

(4) The bearing wall shall continue from the foundations through the entire height and in the same plane.

(5) The bearing walls shall be provided with strengthening columns at all corners, wall intersections, and at window and door jambs. The distance between the strengthening column shall not exceed (3) m. The reinforcement of the strengthening columns shall be not less than four bars and the bar diameter shall be not less than (12) mm. The diameter of column stirrups shall be not less than (6) mm at (200) mm spacing.

(6) The bearing walls shall be provided with peripheral beams along the entire length at floor levels and at foundation level. The reinforcements of the beam shall be calculated to resist a tensile force equal to (6) percent of the total vertical loads in that wall at the peripheral beam level. The reinforcement bars shall be anchored at corners and wall intersections in a good manner.

(7) The distance between two adjacent openings in any bearing wall shall be not less than (1/6) of the sum of their lengths in that wall. Also, the distance between the first opening and the wall edge or corner shall be not less than (0.75) m.

(8) The structure and its various structural elements and details shall comply with the provisions of the Plain and Reinforced Concrete Code.

5/4 DEFINITIONS

5/4/1 Mode Of Vibration

A line showing the amplitudes of the vibration.

5/4/2 Fundamental Mode Of Vibration

Mode of vibration with the fundamental period.

5/4/3 Modal Analysis

Dynamic analysis, based on a finite number of modes of vibration.

5/4/4 Shear Wall

Reinforced or Plain concrete wall forming part of the system designed to resist horizontal loads.

5/4/5 Amplitude Line

Line showing the maximum displacements of the masses.

5/4/6 Spectral Line

Envelope curve of the maximum acceleration of an elementary structure.

5/4/7 Bracing Element

Any part of the system designed to resist lateral forces acting on the portions of the structure and resulting from seismic action, such as shear walls, frames and trusses.

5/4/8 Fundamental Period

The largest natural period for the vibration of the structure.

5/4/9 Relative Amplitude

The ratio between the maximum value of displacement at a specific point or level (z) and the value at any reference point or datum.

5/4/10 Equivalent Lateral Force

Horizontal force expressing the dynamic reaction of the structure during the earthquake.

5/4/11 Base Of Structure

The level at which the earthquake motions are considered to be imparted to the structure or the level at which the structure as a dynamic vibrator is supported.

5/4/12 Accelerogram

Registration of the ground accelaration during the earthquake as a function of time, as obtained from an Accelerometer.

5/4/13 Elementary Structure

Structure of one degree-of-freedom.

5/4/14 Special Structure

A strcture whose fundamental period of vibration may not be determined from table (25), and must be determined by dynamic analysis or direct experiment.

5/4/15 Plastic Hinge

Zone of the element in which, after reaching the ultimate moment, considerable plastic rotation may occure, accompanied by yielding of the steel, without reduction of the bearing capacity of the section.

5/4/16 Dynamic Factor

The ratio of the acceleration of the structure to the acceleration of gravity, which is a function of the free vibration of the structure.

5/4/17 Intensity Factor

Factor expressing the expected intensity of the earthquake anticipated in a geographic region.

5/4/18 Height Factor

Factor indicating the effect of height of the structure in resisting the horizontal forces. It depends on the height of the structure, the level of the point under consideration, the mass and the relative amplitudes of the structure.

5/4/19 Behaviour Factor

Factor indicating the ductility of the structure and its capability to absorb energy to plastic deformation.

5/4/20 Incidence Factor

Factor expressing the percentage of the live load to be used when calculating the stability of structure during an earthquake.

5/4/21 Soil Factor

Factor expressing the mutual influence of the vibrations of the structure and the soil under its foundation, and depending on the difference between the period of vibration of the structure and the characteristic period of the soil at the building site.

5/4/22 Center Of Stiffness, Center Or Rigidity

A point where the resultant of the forces, if passing through it, does not cause torsional moments in the structure.

5/4/23 Box System

A structural system without a complete vertical load carrying space frame. In this system the required lateral forces are resisted by shear walls or braced frames.

5/4/24 Ductile Frame

Frame capable of accomodating considerable reversible horizontal movements by developing plastic hinges.

5/4/25 Braced Frame

A truss system or its equivalent which is provided to resist lateral forces in the frame system and in which the members are subjected primarily to axial stresses.

5/4/26 Space Frame

A three dimensional structural system without bearing walls, composed of interconnected members laterally supported so as to function as a complete self-contained unit with or without the aid of horizontal diaphrams or floor-bracing systems.

5/5 NOTATION

A = Relative amplitude

A_z = Relative amplitude at storey level (z)

a = Acceleration of the structure

B = Width of the structure in the direction of the earthquake

C = The total factor

D_s = Width of the main bracing element in the direction of the earthquake, according to (5/6/2 C)

E = Modulus of elasticity

e = Eccentricity

F = Horizontal force equivalent to the earthquake force

$\bar{F}$ = The alternative horizontal force acting on the structure instead of (F), as required in special cases by this code.

F_n = The equivalent horizontal force acting on the structure at storey level (n)

$\bar{F}_n$ = The alternative horizontal force acting on the structure at storey level (n)

$\bar{\bar{F}}_n$ = The total horizontal force acting at the uppermost level of the structure

F_v = Vertical force related to a building component

F_z = The equivalent horizontal force acting on the structure at storey level (z)

$\bar{F}_z$ = The alternative horizontal force acting on the structure at storey level (z)

F_{zr} = The horizontal force acting at storey level (z) and mode of vibration (r)

G = Dead loads

G_z = Dead loads for storey (z)

g = Acceleration of gravity

H = Total height of the structure

h_z = The distance between the storey level (z) and the reduced level of the base of the structure

J = Overturning factor

K = Incidence factor

L = Total length of structure perpendicular.. to the earthquake action

$\bar{M}$ = Overturning moment

$\bar{M}_B$ = Overturning moment at the base of the structure

$\bar{M}_z$ = Overturning moment at storey level (z)

M_t = Torsion moment

m = Number of modes of vibrations

n = Number of storeys of the building (Number of the last storey)

O = Center of gravity for the vertical loads acting on the structure

Q = Live loads

Q_z = Live loads for the storey (z)

R = Center of stiffness

r = Number of modes of vibration under consideration

T = Fundamental period for building vibration

T_r = Fundamental period for mode of vibration (r)

T_s = Characteristic fundamental period of vibration of foundation soil

V = Total horizontal force at the base of the structure and in any direction

W = Vertical loads

W_z = Vertical loads for storey (z)

z = Number of storey under consideration from bottom to top

α = Intensity factor

β = Dynamic factor

β_r = Dynamic factor for mode of vibration (r)

γ = Height factor

γ_z = Height factor for storey (z)

γ_{zr} = Height factor for storey (z) and mode of vibration (r)

Δ = The maximum horizontal displacement at the top of the structure

Δh = Height of storey

Δ_z = Horizontal displacement for structure at storey level(z)

δ = Soil factor

θ = Behaviour factor

η = Importance factor

5/6 THE CALCULATION OF THE EQUIVALENT FORCES FOR STRUCTURES NOT EXCEEDING (50) m IN HIGHT

5/6/1 Scope

This method of calculation is limited to structures not exceeding (50) m in height, and in which the eccentricity of the center of rigidity from the center of mass does not exceed (1/6) of the total length of the structure in any direction, and other structures that are not defined by this code as slender or special structures.

5/6/2 General

a) The calculation of the equivalent forces is based on modal analysis, and is based on two simplifying assumptions :-

(1) Taking into account the fundamental mode, of vibration only is sufficient to evaluate the forces.

(2) For this mode of vibration an amplitude line forming a traingle may be used (Figure 1).

b) The analysis of the forces acting, during the earthquake shall be carried out, separately, for the two principal directions of the structure.

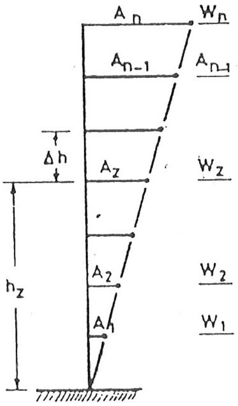

Figure (1)

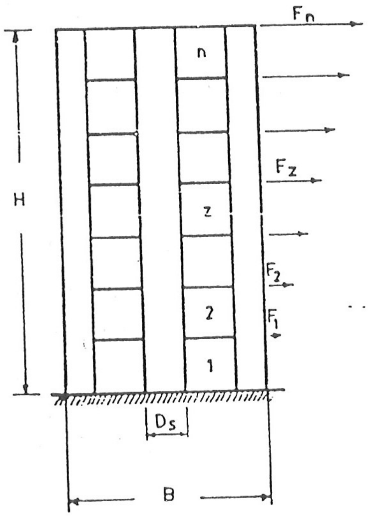

Figure (2)

c) For the purposes of this code, the width of the main bracing element in the direction of the earthquake which is used in the calculation of the ratio (H/D_s) is defined as follows :

* Single shear walls :
  (D_s) is equal to the width of the shear wall.
* Coupled shear walls :
  (D_s) is equal to the total depth of the coupled shear walls plus clear distances between them.
* Ductile moment-resisting frame :
  (D_s) is equal to the whole depth of the frame.

5/6/3 Method Of Calculation For The Static Horizontal Forces Equivalent To Earthquake Force

a) Total horizontal force (V) :
The base shear force acting on any one of the principal axis of the uniform building or structure shall be calculated by the following formula :

$$V = \sum_{z=1}^{n} F_z \qquad (16)$$

b) Equivalent static horizontal force (F_z) acting at level (z) :

(1) The horizontal force (F_z), equivalent to the earthquake force, shall act at the center of gravity of the structure, in any direction.
In multistorey structures, this force shall be applied at the floor level (Figure 2).
The force (F_z), acting at level (z), shall be calculated by the following formula :

$$F_z = \alpha \cdot \beta \cdot \gamma_z \cdot \delta \cdot \theta \cdot \eta \cdot W_z \qquad (17)$$

where

α = Intensity factor
β = Dynamic factor
γ_z = Height factor
δ = Soil factor
θ = Behaviour factor
η = Importance factor
W_z = Storey vertical load
z = Number of floor or mass under consideration from bottom to top
η = Number of last floor or mass of the structure

(2) Accordingly, the base shear force shall be calculated by equations (16), (17) as follows :

$$V = \alpha \cdot \beta \cdot \delta \cdot \theta \cdot \eta \cdot \sum_{z=1}^{n} (\gamma_z \cdot W_z) \qquad (18)$$

(3) If the ratio (H/D_s) of a multistorey building exceeds (3), and the values of (γ_z) are determined in accordance with table (26) [types 2 & 3], the distribution of forces for the floor levels shall be changed as follows :

* The additional force (ΔF_n) shall be calculated by the following equation :

$$\Delta F_n = 0.004\ (H/D_s)^2\ .V \qquad (19)$$

where :

$$\Delta F_n \leq 0.15\ V$$

* The value of the force (F_z) shall be changed to ($\bar{F}_z$) as follows :

$$\bar{F}_z = (V-\Delta F_n) . \frac{\gamma_z . W_z}{\sum_{z=1}^{n} \gamma_z . W_z} \qquad (20)$$

* The total force ($\bar{\bar{F}}_n$) acting at the uppermost level of the building or structure becomes as follows :

$$\bar{\bar{F}}_n = \bar{F}_n + \Delta F_n \qquad (21)$$

Where :

$\bar{F}_n$ = The alternative horizontal force acting on the structure at story level

(4) When (γ_z) is calculated according to type (4) of table (26) on the basis of computed relative amplitudes, the forces (F_z) and force (V) shall be determined according to equations (16), (17) & (18) inspite of that the ratio (H/D_s) is greater than (3).

5/6/4 Vertical Load W

a) The vertical load (W), used for the determination of horizontal forces shall be calculated as follows :

$$W = G + K.Q \qquad (22)$$

where :

G = Dead Loads

Q = Live Loads

K = Incidence factor given in table (22).

b) The vertical loads for the story or mass (z) shall be calculated by the following formula :

$$W_z = G_z + K.Q_z \qquad (23)$$

Table (22)

Incidence Factor (K)

No.	Type of Structures	K
1	Residential and Public Buildings and Structures, such as Universities, Schools, Cinemas, Offices, Trade Centers and Similar Buildings.	0.00
2	Important Buildings and Structures, such as Hospitals, Infirmaries, Emergency Centers, Police Centers, Civil Defence Centers, Fire Fighting Stations, Power Stations, Telecommunication Centers, and Public Buildings designed to be used as shelters after an earthquake.	0.25
3	Important Storage Structures, such as Elevated and Ground Water Tanks, Silos, Liquid Reservoirs, Structural Material Stores and Similar Buildings.	1.00

5/6/5 Determination Of Factors (α, β, γ, δ, θ, η)

a) Intensity Factor (α) :

The country is devided into four geographic zones of different levels of seismic risk, as shown in (Figure 3).

The intensity factor (α), applicable to each zone, and the value indicating the intensity of anticipated ground vibrations are given in table (23).

Table (23)

Intensity Factor (α)

Zone	Earthquake Intensity According To Mercalli Scale	Intensity Factor (α)
A	> 8	0.75
B	> 6 - 8	0.50
C	4 - 6	0.30
D	< 4	0.10

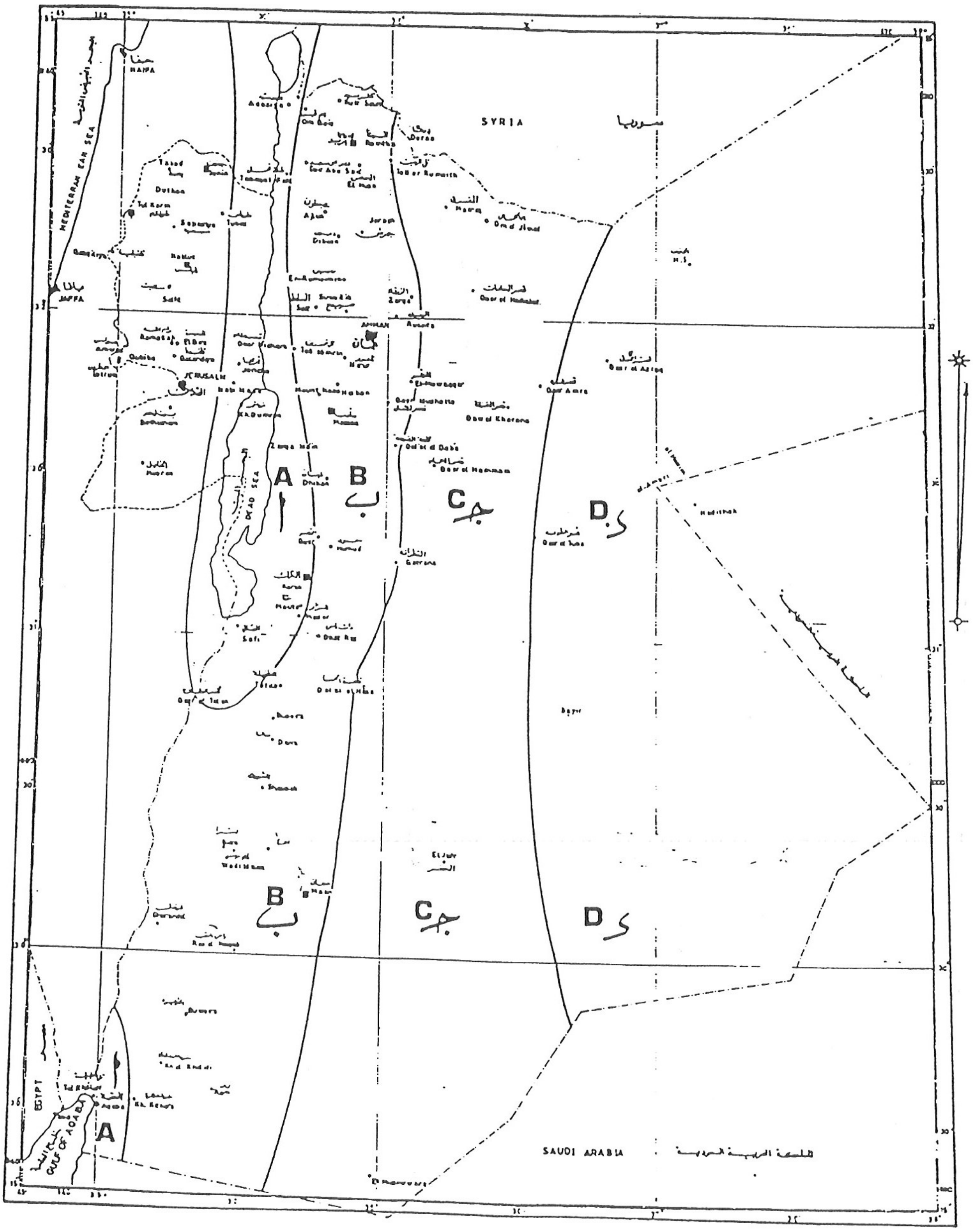
SYRIA
سوريا
HAIFA
JAFFA
DEAD SEA
A
B
C
D
EGYPT
GULF OF AQABA
SAUDI ARABIA

Figure (3)

b) Dynamic Factor (β) :

The values of this factor mentioned in table (24), shall be determined as a function of the fundamental period of the structure. The fundamental period for structures not exceeding (50) m in height shall be determined according to table (25).

Table (24)

Dynamic Factor (β)

Type of Structure	Dynamic Factor (β)
Multistorey structures, with partitions of normal density, such as apartment buildings.	$0.04 \leq \beta = \frac{0.05}{\sqrt[3]{T}} \leq 0.10$
Multistorey structures, without partitions or with partitions of low density, such as storage buildings.	$0.05 \leq \beta = \frac{0.06}{\sqrt[3]{T}} \leq 0.12$
Slender structures, such as chimneys and water towers.	$0.06 \leq \beta = \frac{0.10}{\sqrt[3]{T}} \leq 0.20$
Structures up to 2 storeys high and other engineering structures, such as bridges.	$\beta = 0.1$

Where

T = Fundamental vibration period in seconds and shall be determined from table (25).

Table (25)

Values of Fundamental Period in Seconds (T)

Type of Structure	Fundamental Vibration Period in seconds (T)
Multistorey structures, which are built from plain concrete, stone, block or similar walls.	$T = \frac{0.06H}{\sqrt{B}} \cdot \sqrt{\frac{H}{2B+H}}$
Multistorey structures, which are built from R.C. shear walls.	$T = \frac{0.08H}{\sqrt{B}} \cdot \sqrt{\frac{H}{B+H}}$
Multistorey structures which are built from R.C. frames.	$T = 0.09 \cdot \frac{H}{\sqrt{B}}$
Multistorey structures which are built from steel frames.	$T = 0.10 \cdot \frac{H}{\sqrt{B}}$
Slender and special structures.	Shall be determined analytically or experimentally.

Where :

B = The depth of the structure in the direction of the earthquake (in meters).

H = Total height of the structure in meters, measured from the ground level to the highest point on the structure.

Note : The fundamental vibration period for buildings and structures exceeding (50) m in height or whose fundamental period exceeds (1.2) seconds, and for slender and special structures, shall be determined employing acceptable structural analysis carried out based on the structural properties and deflection characteristics for the earthquake-resisting structure and according to the following equation :

$$T = 2\pi\sqrt{\left(\sum_{z=1}^{n} W_z \cdot \Delta_z^2\right) \div \left(g \sum_{z=1}^{n} \bar{F}_z \cdot \Delta_z\right)} \qquad (24)$$

Where :

g = gravity acceleration which is equal to (9.81 m/sec^2).

c) Height Factor (γ) :

The height factor (γ_z) depends on the level considered and the type of the structure, its value shall be as stated in Table (26).

Table (26)
Values of the Height Factor (γ_z)

Type of Structure	Height Factor (γ_z)
Structures up to two storeys high and other engineering structures, such as bridges.	$\gamma_z = 1$
Multistorey structures in which the height of the storey and the load do not change from floor to floor.	$\gamma_z = \frac{3z}{2n+1}$
Multistorey structures not exceeding (50) m in height	$\gamma_z = h_z \frac{\sum_{z=1}^{n} W_z \cdot h_z}{\sum_{z=1}^{n} W_z \cdot h_z^2}$
Structures for which the relative amplitudes are computed.	$\gamma_z = A_z \frac{\sum_{z=1}^{n} W_z \cdot A_z}{\sum_{z=1}^{n} W_z \cdot A_z^2}$

d) Soil Factor :

(1) The soil factor depends on the foundation soil, its stratum and its physical characteristics, its value shall be calculated by the following formula :

$$0.8 \leq \delta = \frac{0.7}{\sqrt[3]{T-T_s}} \leq 1.3 \qquad (25)$$

Where : δ = 1.3 when $T_s \geqq T$

T_s = The characteristic fundamental period of the soil above bedrock. It dpends on the soil type and the strata thickness that lies above bedrock. Its approximate values are given in Table (27) for buildings not exceeding (50) m in height. For buildings and structures exceeding (50) m in

(50) m in height, the values shall be determined experimentally.

(2) For foundation piles, the ground level shall be considered as the level at the top of the piles.

Table (27)
The values of the characteristic fundamental period for the soil above bedrock (T_s)

No.	Description of the foundation soil above the rocky sub soil	(T_s)
1	Magmatic, sedementary and metamorphic rocks.	0.2
2	Rocky or stabilized gravel over which there may be a layer of compacted cohesive soil or compacted sand up to (15) m thick or soft cohesive soil or loose sand up to (5) m thick.	0.4
3	Layer of compacted cohesive soil or compacted sand, (15) to (80) m thick.	0.4 - 0.8
4	Layer of soft cohesive soil and loose sand, (5) to (140) m thick or a layer of earth fill (2) to (30) m thick.	0.4 - 1.4
5	Layer of soft cohesive soil and loose sand, over (140) m thick, or earth fill over (30) m thick.	1.40

(3) Cohesive soil is compact when its unconfined compressive strength is not less than (0.1) N/mm^2, cohesive soil is soft when its unconfined compressive strength is less than (0.05) N/mm^2.
Sand is compact if its relative density is at least (65 %).
Sand is loose if its relative density is less than (35 %).

(4) The value of (T_s) for soil that lies between items 3 & 4 in Table (27) shall be determined by linear interpolation.
In the absence of particulars on the thickness of the layers, the greater of the two limiting values shall be used.

e) Behaviour Factor (θ) :
The behaviour factor (θ) expresses the capability of the structure to absorb energy, and depends on the ductility of the structure.

The value of the factor (θ) is given in Table (28).

Table (28)
Behaviour Factor (Θ) Values.

No.	Type of Stiffening System	Behaviour Facor (Θ)
1	Framed structures of reinforced concrete, Bridges, retaining walls, slender structures of reinforced concrete such as chimneys, and other structures not stated in this table.	1.00
2	Ductile Frames of reinforced concrete,, desinged to resist horizontal forces, or buildings whose resisting system against horizontal forces as a whole depends on steel frames and bracing trusses.	0.67
3	Buildings or structures depending on shear walls to resist the whole horizontal forces or buildings of Box Structural System.	1.33
4	Structures with dual bracing system consisting of a ductile moment resisting space frame and shear walls using the following design criteria :- (1) The shear walls alone are capable of withstanding all horizontal forces. (2) The ductile frames alone are capable of with-standing at least 25 % of the horizontal forces. (3) Shear walls and ductile frames are capable of withstanding the forces in accordance with their relative rigidities considering the interaction of the shear walls and frames.	0.80

Contd./...

Contd. Table (28)

Behaviour Factor (Θ) Values.

No.	Type of Stiffening System	Behaviour Facor (Θ)
5	Structures with dual bracing system consisting of ductile frames and shear walls, in which the three conditions mentioned in item No. 4 of this table are not satisfied.	1.33
6	Elevated tanks plus full contents or similar structures, with their mass concentrated at the top of a column, on four or more cross-braced legs and not supported by another building, taking into consideration the following condition : $0.12 \leq \beta \cdot \Theta \leq 0.25$	2.50
7	Structures (other than buildings) and other than setforth in this table or structures with their mass concentrated at the top, on one support and not supported by another structure, taking into consideration the following condition : $0.12 \leq \beta \cdot \Theta \leq 0.25$	3.00

f) Importance Factor (η) :

The value of the importance factor of the structure shall be based on its importance and in accordance with the values given in Table (29).

Table (29)
Importance Factor (η) Values.

No.	Type of Structure	Importance Factor(η)
1	Structures of public importance, such as, hospitals, infirmaries, emergency centers, civil defence centers, fire fighting stations, police stations, power stations, communication centers and other structures declared by the authorities to be of public importance.	1.30
2	Buildings that could be used by (200) persons in one hall such as mosques, churches, theaters, cinemas, lecture halls, large shops and similar buildings.	1.20
3	Other structures, including residential buildings.	1.00

5/7 TORSION MOMENT (M_t)

a) The torsion moment (M_t) shall be calculated according to eccentricity (e) between the center of stiffness and the axis of action of forces (the axis of the mass centers of the vertical loads).

b) In any case, even when there is no actual eccentricity in a multistorey structure, the design eccentricity, on both sides of the center of stiffness, shall not be less than that given by the formula :

$$e_{min} = \pm 0.05 \ L$$

Where :

e_{min} = minimum eccentricity for design.

L = the total length of the structure perpendicular to the direction of the earthquake.

In structures, where the eccentricity exceeds L/6, a dynamic analysis shall be made, taking into account the torsional vibrations.

5/8 OVERTURNING MOMENT ($\bar{M}$)

a) The overturning moment at the base of the building or structure shall be calculated by the following formula :-

$$\bar{M}_B = J \ \Sigma \ F_z . \ h_z \qquad (26)$$

Where :

$\bar{M}_B$ = overturning moment at the base.

J = overturning factor, whose value shall be determined from the following relation :

$$1.0 \geq J = \frac{0.6}{\sqrt[3]{T}} \geq 0.45 \qquad (27)$$

b) The overturning moment at any level such as (z) shall be calculated in accordance with the following equation :-

$$\bar{M}_z = \frac{H-h_z}{H} . \bar{M}_B \qquad (28)$$

5/9 THE CALCULATION OF THE HORIZONTAL FORCES FOR BUILDINGS OR STRUCTURES EXCEEDING (50) m IN HEIGHT OR WITH A FUNDEMENTAL PERIOD EXCEEDING (1.2) Seconds

5/9/1 The Value Of The Dynamic Factor (β) :

In structures exceeding (50) m in height or with a fundamental period exceeding (1.2) seconds, the fundamental period shall be determined by analysis or experimentally. The dynamic factor (β) shall be determined according to the value obtained (see item 3, Table 24). The value of the dynamic factor should be not less than (0.06) nor exceed (0.2).

5/9/2 Determination of Height Factor Value (γ_z) :

The height factor shall be determined after the determination of the relative amplitude (A_z) by analysis or experimentally as shown in Figure (4) and in accordance with type 4 in Table (26).

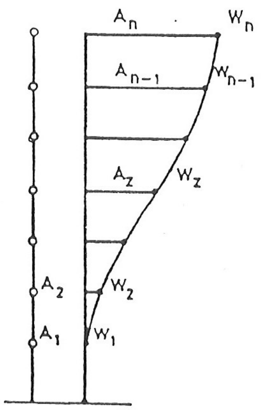

Figure (4)

5/9/3 The Calculation Of The Horizontal Forces For Slender Structures

a) Slender structures such as chimneys, towers and similar structures other than Multistory structures, are those structures that have a ratio (H/D_s) greater than (4) and as shown in Figure (5).

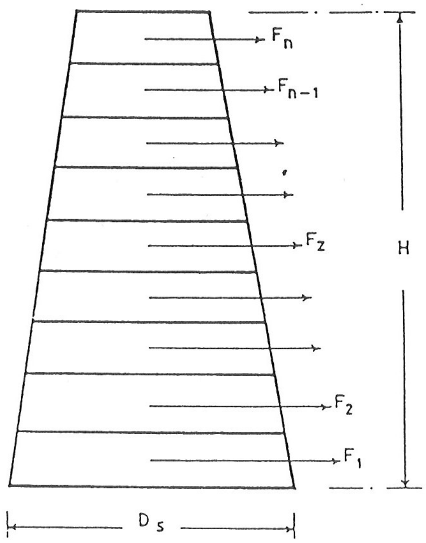

Figure (5)

b) Calculations for slender structures should be carried out on the basis of modal analysis taking into consideration (m) modes of vibration, including the fundamental mode and modes of a higher order. The total number of modes of vibration to be taken into account shall be determined by formula (29) :

$$V_m + 1 \leq 0.1 \sum_{r=1}^{m} V_r \qquad (29)$$

Where :

$$V_r = F_{1r} + F_{2r} + \ldots + F_{zr} + \ldots + F_{nr} \qquad (30)$$

c) For each shape of vibration (r) and each mass (z), the horizontal forces shall be determined seperately by formula (31) :

$$F_{zr} = \alpha \cdot \beta_r \cdot \gamma_{zr} \cdot \delta_r \cdot \theta \cdot \eta \cdot W_z \qquad (31)$$

Where :

β_r = dynamic factor to be determined from Table (24) as a function of period (T_r) .

γ_{zr} = height factor to be determined as shown in Table (26) for type (4), as a function of the relative amplitude (A_z) of the vibration (r) and for each mass level (z) and according to Figure (4).

δ_r = to be determined from equation (25) and as a function of (T_r).

T_r = fundamental period of mode (r).

d) The total forces, acting at mass level (z) due to all modes of vibration, shall be calculated by formula :

$$F_z = \sqrt{F_{z1}^2 + F_{z2}^2 + \ldots + F_{zr}^2 + \ldots + F_{zm}^2} \qquad (32)$$

5/9/4 Special Structures

a) Special engineering structures are structures that include bridges, power stations, suspended structures and similar engineering structures, and amongest them slender structures with ($H/D_s > 4$)

b) The dynamic factor (β) for special structures shall be determined from Table (24), Item Number (4).

c) The height factor (γ_z) shall be determined from Table (26), Item Number (1).

d) When the fundamental period of the structure is determined, analytically or experimentally, the dynamic factor (β) shall be determined from Table (24), and the height factor (γ_z) from Table (26), Item Number (4).

5/10 EQUIVALENT FORCES ACTING ON STRUCTURAL COMPONENTS

The equivalent forces acting on structural components should be calculated according to (5/10/1) and (5/10/2).

5/10/1 Equivalent Horizontal Forces

The different parts of the structures shall be acted upon by horizontal forces determined by :

$$F = C.W \qquad (33)$$

Where :

C = the factor given in Table (30).

W = the vertical load on the component of the structure calculated by formula (22).

Table (30)
Values of Factor (C).

No.	Description of the Structural Component	Description of Loading	Factor C
1	External and internal load-bearing and non-loadbearing walls, partitions, fences, etc.	Perpendicular to plane of structural component.	0.20
2	The joints of external wall panels.	Any direction.	2.00
3	Cornices, parapets, cantilever walls.	Perpendicular to plane of element.	1.00
4	Internal and external decorative elements.	Any direction.	1.00
5	Towers, reservoirs, tanks on towers, chimneys, etc, constituting part of other structures.	Any direction.	0.20

5/10/2 Equivalent Vertical Forces

For cantilevers and beams supporting columns, in addition to other loads, a vertical load (F_v) shall be applied. The load shall be calculated by the following formula :

$$F_v = \pm 0.8 \ \alpha \cdot W \qquad (34)$$

Where :

α = Intensity factor as defined in (5/6/5 a).

W = The vertical load of the column and is calculated by formula (22).

5/11 SPECIAL TECHNICAL REQUIREMENTS

5/11/1 General

a) The designer shall take into consideration the fact that the earthquake forces acting on the structure may be greater than the equivalent forces mentioned in this code and that the dynamic reaction of the structure may be more severe than anticipated. In addition, it has to be kept in mind that there are vertical vibrations which are not taken into account in this code.

During design and detailing, the designer shall use all technical means in order to reduce as much as possible any danger of collapse, detachment of parts of the structure and any other kind of severe damage, by considering the technical provisions and requirements stated in this clause and that stated in the relevant design codes for the structure (Reinforced Concrete Code or Steel Structures Code).

b) Geo–technical studies for the site shall be carried out to define the geological characterastics of rock and soil, stratification, fissures, faults, cracks and water table level.

5/11/2 Structural System

The structural system shall be as clear and simple as possible. In static calculations, bracing elements existing in the structure shall be taken into account. Secondary stability systems shall be designed as an alternative for the transfer of forces, in order to prevent total collapse if part of the main stability system fails.

In order to avoid a high concentration of massess, / it is advisable to distribute masses evenly throughout the structure. Torsion moments arising in structures with wing blocks : L-T or U-shaped structures, must be taken into consideration. Such structures must be divided into rectangular sections with joints as stated in item (5/11/5).

5/11/3 Foundations

a) General :

The foundation of a structure shall be on soil of one type and, in the case of several layers, on one layer. Locating the structure on both sides of geological faults or on water saturated sandy soils, in which there is a danger of liquification, or on loose fill, shall be avoided.

b) Foundation Method :

The foundation method shall be uniform for the entire building. In buildings divided into units, owing to soil conditions, the foundation method for each unit shall be uniform.

c) Stability :

The stability of the structure against sliding and overturning shall be ensured. Special care in this respect is required for structures built on slopes.

d) Connections between Foundations :

Individual foundations shall be connected by means of beams, ties, or straps which shall be located at a level as near as possible to the top level of the foundation and below ground level. These shall be capable of transmitting compression and tension forces equal to at least (1/10) of the vertical load on the column to which they are connected. In reinforced concrete the reinforcement bars of beams or ties shall be anchored in the columns in accordance with the requirements of the Plain and Reinforced Concrete Code.

5/11/4 Shear Walls

a) Shear walls of in-situ concrete :

(1) Design :

The design of shear walls shall be carried out according to the Plain and Reinforced Concrete Code. The reinforcement at each vertical edge shall be not less than that required to resist a tensile force equal to (5) percent of the compression force acting on the whole wall at that level.

(2) Reinforcement around openings :

The reinforcement around openings in shear walls shall be at least two reinforcement bars, 12 mm in diameter. Reinforcement at (45) degrees at corners of openings is advisable.

(3) Coupled shear walls :

Coupled shear walls and beams that couple them shall be designed according to statical calculations taking into consideration the ductility requirements for the beams. Beams between shear walls not considered in the statical calculations as coupling beams shall be designed in the usual method. The tensile reinfrcement in beams that couple shear walls shall be not less than (0.4) percent, and the distance between stirrups shall not exceed (200) mm.

(4) Shear Walls connection to floor slabs :

The connection between the shear walls and the floor slabs shall be continuous. In addition, the floor reinforcement in the shear walls shall be fully anchored.

b) Walls of precast concrete :

Shear walls of precast concrete shall comply with (5/11/9).

c) Bracing elements of steel :

Bracing elements of steel shall be designed as bracing frames (moment resisting) or as trusses (axial force resisting) to transmit horizontal forces, and in the two cases, special care shall be taken for the design and construction of the joints, taking into consideration the possibility of periodic reversible stressing.

Special attention shall also be given to obtaining good connections of the horizontal bracing elements to vertical bracing elements to ensure their spatial stability.

5/11/5 Columns

a) Column design :

The design of columns must not be based on the assumption of a plastic hinge.

b) Connection :

The transmission of the bending moments between column and floor slab or the beams shall be ensured by suitable anchoring of the reinforcement. For reinforced concrete columns, the reinforcement bars shall be anchored with beams or floor slabs to ensure the connection strength.

c) Column stirrups :

Column stirrups shall be closed and it is preferable to use a helical stirrups for circular columns.

d) Columns of ductile frames :

The columns of ductile frames shall be designed to satisfy all requirements stated in the Plain and Reinforced Concrete Code.

5/11/6 Floor Slabs

a) Stiffness :

Floor slabs shall be rigid in their plane and shall be capable of transmitting, without appreciable deformation, the horizontal forces to the vertical bracing elements.

b) Tie girders :

The floor slab shall be completely surrounded by a peripheral tie. The tie shall be capable of transmitting tensile or compressive forces of at least (50) Kilonewtons with the safety factors stated in Plain and Reinforced Concrete Code, or the Steel Structures Code.

Special attention shall be given to the anchorage of the reinforcement at the corners.

c) Transmission of forces in the floor slabs :

If there is an abrupt change in the vertical bracing elements, such as in the transition from shear walls to columns or walls, the transmission of forces in the floor slabs shall be ensured particularly at the level in which the change occures.

The peripheral ties of these floor slabs shall be capable of transmitting tensile or compressive forces of at least (100) Kilonewtons, with the safety factor stated in the design code.

d) The connection between floor slabs and vertical bracing elements :

A sound connection shall be ensured between the floor slabs and vertical bracing elements. In floor slabs of reinforced concrete, the connection shall be ensured by anchoring the reinforcement in the vertical bracing elements.

5/11/7 Joints In Buildings

a) Joints are used to divide buildings structurally into parts and shall be so located as to make the eccentricity stated in (5/7) as small as possible. The building plan shall be divided into rectangular parts as much as possible.

b) Structural joints or expansion joints shall continue and extend in one plane along the entire building height. In general, structural joints shall not extend through foundations except when that is required (see Item 5/11/3).

The width of the joint shall be sufficient to permit non-synchronous vibrations of the adjacent blocks without contact, so as to prevent the hammering effect during earthquake. This depends on the building height and fundamental vibration period. The width of the joint shall in any case be at least (25) mm.

5/11/8 Prefabricated Structures

a) The joints between all prefabricated elements shall ensure maximum spatial stability of the structure.

b) In order to avoid the collapse of the structure in the event of failure of a specific element, secondary stability systems shall be provided as an alternative, and in accordance with Item (5/11/2).

c) In order to ensure the rigidity of floor slabs in their planes, as required in Item (5/11/6), the joints between the elements shall be capable of transmitting compression, tension and shear forces. It is desirable that these joints be of reinforced concrete cast in situ. The edges of the elements along the joints shall be recessed or provided with other means to ensure the transmission of shear forces. The floor slab shall be surrounded by a circumferential tie which satisfies the requirements of (5/11/6 b).

d) Horizontal joints between wall elements shall permit transmission of the tensile forces between them. The joints and the elements of the walls shall be capable to resist a tensile forces equal to (20) percent of the total vertical loads acting on the walls.

5/11/9 Fragile And Brittle Materials

When fragile or brittle materials are used for the fabrication of elements of large size, as in glass facades and the like, special details, joints, and flexible connections shall be provided to prevent breakage of the materials owing to deformation of the structure during the earthquake.

5/11/10 Equipment, Machines and Apparatus

Equipment, machines and aparatus shall be anchored in a manner ensuring horizontal stability.

5/11/11 Reinforced Concrete Ductile Frames

Reinforced concrete ductile frames shall satisfy the requirements of the relevent design code.

5/12 LATERAL DEFLECTIONS OR DRIFT

5/12/1 Lateral deflections or drift of a storey relative to its adjacent storeys shall not ecxeed (0.5) percent times the storey height unless it can be demonstrated by calculation from the efficiency of the structure ductility.

To verify compliance with this requirement, the lateral displacement value shall be multiplied by a factor (R), and the value of (R) shall be calculated by :

$$R = \frac{1}{\Theta} \qquad \text{..........................} \qquad (35)$$

Where :

Θ = The behaviour factor given in Table (28).

5/12/2 All portions of a structure shall be designed and constructed to act as an integral unit in resisting horizontal forces unless separated structurally by a distance sufficient to avoid contact under deflection from seismic action.