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المركز القومى لبحوث الإسكان والبناء

الكود المصرى

لحساب الأحمال والقوى فى الأعمال الإنشائية وأعمال المبانى

اللجنة الدائمة

لاعداد الكود المصرى لحساب الأحمال والقوى فى الأعمال الإنشائية وأعمال المبانى

كود رقم ٢٠١

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Egyptian code for the calculation of loads and Forces in Structural and Building Works 2013

Chapter 8   Seismic Loads on Building

8-1 Introduction

8-1-1 General

All calculated seismic loads in this chapter are considered as design loads at Ultimate limits design method and must reduce by dividing over the factor 1.40 when use it for design using allowable/working stress design method.

8-1-2 Scope & General Considerations

1- Apply the provisions of this section when designing new buildings and when make modifications for the existing buildings.

Moreover, the basic objectives of the application of this section are: -

- To protect People life
- To reduce Structures cracks.
- To remain important constructed civilian facilities (hospitals, airports, firefighting….etc.) works in case of earthquakeske happen by the same efficiency.

2-This chapter contains the minimum requirements and acceptance limits for structural and Building works in the Seismic zones, also contains the basics factors to calculate loads due to earthquakes.

3-Must take into consideration the requirements of this code and complementary to the requirements of all other relevant codes when design of all structural elements of the Facilities located in seismic zones.

4-This Chapter does not apply to the special constructed facilities like nuclear Stations, dams, etc. which require a special studies.

5-This Chapter contains the general rules to calculate the loads resulting from seismic forces and must be used in parallel with other design codes for all construction materials as the concrete and Steel Facilities, etc.

6- Sophisticated methods can use to isolate the foundations such as the use of rubber bases and so on after making the necessary studies of consulting firms even this code did not include any recommendations in this regard.

7- Does not allow any amendments to work at all during the implementation, as well as running through the origin, but at the urgent need for it, provided the audit work full design of origin in order to determine the effect of these modifications on the seismic behavior of origin.

8- Taken into consideration not taking the design loads, earthquakes and wind together in the same load case and one of them is taken as biggest impact in the design of facilities and its various elements.

9- Loads calculations due to earthquakes, as the following:-

- The facilities structures are designed by engineers with prior experience design to resist earthquakes
- Construction execution is by specialized companies with efficient and sufficient experience under the supervision of an engineering specialist with a commitment to apply the rules of quality control during all stages of execution.
- All materials and components used must conform to the specifications, technical assets, code requirements, and specifications of the Egyptian project specifications and the manufacturer.
- Regular continuous maintenance is required for structure.
- Structure must use according to the purpose for which it was created and according to the design requirements.
- Non-structural elements like partition and so may affect on the dynamic behavior of Structure.

8-1-3 Definitions

- Response Modification Factor (R)

Coefficient depends on ductility range of the structural system and represents by ratio between the forces generated within the structural elements of the system if it had acted fully flexible (without occurrence of elastic formations) to the generated forces if elastic formations happen to the structural system which exhaust a part of the seismic energy impact .

- Importance Factor

It is the Coefficient associated with the consequences of the collapse of structure depending on the structure degree of importance of usage.

- Non-Structural Elements

  Is an architectural, mechanical and electrical element, which does not bear any structural loads result of non-inertia or connecting method to the structure

- Response Spectrum

  It is a Curve represents a change in maximal response of buildings or structural elements with the change of the value of the it's natural frequency as a result of an certain earthquake or an average for selected earthquakes groups.

- Return period

  It is the period in years, which is statistically expected after an earthquake happen with the same specific force

- Shear Wave in Soil

  Earthquakes move from one place to another by vibration waves in the soil and one of these types of waves are waves near the earth's surface which the soil moves in similar to the movement of the shear.

- Artificial Earthquake Records

  Earthquakes are not real but devising their records based on mathematical for random statistical symmetry to earthquakes.

- Damping Ratio

  It is the Factor representing the rate of depression and damping of the building vibration as a result of its construction material and structural system.

- Mode Shape

  It is the shaped of structure formation when free Vibration at the natural frequency.

- Storey Drift

  It is the value of Horizontal movement as a result of earthquakes at a certain floor level minus the horizontal movement for the underneath floor level

- Fundamental Period

  It is the periodic time of basic seismic wave of structure

- Frequency mass

  It is the part of structure mass which participating in a typical certain form.

- Horizontal Inertia

  It is the force required to move the structure horizontally by a unit distances.

- Basic shear Force

  It is the horizontal forces caused by earthquakes loads at the level of the Structure foundations

8-1-4 Reference Codes

1- European unified code

(Eurocode 8 :BS EN 1998-1:2004 – BS EN 1998-2:2005).

2- Egyptian code for Design and construction of concrete structures (Code No.203-2007).

3- Egyptian code for Steel Construction and Bridges (code No.ECP205-2007/2008).

4- Egyptian code for soil mechanic and foundation design and construction (Code No.202/2001).

5- Egyptian code for design Basics and conditions of Building construction (Code No.204/2005

6- Global Seismic Hazard Assessment Program (Relemr,USGS/UNESCO,Prof.Samir Riad et. Al.).

7- Seismo-Techtonics & Seismic Hazard Assessment for Egypt , Riad &El-baz,2002)

8-2 Basic requirements for design

8-2-1 Return Period

Earthquakes Return period chosen to achieve the design and implementation of structures, which located in high zone seismic impact of the following requirements by adequate degree:-

A-No Collapse Requirement

Must design and construct structures to resist design loads related to earthquakes without whole collapse of the structure or partially of its elements and thus retains the structure stable with its functions after earthquakes probability exceeded the sturdy design by 10% in fifty years (period reference for earthquake 475 years).

B-Damage Limitation Requirement

Must design and construct of facilities to resist loads resulting from earthquakes without crack happens after an earthquake probability exceeded the design force by 10% in ten years (earthquake return period 95 years).

C-Increase of Earthquake Safety

This is done by the classification of structures facilities according to the degree of importance , determines for each structure the importance factor(γ_I) and according to table (8-9) this parameter depends on the default earthquakes return period of (earthquakes default return period is 475 years for regular buildings).

8-2-2 Limit States

Make sure that the following limits statements follows the basic requirements set out in item (8-2-1).

8-2-2-1 Ultimate Limit States (ULS)

It specializes in structural failure forms, which affect on the life seriousness and need to achieve the following:-

1- Assurance of structural system achieves resistance and ductility in accordance with item (8-2-2).
2- Resistance and ductility of structure must link to the allowed level of non-elastic dynamic response. When applying this relationship between resistance and ductility it is governed by the values of modified reactions factor (Force reduction) R and in Annex (8-A).
3- Assurance of structure stability as a whole under the influence of the design earthquake loads, as well as ensure safety against sliding and the overturning in accordance with item (8-8-2-4) describing stability requirements.
4- Assurance of foundations elements soil bearing able to withstand the structure loads without high differential settlements between different foundations, or high-value strains in linked Foundations elements.
5- Taking into consideration the impact of design secondary factors on the design values.
6- Assurance of earthquakes design loads calculation that non-structural elements not danger to life and do not have a specific effect on the response of structural elements.

8-2-2-2 Serviceability Limit States (SLS)

It is the limits that affect negatively on the usage of structure, to achieve must do the following:-

1. To be assure of serviceability limits calculations according to contained item (8-8-3).
2. Make sure there is a high degree of confidence of unacceptable cracks absence and not exceed permitted movement limits and other related limits of structure cracks in different parts of this code.
3. Make sure that the structural system in important Structures facilities and civil defense has resistance and efficiency confirms the continuity of operation of the facilities in this vital structure after an earthquake happen with adequate period of return.

8-3 Soil Considerations

8-3-1 General

1. Geotechnical studies are necessary with a sufficient depth to determine the quality of the soil and classified according to the divisions mentioned in item (8-3-2) and shown in the table (8-1).
2. Nature of the soil foundation at chosen construction site should not exposed to risks in the event of earthquakes (cracked earth, the collapse of bridges, imbalance tendencies and settlements resulting from soil liquefaction or increase the relative density.
3. In the case of Structure degree of importance is regular or low ($\gamma_1 \leq 1.0$) located at seismic zones I to III (check items 8-7-6 and 8-4-1) can determine the loads of earthquakes considering soil classification is C.
4. In the case of Structures degree of importance high($\gamma_1 > 1.0$) (check table 8-9) and are located in seismic zones V and IV, it must specify the earthquake loads according to the classification of soil beneath the building based on actual measurements of shear Wave Velocity up to 30m depth in construction site.

8-3-2 Classification of Subsoil Conditions

Soil behavior depends on the quality of the soil, which can be classified into five divisions as A, B, C, D, as shown in Table No. (8-1).

Make studies for determination the soil factors. whether the site soil is different from what stated at table (8-1) such as soil potentially liquefy or mud delicate or clay alluvial weak with thickness not less than 10 m and a factor of plasticity is greater than 40% and the moisture content high and the value of the frequency of shear waves $V_{s.30}$ less 100m/s

Table (8-1) Soil layers classification under Foundations

Soil Classification	Description longitudinal section of soil	N_{SPT} Number of beats per 30 cm	C_u Cohesion Resistance KN/m2	❖ $V_{s,30}$ Shear Wave Velocity m/s
A	Rock or rock formations resembling contain a weak surface layer have a thickness of at most 5 m	---	---	>800
B	Deposits extends for tens of meters thick composed of (sand + gravel) dense or clay with heavy resistance cohesion C_u shown in the table, with the increasing values of mechanical properties gradually with depth.	>150	>250	360-800
C	Deep soil deposits of non-cohesive (sand+gravel) medium to heavy or clay with resistance cohesion C_u shown in the table, thickness ranges from tens to hundreds of meters.	15-50	70-250	180-360
D	Soil is non-cohesive (sand, Gravel) loose to medium density (may be present by cohesive layers such clay, loam or the prevailing coherent soil with cohesion resistance C_u shown in the table.	<15	<70	<180
E	Soil Section consists of the surface layer of river sediment V_s, such C or D with variable thickness from 5-20m and the material underneath are strongest V_s more than 800m/s	----	---	----

❖ Incase site soil is variable, it must be classified according to the average value of shear wave velocity measured up to depth of 30 m from the earth surface or use N_{SPT}

In the case of soil stratification, the average value for shear wave velocity $V_{s.30}$ calculated from the following equation:-

$$V_{S,30} = \frac{H_{s,30}}{\sum_{i=1,N_s} (h_i / V_i)} \qquad (8\text{-}1)$$

When:

h_1 soil i layer thickness

V_i shear wave velocity for soil layer i for N_s of soil layers

H_s total thickness of soil layers $H_s = \Sigma h_i$

N_s Number of soil layers

In the case of the end of the stratigraphy by extended rocky layer then the calculation the shear wave velocity $V_{s.30}$ taken into consideration 5 meters of this rock layer only in order to show stratigraphy of the weak soil above this rock layer.

8-4 Earthquake Actions

8-4-1 Earthquake Zones

1. Area of EGYPT divided to Five Zones according to EARTHQUAKE INTINSTY depending on the value of the design ground acceleration in accordance with the Table (8-2-A)

Table (8-2-A) Egypt Zones according to earthquake intensity

Zone	Value of design ground acceleration a_g
First	0.10 g
Second	0.125 g
Third	0.15 g
Forth	0.20 g
Fifth A	0.25 g
Fifth B	0.30 g

2. determination the seismic effect in this chapter on the basis of the value of the parameter a_g which represents the ground acceleration movement in a rocky layer or strong soil and knows as design ground acceleration as there are other important factors affecting the Select seismic load, such as the importance factor of structure and modification reactions factor.
3. It should refer to the seismic map contained in Figure (8-1) identified as the reference earthquakes period span of 475 years and Table (8-2-B) supplementing them and must refer values mentioned in contained map to ground Acceleration $g=9.81\ m/sec^2$.
4. Buildings must be design to the maximum value of design ground acceleration for each zone.

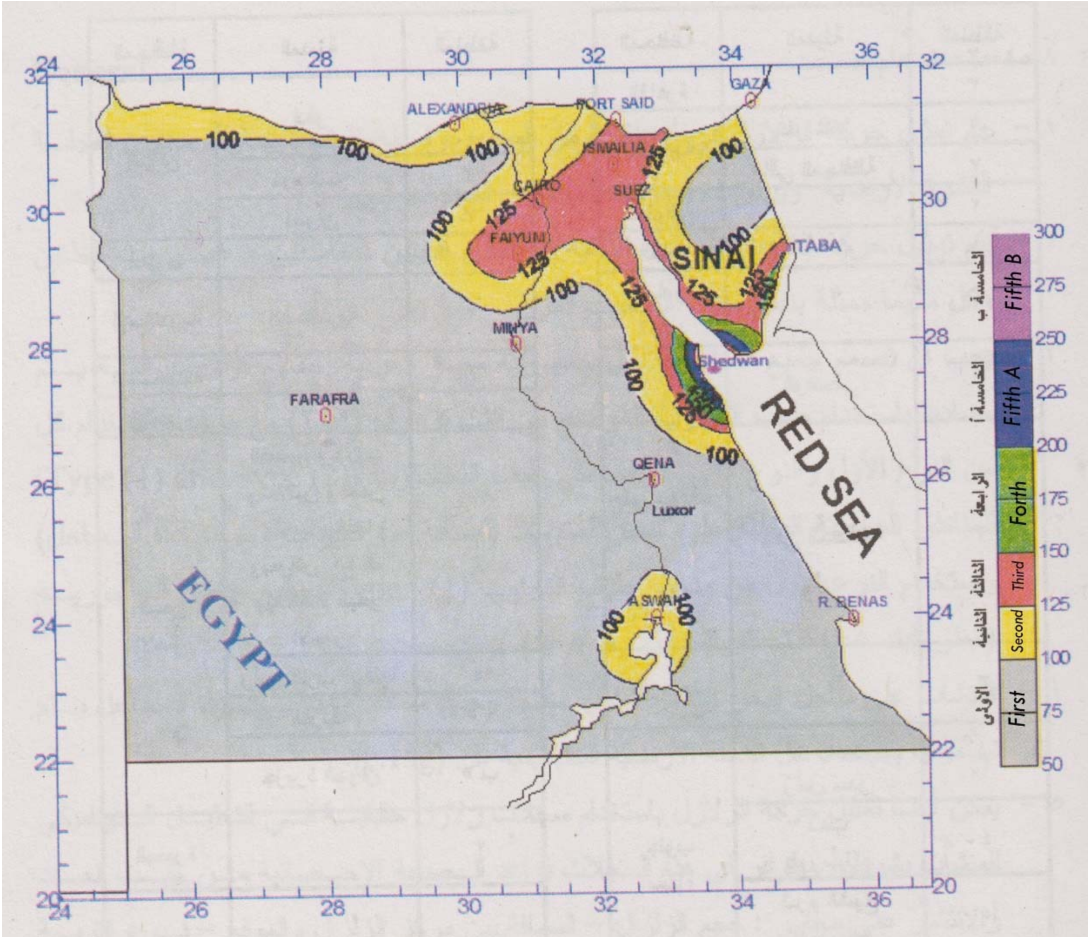


Figure (8-1) Seismic effect Zones

Check Table (8-2-B)

Table (8-2-B) Seismic effect Zones for Cities

Governorate	City	Zone
Aswan	Edfo	1
	Kom Ambo	2
	Aswan	3
Assuit		1
Alexandria	Alexandria	2
Ismailia		3
Luxor		1
Red Sea	Quseir ,Halaib& Shalateen and South Safaga cities width 40km parallel to red sea	3
	Ras Gharib-Safaga	4
	Hurughada	5A
	Shedwan Iland	5B
Albehaira		2
Giza		2&3
Aldakahlia		2
Suez	Suez	3
Alsharqia	Belbis- Abu Hamad, 10th of ramadan	2
	The Rest	3
Algharbia		2
Fayoum		3

Governorate	City	Zone
Cairo		3
Alkaliobia	Kafr shoukr	2
	The Rest	3
Almonoufia		2
Minia		1
Alwadi algadeed		1
Bani Suif	alwasta	3
	The Rest	2
Port said		3
South Sinai	Abu Redis-Ras Sedr	3
	Dahab-altor	4
	Sharm alshikh-Noibaa	5A
	Taba	5B
Domiatt		2
Sohag		1
North Sinai		2, 3
Qna		1
Kafr Alshikh		2
Marsa Matrouh	Marsa Matrouh	2
	Saloum	

8-4-2 Basic Representation of Earthquake Action

8-4-2-1 General

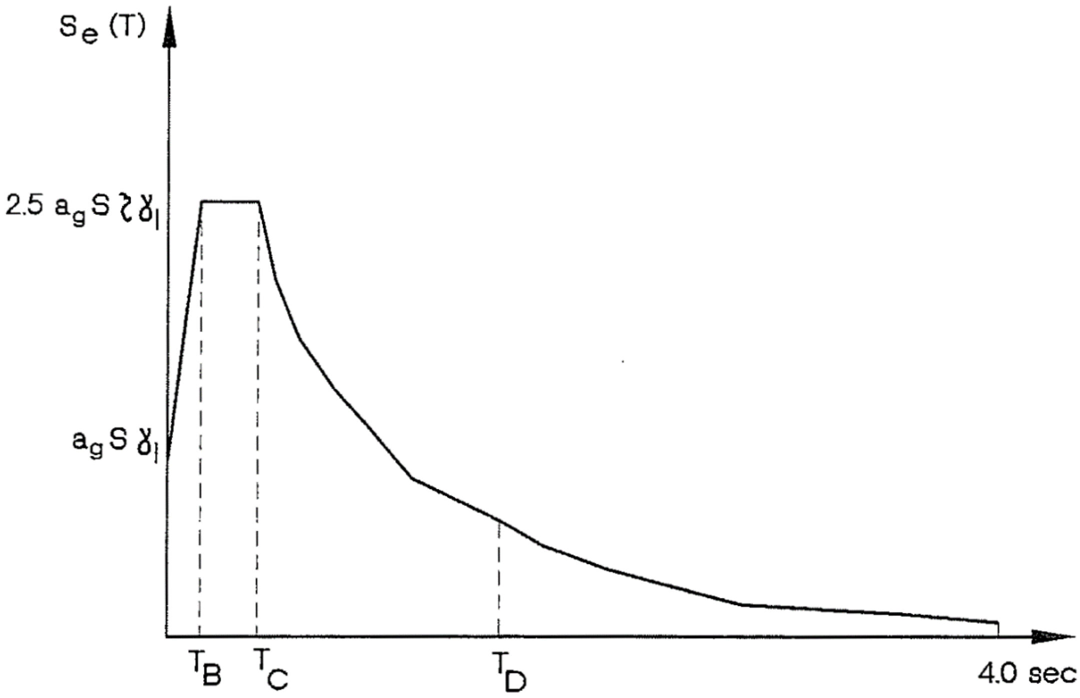
1. Movement of earthquakes represented at any point of the surface by spectrum elastic response of the Earth's crust acceleration and symbolizes after mention by Elastic Response Spectrum.

2. Horizontal movement of the Earth's crust Is represented by a tow horizontal perpendicular forces and are not linked which are represented in the same Elastic Response Spectrum.

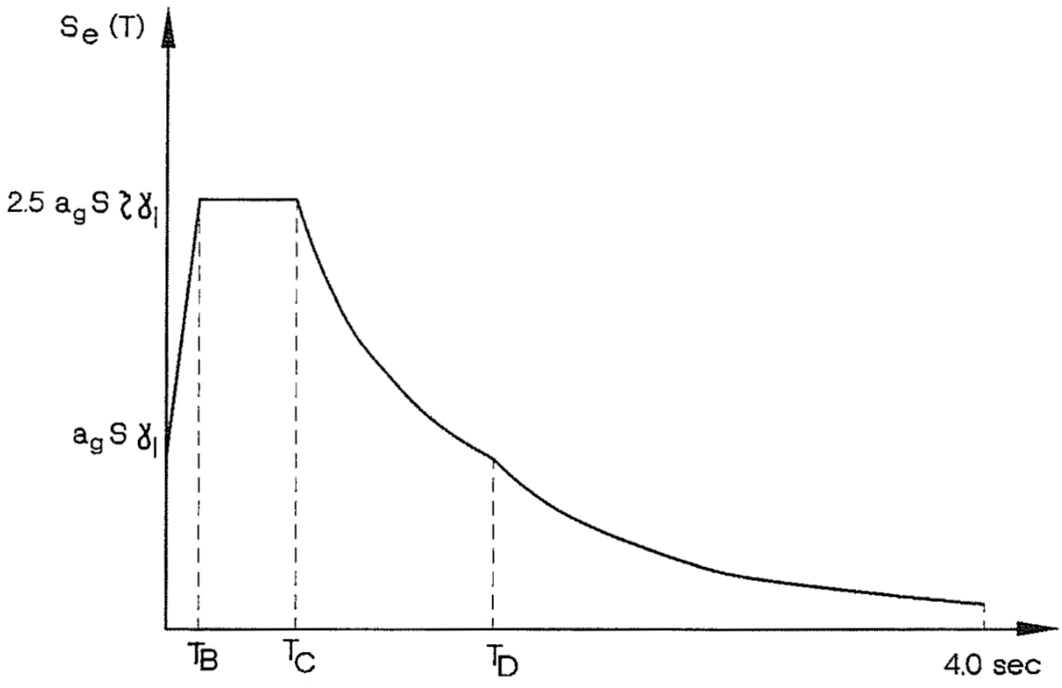
3. All structures within the Arab Republic of Egypt must be design to resist seismic forces, which calculated using Response Spectrum shown in Figure (8-2). Consider to use Type1 and Type 2 from Response Spectrum Curve of coastal areas around the Mediterranean Sea along 40 km parallel to the coast. Moreover, use type1 from Response Spectrum Curve for all of all zones of the republic (look item 8-4-2-2 and Table 8-2).

4. All structures on the Red Sea coast south of SAFAGA till distance of 40 km along the coast are designed so that the design ground acceleration at least (0.15g).

5. Earthquakes movement can also represent by use real earthquakes records in Dynamic Analysis of structures. Condition that is available in these records rules of health statistics in terms of the number and spread on axes: the size of the quake - the distance between the epicenter and the location - the type of soil the earthquake measured. The properties that make them compatible with the value of the design ground acceleration in terms of the intensity of the quake use. That is the adoption of these records are through official specialized centers.



Type (1) All Zones of Egypt



Type (2) Costal Zones on Mediterranean Sea

Figure (8-2) Horizontal Elastic Response Spectrum

8-4-2-2 Horizontal Elastic Response Spectrum

Is determined according to the following:-

Check figure (8-2)

$$0 \le T \le T_B \quad : \quad S_e(T) = a_g \gamma_I S \left[1.0 + \frac{T}{T_B}(2.5\ \eta - 1.0)\right], \quad (8\text{-}2)$$

$$T_B \le T \le T_C \quad : \quad S_e(T) = 2.5\ a_g \gamma_I\ S\ \eta\ , \quad (8\text{-}3)$$

$$T_C \le T \le T_D \quad : \quad S_e(T) = 2.5\ \ a_g\ \gamma_I\ S\ \eta \left[\frac{T_C}{T}\right], \quad (8\text{-}4)$$

$$T_D\ \le T \le 4\ \text{sec} \ : \quad S_e(T) = 2.5\ \ a_g \gamma_I\ S\ \eta \left[\frac{T_C\ T_D}{T^2}\right] \quad (8\text{-}5)$$

When

$S_e\ (T)$ Horizontal Elastic Response Spectrum for standard return period.

T Periodic Time for structure basic seismic wave.

a_g Design ground acceleration for standard return period(475 years for building with same degree of importance) (table-8-2-A).

T_B ,T_C = limits of constant value for elastic response spectrum (table8-3).

γ_I = Building degree of importance (table8-9).

T_D = Specified value for begin of the constant displacement spectrum (table8-3).

η = Corrective damping Factor for Horizontal Response Spectrum (table8-4).

S =Soil coefficient (table8-3).

- Displacement Based Design method can be used by using both types of Response Spectrum curve given on figures (8-2A) , (8-2B) after convert both to displacement spectrum curve.
- Factors Values T_B, TC, TD, S for classified soil A, B, C, D&E are taken as shown in Table (8-3).

Table (8-3) factors Values T_B, TC, TD, S

(A) Type 1 Response Spectrum Curve

Subsoil Class	S	T_B	T_C	T_D
A	1.0	0.05	0.25	1.2
B	1.35	0.05	0.25	1.2
C	1.5	0.10	0.25	1.2
D	1.8	0.10	0.30	1.2

(B) Type 2 Response Spectrum Curve

Subsoil Class	S	T_B	T_C	T_D
A	1.0	0.15	0.4	2.0
B	1.2	0.15	0.5	2.0
C	1.25	0.20	0.6	2.0
D	1.35	0.20	0.80	2.0

✓ S factor should modify if structure built on cliff according to special studies.

Correction Damping Factor η, η_V determined according to table (8-4).

Table (8-4) Values of Correction Damping Factor η, η_V

Type of Structure	η_V	η
Steel with welded connection	1.00	1.20
Steel with Revit connection or Bolt Connection	0.75	1.05
Reinforced Concrete	0.70	1.00
Per-Stressed Concrete	0.75	1.05
Reinforced Brick Walls	0.65	0.95

8-4-2-3 Vertical Elastic Response Spectrum

1- The vertical component of earthquake movement represented by response spectrum $S_{ve}(T)$ according to equations from (8-6) to (8-9) with the use of the spectrum values shown in the table (8-5).

$$0 \leq T \leq T_B \quad : \quad S_{ve}(T) = a_{vg}\ \gamma_I \left[1.0 + \frac{T}{T_B}(3.0\ \eta_v - 1.0)\right], \qquad (8\text{-}6)$$

$$T_B \leq T \leq T_C \quad : S_{ve}(T) = 3.0\ a_{vg}\gamma_I\eta_v \ , \qquad (8\text{-}7)$$

$$T_C \leq T \leq T_D \quad : S_{ve}(T) = 3.0\ a_{vg}\ \gamma_I\ \eta_v \left[\frac{T_C}{T}\right], \qquad (8\text{-}8)$$

$$T_D \leq T \leq 4\text{ sec} : S_{ve}(T) = 3.0\ a_{vg}\ \gamma_I\ \eta_v \left[\frac{T_C\ T_D}{T^2}\right] \qquad (8\text{-}9)$$

Where:

$S_{ve}(T)$ Elastic response spectrum for standard return period.

a_{vg} Vertical component for design ground acceleration.

η_v Corrective Damping Factor for vertical response spectrum table (8-4).

Table (8-5): values of the elastic vertical response spectrum

Spectrum	a_{vg} / a_g	T_B	T_C	T_D
Type (1)	0.90	0.05	0. 15	1.0
Type (2)	0.45	0.05	0.15	1.0

2- The vertical component of design ground acceleration (a_{vg}) from response spectrum does not depend on soil classification.

8-4-2-4 Peak ground Displacement

The value of the maximum displacement of the earth's crust can calculate at earthquakes site (d_g) as follows unless it is determined from a more accurate studies :

$$d_g = 0.025 \ a_g \ \gamma_I S \ T_C T_D \qquad (8\text{-}10)$$

When the values of T_D,T_c,S,a_g are determined in item (8-4-2-2).

8-4-2-5 Horizontal Design Spectrum (for Elastic Structural Analysis)

Structures can be design to seismic loads less than what estimated from the elastic response spectrum because of the structural system's ability to deflect energy by occurrence plasticity formations (after elasticity stage).

1- the design horizontal response spectrum determined by the value of for a standard return period by the following equations:

$$0 \leq T \leq T_B \quad : S_d(T) = a_g \ \gamma_I \ S \left[\frac{2}{3} + \frac{T}{T_B}\left(\frac{2.5\eta}{R} - \frac{2}{3}\right)\right], \qquad (8\text{-}11)$$

$$T_B \leq T \leq T_C \ : S_d(T) = a_g \ \gamma_I \ S \ \frac{2.5}{R}\eta \ , \qquad (8\text{-}12)$$

$$T_C \leq T \leq T_D \ : S_d(T) = a_g \ \gamma_I \ S \ \frac{2.5}{R}\left[\frac{T_C}{T}\right]\eta \ , \qquad (8\text{-}13)$$

$$\geq [\ 0.20\ ] \ a_g \gamma_I$$

$$T_D \leq T \leq 4 \text{ sec} : S_d(T) = a_g \ \gamma_I \ S \ \frac{2.5}{R}\left[\frac{T_C \ T_D}{T^2}\right]\eta \qquad (8\text{-}14)$$

$$\geq [\ 0.20\ ] \ a_g \gamma_I$$

Where:

S_d (T) Horizontal Design Spectrum (for Elastic Structural Analysis)

a_g Design ground acceleration for standard return period.

Y_I Building degree of importance

R Modification reactions factor (reduction of forces) depending on the structural system of the building in accordance with the table (8-A) of Annex (8-A).

2- Factors Values of T_D,T_C,T_B,S shown in table (8-3).
3- Design response spectrum, which determined using the above equations, is not enough to design structure with rubber buffer base against ground movement or have added elements to absorb energy.

8-4-2-6 Alternative Method for determination Horizontal Design Spectrum (for Elastic Structural Analysis) in case base periodical Time T more than T_B

In case of base periodical time T more than T_B , it possible to calculate the horizontal design spectrum response S_d(T) from shown equation in annex (8-C) where T is the structure Fundamental period time as equations (B-1) or (B-2) or from structure dynamic analysis . note that the base period time must achieve Participating Mass over 90%.

8-4-2-7 Vertical Design Spectrum (for Elastic Structural Analysis)

Vertical design response spectrum (Elastic analysis of structural) is equal to the vertical elastic response spectrum, taking into consideration (R=1.0). Except water tanks shall be taken in accordance with what is stated in Part 10.

8-4-3 Alternative Representation of the Earthquake Action-Time History Representation

8-4-3-1 General

1- Movement of earthquakes can represented in terms of the ground acceleration with time as well as speed and displacement with time.
2- When make structure spatial model (3D), the earthquake movement must watched by three records for ground acceleration in the three dimension (East-West)(North-South) Elevation.
3- Movement of earthquakes can represented in terms of Artificial Earthquake Records concluded from available Seismological studies, and historical records and derived in accordance with item (8-4-3-2).

8-4-3-2 Artificial Earthquake Records

8-4-4 Spatial Model of Earthquake Action

In the case of special character structures, which is not true to assume affection on all pivot points of Structure by the same seismic record. Must represent the structure as spatial model takes into account the change in the characteristics of the seismic waves spatial from pivot points to the other. it should be compatible with used elastic spectrum response according to item (8-4-2-2) and (8-4-2-3).

8-5 Combination of the Earthquake Action with other Actions

The design Values of seismic loads summation factors with the other loads summation cases according to deferent design codes.

8-6 Characteristics of Earthquake Resistant Buildings

8-6-1 Exception Cases for ignorance of seismic loads impacts

1- Possible to make exception for bearing walls buildings from earthquakes loads impact calculation according to the requirements of the Egyptian CODE for the design and execution of the buildings code no.204 issued 2005.
2- Upon the Technical estimation of designer except the concrete or steel structures from earthquake loads impact calculation in case of matching all the following conditions:-
   - The structure purpose is Residential.
   - Building height from foundation level not exceed 10 m foe Zone1 and 8m for Zone 2.
   - Elements and vertical structure systems such as walls and columns continuing from foundation top level to the end of structure.
   - Structure Columns, which have adequate inertia in both main direction of the structure.
   - External columns and stair space surrounded columns connected with beam of wide inertia not less than 25 cm in case of concrete structure.
   - The need to achieve the requirements for construction details contained in the codes concerned to ensure at least adequate ductility.

8-6-2 Basic Principles of Conceptual Design

1- Must take into consideration the seismic risk factor in the initial stages of the structure design in seismic zones.
2- Fundamentals governing the initial design and selection of the structural system of the building are:
   - Simplicity of construction.
   - Regularity and symmetry.
   - Resistance and inertia in two directions.
   - Resistance and Inertia for torsion moments.
   - Plane effect on the floor level
   - Adequate foundations.

8-6-3 Structural Regularity

8-6-3-1 General

8-6-3-2 Criteria for Regularity in Plan

8-6-3-3 Criteria for Regularity in Elevation

8-6-3-4 Determination conditions for adjustment reaction factor R in case other structural system use.

8-7 Structural Analysis

8-7-1 Structural modeling

8-7-2 Accidental Torsion

8-7-3 Methods of Calculating Earthquake Effects

8-7-3-1 General

1- The basic method to calculate the effect of earthquakes loads are response spectrum method using the structure elastic model and design spectrum shown in Item (8-4-2-5) and the designed response spectrum in item (8-4-2-6) can be used if matches with the conditions mentioned in that item .

2- The following methods can be used to calculate earthquakes affect loads, according to the nature of the building system:

A. Simplified Modal Response Spectrum Method (equivalent static load method) Used in the case of facilities structures that meet the conditions set out in item (8-7-3-2).

B. Multi-Modal Response Spectrum Method (Multi-patterns) Used for all types of structures as shown in item (8-7-3-3).

3- Time History Analysis method can use as an alternative method according to item (8-7-3-4)and in that case the Coordinates of earthquakes record derived from the standard return period item (8-4-3) and item (8-2-1) must multiply by structure importance factor γ_I shown in item (8-7-6).

4-

8-7-3-2 Simplified Modal Response Spectrum Method

8-7-3-2-1 General

1- This method is applied to structures which can be represented two plane perpendicular models, which mainly affected by their response main dynamic vibration waves on the structure at each level.

2- Structures must achieve the following:-

A. Regularity requirements in the horizontal and vertical projection according to the terms (8-6-3-2),(8-6-3-3).

B. To be the structure with basic periodical time in both directions is less than or equal to any of the following values

$$T_I \leq 4.0\,T_C \quad \text{or} \quad T_I \leq 2.0 \ \text{Seconds}$$

According to T_C mention in table (8-3) in this chapter

8-7-3-2-1 Ultimate Base Shear Force

1- Ultimate base shear force F_b (affect on Foundation top level) calculated for each main direction as the following:-

$$F_b = S_d(T_I).\,\lambda\, W / g \qquad (8\text{-}16)$$

When

S_d (T1) Design Spectrum Coordination for elastic structure analysis according to items (8-4-2-5) or (8-4-2-6) at wavelength time (T_I).

T_I Structure main Periodical Time in analysis direction.

W structure gross design weight above foundation top level and calculated as in item (8-7-1) clause (4).

ƛ correction factor according to the following:-

$\lambda = 0.85$ if $T_1 \leq 2\,T_c$
or
$\lambda = 1.0$ if $T_1 > 2\,T_c$ if structure stories more than tow

2- The main Periodical Time is calculated T_I for structure in two-way analysis using approximate equations calculated from the principles of dynamic analysis of structures and in accordance with Annex (8-B).

8-7-3-2-3 Distribution of the Horizontal Earthquake Forces

1- The Main displacements of the basic formation for the building plane model in both Horizontal perpendicular directions using the methods of structural dynamics or approximately by using horizontal linearly increased offsets over the entire height of the building.
2- Determine the earthquakes loads for each plane model separately using horizontal Force F_i for each story mass m_i.
3- Horizontal forces shall distributed at each floor level according to the following Equation:-

$$F_i = \left[\frac{u_i \quad W_i}{\sum\limits_{j=1,n} u_j \quad W_j} \right] . \; F_b \qquad (8\text{-}17)$$

When

F_i Horizontal Forces affecting on the Floor i

F_b Base shear force resulting from earthquake on the structure as equation (8-16).

u_i , u_j Mass displacement m_i , m_J on main structure modal.

W_i , W_j Mass weights m_i ,m_J calculated as item (8-7-1) clause (4).

n Number of stories above foundation level.

4- When the main dynamic modal is represent by approximate method by horizontal linear increased movement over height , horizontal forces F_i calculate from the following equation:-

$$F_i = \left[\frac{z_i \; W_i}{\sum\limits_{j=1,n} z_j \; W_j} \right] . \; F_b \qquad (8\text{-}18)$$

When

Z_i ,Z_J is mass height m_i ,m_J above foundation level.

5- Horizontal Forces F_i which calculated from equations (8-17) or (8-18) distributed on horizontal loads resistance elements according to actual inertia considering floors slabs are infinite inertia.

8-7-3-2-4 Accidental Torsional Effects

1- When using Spatial model in the analysis it is adding additional effect torsion moments calculated from the equation:-

$$M_{ti} = e_{ai} \cdot F_i \qquad (8\text{-}19)$$

When

M_{ti} Floor Torsion moment I around vertical axis.

e_{ai} Additional decentralization for floor mass I according to equation (8-15) for all directions.

F_i Horizontal forces affect on the floor, calculated as item (8-7-3-2-3) in separate direction.

2- In the case of the symmetry of inertia horizontal distribution and mass in section plan also when solving using a spatial model and no other accurate way than mentioned in item (8-7-2), can take into account the impact of extra torsion moments by enlargement the horizontal forces caused by earthquakes in the elements of resistance and estimated in accordance with item (8-7-3-2-3) clause (5) , using multiply special factor of torsion moments distribution calculated from the equation:-

$$\delta = 1.0 + 0.6 \left[\frac{x}{L_e}\right] \qquad (8\text{-}20)$$

When

X distance between structure element and center of building in section plan.

L_e distance between the external tow structure elements, which resist horizontal loads, measured in the perpendicular direction on the direction, which calculate earthquake loads on.

3- Must calculate the effect of horizontal forces in accordance with clause (2) with a variable signs (positive and negative), and so is taking the same sign for all floors (all positive or all negative).

4- In the case of two separate perpendicular level analysis using the two models, the impact of torsion moments can be calculate by multiplying the value of the additional calculated torsion moments influence from the equation (8-15) and replace the factor 0.6 by factor 1.20 in Equation (8-20).

8-7-3-3 Multi-Modal Response Spectrum Method

8-7-3-3-1 General

1- Used this method to analyze the structures that do not meet the requirements in item (8-7-3-2-1), clause (4), for the simplified response spectrum method. It can also use this method for the analysis of structure that meet the requirements conditions of the simplified response spectrum method. item (8-7-3-2).

2- Possible to make analysis using tow plane models in tow perpendicular directions for structures, which meet the uniformity conditions in section plan, item (8-6-3-2).

3- Must make spatial model to analyze the structures, which do not matches the uniformity conditions in section plan.

4- In case of spatial model use in analysis, must locate all seismic loads over all adequate horizontal directions (according to structural distribution of building) and according to Horizontal perpendicular axis. For the structures, which have structural resist elements in tow perpendicular directions, all seismic loads in those two direction must take in consideration.

5- In case of dynamic analysis ,it must take in consideration all the effects resulting from vibration waves which affect also in total reaction of the building , and to achieve that must follow the after mention two conditions :-

   a) Total amount of affecting mass (which taken into consideration when calculate the building reaction) not less than 90% of the structure gross weight.
   b) All affecting mass over 5% of structure gross weight must take into consideration.

   Note: The affecting mass m_K encounter to modal K ,determine as shear force F_{bk} encounter to modal K which also affecting on seismic load directions is equal to

   $$[\ F_{bk} = S_d(\ T_k)\, m_k\ ]$$

6- In case of spatial Model use, it must achieve the previous requirements in separate directions.

7- If the requirements are not met in clause (5) (such as the case of structures that have high participation rate of torsion waves), the minimum number of waves K taken into account in the analysis must achieve both of the following conditions exist:

$$k \geq 3.0\ \sqrt{n} \qquad (8\text{-}21)$$

and

$$T_k \leq 0.20 \text{ sec.} \qquad (8\text{-}22)$$

When

K Number of waves taken into consideration.

n Number of floors above foundation level.

T_k Wavelength time for Modal K.

8- When use this method the following must achieved:-

   a) Summation of calculated horizontal shear forces at foundation level not less than (85%) of the summation of calculated shear forces by the equivalent static load method as mention in item (8-7-3-2-2).

b) In case conditions not matches above mention (a) item, calculated shear force value must increase by multi-modal response spectrum method to achieve that shear force summation equal to (85%) of calculated shear force shown in item (8-7-3-2-2).

8-7-3-3-2 Combination of Modal Responses

1- Can be considered modal response I , j (including all of displacement and rotational modal resulting from Torsional) separate from each other and that when it is time wavelength T_j ,T_i meet the following requirement:-

$$T_j \leq 0.90 \quad T_i \qquad (8\text{-}23)$$

2- When consider all reactions of modal response (check item (8-7-3-3-1) clause (5) to (7) separate from each other's, then the maximum limit for seismic loads impact could get by the Square root method of the sum of squares of values (SRSS):

$$E_E = \sqrt{\Sigma E_{Ei}^{2}} \qquad (8\text{-}24)$$

When

E_e Seismic loads impact (Force, displacement,….etc.)

E_{ei} Value of Seismic loads impact resulting from vibration by modal i

3- If clause (1) does not achieved, must use other more accurate methods such as Complete Quadratic Combinations – CQC) to collect maximum limit for modal response reaction.

8-7-3-3-3 Torsional Effects

1- When use spatial model in analysis , must consider additional torsional effects calculated from equation (8-19) clause (1) in item (8-7-3-2-4).in that case it possible to calculate additional torsional effect from the envelope value resulting from static loads of torsional set around vertical axes for each floor (i).
2- It must calculate loads impacts in accordance to clause (1) with variable signs (negative or positive). Taking into concern all floors take the same sign (all positive or all negative).
3- In case of use two-plane model separate and perpendicular, then the torsional effects calculate accordance to clause (4) in item (8-7-3-2-4).

8-7-3-4 Time-History Method

1- When use time-history method, the fundamental requirements (item 8-2-1) in this chapter must achieved by Confidence level compatible with spectrum response method.
2- When use this method it must consider the following:-
    a) Horizontal Shear force summation which calculated at foundation level not less (85%) of horizontal Shear force summation which calculated by equivalent static load method according to item (8-7-3-2-2).
    b) In case conditions not matches above mention (a) item, calculated shear force value must increase by Time-History method to achieve that shear force summation equal to (85%) of calculated shear force shown in item (8-7-3-2-2).

3- Can calculate the dynamic response time by using numerical integration of the differential equations of motion using the records of earthquakes in specific item (8-4-3-2) to represent the movement of the Earth's crust.
4- When the assuming non-elastic response of the structure, it must apply item (8-7-3-3-1) clause (3).
5- At least must use three recordings of earthquakes with take the maximum values of the internal forces in different structural elements, and in the case of the use of seven or more records, it would be taking the averages of the numerical values of the internal forces.

8-7-3-5 Combination of the Components of the Earthquake Action

8-7-3-5-1 Horizontal Components of the Earthquake Action

1- Horizontal component of seismic loads (item 8-4-2-1 clause2)Can be considered

Affecting together simultaneously at the same time.

2- The Cases of seismic loads horizontal components summation figure (8-4) as following:-
  - Structural response for each horizontal component must compute separately in accordance with the rules of collecting modal reactions of spectrum response and set out in item (8-7-3-3-2).
  - Maximum value E_T of seismic loads impact on structure resulting from horizontal component in perpendicular separate direction of seismic loads by the method of square root of the square total of reaction components in each direction.

$$E_T = \sqrt{E_{(Fx)}^2 + E_{(Fy)}^2}$$

3- As alternative for item (2) it possible to collect all impact of seismic loads horizontal components in two directions from the following:-

$$E_T = E_{(Fx)} + 0.3\ E_{(Fy)}$$

$$E_T = 0.30\ E_{(Fx)} + E_{(Fy)}$$

Where:

\+ Symbolizes in conjunction with the

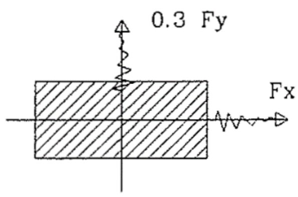
$E_{(FX)}$ Seismic loads impact resulting from earthquake impact on X axis of the building.

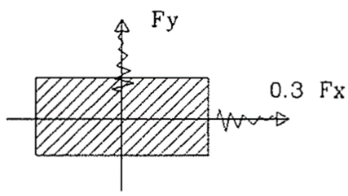
$E_{(Fy)}$ Seismic loads impact resulting from earthquake impact on Y axis of the building.

4- Each component must take the sign in the biggest impact direction on Structure.
5- For structures which meet requirements of regularity in section plan , where resistance to horizontal loads through the walls only, can take loads of earthquakes in both horizontal perpendicular directions of structure as individual.
6- When use time-history method (item 8-7-3-4) by spatial model of structure, Can use the time record of earthquakes in both horizontal direction together at the same time by the previous proportions.

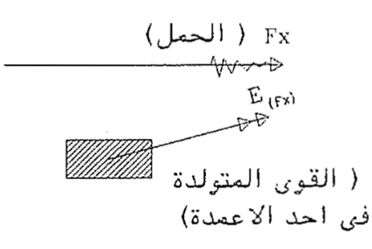
Earthquake on X Direction

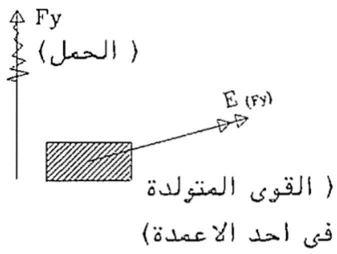
Earthquake in Y Direction





A-General State (Summation of two components loads)





Force in some column

Force in some column

Design Forces

$E_T = \sqrt{E^2_{(Fx)} + E^2_{(Fy)}}$	$E_T = \sqrt{E^2_{(Fy)} + E^2_{(Fx)}}$
أو	أو
$E_T = E_{(Fx)} + 0.3\, E_{(Fy)}$	$E_T = E_{(Fy)} + 0.3\, E_{(Fx)}$

B- Case of individual loads analysis

Figure (8-4) Summation Seismic loads in two directions

8-7-3-5-2 Vertical Component of the Earthquake Action

1- Must consider the vertical component of seismic loads which defined I item (8-4-2-3) when calculates affecting forces on structure in the following cases:-
  - All the structures in case of vertical component for design ground acceleration (a_{vg})is more than 0.25g.
- Horizontal and quasi-horizontal elements with span of 20m or more.
- Horizontal and quasi-horizontal cantilever with span more than 5 m.
- Pre-stressed horizontal and quasi-horizontal Beams.
- Bearing beams for columns (old building), but where new building establish must make special studies in case of allowance of this structure system.
- Base isolated structured.

2- The summation of the three component of seismic loads (except wall bearing structures) will be as the following:-

$$
\begin{array}{lllll}
E_{(Fx)} & + & 0.30\, E_{(Fy)} & + & 0.30\, E_{(Fz)} \\
0.30\, E_{(Fx)} & + & E_{(Fy)} & + & 0.30\, E_{(Fz)} \\
0.30\, E_{(Fx)} & + & 0.30\, E_{(Fy)} & + & E_{(Fz)}
\end{array}
$$

Notice to take the sign of each component according to the biggest impact direction of structure.

3- it possible to make analysis for determinate the impact of the vertical component of seismic load based on structure partially representation include the elements under consideration which use to calculate mentioned vertical component in clause (1) without ignorance the inertial of adjacent elements.

4- Vertical component impacts only taken into consideration for under study elements clause (1) and other secondary supporting elements.

5- In case of non-linear static analysis for structure, it possible to ignore the vertical component of seismic loads.

8-7-4 Displacement Analysis

1- Displacement resulting from earthquake based on elastic modal of structure system d_s is determined according to the following simplified equation :-

$$d_s = 0.7\, R\, d_e \qquad (8\text{-}25)$$

Where

d_e Point Displacement in structure system calculated by horizontal design spectrum response (Elastic structural analysis) shown in item (8-4-2-5) or (8-4-2-6).

R Reaction modification factor (forces reduction) according to the building structural system table (8-A) from annex (8-A).

And to notice that d_s must not exceed than the calculated displacement from the analysis by horizontal Elastic spectrum response shown in item (8-4-2-2).

2- It possible to calculate the displacements (d_s) by applying horizontal Elastic spectrum response equations (equation 8-2 till 8-5) multiplied by 0.7 factor and proceeding elastic analysis for structure.
3- When calculating displacement by Multi-Modal Response Spectrum Method item (8-7-3-3) or Time-History Method item (8-7-3-4) the value Should not be less than (85%)of calculated displacements by simplified spectrum response method (equivalent static load method) item (8-7-3-2).
4- When calculate Displacements, the torsional effects of earthquake must take into consideration.
5- In case of proceeding non-Linear analysis for structure (even Static or Dynamic) the displacement values must be the same values calculated from this analysis without taking into account the adjustment factor (R equal to the value of one true at all stages of accounts when calculating the loads resulting from earthquakes.

8-7-5 Non-Structural Elements

8-7-5-1 General

1- The non-structural elements in structures (Parapet, End walls , Antennas,mechanical facilities,curtain walls , partition, rails and others) Which represent a danger to scare off in the case of collapse or affect on structure Skelton of the building or important services must be designed to resist loads resulting from earthquakes.
2- In the case of a non-structural elements of great significance or dangerous should include seismic analysis a true representation of all the elements of structure as well as the use of the adequate spectrum concluded from the reaction of bearing structural elements of the structural system resistant to earthquakes.

8-7-5-2 Analysis

1- All non-structural elements and connecting joints must checked for resistance in all loading (dead, live, or seismic).
2- The seismic impact on non-structure elements must consider as horizontal force (F_a) affect on the center of the element mass in the biggest effected direction and calculated the value of this force from the following equation:

$$F_a = (S_a \; W_a \; \gamma_a) / R_a \qquad (8\text{-}26)$$

Where:

W_a The weight of non-structure elements.

S_a Earthquake factor belong to non-structure elements as clause (3) in this item.

γ_a Importance factor belong to non-structure elements as item (8-7-5-3).

R_a Reactions adjustment factor belong to non-structure elements as table (8-8).

3- Earthquake factor belong to non-structure elements S_a is determined according to the following equation:-

$$S_a = \alpha . S \left[\frac{3(1.0 + z_a/H)}{1.0 + (1.0 - T_a/T_i)^2)} - 0.50 \right] \geq \alpha \qquad (8\text{-}27)$$

Where:

α The ratio between earth Design acceleration (a_g) and ground acceleration g.

S Soil coefficient

T_a Base periodical time for non- structure elements.

T_i Periodical time for structure in the analysis direction.

z_a Height of the non-structure element above building foundation level.

H Total height of the building above foundation level.

8-7-5-3 Importance Factors and Response modification Factors

1- Importance factor γ_a must not exceed 1.50 for the following non-structure elements:
   - Systems connect the equipment and machinery required for rescue Systems.
   - Reservoirs and containers containing toxic or potentially explosive elements, which is supposed to be seriousness on the spirits.
2- Possible to take Importance factor γ_a for non-structure elements as the same Importance factor value for the same structure as item (8-7-6) in all the other cases.
3- The value of reaction adjustment factor for non-structure elements shown in table (8-8).

Table (8-8) values of reaction adjustment factor R_a for non-structure elements

Types of non –structure elements	R_a
o Parapet and Cantilever o Signs and Information Boards o Chimneys, towers, and reservoirs mounted on brackets, which restricted to a distance of more than half of the structure rise.	1.0
o Internal and External Walls o Partitions and frontage. o Chimneys, towers, and reservoirs mounted on brackets, which not restricted to a distance less than half of the structure rise.or connecting to structure at top of the center of mass o Starter bars and anchors supporting book shelves from slab o Starter bars for false ceiling and light units	2.0

8-7-6 Importance Categories and Importance Factors

1- Structures usually classified into four groups of importance depends on the size and use of structure and the value and importance of public safety and the potential for loss of life in case of collapse, according to the table (8-9).

2- Important Groups is distinguishable by the importance factors γ_I , according to the item (8-2-1).

3- Importance Factor (γ_I =1.0) is linked to a design seismic event with a standard record time of return as item (8-2-1).

Table (8-9) Importance Groups and Importance Factors γ_I

Importancee Groups	Structures	Importance Factor γ_I
I	Structures that must operate efficiently during and after the occurrence of the earthquake and used for emergency purposes, which represent great importance to the safety of the public, such as hospitals, fire stations, power stations, police stations, emergency centers, communications etc.	1.40
II	Structures that have the importance of the presence of seismic resistance for the impact of the collapse of the loss of life, such as schools, halls, places of worship, cultural centers, tanks, chimneys and silos etc.	1.20
III	Structures, regular and non-associated in any other group.	1.0
IV	Structures of the importance of a few of the public safety facilities such as agricultural, temporary structures etc.	0.80

8-8 Safety Verifications

8-8-1 General

1- Special precautions must be observed in item (8-2) to achieve safety limits for contained items (8-8-2),(8-8-3).

8-8-2 Ultimate limit Stat (ULS)

8-8-2-1 General

- In the case of design for earthquake resistance, the safety against collapse (the Ultimate collapse limit) is investigator if the following requirements are available for each of the resistance, Ductility, Balance, Slabs, Foundation stability and seismic intervals.

8-8-2-2 Resistance Conditions

1- Must achieve the following relationships for all structural elements, as well as connections and non-structural elements described in item (8-7-5-1) clause (1).

$$E_d \leq R_e \tag{8-28}$$

Where:

E_d Value of the impact of design loads according to the design situation to resist earthquakes include secondary effects if necessary; require that (Check clause2)

R_e Supposed element design Resistance, according to design rules for the construction various materials contained in Egyptian design Codes

2- Secondary effects (P-Δ) are not taken into account if the following condition check each floors

$$\theta = \frac{P_{tot}\ d_r}{V_{tot}\ h} \leq 0.10 \tag{8-29}$$

Where:

θ The sensitivity factor of the Interstorey drift of the floor.

P_{tot} Vertical loads at the under study floor level, according to the assumptions set for by the impact loads resulting from earthquakes.

d_r The design Interstorey drift of the floor capacity of the difference between the average lateral movement at the top and bottom of the under study and calculated in accordance with item (8-7-4).

V_{tot} The total shear forces resulting from the earthquake.

h Floor height.

3- In case of ($0.10 \leq \theta \leq 0.20$) it possible to take into consideration the secondary effects (P-Δ) by approximate method through multiplying seismic forces by factor I/(1-θ).
4- In case of ($0.20< \theta \leq 0.20$),must proceed the analysis by (P-Δ) method.
5- It is not allowable to increase factor θ over 0.30.

8-8-2-3 Ductility Conditions

1- Make sure that the structural elements and structure as a one unit containing required ductility, taking into concern the possibility of low ductility that depends on the system and structural adjustment reaction factor.
2- Must achieve the Egyptian standard which concern about ductility and construction material resistance include capacity design provisions in case for determination the resistance of

deferent structural elements and assurance of elastic joints occurrence to avoid brittle failure mode.

8-8-2-4 Equilibrium Conditions

Must be achieved equilibrium of the building under the influence of loads collection mentioned in item 98-5), especially for overturning and sliding.

8-8-2-5 Resistance of Horizontal Diaphragms and Bracings

Slabs and diaphragms in horizontal planes must have additional resistance to transfer seismic loads to other deferent structural system to resist lateral related loads.

8-8-2-6 Resistance of Foundations

1- Should review the design of foundations, according to the Egyptian Code for Soil Mechanics and design and implementation of the foundations.
2- For shallow foundation ,structure design use a value for adjustment reaction factor (R) equal to 60% of adjustment reaction factor which use in top Skelton but to not less than (1.0).
3- Separate Shallow Foundations which not linked by ground beams is excepted from item (2) where consider adjustment reaction factor (R) equal to (1.0).
4- Piles and piles caps design according to adjustment reaction factor (R) equal to (1.0).
5- Piles and piles caps design based on assumption of elastic joints at connection places with caps and in that case the value of R is equal to (2.0) when design vertical piles and equal to (1.5) when inclined piles case . All reinforcement details must considered to the joint elastic in elements facing vertical loads and binding moments as Egyptian standard mention.
6- The design must include safety factors for foundation against soil collapse and sliding results from seismic.

8-8-2-7 Requirements of Earthquake Separation

8-8-3 Serviceability Limit States (SLS)

8-8-3-1 General

1. Requirements are considered serviceability limit realized under the influence of earthquake loads if the displacements calculated under the impact of loads, resulting from the possibility of earthquakes larger than the design does not exceed the existing in item (8-8-3-2).
2. Additional requirements are requested to serviceability limit in the case of importance structures for the civil defense or which containing sensitive materials or equipment

8-8-3-2 Limitations of Interstorey Drift

1. Unless not specified in the design codes for different materials, it must take into concern the following limits:
   a) Structures that have an adjacent brittle non-structural elements such as wall bearing building:

$$d_r / \nu \leq 0.005\ h \qquad (8\text{-}30)$$

   b) Structures that have ductile non-structural elements:

$$d_r / \nu \leq 0.0075\ h \qquad (8\text{-}31)$$

c) Structures that have non-structural elements fixed by some method which prevent the interference with structural movement of the building:

$$d_r / \nu \leq 0.01 \ h \qquad (8\text{-}32)$$

Where;

d_{rv} Interstorey Drift for floor for case Serviceability Limit States (SLS).

d_r Interstorey Drift for floor estimated as the deference between average gravity movement (d_s) at top and bottom of under study floor and calculated as item (8-7-4).

h Floor height.

V displacement reduction factor (considering earthquake return time less than in design and meet the Serviceability Limit States).

2. Reduction factor depends on structure importance degree as item (8-7-6) and table (8-10)

Table (8-10) Displacement reduction Factor V

Importance groups	I	II	III	IV
Reduction Factor V	0.4	0.4	0.5	0.5

Annex (8-A) Response Modification (Force Reduction) Factors R

Annex (8-B) Approximate Formulae for the Fundamental Period of Buildings

B-1 General

Approximate methods can use to calculate the Fundamental period time as explained in items

(B-2), (B-3).

B-2 The First Method

1. Possible to calculate the value T_l for structures over 60 m height by approximate method from the following equation:

$$T_1 = C_t \ H^{3/4} \qquad (B\text{-}1)$$

Where;

T_l Fundamental period of building by second.

C_t Factor depends on structural system and construction materials as:

0.085 Steel spatial frame resist moments.

0.075 Concrete spatial framed and steel frames with axial diaphragms to resist moments.

0.050 All other Structures

H Structure height by meter measured from top of foundation.

B-3 The Second Method

- Possible to use Rayleigh formula to determine the Fundamental period time according to the equation:

$$T = 2\pi \sqrt{\frac{\sum_{i=1}^{n} W_i \, u_i^2}{g \sum_{i=1}^{n} F_i \, u_i}} \qquad (B\text{-}2)$$

Where:

g The ground gravity acceleration

W_i the design weight for structure at floor i

F_i Horizontal force at floor I as equation (8-18).

n building number of story.

- The value of (T) determined from equation (B-2), must not exceed 1.20 of calculated from equation (B-1).

B-4 The Third Method

Possible to calculate (T) from spatial analysis by computers, but must not exceed 1.20 calculated from equation (B-1).

Annex (8-C)

In case the Fundamental period time T is more than T_B ,the design horizontal spectrum response $S_d(T)$ determine from the after mention equations where (T) is the Fundamental period time for structure according to equations (B-1) or (B-2) or structure dynamic analysis

$$0 \le T \le T_C \quad : S_d(T) = a_g \gamma_I S \frac{2.5}{R}$$

$$T_C \le T \le T_D \quad : S_d(T) = a_g \gamma_I S \frac{2.5}{R} \left[\frac{T_C}{T}\right] \ge [0.20] \gamma_I a_g$$

$$T_D \le T \le 4\text{sec} \quad : S_d(T) = a_g \gamma_I S \frac{2.5}{R} \left[\frac{T_C T_D}{T^2}\right] \ge [0.20] \gamma_I a_g$$