SYRIAN SEISMIC CODE 2004[1]:

Two static methods have been issued in Syrian building code 2004 to calculate the lateral seismic forces in the building.

<u>The First Static Method:</u>

It is the same method in the previous code (1995) with few modifications. It is based on determination of a ***design base shear force (V)***, which is then distributed in a specific pattern over the height of the structure for structure analysis of lateral load resistance.

The total design base shear in a given direction (V) is given by:

$$V = (ZIKCS) * W$$

Seismic Zone Factor (Z):

It is represent the peak ground acceleration in studied site as a percentage of gravity acceleration g (9.81 m/sec^2). Z factor for each zone is shown in the table below:

Seismic Zone	**0**	**1**	**2A**	**2B**	**2C**	**3**
Z factor	**0**	**0.075**	**0.15**	**0.20**	**0.25**	**0.3**

Importance factor (I):

Occupancy Category	**I**
All important structures which are required for continued operating during earthquakes such as: hospitals, fire and police stations, …..etc.	**1.50**
All Structures with occupancy more than 300 persons.	**1.25**
All others structures.	**1.00**

I value not less than 2 for atomic structures and all hazardous structures.

Ductility Factor (K):

Building Type or description	**K**
All buildings not mentioned in this table	**1.00**
Bearing wall system	**1.30**
Building Frame System or Mixed System according to the following designing case: -Frames can bear 25% of the total lateral loads. -Frames can bear 50% of the total lateral loads.	**1.00** **0.80**
High tanks of water and similar which carried by a group of columns not less than four.	**2.50**
Special Building such as: Chimneys, T.V towers …..	**2.00**

[1] The original Code is in Arabic and it has been translated to English by Eng. Hussam Eldein Zaineh, National Earthquake Center (NEC).

Dynamic Factor (C):

It represents the percentage between equivalent acceleration of the structure to the ground acceleration and it defined from this equation:

$$C = \frac{1}{10T^{\frac{2}{3}}}$$

Where:

T: is the fundamental period of the structure (sec) in a given direction, calculated by:

1- approximate determination in case of shear wall system structures:

$$T_{(\text{sec})} = 0.08N$$

Where, N is the number of stories.

2- approximate determination in case of frame system structures:

$$T = 0.1N$$

3- also, T must be estimated by using this approximate equation:

$$T = \gamma_t.(h_n)^{3/4}$$

Where:

h_n : building height from the base up to level n in meters.

γ_t =0.0853 for steel frame.

γ_t =0.0731 for RC frame.

γ_t =0.0488 for other buildings.

Note 1: T is the minimum value from previous three equations.

Note 2: C is equal to 0.15 for buildings consist of only one or two stories.

Note 3: in other cases C must be less than 0.18.

Note 4: in all cases, K.C must be less than 0.38 and more than 0.09.

Soil Coefficient (S):

1- in case of $\frac{T}{T_s} \leq 1$:

$$S = 1.0 + \frac{T}{T_s} - 0.5\left(\frac{T}{T_s}\right)^2$$

2- in case of $\frac{T}{T_s} > 1$:

$$S = 1.2 + 0.6\frac{T}{T_s} - 0.3\left(\frac{T}{T_s}\right)^2$$

T_s: the characteristic site period (sec).

Total weight (W): is equal to all dead loads and 25% of live loads.

Lateral Loads distribution:

1-Regular structures or structural frame system:

The total lateral force (V) shall be distributed over the height of the structure in conformance with formulas:

$$V = F_t + \sum_{i=1}^{n} F_i$$

Ft: The concentrated force at the top of the structure shall be determined from the formula:

$$F_t = 0.07 \times T \times V$$

The value of (F_t) need not exceed (0.25 V) and may be considered as zero where T is 0.70 sec or less.

T: the fundamental period of the structure (sec) in the considered direction.

The remaining portion of the base shear (V- F_t) shall be distributed over the height of the structure According to the following formula:

$$F_x = \frac{(V - F_t) w_x h_x}{\sum_{i=1}^{n} w_i h_i}$$

Where:

w_x: the vertical concentrated load at level x which equal to the weight of this level.

w_i: the portion of (w) located at assigned to level i.

h_x: height above the base to level x.

h_i: height above the base to level i.

F_x: design seismic force applied at level x in the gravity center of this level.

2- Irregular structures:

The dynamic lateral-force procedure shall be used to analysis these kind of structures.

The Second Static Method:

It is based on determination of a ***design base shear force (V)***, which is then distributed in a specific pattern over the height of the structure for structure analysis of lateral load resistance.

The total design base shear in the considered direction (V) is given by:

$$V = \frac{C_v I}{RT} W$$

The total design base shear need not exceed the following:

$$V = \frac{2.5 C_a I}{R} W$$

The total design base shear shall not be less than the following:

$$V = 0.11 C_a I W$$

In addition, for Seismic Zone 4, the total base shear shall also not be less than the following:

$$V = \frac{0.8 Z N_v I}{R} W$$

Where C_a, C_v, N_a and N_v from tables (3-9), (3-10), (3-11) and (3-12) respectively.

Seismic Zone Factor (Z):

Seismic Zone Factor as it mentioned in the first method.

Importance factor (I):

Importance factor (I) as it mentioned in the first method.

Structure period (T):

The value of T shall be determined from one of the following methods:

1. *Method A:* For all buildings, the value T may be approximated from the following formula:

$$T = C_t (h_n)^{3/4}$$

Where:

h_n : building height from the base up to level n in meters.

C_t=0.0853 for steel moment resisting frames.

C_t= 0.0731 for reinforced concrete moment-resisting frames and eccentrically braced frames.

C_t=0.0488 for all other buildings.

Alternatively, the value of C_t for structures with concrete or masonry shear walls may be taken as:

$$C_t = 0.0743 / \sqrt{A_c}$$

Where Ac in m^2 and shall be determined from the following formula:

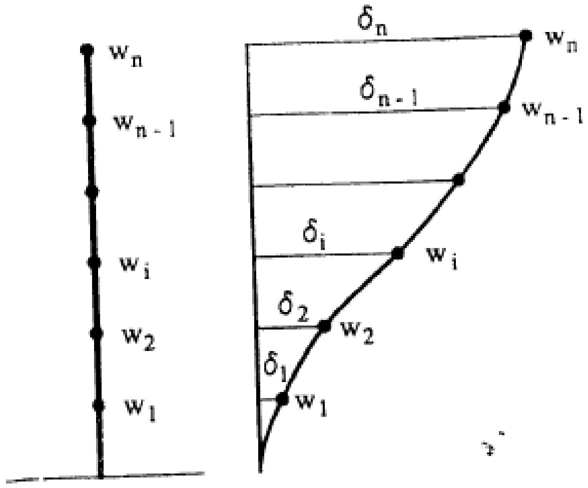
$$A_c = \sum A_e [0.2 + (D_e / h_n)^2]$$

The value of D_e/h_n used in previous formula shall not exceed 0.9.

2. Method B: The fundamental period T may be calculated using the structural properties and deformational characteristics of the resisting elements in a properly substantiated analysis. The analysis shall be in accordance with the requirements of Section 4.2.2. The value of T from Method B shall not exceed a value 30 percent greater than the value of T obtained from Method A in Seismic Zone 4, and 40 percent in Seismic Zones 1, 2 and 3. The fundamental period T may be computed by using the following formula:

$$T = 2\pi \sqrt{(\sum_{i=1}^{n} w_i \delta_i^2) \div (g \sum_{i=1}^{n} f_i \delta_i)}$$

The values of f_i represent any lateral force distributed approximately in accordance with the principles of Formulas (4-13), (4-14) and (4-15) or any other rational distribution. The elastic deflections, δi, shall be calculated using the applied lateral forces, F_i.



The elastic deflections, δi

Simplified design base shear:

a. *General:* Structures conforming to the requirements of section 3-9-2 may be designed using this procedure below.

b. *Base shear:* The total design base shear in a given direction shall be determined from the following formula:

$$V = \frac{3.0C_a}{R}W$$

Where, the value of C_a shall be based on Table 9-3 regarding the soil profile type. When the soil properties are not known in sufficient detail to determine the soil profile type, Type S_D shall be used in Seismic Zones 3 and 4, and Type S_E shall be used in Seismic Zones 1, 2A and 2B. In Seismic Zone 4, the Near-Source Factor, N_a, need not be greater than 1.3 if none of the following structural irregularities are present: Type (1, 4 or 5) of Table (3-4), or Type (1) or (4) of Table (3-5).

c. *Vertical distribution:* The forces at each level shall be calculated using the following formula:

$$F_x = \frac{3.0C_a}{R}w_i$$

Where, the value of C_a shall be determined in Subsection (4-3-3-b).

d. *Applicability:* Sections (4-2-2), (4-2-3), (4-3-1), (4-3-2), (4-6), (4-10), (4-11) and 5 shall not apply when using the simplified procedure.

EXCEPTION: For buildings with relatively flexible structural systems, the building official may require consideration of P-Δ effects and drift in accordance with Sections (4-2-3), (4-10) and (4-11). While Δ_s shall be calculated using design seismic forces from Subsection (4-3-3-b).

Where used, Δ_M shall be taken equal to 0.01 times the story height of all stories.

In Section (7-11-8), Formula (7-2) shall read:

$$F_{px} = \frac{3.0C_a}{R} w_{px}$$

And need not exceed ($1.C_a.w_{px}$), but shall not be less than ($0.5.C_a.w_{px}$). R shall be taken from Table (3-6).

Vertical Distribution of Force:

The total force shall be distributed over the height of the structure in conformance with Formulas (4-13), (4-14) and (4-15) in the absence of a more accurate procedure.

$$V = F_t + \sum_{i=1}^{n} F_i \qquad (4-13)$$

The concentrated force F_t at the top, which is in addition to F_n shall be determined from the formula:

$$F_t = 0.07T.V \qquad (4-14)$$

The value of T used for the purpose of calculating F_t shall be the period that corresponds with the design base shear as computed using Formula (4-4). F_t need not exceed 0.25V and may be considered as zero where T is 0.7 second or less. The remaining portion of the base shear shall be distributed over the height of the structure, including Level n, according to the following formula:

$$F_x = \frac{(V - F_t)w_x h_x}{\sum_{i=1}^{n} w_i h_i} \qquad (4-15)$$

At each level designated as x, the force F_x shall be applied over the area of the building in accordance with the mass distribution at that level. Structural displacements (figure 4-2) and design seismic forces (figure 4-3) shall be calculated as the effect of forces F_x and F_t applied at the appropriate levels above the base.

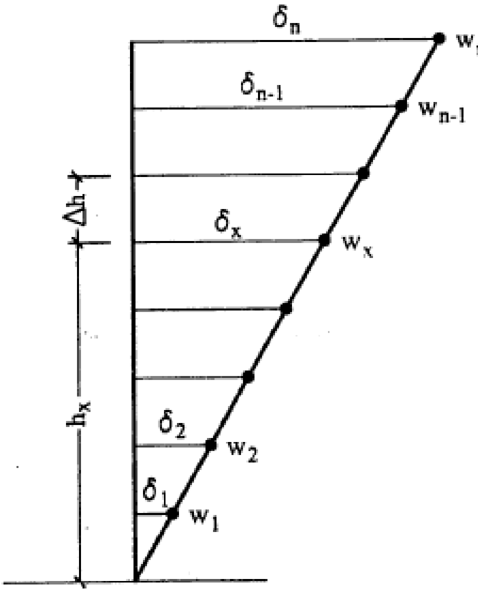


Figure (4-2): Structural displacements

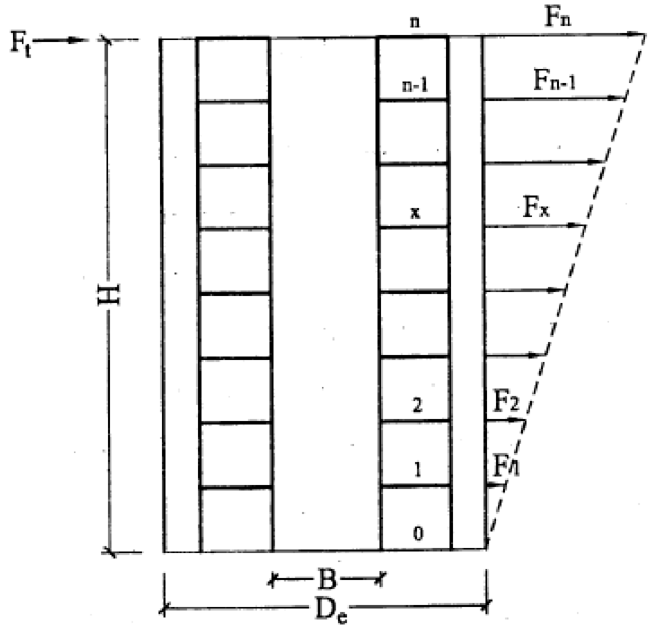


Figure (4-3): Design Seismic Forces

Dynamic Analysis Procedures:

1. General:

Dynamic analyses procedures, when used, shall conform to the criteria established in this section. The analysis shall be based on an appropriate ground motion representation and shall be performed using accepted principles of dynamics. Structures that are designed in accordance with this section shall comply with all other applicable requirements of these provisions.

2. Ground Motion:

The ground motion representation shall, as a minimum, be one having a 10-percent probability of being exceeded in 50 years, shall not be reduced by the quantity R and may be one of the following:

2.1. An elastic design response spectrum constructed in accordance with Figure 5-1, using the values of C_a and C_v consistent with the specific site. The design acceleration ordinates shall be multiplied by the acceleration of gravity (9.815 m/sec^2).

2.2. A site-specific elastic design response spectrum based on the geologic, tectonic, seismologic and soil characteristics associated with the specific site. The spectrum shall be developed for a damping ratio of 0.05, unless a different value is shown to be consistent with the anticipated structural behavior at the intensity of shaking established for the site.

2.3. Ground motion time histories developed for the specific site shall be representative of actual earthquake motions. Response spectra from time histories, either individually or in combination, shall approximate the site design spectrum conforming to Section 5-2-2.

2.4. For structures on Soil Profile Type S_F, the following requirements shall apply when required by Subsection (3-9-4-d):

2.4.1 The ground motion representation shall be developed in accordance with Items 2 and 3.

2.4.2 Possible amplification of building response due to the effects of soil-structure interaction and lengthening of building period caused by inelastic behavior shall be considered.

2.5. The vertical component of ground motion may be defined by scaling corresponding horizontal accelerations by a factor of two thirds. Alternative factors may be used when substantiated by site-specific data. Where the Near Source Factor, Na, is greater than 1.0, site-specific vertical response spectra shall be used in lieu of the factor of two-thirds.

3. Mathematical Model:

A mathematical model of the physical structure shall represent the spatial distribution of the mass and stiffness of the structure to an extent that is adequate for the calculation of the significant features of its dynamic response. A three-dimensional model shall be used for the dynamic analysis of structures with highly irregular plan configurations such as those having a plan irregularity defined in Table (3-5) and having a rigid or semi-rigid diaphragm. The stiffness properties used in the analysis and general mathematical modeling shall be in accordance with Section 4-2-2.

4. Description of Analysis Procedures:

4.1. Response spectrum analysis: An elastic dynamic analysis of a structure utilizing the peak dynamic response of all modes having a significant contribution to total structural response. Peak modal responses are calculated using the ordinates of the appropriate response spectrum curve which correspond to the modal periods. Maximum modal contributions are combined in a statistical manner to obtain an approximate total structural response.

4.2. Time-history analysis: An analysis of the dynamic response of a structure at each increment of time when the base is subjected to a specific ground motion time history.

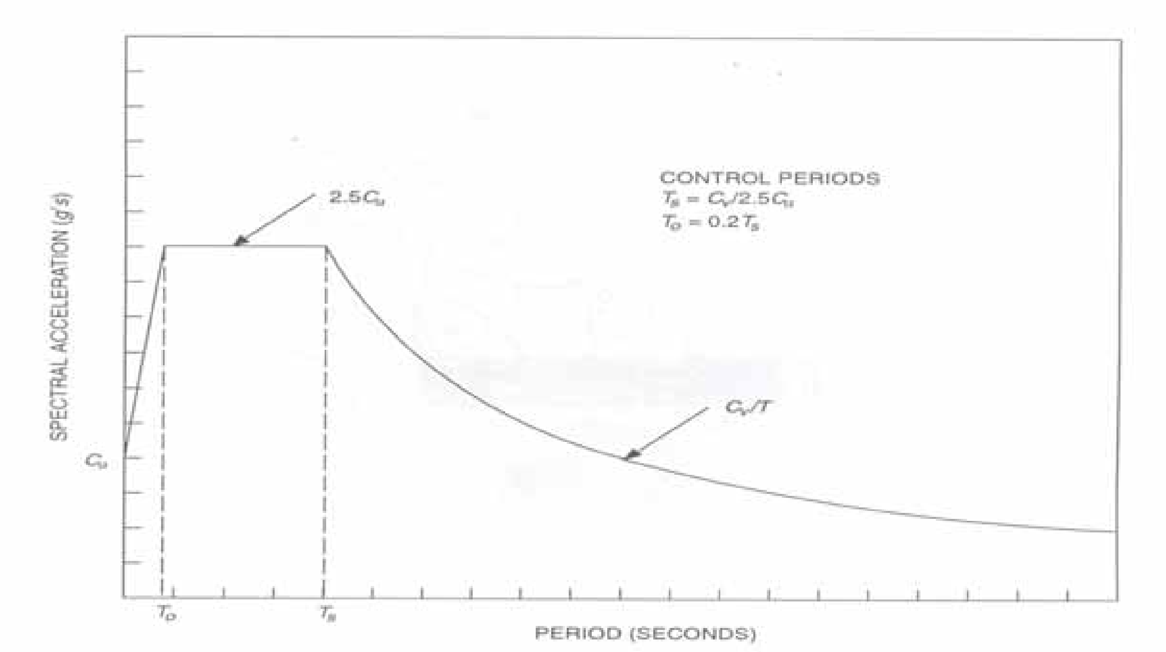


Figure (5-1): Design Response Spectrum

Table (4-2) shows the value of R factor for most common structural systems in Syria.

No.	Lateral Force resisting System Description	R
1	Special Moment Resisting Frame Systems.	**8.0**
2	Dual System With Special Moment Resisting Frames which are capable to resist at least 50% of Prescribed Seismic Force.	**7.5**
3	Dual System With Special Moment Resisting Frames which are capable to resist at least 25% of Prescribed Seismic Force.	**6.5**
4	Dual System With Special Moment Resisting Frames which are capable to resist at least 10% of Prescribed Seismic Force.	**5.5**
5	Bearing Shear Wall System without Special Moment Resisting Frames	**4.5**

Table (3-9), Seismic Coefficient C_a

Soil Profile Type	Seismic Zone Factor, Z				
	Z = 0.075	**Z = 0.15**	**Z = 0.2**	**Z = 0.3**	**Z = 0.4**
S_A	0.06	0.12	0.16	0.24	0.32 N_v
S_B	0.08	0.15	0.20	0.30	0.40 N_v
S_C	0.09	0.18	0.24	0.33	0.40 N_v
S_D	0.12	0.22	0.28	0.36	0.44 N_v
S_E	0.19	0.30	0.34	0.36	0.36 N_v
S_F	See Footnote[1]				

[1] Site-specific geotechnical investigation and dynamic site response analysis shall be performed to determine seismic coefficient for Soil Profile Type S_F

Table (3-10), Seismic Coefficient C_v

Soil Profile Type	Seismic Zone Factor, Z				
	Z = 0.075	**Z = 0.15**	**Z = 0.2**	**Z = 0.3**	**Z = 0.4**
S_A	0.06	0.12	0.16	0.24	0.32 N_v
S_B	0.08	0.15	0.20	0.30	0.40 N_v
S_C	0.13	0.25	0.32	0.45	0.56 N_v
S_D	0.18	0.32	0.40	0.54	0.64 N_v
S_E	0.26	0.50	0.64	0.84	0.96 N_v
S_F	See Footnote[1]				

[1] Site-specific geotechnical investigation and dynamic site response analysis shall be performed to determine seismic coefficient for Soil Profile Type S_F

Table (3-11) NEAR- SOURCE FACTOR N_a[1]

Seismic Source Type	Closest Distance to Known Seismic Source[2]		
	≤ 2 km	**5 km**	**≥ 10 km**
A	1.5	1.2	1.0
B	1.3	1.0	1.0
C	1.0	1.0	1.0

[1] The Near-Source Factor may be based on the linear interpolation of values for distances other than those shown in the table.

[2] The closest distance to seismic source shall be taken as the minimum distance between the site and the area described by the vertical projection of the source on the surface (i.e, surface projection of fault plane). The surface projection need not include portions of the source at depths of 10 km or greater. The largest value of the Near-Source Factor considering all sources shall be used for design.

Table (3-12) NEAR- SOURCE FACTOR N_V[1]

Seismic Source Type	Closest Distance to Known Seismic Source[2]			
	≤ 2 km	**5 km**	**10 km**	**≥ 15 km**
A	2.0	1.6	1.2	1.0
B	1.6	1.2	1.0	1.0
C	1.0	1.0	1.0	1.0

[1] The Near-Source Factor may be based on the linear interpolation of values for distances other than those shown in the table

[2] the closest distance to seismic source shall be taken as the minimum distance between the site and the area described by the vertical projection of the source on the surface (i.e, surface projection of fault plane). The

surface projection need not include portions of the source at depths of 10 km or greater. The largest value of the Near-Source Factor considering all sources shall be used for design.

Table (3-13) SEISMIC SOURCE TYPE[1]

Seismic source Type	Seismic source Description	Seismic source Definition	
		Maximum Moment Magnitude, M	**Slip Rate, SR (mm/year)**
A	Faults that are capable of producing large magnitude events and that have a high rate of seismic activity	M ≥ 7.0	SR ≥ 5
B	All faults other than type A and C	M ≥ 7.0 M < 7.0 M ≥ 6.5	SR < 5 SR > 2 SR < 2
C	Faults that are not capable of producing large magnitude earthquakes and that have a relatively low rate of seismic activity	M < 6.5	SR ≤ 2

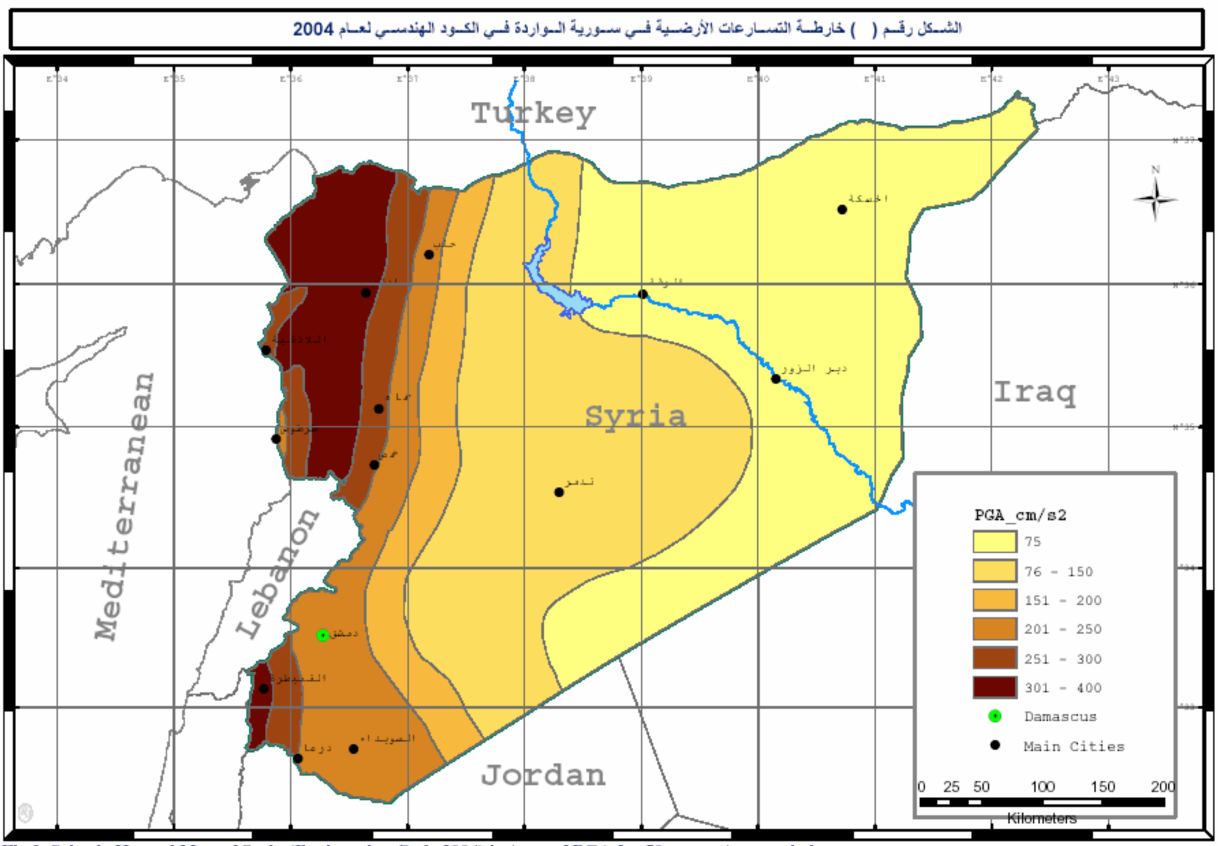


Fig.9. Seismic Hazard Map of Syria (Engineering Code 2004) in term of PGA for 50 year return period.

PGA distribution for 10% probability of exceeding in 50 years (Return Period 475 years)