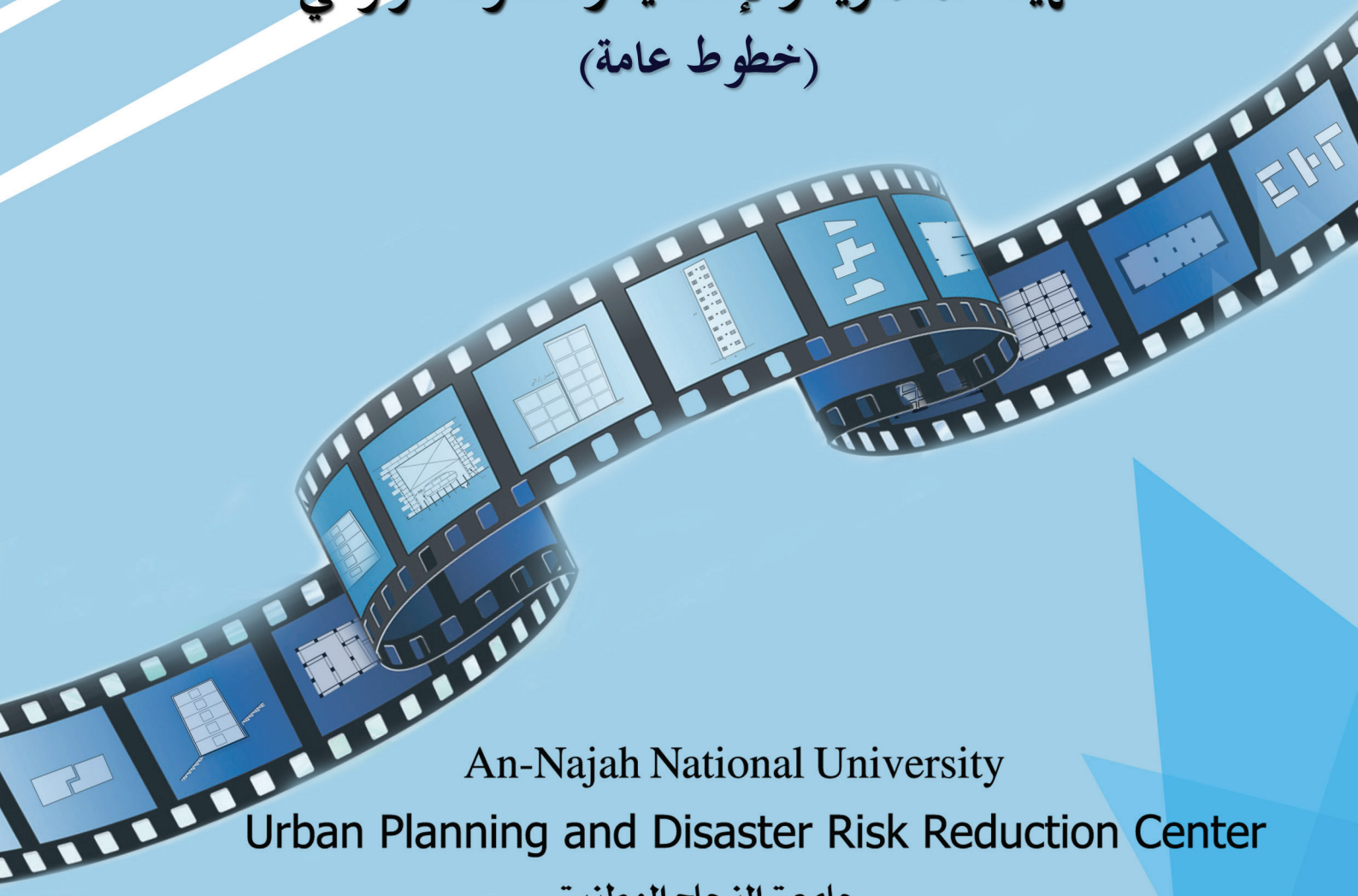
EUCENTRE

IUSS
Sapere Aude
Istituto Universitario di Studi Superiori Pavia

SEVENTH FRAMEWORK PROGRAMME

Seismic Performance and Building Configuration
(Conceptual Design)

الهيئة المعمارية والإنشائية والسلوك الزلزالي
(خطوط عامة)



An-Najah National University

Urban Planning and Disaster Risk Reduction Center

جامعة النجاح الوطنية

مركز التخطيط الحضري والحد من مخاطر الكوارث

Seismic Performance and Building Configuration
(Conceptual Seismic Design)

There are several methods used in designing earthquake resistant buildings, each with a specific safety factor. Normal buildings can be seismically designed using normal design methods or so called "simplified methods". Other buildings such as hospitals, important and/ or sensitive buildings like civil defense, government or public utility buildings require an advanced level of safety.

Generally, a normal seismic design would increase the cost of the building at a rate of 3% -5%, whereas the seismic design of a sensitive or important building would increase the cost at a rate of 10%-15%.

The requirements of the design are determined by the importance of the building and the level of the required safety factor. The alignment of a building to the regulations and standards of the Seismic Performance and Building Configuration will contribute to its ability to withstand seismic forces. This is generally known as Conceptual Design in engineering and participates in decreasing the seismic vulnerability of the buildings.

N.B. For more details on significant regulations related to seismic design please see the tables and figures, or further publications[1].

Generally these significant regulations can be summarizing as follow:

Landslides

Standards seek to avoid building on steep lands, especially those with a rocky terrain or with an unstable geological structure: such as clay soil or marl stones. This type of terrain is prone to problems and movement even without earthquakes. Ideally before deciding to build on this type of soil, a slope stability analysis should be done in order to determine the safety factor against landslide.

Site effect and seismic amplifications factors

This is to avoid seismic amplification (Resonance), which results when the natural frequency of the building matches that of the construction site. Seismic requirements seek to avoid construction on the land where resonance is expected.

Note: To find the natural frequency and the seismic amplification factor of a construction site specific seismic maps or an experimental seismic study of the site is required.

1 - Dabbeek, J (2010): Architectural Design for Earthquake Resisting Buildings, Seismic Performance and Building Configuration, An-Najah National University.

High rigidity at foundation level

Avoid the extra stresses in the structural elements of buildings by ensuring the rigidity of the foundation, through utilizing highly rigid foundations that match the type and nature of the soil.

Weight of building

Weight of the building should be reduced as much as possible. Symmetry and regularity in the distribution of the masses (weights) resulting from the weight of the structural and non-structural elements of the building in the vertical and horizontal plans are required.

Regularity of horizontal and vertical plan

The achievement of symmetry and regularity in the shapes of the vertical and horizontal plans of buildings is required. However, if that is not possible due to architectural and functional reasons or due to the nature and the shape of the land, the use of seismic joints that divide the building into regular and separate parts, or provide the critical zones in the building with rigid structural vertical elements (ex. shear walls) to improve its seismic performance will be essential.

Distribution of vertical structural elements

The distribution of vertical structural elements (Columns and shear walls) symmetrically around axis X and Y is required. In addition, the spans between these vertical elements are preferred to be equal. However, if this is not possible for architectural or functional reasons, the differences between the lengths of two adjacent spans should not exceed 25% for the consecutive vertical structural elements.

It is essential to ensure symmetry, continuity and rigidity of the structural vertical elements (Columns and shear walls), which allows the gradual reduction of the rigidity of the vertical structural elements.

Slenderness ratio of the buildings

It is essential to avoid using slender buildings (a slender building is a building whose height-to-width ratio is larger than or equal four). Where that is not possible for reasons such as the size or the shape of the land, the building is designed as a tower and the seismic design requirements for towers should be achieved.

Adjacency of buildings

The provision of sufficient spacing between adjacent buildings, and between the parts of a building, so as to avoid pounding when exposed to seismic movements. This spacing is designed and executed as a “seismic joint” and the width of this joint (denoted as ‘d’) is calculated according to the design code. The value of (d) mainly depends on the height, width, story height and type of structural system used.

N.B. If there are other kind of joints in the building, they should be executed based on the requirements of the seismic joint.

Soft storey or weak storey

Avoid using or forming the “soft story”, which is to have one or more stories in the building that consist only of columns without walls, and the rest of the stories have columns with infill or bearing reinforced concrete walls. If this is not possible due to architectural or functional reasons, such as the need to use one or more floors for car parking or any other services, a limited number of walls should be integrated and distributed in a way that does not obstruct the movement of vehicles or the function of the story.

Cantilever systems

Avoid using the cantilever systems, mainly with long spans and heavy dead loads. If this could not be achieved due to certain functional or architectural reasons, the special methods for analyzing and designing the loaded cantilevers should be used.

Formation of short columns

The Short Columns or the phenomenon of Formation of Short Columns should be considered because of the high seismic shear forces that may develop in these members. In case the short columns could not be avoided due to any functional or architectural reasons, adequate shear capacity for these columns should be maintained. This is could be done by providing the Required Confinement for the columns by decreasing the spacing between the hoops/stirrups and by replacing the 8mm stirrups with 10mm. It could also be achieved by using concrete with better quality and higher strength.

The short columns can be found in areas between adjacent windows and in column necks below the ground floor. They can also be found when having additional slabs within the same floor.

Reinforced Concrete Frame Requirements

When using reinforced concrete frames, the column should be designed to be stronger than the beam, i.e. adopting the principle of strong column-week beam. In this case, there is a need to use the relevant types and dimensions of the columns. To have a reinforced concrete frame, the following should be performed:

- The long dimension of the column to be with the short dimension of the building and with the long of the room and to be as much proportional as possible.
- Using dropped beams and avoiding the use of hidden beams. The width should not be less than 25 cm and not less than the width of the column.
- Avoid using high longitudinal steel reinforcement in columns (ρs), and using a value which is around the minimum,ρs= 1 %.
- Avoid using high values of the longitudinal tensile steel reinforcement in beams (ρs), and using a value which is around the minimum.
- Increasing the number of stirrups in beams and columns where the shear stresses are high and using a diameter of 10mm instead of 8mm. Also the stirrups should be bent at an angle of 135 degrees instead of 90, thus keeping closed tightly when subjected to earthquake forces. (See attached details on reinforcement).

- Ensuring the continuity of the columns stirrups in the beams at the joint area.
- Considering the building codes for the frames. The moment resisting reinforced concrete frames are classified into three types: Special Frames; Intermediate Frames; and Ordinary Frames, with each one having its own seismic behavior and reinforcement. For more details about the calculation of the horizontal seismic force that the buildings are subjected to, according to the type of reinforced concrete frames, and in addition to the details of reinforcement for each type, see the Jordanian Building Code 2005 and 2006 or other international codes (UBC, IBC, ACI, etc).

External Walls

- Paying close attention to the concrete external walls, reinforced concrete, and concrete-stone walls, through ensuring appropriate details of implementation, and the need to provide uniformity in the distribution of these walls, in view of the important and distinct impact and on buildings behavior under earthquake loading.
- Reinforcement around the openings of windows, doors and roofs (see the reinforcement details attached in the newsletter).
- Ensuring the bonding of the masonry stone walls with the concrete using the appropriate tools to avoid the risk of falling especially in buildings more than four floors.
- Avoid using the concrete stone walls in buildings higher than 10 floors

Non-structural elements

- In both cases, when connecting the non-structural elements with the structural or isolating them, we should not allow the collapse or breakdown of the non-structural elements such as concrete blocks, especially in essential buildings like hospitals.
- Avoiding passing the electro- mechanical installations through the vertical and horizontal structural elements and solving this using the special trenches or ducts.

Common mistakes in local practices

Avoid common construction mistakes:

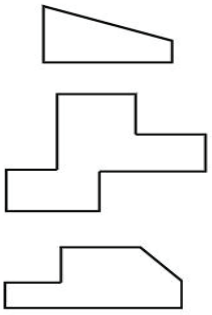
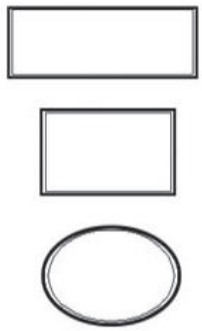
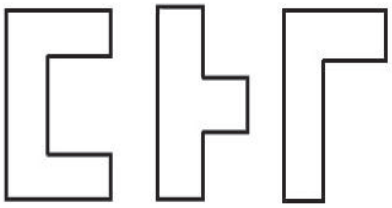
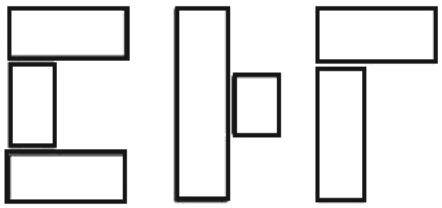
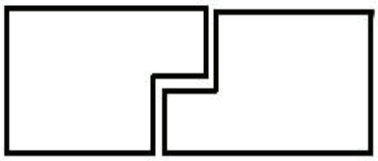
- Making sure the stirrups are fixed properly to avoid moving during casting of concrete.
- Providing sufficient lengths of steel overlap.
- Maintaining the longitudinal bars straight especially at the edges and intersection points.
- Casting the concrete according to specifications, where it is not allowed to cast the concrete at a height over 1.5 m, in order to avoid segregation.
- Maintaining verticality for the vertical structural elements (columns and walls).
- others

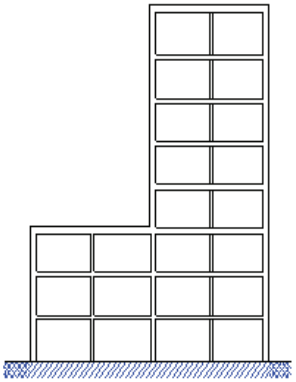
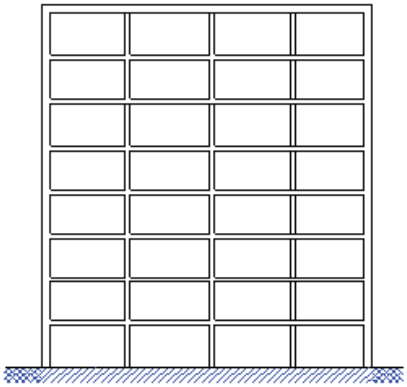
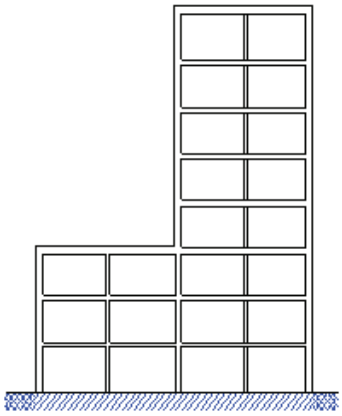
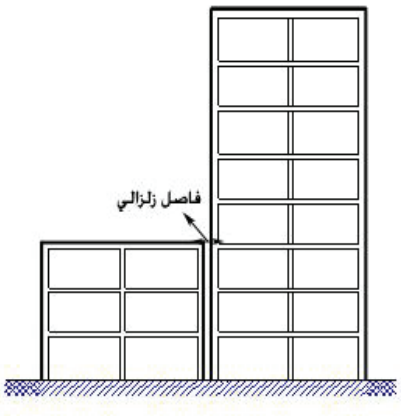
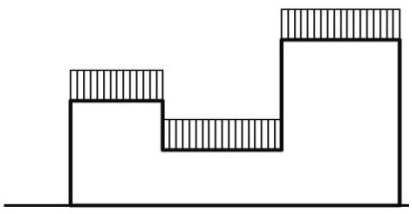
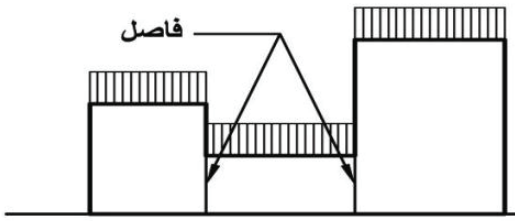
Note: The results of scientific committees' studies show that more than 50% of building failures caused by earthquakes were mostly related to mistakes during construction.

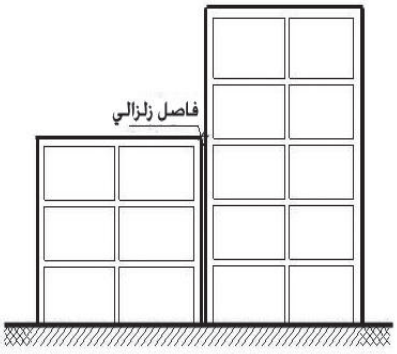
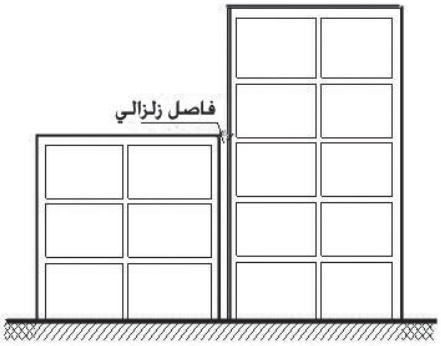
الهيئة المعمارية والإنشائية والسلوك الزلزالي

Seismic Performance and Building Configuration

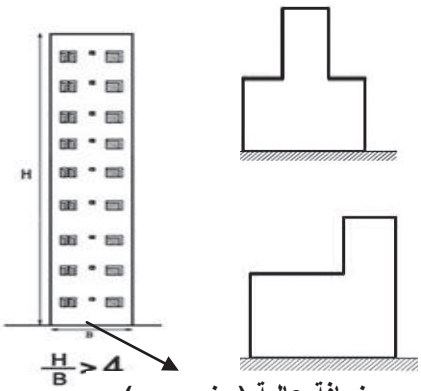
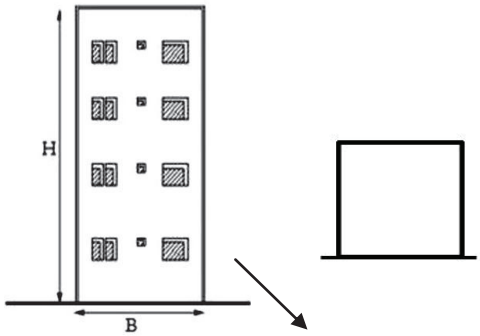
Horizontal and Vertical Configuration of Buildings الهيئة الأفقية والرأسية للمباني

	غير مرغوب، وله قابلية للإصابة الزلزالية (No) Undesirable and Vulnerable seismically	مرغوب ومفضل زلزاليا (Yes) Desirable and preferred seismically
1	 مساقط أفقية عشوائية Irregular plans	 مساقط أفقية منتظمة Regular plans
2	 عدم تماثل المساقط الأفقية للمباني Irregular plans	 يكمن الحل في عمل فاصل زلزالي بعرض كاف أو تقوية منطقة الالتقاء Regular plans
3	مسقط أفقي  خط مسار الفاصل الزلزالي غير مستقيم Seismic joint alignment	مسقط أفقي  خط مسار فاصل زلزالي على شكل خط مستقيم Seismic joint alignment

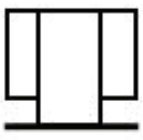
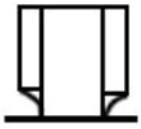
	غير مرغوب، وله قابلية للإصابة الزلزالية (No) Undesirable and Vulnerable seismically	مرغوب ومفضل زلزاليا (Yes) Desirable and preferred seismically
4	 تراجع في الطوابق (Setback)	 انتظام بدون تراجع في الطوابق
5	 عناصر المبنى وكتله متلاصقة (Setback)	 وجود فاصل زلزالي (seismic joint)
6	Without seismic joints  بدون فواصل	With seismic joints  وضع فواصل بسبب اختلاف ارتفاعات المباني أو/ واختلاف الأنظمة الإنشائية

	غير مرغوب، وله قابلية للإصابة الزلزالية (No) Undesirable and Vulnerable seismically	مرغوب ومفضل زلزاليا (Yes) Desirable and preferred seismically
7	 عرض الفاصل الزلزالي غير مناسب ويمكن حصول تصادم بين الجزئين (المسافة صغيرة بين المبنيين أو جزئي المبنى) seismic joints - not suitable	 عرض الفاصل الزلزالي مناسب (المسافة كافية بين المبنيين أو جزئي المبنى) Suitable seismic joint

- التناسب بين أبعاد المباني Proportion of building Size

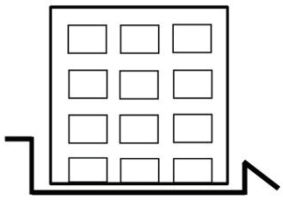
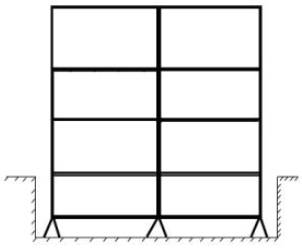
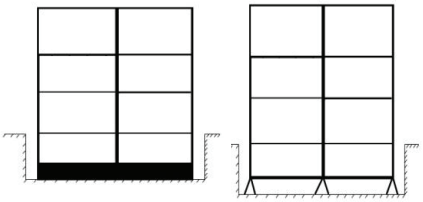
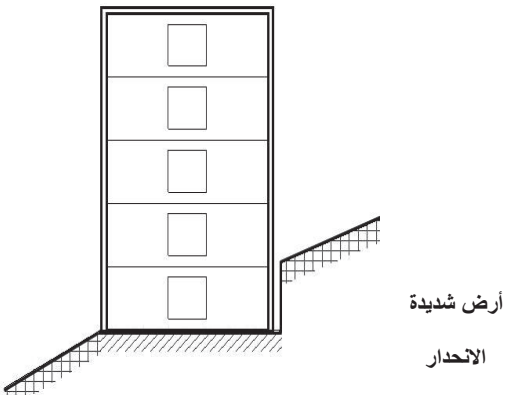
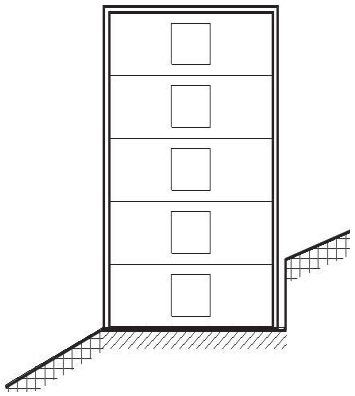
8	 نحافة عالية (مبنى برجي)	 نحافة مقبولة

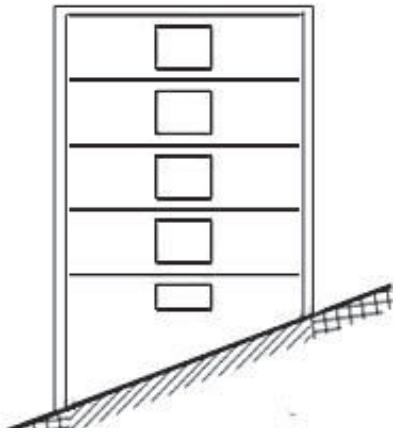
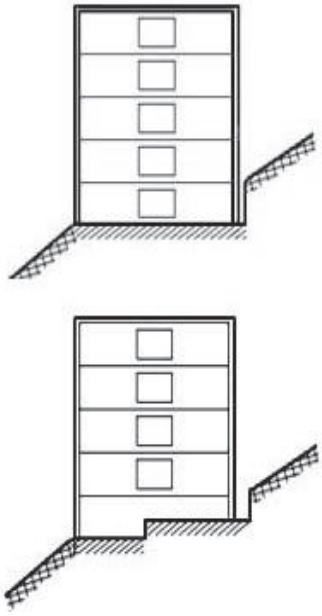
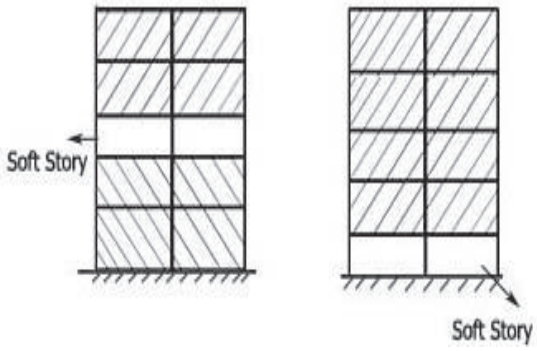
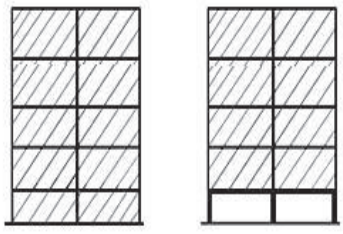
- البروزات المعمارية والطيرانات Cantilever Systems

9	 الطيرانات المحملة	  تجنب الطيرانات المحملة أو تدعيمها بنظام خاص

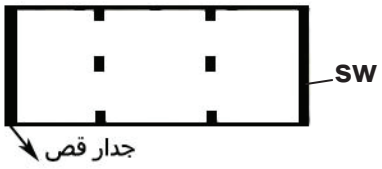
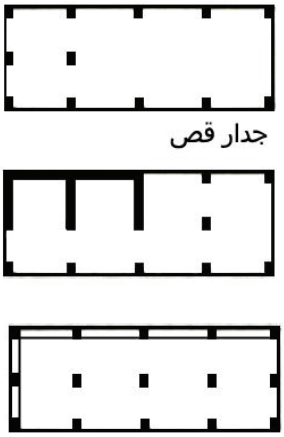
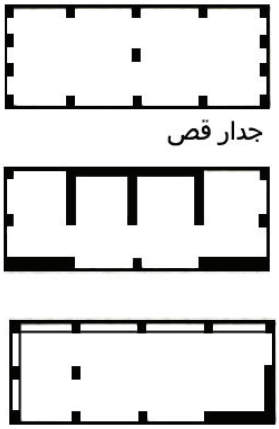
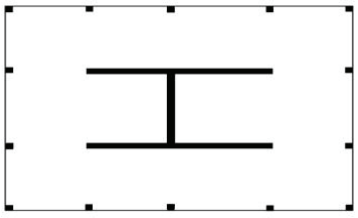
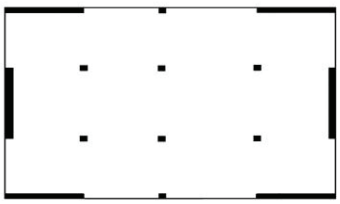
- نوعية التربة وطبوغرافية الموقع وصلابة الأساسات

Site Condition and Rigidity of Building Foundations

	غير مرغوب، وله قابلية للإصابة الزلزالية (No) Undesirable and Vulnerable seismically	مرغوب ومفضل زلزاليا (Yes) Desirable and preferred seismically
10	 البناء على الميول الجبلية بدون جرف يسبب اختلاف في صلابة الطابق الأرضي	 صلابة متساوية في الطابق الأرضي
11	صلابة ضعيفة عند مستوى الأساسات  قواعد منفصله مع جسور ربط ضعيفه Weak tie beams with isolated foundations	صلابة قوية عند مستوى الأساسات  Rigid foundation استعمال القواعد المتصلة أو ربط القواعد المنفصلة بجسور ربط قوية أو استخدام الفرشة، وذلك بما يتناسب مع نوع التربة
12	 تربة الموقع طينية أو حورية Clay or marl lime stone	 أرض صخرية صلبة Hard rock الصخر متماسك وغير مفكك

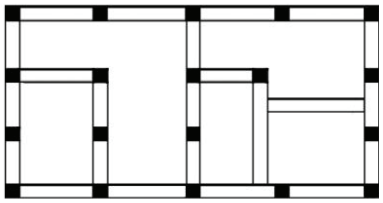
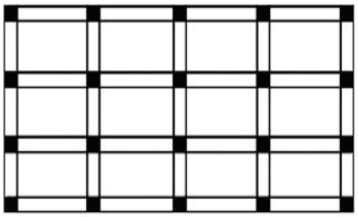
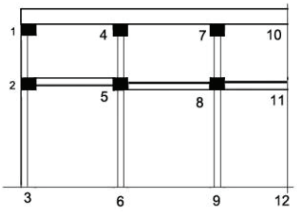
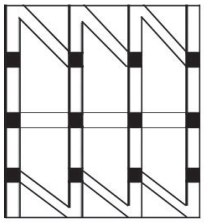
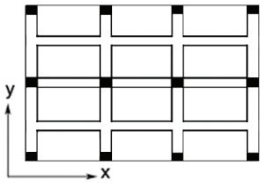
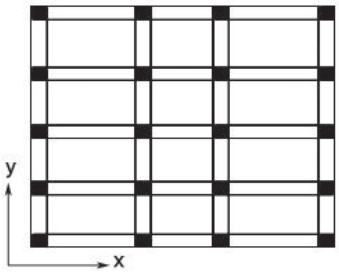
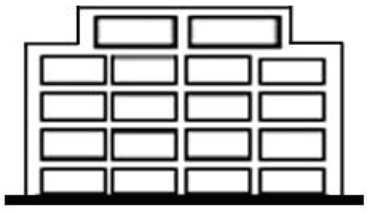
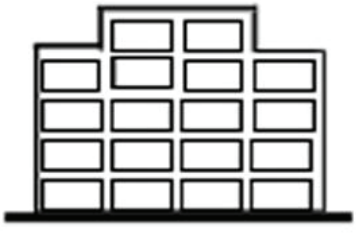
	غير مرغوب، وله قابلية للإصابة الزلزالية (No) Undesirable and Vulnerable seismically	مرغوب ومفضل زلزاليا (Yes) Desirable and preferred seismically
13	 أرض منحدرة - صخرية صلبة Site with slop and hard rock	 أرض منحدرة صخرية صلبة Site with slop and hard rock
		• الطابق الرخو Soft Story
14	 تغيير مفاجئ في صلابه المبنى في المستوى الرأسي تشكيل ظاهرة الطابق الرخو في الطابق الأرضي (soft story)	 زيادة صلابة الطابق الأرضي من خلال اغلاق بعض الواجهات أوعمل إطارات خرسانية مسلحة صلبة جداً Adding few walls or using rigid frame in the ground floor

- توزيع العناصر الإنشائية الرأسية (الأعمدة وجدران القص)
- **Distribution of vertical structural elements**

	غير مرغوب، وله قابلية للإصابة الزلزالية (No) Undesirable and Vulnerable seismically	مرغوب ومفضل زلزاليا (Yes) Desirable and preferred seismically
15	 فرق كبير في الصلابات بين المستويين X و Y	 تماثل في الصلابة في المستويين الافقيين
16	 توزيع غير متماثل للعناصر الإنشائية الرأسية يزيد من عزم الالتواء	 توزيع متماثل للعناصر الإنشائية الرأسية -تقليل أثر عزم الالتواء الدورانى-
17	 توزيع أوتركيز جدران القص في وسط المبنى يحد من قدرة المبنى لمقاومة عزم الالتواء	 توزيع جيد لجدران القص في أطراف المبنى يقلل أثر عزم الالتواء

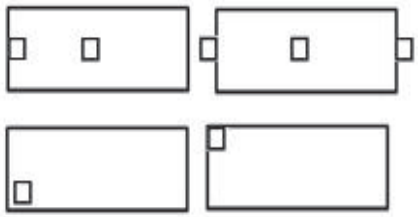
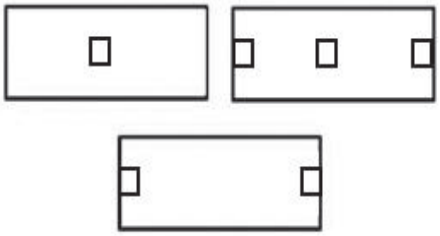
- توزيع العناصر الإنشائية الرأسية (الأعمدة وجدران القص)

Distribution of vertical structural elements

	غير مرغوب، وله قابلية للإصابة الزلزالية (No) Undesirable and Vulnerable seismically	مرغوب ومفضل زلزاليا (Yes) Desirable and preferred seismically
18	 عشوائية توزيع العناصر الانشائية	 توزيع منتظم ومتماثل
19	 تحميل منحرف عن مراكز الأعمدة  وجود الجسور باتجاه واحد فقط   سلوك غير منتظم للإطارات بالاتجاه x	 اتباع نظام الشبكات في توزيع الإطارات والجسور والأعمدة بالاتجاهين x و y يضمن سلوكاً سليماً لها عند تعرض المبنى للزلازل
20	 عدم استمرار الأعمدة العلوية على محاور الأعمدة السفلية	 تأمين استمرارية منتظمة للأعمدة على محاور مستمرة من الأساسات وحتى آخر طابق

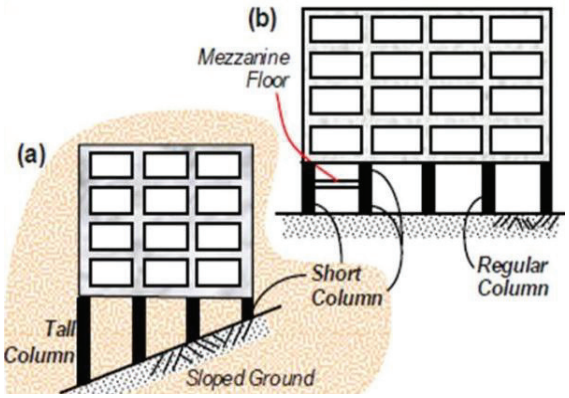
- مكان بيت الدرج والمصاعد

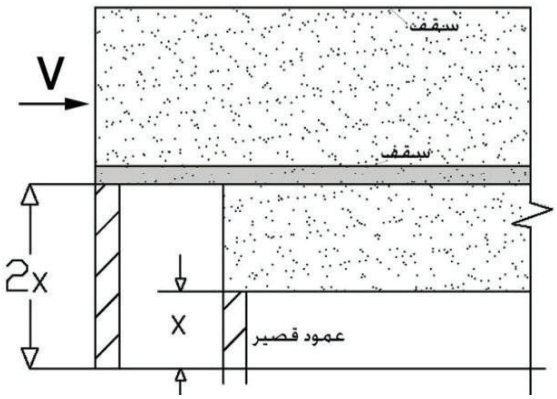
Location of staircase and elevators

	غير مرغوب، وله قابلية للإصابة الزلزالية (No) Undesirable and Vulnerable seismically	مرغوب ومفضل زلزاليا (Yes) Desirable and preferred seismically
21	 توزيع غير متماثل	 توزيع متماثل للعناصر لمكان بيت الدرج

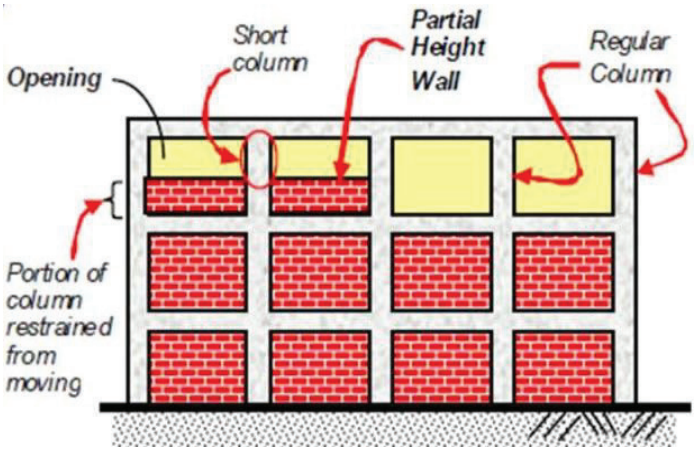
- تشكيل الأعمدة القصيرة

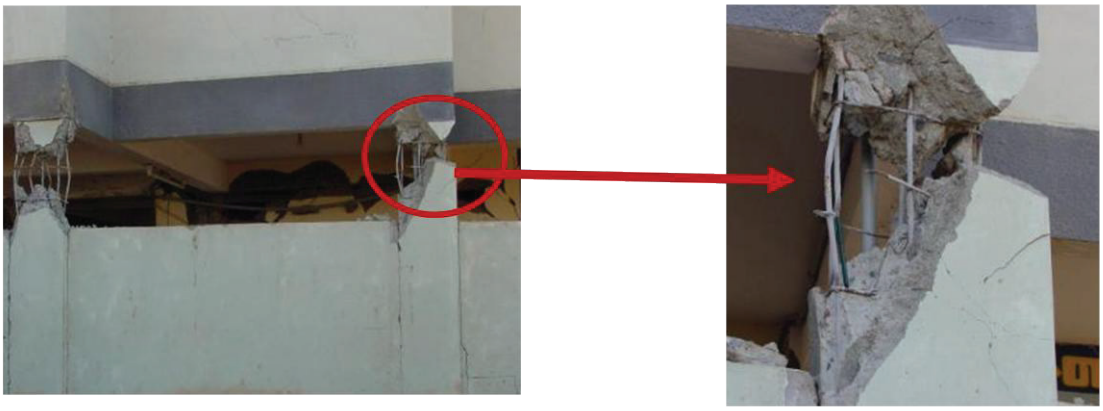
- **Formation of short columns**





يتعرض العمود X لقوى زلزالية مقدارها 8 أضعاف القوى الزلزالية التي يتعرض لها العمود X2

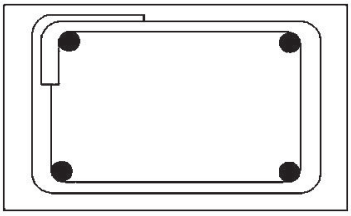


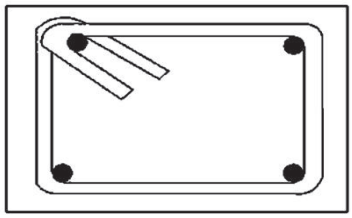


انـهيارات الأعمدة القصيرة تحت تأثير القوى الزلزالية الأفقية

Failures and damages due to formations of short columns and lack of required confinements

- **كانات/ أساور الأعمدة والجسور (Confinement requirements)**

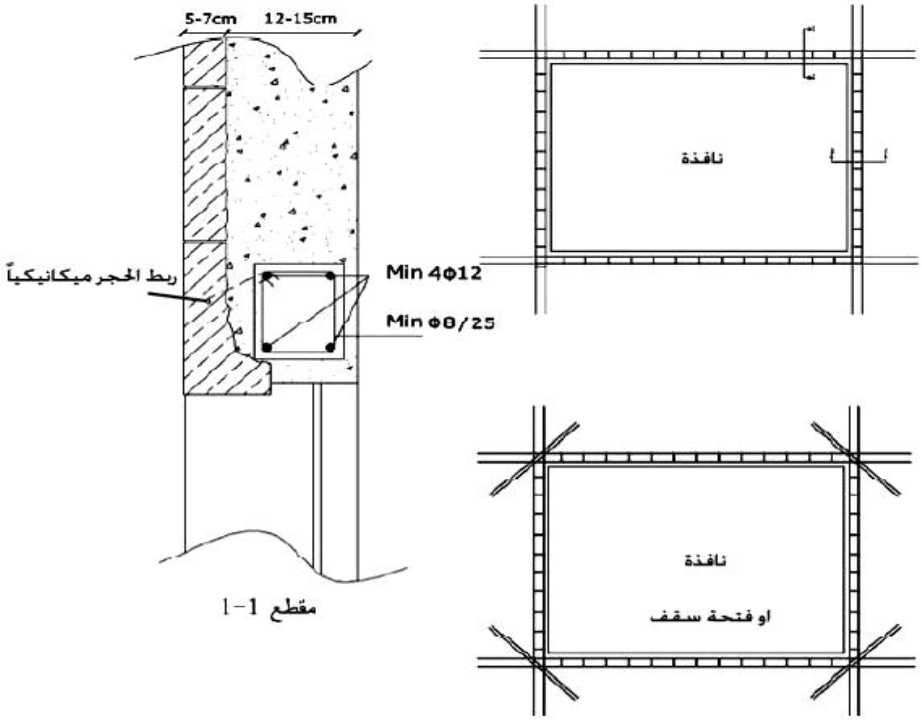


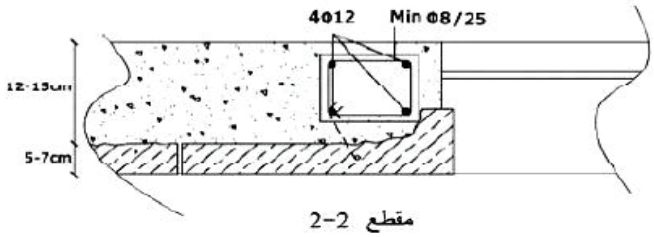


لتأمين الإحاطة المطلوبة (التسليح العرضي المطلوب)، إضافة لزيادة قطر حديد التسليح العرضي يتم تكثيف الكانات ووضع أكثر من كانة في المقطع الواحد للعنصر الإنشائي، وبما يتناسب مع شكل هذا العنصر.

التسليح حول فتحات النوافذ والأبواب والفتحات الموجودة في الأسقف

Reinforcement details around the openings

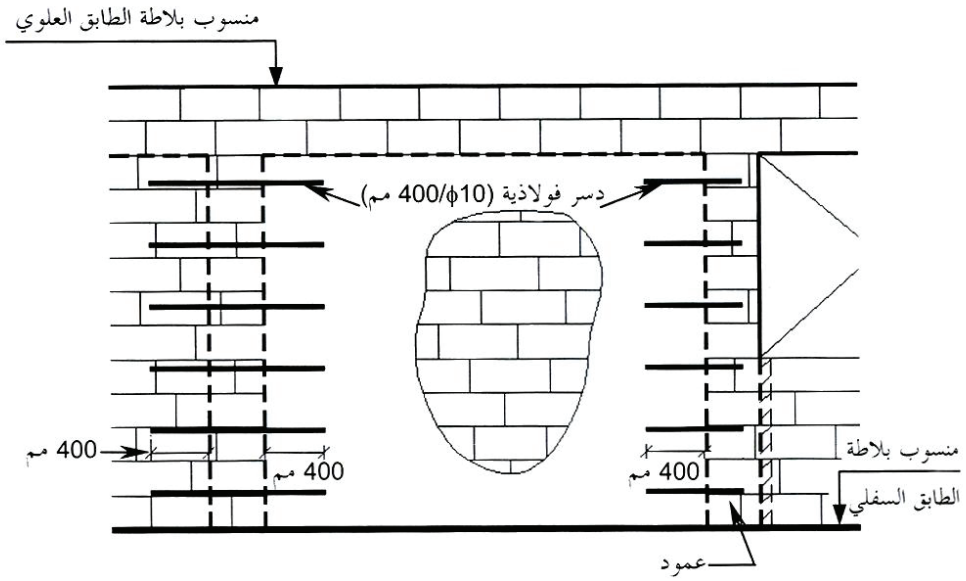




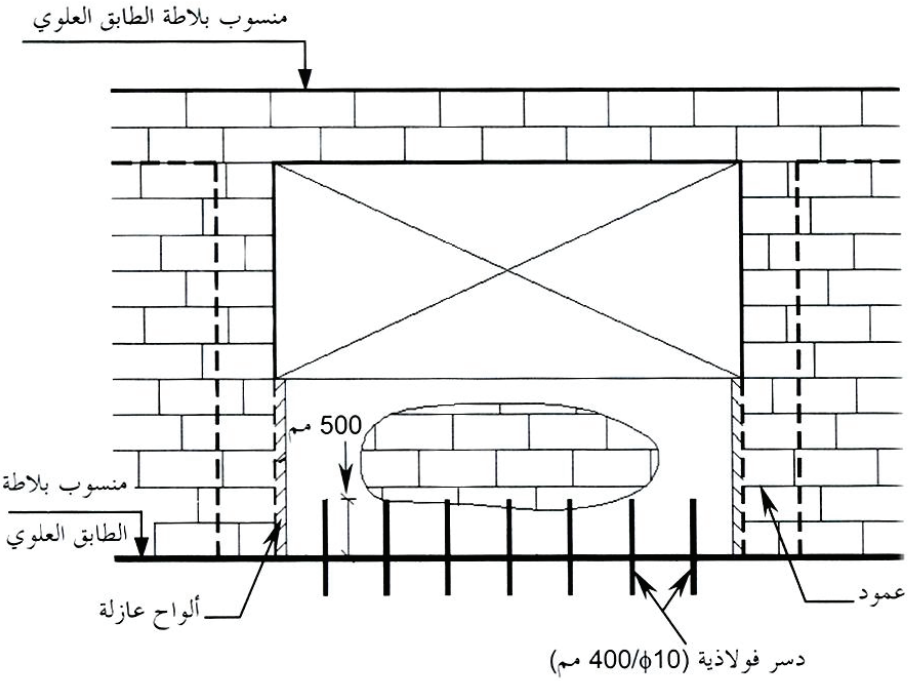
المرجع: كتاب الهيئة المعمارية والإنشائية للمباني المقاومة للزلازل، د. جلال الدبيك 2010

ربط الجدران الحجرية- الخرسانية مع العناصر الإنشائية (النظام الإنشائي)

Fastening the masonry- concrete walls with the structural elements



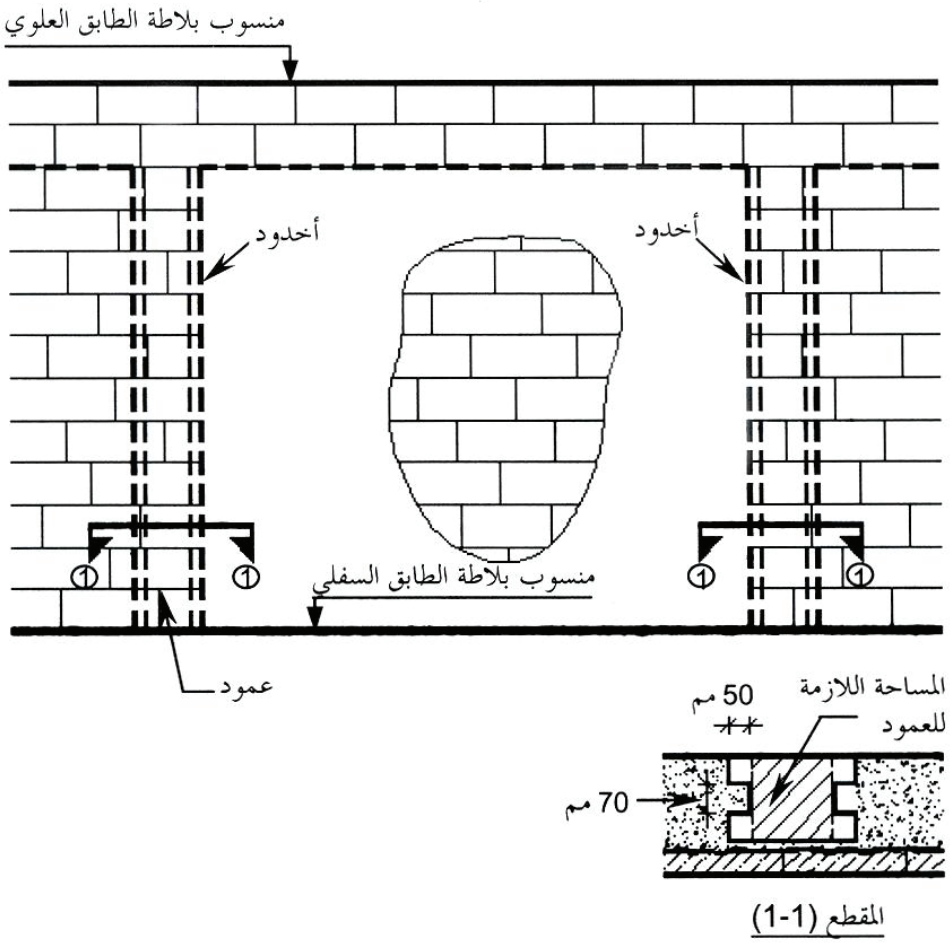
تفصيلة تبيّن الدسر الفولاذية المستخدمة لربط الأعمدة مع الجدار الحجري



تفصيلة للجدار الحجري المُصفّح بالخرسانة في مناطق الفتحات

المرجع: كودة المباني المقاومة للزلازل - الكود الأردني (2005-2008)

تنويه: تربط الجدران الحجرية- الخرسانية مع عناصر النظام الإنشائي للمبنى (الأعمدة أوالجسور)، ويمكن استخدام دسر قطر 8Øمم أو 10Ø مم، ويمكن أن يتم ربط الجدار مع الأعمدة والأسقف (الجسور)



(ج) تفصيلة للأخدود في مناطق التقاء الأعمدة مع الجدار الحجري

المرجع: كودة المباني المقاومة للزلازل - الكود الأردني

المراجع References :

- التصميم المعماري للمباني لمقاومة الزلازل -الهيئة المعمارية والإنشائية والسلوك الزلزالي للمباني، كتاب منهجي، د.جلال الدبيك (2010).

- كودة المباني المقاومة للزلازل - الكود الأردني، 2005 و 2008.

- نشرات التصميم الزلزالي السريع للمباني العادية، الصادرة عن مركز علوم الأرض وهندسة الزلازل، ونقابة المهندسين ، 1996 و 1999.