Constructions Resistant to Natural Disasters and Eco-Friendly sustainable and green Buildings

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Dedicated to my father

A steadfast mountain and supporter of me throughout my life

Dedicated to my mother

The stone of patience that taught me the alphabet of life

Dedicated to my brothers

My kind companions, my life

Foreword

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Construction and methods of strengthening buildings against natural disasters

Earthquake and methods of dealing with it

An earthquake is a sudden tremor of the earth's solid crust that occurs from time to time in areas that are on the seismic dam, usually due to the occurrence of major earthquakes, parts of the earth are broken. Earth's rupture is accompanied by energy depletion and loss, which reduces the severity of the earthquake. One of the problems that occur due to earthquakes in the earth is the movement of faults created by earthquakes and rupture of different layers of the earth and fractures and cuts in buildings, which leads to the creation of areas with less resistance and more vulnerability. The location of settlements and other man-made facilities is completely influenced by environmental and tectonic factors. Today, due to rapid population growth, which has led to the inevitable development of construction, the pressure of human needs on the ground is increasing day by day, and the use of areas around cities and villages to build houses and economic and industrial facilities is increasing.

The amount of damage to buildings in different cities as a result of earthquake vibrations depends on several factors. The most important factors affecting the vulnerability of cities to earthquakes can be mentioned as an example:

1. The magnitude, intensity and duration of the earthquake

2. Geological conditions of the region

3. Maximum seismicity of faults

4. Type of faults

5. Distance from seismic sources

6. The condition of the structures in the area for resistance

7. Proximity to areas with high population density

Factors affecting the vulnerability of cities to earthquakes can be divided into two general categories:

- Factors that are considered as humanizing factors and the way of its development and change process is more human and in general is the result of direct human intervention.

- Factors that are based on natural roots, while how human behavior and interventions can play a decisive role in how this type of natural condition occurs in human life.

Human factors

Type of material

The criterion of the type of structural materials is one of the important and effective criteria in determining the coefficient of vulnerability of cities to earthquakes. Regarding the type of materials used in structures, usually structures made of materials with high strength and standard have good earthquake safety and provide high security for residents. Statistics of past earthquakes show that in most cases, in societies that have always had high economic development and a lot of attention to research, as well as the construction of structures with engineering materials and earthquake resistant, the occurrence of earthquakes of even 7 magnitude It has also caused few casualties and this can be a reason for the very high importance of the type of materials used in the construction of buildings.

Quality of buildings

This index has a very important effect on the vulnerability of the building. High quality (new) buildings are more likely to withstand earthquakes than dilapidated and restored buildings.

It should be noted that the age of a structure does not necessarily have a direct relationship with quality, but in most cases, buildings older than 30 years need to be repaired, At the same time, non-observance of the principles of earthquake regulations in the construction of the building also reduces the quality of the building. The use of durable materials in the construction of buildings is one of the most important factors in ensuring the quality of structures.

population density

An indicator that characterizes the population load in the event of an earthquake, and as a result, with increasing population density, the speed of shelter and delivery and relief services decreases, and vice versa.

It should be noted that the discussion of population density in areas that have many problems due to other indicators is doubly valuable because high population density in these areas, significantly increases the number of casualties.

Family size

A high household size index in a residential unit increases the likelihood of increasing human casualties, so in areas with a higher household size index in a residential unit, there will be a lot of human casualties during an earthquake. In this way, the less free space in residential units, the greater the degree of vulnerability and vice versa. Of course, in discussing the household dimension, it should also be noted that the dimensions of the housing unit can be considered important in relation to the household dimension living in that unit.

Land use

Depending on the user, the probability of vulnerability increases or decreases.

One of the most important activities that is widely carried out in urban lands is residential activities. At the same time, there are uses in the city that are vital in discussing how to control an earthquake crisis and reduce its adverse effects.

That is why in these cases, the importance of the building is raised. The importance of the building is in fact a factor proposed by Regulation 2800 to calculate the seismic force in buildings and indicates that important buildings such as large government offices and facilities, hospitals, fire stations, educational facilities, training centers Excellent and law enforcement agencies should be built with greater reliability than a simple multi-storey building.

The death toll is high if these types of buildings, which play the role of think tanks or crisis management, are destroyed, or if there is a great need for them after the earthquake.

Passages

Network vulnerability deals with the spatial structure of the network and is used in the field of public evacuation to identify vulnerable parts of the urban structure. This vulnerability to the network structure is due to the fact that in the road network, the more intersections there are and the wider the passages, the faster and easier access and assistance is provided; Because if one of the roads is blocked or destroyed, the desired location can be reached from other routes and On the other hand, special attention should be paid to the category of road traffic, and the flow of traffic in communication networks, especially during peak hours. By studying the condition of the passages, the vulnerable parts can be identified at the time of evacuation. In this, ease of access plays a vital role.

Number of floors

The number of building floors is a very important indicator in relation to the ratio of the width of the passages and the height of the walls of the buildings. This is because as the number of building floors increases and the passages become narrower, the probability of the passages being closed due to the rubble of high-rise buildings increases, which disrupts the relief work; Also, due to the large population living in multi-storey apartments, evacuation of residents in these units is slower at the time of the accident.

Building density

It is an important indicator that as it increases, the probability of destruction and vulnerability increases and is the percentage of land area that is used vertically for construction. It is necessary to explain that in the discussion of building density, the width of the passage is definitely one of the important categories in the process of granting densities.

Hazardous facilities

Hazardous facilities are those facilities that are associated with hazardous materials. These facilities can cause secondary hazards such as fire and explosion. In the event of an earthquake, having a list of these facilities and identifying them can minimize the damage.

In the field of user vulnerabilities in terms of compatibility and incompatibility with endangered areas, the issue of user vulnerabilities to each other is raised. So that the deployment of applications that have a high potential for harm, along with other uses, increases the level of vulnerability. Therefore, transferring the above uses or considering the appropriate privacy for them can be a good way to reduce the amount of damage.

Natural factors

Based on the experiences of earthquakes that have occurred in most parts of the world so far, and by examining the root causes and effective destruction of buildings due to earthquakes, most experts believe that the damage to buildings depends significantly on the construction and for this reason, in countries that have done extensive research on the issue of earthquake resistance of structures, in some cases, the destruction of the building during the earthquake has taken place in a situation where the building has fallen to the ground relatively safely, and This is in a situation where it has played a key role in the destruction of structures, land and geological conditions.

In soft soils, especially where the texture of fine materials and materials are saturated with water, subsequent shocks and acceleration increase the vibration waves much more. In the Alaska earthquake, for example, most buildings were damaged, even those built according to building codes, while in other cities the damage was not as great. The type of land on which the buildings were built was the main reason for the difference in the amount of destruction, Because the buildings of this city were built on discontinuous sediments, while the city of Vitter, which was closer to the epicenter of the earthquake and was built on hard granite rocks, suffered less damage.

In general, one of the most important characteristics of soil engineering is the issue of their shear strength. However, a soil mass resists the stresses to a certain extent, and if the stress continues, the soil loses its strength and breaks, and therefore the maximum resistance of the soil to rupture is called the shear strength of the soil and too much stress leads to cuts in the soil. The amount of shear strength in different soils is different and several factors are involved in reducing or increasing the shear strength of the soil, here are the most important factors affecting the shear strength of soils:

- Internal friction between grains
- Soil adhesion

In general, in coarse-grained soils such as sand, the internal friction force is very important, and in fine-grained soils such as clays and some silt, the issue of adhesion is a very important factor in the behavior of soils.

Transverse wave velocity (Vs)

Shear wave velocity factor in seismic vulnerability:

The speed of earthquake waves depends on the specific gravity and lubricity of the rocks that pass through them. The speed of earthquake waves is high in dense and hard rocks and low in lighter and softer rocks. In addition, increasing the pressure increases the speed of the waves and increasing the temperature reduces the speed of the earthquake waves.

Therefore, the velocity of S waves in different formations is different. So that this speed is 3.2 km / s in basalt and 60 m / s in soft sand. The velocity of waves propagating anywhere in the body is a function of the density and modulus of elasticity at that point.

Geotechnical properties of the constituent materials of a site have a major effect on seismic characteristics. Past earthquakes have shown that often, the damage to structures built on soft soils is far greater than that on structures built on hard soils. Studies on strong ground motion well indicate changes in the amplitude and frequency content of seismic waves by alluvium.

عمق سطح ایستابی

Paying attention to the depth of the water table for zoning areas against earthquake risk and the joint impact of water and soil in the study of geotechnical issues and soil bearing capacity is of particular importance. Although in continuously grained soils, the presence of water in the soil itself is insignificant, in some soil layers, a high percentage of fine-grained materials, especially clay particles, are present.

The presence of water resources in these layers is an important factor in reducing the mechanical properties of the soil and reducing the bearing capacity and increasing soil subsidence under load; therefore, it is necessary to study the combined effects of water and soil in places where the groundwater level is high.

The presence of water in the soil has a great effect on the engineering properties of soils and plays an important role in all soil mechanics issues, therefore, due to the presence of water in the soil, if the soil is stressed during an earthquake, only the components and grains of the soil are resistant to deformation or failure, and the water between the pores has no resistance, and consequently the water is neutral It works.

Distance from the fault

Substrates dedicated to urban and industrial constructions should be selected in areas where the boundaries of fault lines are observed and have the necessary stability to reduce the risks of possible earthquakes. for strike-slip faults, a width of between 100 and 300 m is sufficient, while for tensile or normal faults it is up to 500 m. However, in order to observe the boundaries of compressive or inverse faults whose fractures may be formed in several series parallel to each other on the ground, according to the general aspects and executive points, an area between 1000 and 3000 meters along the length of both sides of the fault is considered.

In general, it can be said that in parallel with the distance from the fault lines, we see an increase in the level of desirability in relation to the issue of earthquake risk.

Maximum seismicity of the fault

Due to the accumulation of strain energy in faults and the mechanism of occurrence of most tectonic earthquakes, the length of the fault is one of the main characteristics of an earthquake and the results of most researchers are based on providing a relationship between the length of the fault and its maximum seismicity. Of course, the entire length of the fault will certainly not play a role in storing the desired energy. In this regard, on average, it is assumed that half the length of a fault is lost in the relationship.

Maximum earthquake acceleration

It is a measure of the force exerted on the structure. Some of the characteristics of ground movements include:

Maximum ground motion and maximum acceleration, maximum speed and maximum ground displacement.

The duration of intense movements and frequency content have a major effect on the response of the structure to earthquakes, so that the maximum movements of the earth mainly affect the amplitude of vibrations. The duration of intense movements has a significant effect on the intensity of movement and vibration of the structure, so that an earthquake with a maximum average acceleration and a long duration lasts more damage than an earthquake with a larger acceleration but a shorter duration. The dependence of the maximum acceleration of the earth on the distance to the epicenter of the earthquake has been defined as reduction by many researchers. According to these studies, the maximum ground acceleration decreases with increasing distance to the epicenter.

Earthquake duration

The length of time that a structure is affected by earthquakes is one of the most important parameters in assessing the amount of damage caused by earthquakes. It seems that the repetitive period of ground movements increases the accumulated stress in the soil and the structure on it and in addition to effects such as increasing the pore water pressure, by creating cracks and displacement can erode the natural stability of soil and building materials.

According to estimates, the duration of the earthquake in the soil is longer and almost twice as long as the duration of the earthquake in the rock bed, Also, duration is directly related to the strength of the earthquake, so that with increasing the strength of the earthquake, the duration also increases.

Therefore, damage to buildings, in addition to the method of construction and type of materials used and the type of land on which the structure is built, also depends on the continuity of the earthquake and can even lead to damage if the above principles are observed.

Earthquake retrofitting of buildings

A building, whether metal or concrete, must be resistant to lateral forces (earthquakes) in addition to the required durability in the estimated time for operation.

Today, earthquakes and their irreparable damage are unbearable events for engineers. Reinforcement of buildings has long been done according to the level of knowledge and awareness of the people, but the main problem is to find an efficient and effective way to do so. Choosing the wrong method of building reinforcement can also worsen the performance of the structure, so finding an efficient and appropriate solution to increase the building's resistance to lateral forces (seismic) is the current concern of many engineers. A building needs to be reinforced due to design errors, out-of-date regulations, executive problems, corrosion of materials used over time, increasing the load-bearing capacity of the building, as well as changes in use. So far, various methods have been invented to strengthen the building, which according to the growing needs of society and the advancement of technology, new methods and materials are used to strengthen the building and has replaced traditional methods such as steel jackets, concrete jackets, retractable cables, braces, shear walls ,the use of steel plates and …

Today, new methods such as building retrofitting with FRP, partition panels and… have replaced other traditional methods in the retrofitting industry.

Investigation of traditional methods of building reinforcement

1.Earthquake resistance of the building with concrete jacket

This method is used to strengthen weak concrete structural components such as beams, columns, foundations and shear walls to increase the compressive and shear strength as well as increase the ductility.

In this method, we first make holes with certain distances around the weak members, then we place a steel mesh with ribbed reinforcements around the member. In the next step, the holes created by the epoxy adhesive are filled and the reinforcements are placed in them in a L-shaped shape. Molds are then placed around the member and filled with concrete. The use of concrete jacket increases the load-bearing capacity of the building against lateral forces (earthquakes) and gravity. In the concrete jacket method, by enclosing the concrete, we increase the shear capacity, increase the flexural capacity and also increase the stiffness in the frame joints. No need for fireproof coating, fast connection between members and the possibility of modifying the frame joints are the advantages of concrete jacket, however, using the concrete jacket method, by increasing the dimensions of the structural members and reducing the available space, causes a significant increase in the weight of the structure, Also, the need for high formatting and execution operations and high time and cost, lack of use and damage and damage to other structural members has caused to use newer methods in the building reinforcement industry.

2. Earthquake resistance of the building with steel jacket

Steel jacket is one of the methods of strengthening the weak components of concrete buildings. Building reinforcement with jacket includes increasing compressive strength, shear strength, flexural strength and ductility of the structure. This method does not gain much weight compared to concrete jacket and is easier to implement. Also, like the concrete jacket method, there is no need for molding, so it is not architecturally problematic.

In this method, damaged structural components such as beams and columns are reinforced using steel sheets so that the steel sheets are connected to the damaged member by bolts. Reinforcement of the building with a steel jacket can be done in any section and floor and there is no need to reinforce from the foundation to the desired column.

Disadvantages of steel jacket include high cost, need for fireproof coating in important buildings, Not resistant to fire , difficulty of execution and need for a large volume of grout. The use of steel jacket reinforcement method causes the members to corrode and rust over time, Also, for planting bolts and steel cutters, structural members may be damaged.

3. Earthquake resistance of the building with prestressing and retraction

It is a method for strengthening reinforced concrete buildings and structures that is done by high-strength steel threads or reinforcements.

Prestressing means the creation of a permanent constant stress in a concrete member, which as a result of this constant stress, some of the stresses created by the dead and living load are neutralized which this increases the carrying capacity. In other words, the compressive force required in concrete is produced by tensile strength of high-strength steel.

In this method, the cables are first stretched between the two ends of the element on the prefabricated substrate, The desired element is then concreted and after reaching sufficient strength, prestressed cables are cut at both ends of the beam and the prestressing force is applied as a compressive force to the member or element. As a result, when the steel is stretched before concreting, it is called prestressing. The application of prestressing in concrete slabs on the ground, is the construction of parking lots, buildings and…

Pas keshidegi

In this method, a hollow sheath is installed in the passage of cables or prestressed reinforcement. The cables are then passed through the sheaths so that both ends are out of the sheath. In the next stage, concreting is done. After the concrete reaches sufficient strength, the cables are pulled by the jack and secured with a strap. Stretching is used in the manufacture of precast concrete parts.

The use of prestressed and retracted strengthening methods increases the life of concrete and reduces the dimensions of the foundation and also creates a one-piece concrete roof, which in turn increases safety against lateral loads (earthquakes). It also reduces the height of the beam and the thickness of the slab, which reduces the vibration caused by impact and dynamic loads (earthquake). Also, this method reduces dead load and cracks in the building and increases control and deformation in structures.

In these methods, concrete has the role of full load-bearing without creating cracks and reinforcements are used to control cracks in the lower area. The best way to choose the amount of pre-compression force is to balance the percentage of loads, which leads to a reduction in the amount of steel used and crack control in concrete.

4. Earthquake resistance of the building with Shear wall

By using shear walls in steel and concrete structures, by increasing the stiffness of the structure, in addition to increasing the load-bearing capacity, it causes a unique increase in lateral force bearing (earthquake).

In structural engineering, shear wall refers to a wall that is responsible for neutralizing the effect of lateral loads on the structure. They are called shear walls because these walls create shear forces in the structure to deal with lateral forces. Shear walls are larger than other members of the structure, such as beams and columns, so that it can have a high stiffness, and this causes the shear walls to absorb all the seismic force entering the building. Because the force moves towards the stiffness in the building, the higher the stiffness, the more force is absorbed and damage to other structural elements is prevented.

Shear wall greatly increases the strength, stiffness and ductility of the structure and improves the seismic behavior of the structure and reduces deformation and damage to other concrete elements of the structure. Of course, it should be noted that due to the high stiffness of the shear walls, usually a lot of forces are created in the foundation below them, which requires strong reinforcement of the existing foundation or the addition of piles at the foot of the shear walls. The connection of the shear wall to the structure must be such that it can transfer the floor force to the wall so that the wall can absorb the seismic force and prevent the lateral deformations of the building with its hardness. For this purpose, in the level of the roofs, suitable connections should be established by planting bolts between the shear wall and the slab. It is also possible to establish good coherence between the wall and the existing structure by planting bolts in beams and columns and covering these elements in the shear wall concrete. Such reinforcements in the shear wall must be continuous in the floors so that the seismic forces can be continuously transmitted at the height of the wall from top to bottom and finally to the foundation. We cut the hard wall in certain places that we want to transfer the seismic force there.

Things to consider in shear wall design are: high energy absorption capacity, high strength, ductility and minimal reduction in stiffness. Because if the shear wall is not designed properly, it is prone to shear failure. The shear wall is located in the peripheral areas of the plan for a better position of the center of gravity so that it absorbs and neutralizes dead loads and maximum tensile and flexural stresses due to lateral loads. The deformation of the shear wall structure is in bending. Shear walls can be flat, but L-shaped, T, I and U-shaped profiles are used to create more flexural stiffness and better plan compatibility.

5. Earthquake resistance of the building with braces

The use of braces in strengthening the concrete building against earthquakes is a very efficient and effective method that in addition to increasing the shear strength and increasing the stiffness of the building, reduces the need for structural ductility. Earthquake resistance of the building with braces also, like the shear wall method, it increases the stiffness and strength of the frame. Faster execution of the brace than the shear wall has made it more common. Improper implementation of braces causes torsion and instability of the structure. In the bracing method, the added members must have high compressive and buckling resistance. Braces are also made using studs and shields as well as I-shaped and are used as X, K and V-shaped between two columns in the floors in one or two directions of the building.

Braces are generally divided into two categories: convergent braces and divergent braces. Due to the difficulty of implementation and high cost, the divergent system is not very common in earthquake resistance of buildings. Convergent bracing systems (cross braces) have received unparalleled attention in the steel and concrete building reinforcement industry. Braces may be designed to withstand tensile and compressive forces, but are more designed to withstand tension.

In low-rise buildings with low lateral loads, braces that only withstand tension are responsive. When using braces, adjacent columns should be reinforced for cutting and also the foundation should be controlled to increase the force due to the tension and pressure created. The advantages of using braces in building reinforcement include suitable speed for execution, reasonable cost to increase and strengthen the rigidity and strength of the structure and its appropriate weight. Concentration of forces in the braced opening, increasing the axial force in the columns and, of course, the need to strengthen them, creating high forces in the foundation and the need to strengthen them are the disadvantages of braces.

Investigation of new methods of building retrofitting

1- Earthquake resistance of the building with FRP method

With the advancement of technology and the growing need of society for easier and more efficient methods and covering the weaknesses of traditional methods in the building retrofitting industry, the use of polymer composite materials called FRP in the building retrofitting industry, a new and efficient method, and It is a good alternative to the classic methods mentioned.

FRP materials are made from a combination of fibers and resins. In the retrofitting process, resin (epoxy resin) is used to create an integrated layer, as well as the FRP system adhering to the concrete surface and creating a coating to protect the materials. FRP retrofitting method, like other traditional methods, does not have the increase of element dimensions, weight increase of structure, difficulty of execution, damage to other structural members, cessation to use during retrofitting and other disadvantages of previous methods. The use of FRP is very important due to its low weight, high execution speed, high strength and no architectural restrictions, especially in concrete buildings. The use of FRP method, in addition to strengthening the building elements, protects the structure against chemical corrosive agents. FRP fibers have a very high tensile strength compared to steel sheets. The use of FRP increases the flexural strength, shear strength, compressive strength of the element, as well as corrosion resistance and increase the durability and life of the structure, increase ductility and control the crack width are other advantages of using FRP. FRP can be used to reinforce a variety of building elements such as beams, columns, walls, foundations, slabs, etc.

2. Earthquake retrofitting of buildings with seismic isolation method

In earthquake resistance of buildings is using seismic isolators to control seismic vibrations from the ground to buildings. In this method, the main goal is to reduce the seismic response, force and acceleration of the earthquake input to the structure. Seismic separators are installed horizontally to create flexibility at the base of buildings. In addition to separators, Miran (moving) components are used to limit the range of motion caused by the seismic force. Installation of buildings on a seismic system prevents the transfer of much of the horizontal movement of the earth to the building (reduces the effect of the earthquake by up to 80%), which leads to a sharp reduction in floor acceleration and interclass displacement.

A seismic isolator must be able to withstand the vertical forces due to the weight of the structure and the earthquake response during an earthquake. It most have high absorption capacity and also have the necessary flexibility in the horizontal direction.

Types of seismic isolators

1- Rubber separators

• Rubber separators with steel sheets and low damping

• High damping rubber separators

• Rubber separators with lead core

Rubber separators are used to increase the natural periodicity of the structure.

2- Friction separators

• Friction separators

• Friction elastic separators

• Pendulum friction separators

Friction separators are used to control the maximum force transmitted to the building and energy dissipation at the separator site.

For simultaneous use of the capabilities of rubber and friction separators, these two systems are combined in the following cases

• Combination of friction and rubber separators series

• Parallel combination of friction and rubber separators

Advantages of seismic isolators

• Maintaining the use of the structure during and after the earthquake and providing uninterrupted performance level (IO)

• Reduce the seismic force applied to the structure by more than 60%

• Reduce structural and non-structural damage to zero

• Reduce the volume of materials required for construction by more than 20%

• Reduce the need to use lateral bearing systems such as braces or shear walls

• Usability in existing structures

3. Earthquake retrofitting of buildings using dampers

The use of dampers or dampers in earthquake resistance of the building is an efficient and modern method. The main role of dampers is to dissipate seismic energy entering the building, as a result of which the seismic force either does not enter the building or a small part of it goes to the building. Reduce floor relocation and relative displacement of floors (drift), significant reduction of floor acceleration, reduction of construction cost due to the use of sections with less capacity and also reduction of possible damages are the advantages of using dampers. The building resistant to dampers against all kinds of dynamic loads caused by earthquakes or winds shows appropriate and desirable behavior

Types of dampers

External damping of viscose (bare)

It is a type of damping caused by air, water and environmental conditions around a structure and in comparison with other types of damping is very small and in most cases can be ignored with a good approximation.

Friction damping

This damping, also called Columb damping, is caused by friction at joints or support points. It is constant regardless of speed and displacement and is dealt with in two ways depending on the amount of displacement. If the amount of displacement is small, it is considered as a bare internal damping, and if the amount of displacement is large, it is considered as a hysteresis damping. An example of this attenuation is in the case of interframe masonry walls, where the physical friction increases when the wall is cracked and there is an effective resistance to vibration.

hysteresis damping

This damping occurs when the behavior of the material under the reciprocating load is in the elastic range. The area of the hysteresis cycle actually represents the amount of energy lost in each loading cycle.

Radiation damping

When a building vibrates, elastic waves propagate in the infinite environment of the ground beneath the building. The energy injected into the structure is quenched in this way. This damping is a function of the Young's elastic coefficient (linear), Poisson's ratio (U) and the density (P) of the earth, and also depends on the mass per unit area of the structure (A / M) and the stiffness coefficient on its mass (m / k).