Improving Resilience Of Healthcare and Critical Facilities

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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

Resilience of vital centers such as hospitals, airports, fire stations, etc. against natural disasters and emergencies is one of the main concerns of countries and their engineers, whose service in these conditions is very important. Especially hospitals, which play an essential role in the current situation in the world, where the coronavirus has reached the epidemic stage. In this book, it is tried to first evaluate the existing buildings in terms of vulnerability to multiple hazards and then to examine them in terms of structural and non-structural safety, and according to the various solutions available, retrofitting is performed. In the following, the construction and implementation of hospitals are analyzed and examined. It is hoped that this book will be a small step towards helping to build and sustain vital centers in our beloved country.

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Vulnerability assessment against multiple hazards

Earthquake response and its relationship with urban planning

Iran has always witnessed large earthquakes and heavy damage due to its geographical location and location on the global earthquake belt. On the other hand, the classification of Iran's geographical area based on historical data shows that Tehran province is ranked sixth in the country with 15 destructive earthquakes throughout history. In addition, Tehran is one of the cities on the earthquake line. Of course, most cities in Iran have such conditions. But according to experts, the only city that may be severely damaged by a moderate earthquake on an engineering scale is Tehran (Zangi Abadi et al, 2009: 93).

In addition, considering the unique features of Tehran such as intense construction concentration, lack of open spaces, non-compliance with the required standards in most structures in different areas (especially the central context), large population, non-compliance with per capita and ... in case of danger , It faces many different problems compared to other cities, making the sensitivity of this issue even clearer. Therefore, it seems necessary to use alternative methods beyond construction measures to increase the safety of the city against earthquakes. In this regard, recognizing vulnerable and resilient areas in the city and proper planning to prevent or reduce the effects of potential danger is very vital and important. On the other hand, such a study can be considered as the most effective method of optimal allocation of urban resilience funds.

Common adverse effects from natural disasters, including earthquakes, include a combination of physical damage and dysfunction of urban elements. Destruction of residential areas, road network and access to bridges and communication roads, basic facilities such as water tanks, power plants, telephone lines, electricity, water, gas, etc. pipelines are among them. In addition to direct damage from the destruction of buildings and facilities, damage from consequential events such as fires, floods from breaking dams or pipelines, falling mountains, and the spread of hazardous materials must also be considered.

In addition to the stated injuries, the rate of human casualties is another factor that increases the dimensions of the crisis. The death toll increases especially in densely populated areas or when the tissue is compacted and the buildings are close together and not earthquake resistant. Some of the casualties in the days following the earthquake are due to floods, water cuts or pollution, injuries and lack of public health, especially due to the concentration of population in the camps and the prevalence of certain diseases, lack of food resources (Hamidi, 1995: 1654).

According to the description of the earthquake, its characteristics and effects, it can be said that the earthquake is not only a disaster but also one of the most unavoidable natural events that cause the forces trapped in the earth's crust to be released and depreciated and the bed of human life and activity of billions of years has restored inner peace.

In fact, earthquakes as a natural phenomenon in itself do not lead to adverse consequences, what makes this phenomenon a disaster is the lack of prevention of its impact and unpreparedness to deal with its consequences and until the human habitat is not adequately protected against earthquakes, we will inevitably have to wait for its many damaging consequences. (Habib,1995:1654).

In general, disaster equals the sum of vulnerabilities and risks (Mohammadi & Mosayeb Zade, 2008: 118) this means that it is vulnerability to natural hazards that exacerbate their effects and consequences. Therefore, the main issue regarding how and to what extent the earthquake affects the settlements is to identify the vulnerability of urban environments and the causative factors and measure it.

Vulnerability

Urban vulnerability is the amount of damage that occurs in the event of an accident to a city and its components and elements (Pooyan & Nateghi Elahi, 1999:777)

In the earthquake literature, vulnerability is defined as the degree of tolerance, resilience or rescue from the effects of a natural disaster in the long run and similarly in the short term (Habibi et al,2008;29)

Studies on vulnerability have generally focused on two areas:

Preliminary studies on accidents have identified risk factors as the cause of vulnerability. Accordingly, the vulnerability of residents of seismically active areas or flood-prone areas is due to living in these areas, and in areas where the frequency and severity of these phenomena are higher, the vulnerability is higher.

Another group of studies in this field focuses on the fact that risk is a normal physical feature of the areas where accidents occur and the vulnerability of different groups of people living in high-risk areas varies depending on their standard of living and their social and economic status in different parts of the world, Vulnerability is therefore not the result of risk-taking but of social, economic and political processes and accident is a final state that arises from these processes (Pooyan & Nateghi Elahi,1999:778-779).

There are different strategies to deal with the effects of earthquakes and reduce vulnerability to it, and urban planning as an interdisciplinary knowledge can play a major role in achieving the goals and plans of each of them at the residential level.

In the following, after introducing some of the most common solutions to earthquakes, the role of urban planning in this regard will be explained.

Crisis Management

Crisis management refers to a set of measures that are taken before, during and after an accident to reduce its effects and complications as much as possible. These actions vary according to the types of natural and environmental disasters that occur (Abdollahi, 2004: 60).

Earthquake crisis management can be interpreted as mobilizing and organizing all the facilities and capabilities of the country to deal with the crisis caused by the earthquake and turning it into normal conditions and an opportunity for the optimal reconstruction of vulnerable cities (Takbiri, 2005: 51).

Accident planning

It is known as one of the types of urban planning and is a comprehensive process for creating preparedness and response in the face of accidents, which is carried out in two time periods before the accident and after the accident. Pre-accident planning is a set of actions that either prevents the accident or reduces its complications and prepares the community to respond to the effects of the accident and is divided into three stages of accident prevention, reduction of accident complications and preparedness against it. Post-disaster planning is a process to determine the necessary post-disaster measures to make the best use of available resources and facilities which includes the stages of immediate rescue, reorganization and reconstruction (HatamiNejad et al, 2009: 2).

Risk management and risk assessment

At present, due to the natural, social and physical risk management conditions prevailing in urban spaces, to deal with natural disasters, especially earthquakes, which can not be accurately predicted, risk management or risk is used instead of crisis management. Risk-taking is defined as the uncertainty of the occurrence of damage (Ahmadi & Sheikh. Kazem, 2006.2).

One of the most important pillars of risk management is disaster risk assessment. There are two issues in disaster risk assessment: One is to clarify urban planning in relation to disaster prevention, which includes the structure and environment of the city. Another is to estimate the demand for damages.

Guiding principles in contingency planning in disasters

1.Contingency planning should be a continuous process. There is no end to planning, so the program must be constantly tested, modified and reviewed.

2. Contingency planning is a process for being aware of the unknown in the event of an accident, so the plan should consider all possible situations and think about them. It is not necessary to prepare a plan for all the risks, but it is better to consider the most probable ones.

3. The main purpose of this program is to determine and determine appropriate actions in the event of accidents and disasters, so the responsibilities and duties of all individuals and personnel must be carefully defined.

4. Contingency planning should be based on the probability of occurrence of events, recorded hazards and the scenario of accidents and disasters that are likely to occur.

5. Contingency planning should be based on accurate knowledge and evidence and information on available hazards and conditions.

6. Planning should be considered as an educational activity so that participants can learn more about their organization.

7. The planning team should be proportionate, and all influential people should be involved in the planning, and the group should be well supported.

8. Planning should be as simple as possible and should not be confusing, simplicity is the best policy.

9. The program must be flexible and usable in any situation.

10. Contingency planning should be a starting point for disaster response measures.

11. Contingency planning should enable the development of emergency response strategies.

Contingency planning process in disasters

1. Project definition

2. Forming a planning group

3. Analysis of possible problems based on a specific scenario such as an earthquake

4. Resource analysis

5. Description of duties and responsibilities

6. Explain the management structure

7. Development of strategies and systems

1.Project definition

At this stage, the goals, scope and context of the program should be stated and the actions required should be described, as well as the resources needed to take action at this stage. The above step should be based on risk analysis and risk analysis performed in the previous steps. For example, developing an earthquake preparedness plan for a hypothetical hospital with the goal of keeping it active, increasing hospital capacity by up to 50 percent, evacuating unnecessary wards, and establishing stable relationships with operations guidance centers is an example of a project definition.

2.Forming a planning group

The hospital contingency planning group consists of different people. The composition of this group is determined in such a way that the participation of all units in the design, collection of required information, executive guarantee and commitment of the units to the program is maximized. The following criteria are recommended for selecting group members:

- Group members should be aware of their duties and unit role in the event of a disaster.

- These people should be actively involved in the stages of prevention, preparedness, response and recovery in previous incidents and be experienced people.
- These individuals need to have a good legal status on their behalf to accept responsibility.
- These people need to have the ability to participate in the planning group.

3.Analysis of possible problems based on a specific scenario such as an earthquake

At this stage, with more details, the risks, vulnerabilities and their causes, possible response strategies, response preparedness and recovery strategies and the initiators of these strategies are reviewed and analyzed, and the necessary information is provided for the next steps. Also, the analysis of problems at this stage should be based on possible scenarios such as earthquakes, floods and fires.

The table below shows the analysis of possible problems during lightning floods.

Possible problems	Hospital flooding
The reasons	Lack of hospital readiness and problems in building engineering and non-standard height of the hospital in relation to the city and reputable rivers
Strategies Preventive	Designing a seal around the hospital, early warning and evacuation of hazardous areas, forecasting suction pumps and drainage
Response strategies, recovery	Evacuation of hazardous areas, use of suction pumps and drainage of water, ensuring health and safety in evacuated areas, transfer of patients and personnel to safe areas
Incident initiator	Heavy rains and siege of the hospital with water, destruction of vegetation in

	the area and disregard for rivers

Preventive strategies refer to all the measures that are put on the agenda to prevent the occurrence of a possible problem. These measures must be taken in the pre-accident phase.

Response strategies and improvement of all actions taken at the time of the accident to deal with the problems caused by the accident. In this case, the problem has not been prevented before.

By analyzing possible problems, accident management strategies are extracted, and if these strategies are extracted by members of the planning committee as expert forces, they will be very practical and will provide a basis for generating new ideas. The important issue is that because the group is responsible for implementing prevention, preparedness, response and recovery strategies, their participation in the development of these strategies from the beginning increases the guarantee of their implementation.

4.Resource analysis

At this stage, in order to implement the developed strategies (prevention and response), the following items are identified:

What resources and facilities are needed, what is the current state of inventory and storage of resources, what is the gap between the need and the current situation, and who is responsible for filling this gap? The following questions may also be helpful at this stage:

- What are the preventive response and recovery strategies?
- What resources are needed to implement these strategies?
- What resources are available?
- What organization, unit or individual is responsible for these resources?
- What is the difference between available resources and required resources?
- If there is a difference, who is responsible for compensating for this deficiency?
- Is the use of available resources effective in these circumstances or not?

Predicting the resources needed for the actions taken in the event of a disaster is one of the main pillars of the program and providing adequate and sufficient manpower is essential.

5.Description of duties and responsibilities

In formulating a plan, it is necessary that the job descriptions of individuals be precisely and clearly defined, and as a general rule, that each person assume the same responsibilities that he or she was normally responsible for performing.

6.Explain the management structure

In designing the accident command system, the program and structure of the national hospital management should be considered. The model of the national health management program is also the accident management approach in hospitals. In order to create an agile, light and efficient management structure, it is necessary to define the accident command system based on the national model of the hospital accident command system and the position of each person in this system and the job description of each post to be fully and comprehensively defined. To play their role. Obviously, under normal circumstances, the hospital management operates according to its current and current structure, and the Accident and Disaster Committee, headed by the head of the hospital, develops the hospital accident command system and follows its training. In any case, establishing an accident command system is an important step that is one of the pillars of accident management. The most important management concept that should be considered in the management structure is coordination.

Coordination means regular and systematic analysis of available resources and providing relevant information for the components and elements of the organization, individuals and other organizations. For example, the coordination center collects information on the extent of injuries and injuries, the status of health care centers, the number of trained personnel, resources, and the transfer of this information to health-related organizations and units.

In order to streamline the operations of the hospital accident command system, the use of the well-known model of intelligent command can provide empowerment tools to hospital managers and staff to perform their duties in the best way.

Five components of intelligent command

1. Command: This component of the five components of intelligent command puts an individual in charge of directing the entire operation and, by delegating full authority, allows him to execute his decisions correctly, which are the result of analyzing the situation and the information received. All units must carry out the commander's orders well and be accountable to him. Individual guidance by the commander is exercised vertically and commands are in all operational categories.
2. Control: It is to monitor and influence the whole process of operations and it is necessary to consider all developments and variables at the time of response and even if necessary for the unforeseen variables and affecting the process of operations, appropriate decisions are made.

Control involves stopping the spread of the crisis, and this is considered the first step in crisis control. In short, control is finding the causes and controlling problems. Speed of action is the key word in control. If the command fails to exercise proper control over the incident, the emergence of secondary crises resulting from the primary crisis is definite, in which case sometimes the secondary harmful effects can appear more complex and pervasive than the incident itself.

3. Connections: Proper communication requires effective and two-way flow of information between headquarters and queues. This relationship is established internally and externally. The tools of this important discussion should be designed in a multi-layered way so that if one layer is disturbed, communication in other layers will not be a problem. Communication with the mass media and informing the public about the crisis situation can be effective in controlling the scope of the crisis and prevent the emergence of secondary crises resulting from the primary crisis.
4. Computer: Creating a secure computer network can provide fast, low-cost and direct communication between the various layers of operations and command, and the use of this technology can be very effective in data classification, data analysis and analysis, and information production.

5. Information intelligence: The key to crisis decision making is to turn the received data into smart information. This issue is so important that crisis management is considered as information management. In order to make the right decision, information and data should be collected and summarized from the current and current situations, as well as from the public opinion and the demands of the officials and the analysis of the surrounding environment. To create information intelligence, four principles must be considered:

1. Orientation of data

2. Data collection

3. Data processing

4. Distribution of information between officials and respondents to the incident and the public

In short, information intelligence is knowing the situation and the situation to find the best solution to problems.

The role of urban planning in dealing with crisis and reducing vulnerability

The first and most important role of urban planning and especially urban planning in dealing with crises is to increase safety in settlements. In other words, creating a safe environment is one of the most basic goals of urban planning. On the other hand, the role of urban planning in crisis management and prevention of its effects cannot be ignored, which is described below.

Settlement safety and urban planning

In general, there are two basic solutions for the safety of biological centers against earthquake hazards.

The first solution is the relative stability of urban elements and components against earthquake hazards.

By observing the criteria and strategies related to effective spatial, physical and functional factors, physical injuries can be minimized during an earthquake in order to minimize human, financial and functional injuries caused by physical injuries and consequently social and economic injuries. In this case, the need to follow the rules and strategies related to the rest of the sequence of the time of the earthquake is minimized. Therefore, the role of urban planning will be limited and the main role will be played by engineering and design of physical elements (buildings, structures, etc.) and installation and equipment elements.

The second solution is the relative resilience of the city against earthquake hazards. ننوشتم.

In this case, the role of urban planning is very important (Jadali, 1995, 1605)

What has so far been considered as safety has paid less attention to the second solution (relative resilience of the city to earthquake hazards) and in fact, much of the scientific effort to reduce earthquake hazards has been in the field of civil engineering, ننوشتم

But among these various levels, the most effective level to reduce the vulnerability of cities to earthquakes is the middle level or urban planning (Ahmadi, 1997: 62-64).

Crisis management and the role of urban planning

Establishment of many human settlements on lands exposed to natural disasters, especially in Iran, attention to policies and programs to reduce harm and crisis management, as an integral part, makes urban planning inevitable. But crisis management should not be considered only as an operational organizational action, but should pay attention to the impact of physical and functional design and organization of settlements in its size (Hamidi, 1995: 1653).

The most important and effective role of urban planning can be considered in the pre-crisis period to reduce the effects of the crisis when it occurs and facilitate other stages of crisis management. The stages of the crisis are as follows:

-Earthquake stage: Its time scale is in seconds to a maximum of minutes.

- Escape and shelter stage: in the first hours after the accident and the occurrence of secondary accidents after that.

-Rescue and relief phase: starts from the early hours and continues for weeks.

- Temporary accommodation phase: lasts from the first days to months.

- Cleaning and reconstruction phase: starts from the first days for cleaning and continues until the end of the year for reconstruction operations.

Vulnerability of cities to floods

Today, population growth, expansion of industrial facilities, lack of space for construction, especially in metropolitan areas, have caused drastic changes in the morphology of catchments. Also, land leveling, encroachment on rivers and canals, changes the pattern of natural drainage and flow in the city (Sepehr and Kavian, 126: 1393). This has increased the risk of flooding and flooding of roads and increased maintenance costs of the city and has increased the potential loss of life and property. According to studies, the expansion of cities in the catchment area increases the impermeability levels, increases the volume of runoff and floods, reduces the concentration time, increases the maximum instantaneous discharge and changes the quality of floods (Hosseinzadeh and Jihadi Torghi, 1386: 145).

Floods are one of the most destructive natural hazards, and reparations are costly, especially in areas where human development is evident (such as cities). Urban development, especially along rivers, has increased flood damage in recent decades (Ghahroudi Tali, 2012: 2).

Awareness of the level of risk in different areas of the city and attention to the issue of urban flood management as one of the important axes in addressing urban issues with emphasis on preserving the urban environment is important (Sadeghloo and Sajasi Gheidari, 2014: 128-105).

Floods are one of the known natural disasters, which according to the International Database of Disasters in the field of natural disasters, along with earthquakes and droughts have the highest rank in terms of financial and human losses (International Risk Database, 2016). At least one-third of all natural force losses can be attributed to flooding (Laster: 1999; Hanson et al., 2008: 480-465; Rashid 2011: 45-35).

With the rapid growth of urban planning and the creation and development of infrastructure, floods in urban areas have become more and more severe (Bhatacharya, 2010), Therefore, due to the expansion of urbanization and climate change, it is necessary to build an effective flood control system and efficient drainage mechanism in cities (Chang et al., 2008: 24-24).

Flood instability is variable and complex and flood production in a watershed depends on several factors such as watershed characteristics, load, infiltration, and previous conditions (Sing, 1996: 8). Since the collection and disposal of runoff caused by rainfall along the river is actually considered a kind of safety, health and welfare measures (Qanavati et al., 2012, 121).

The first step in reducing the harmful effects of floods is to identify flood-prone areas and zoning of these areas in terms of flood risk so that the harmful effects of urban floods can be prevented as much as possible based on the results obtained with integrated management and comprehensive urban planning. (Ahmadzadeh, 1394: 23-1).

Flood risk zoning map can be used as an effective tool in planning the future development of the city, as well as to identify areas where the development of flood drainage and drainage infrastructure is needed (Buchele et al., 503: 2006-485).

There are multivariate models for vulnerability zoning, which include functions related to fuzzy sets or artificial neural networks. In these uncertain sets, the presence of factors is calculated as membership in the range of zero to 1 or the coefficient of importance based on the frequency of events (Zhou, 2001: 77-57 and Fine, 1999).

Flood resistance methods

Foundation:

The foundation prevents the building from sinking into the ground. This is one of the causes of the destruction of the building and it is doubly important about the flood. Because floods weaken the ground and increase the likelihood of sinking, the foundation must be built firmly.

The shape and strength of a building is determined by the type of building and the force it exerts on the soil. There are different types of foundations. In flood retrofitting of buildings and in structural retrofitting, porous foundation design is a good way to strengthen the building.

When the foundation of a building is porous, water flows through the building and floods the building without damaging it. Alternatively, the building can be built on foundations with detachable walls. When a flood occurs, these walls come off and the building is not damaged.

Building glass

One of the causes of building destruction, which is also dangerous, is the breaking and scattering of glass shards. In natural disasters such as floods, earthquakes and hurricanes, glass is also vulnerable and dangerous. Under the pressure that is applied to the building or due to the rapid impact of objects with glass, the probability of their breaking and shattering increases.

The use of polymer coated glass sheets strengthens the glass and prevents it from breaking and damaging it. The use of polymer for glass coating in flood resistance of buildings is not a new phenomenon and has different functions.

Waterproofing the floor of the building

One of the most important measures in building flood resistance is waterproofing the floor of the building. Today, they do this with the use of nanomaterials and even make empty spaces and waterways waterproof.

Waterproofing and dehumidifying different parts of the house helps it to withstand floods.

Use of flood protection parts

Flood protection parts are parts that are widely used in standard construction and can be prevented from flood damage by connecting them together and placing them in a suitable place in residential and commercial buildings. The foam used in the floor of these parts retains water and prevents it from leaking.

Due to the simplicity and low weight of this system, its use does not require special training. Cost-effectiveness and high quality of floodproof parts make them a more effective solution compared to sandbags.

Vulnerability to lightning

Lightning is a natural atmospheric phenomenon and there is no way to prevent lightning from escaping. Direct and indirect lightning strikes buildings and transmits them through service lines to them can be harmful and dangerous to humans, buildings and their valuable contents. Therefore, it is necessary to take the necessary measures to protect against lightning.

The following factors determine the type and severity of a building vulnerability to lightning:

1- Body and structure of the building (wood, brick, reinforced concrete, steel frame)

2- Use of the building (residential, hospital, industrial site, school, farm, etc.)

3- Residents and contents of the building (humans, livestock, flammable and explosive materials, sensitive electrical and electronic equipment, etc.)

4- Input service lines (telecommunication lines, plumbing facilities, etc.)

5- Existing or provided protective measures (necessary measures to reduce physical injuries and damage to equipment)

6- Extent of hazards (possibility of evacuating the building, peripheral and environmental hazards)

<u>Sources and types of damage to a structure</u>

Depending on the type and location of the lightning discharge, the following conditions will cause damage to a structure:

1-Direct hit to the building.

2- Impact in the vicinity of the building.

3- Direct hit to the input service lines.

4- Impact near the input service lines.

Lightning strikes the building due to the energy generated in the conductors of the current passage or the discharge point of the electric charge can lead to mechanical damage, fire and explosion due to heat generated at the spark point.

The ohmic and inductive coupling on the conductors causes severe potential differences and transmits part of the lightning current to the installation. In this case, the damage caused by the potentials endangers human lives.

Lightning strikes the service lines of buildings can cause lightning to flow into the building and cause sparks and sudden overvoltages. These sparks may result in physical injuries, fire and explosion. These shock currents, which cause dangerous potential differences on the conductors, will be one of the causes of damage to humans due to contact with unauthorized voltage. Failure of electrical and electronic equipment is the result of current transfer into the structure.

Types of lightning:

1-Downward lightning, in which the arrow of attack starts from the cloud to the ground. This lightning usually discharges in the plains.

2- Upward lightning, in which the arrow of attack from the structures and installations on the ground to the cloud begins. Electricity and telecommunication towers, tall buildings, structures built on hills, form such lightning.

A thunderbolt consists of one or more discharges:

1-Short stroke and the main one, which lasts less than 2 ms

2- Long Stroke, which lasts more than 2 ms.

Since the electric charge of the earth is assumed to be zero (neutral), lightning can be called positive if the positive charge of the cloud with the earth is neutralized, and lightning can be called negative if the negative charge of the cloud with the earth is neutralized. Negative lightning strikes usually have multiple strokes.

Lightning protection system:

It is a complete protection system, so that it reduces the damage caused by direct lightning strike to a building and also protects people and internal equipment. This system includes external and internal protection.

Exterior protection system:

It is part of a protection system that includes air terminals, current-reducing conductors and ground terminals.

Internal protection system:

It is part of the protection system, which includes the potential of electrical conductors by providing safety distances in the protected structure.

As mentioned above, lightning strikes in several ways, a direct hit to the lightning rod or the body of the building and a side impact as follows:

1-Creating an electromagnetic field around the impact site and mounting part of it on the shield and entering the equipment and final damage

2- Discharge in the relevant earth well and electrify the surrounding land and affect the surrounding lands (wells).

3- Lightning strikes the transmission line.

In the case of protection of the first paragraph, there is definitely a need for an earth well and the electronic earth system has no application in this area.

In the case of the second paragraph, if a part of the lightning enters the system through the shield, due to the direct connection of the electronic earth to the body, the relevant equipment and shield will pull the attack towards it and discharge it. If the surrounding ground is electrified, due to the fact that the equipment body is not directly connected to the ground earth well and is connected to the electronic earth, as a result, no problem will occur on the equipment body.

In the case of the third paragraph, since the electronic ert itself is the first consumer (it is placed in series with the consumer) it is protected by both abrupt disconnection and connection and the use of arresters.

Damage caused by liquefaction

Lubrication process

Liquefaction is the process by which sediments under the surface of the water temporarily lose their strength and act as a viscous liquid instead of a solid. The most sensitive types of sediments are sandless and clayless sediments and sometimes quicksands. Factors that cause liquefaction in the soil are: Seismic waves and primary shear waves that, by passing through saturated grain layers, cause deformation and granulation structure and movement and displacement of loose grains. If drainage is not carried out, the fall of the particles will increase the pore water pressure between the grains, and if the pore water pressure increases to about the weight of the covering soil, the gravel layer will temporarily behave like a viscous liquid. In such circumstances, it can be said that liquefaction has occurred.

In post-liquefaction conditions where the soil has low shear strength, it will be possible to deform extensively in a way that causes damage to the structures. The conditions under which the soil liquefies depend primarily on the looseness of the soil, the amount of cement or clay between the particles, and the amount of drainage constraint. The amount of soil deformation due to liquefaction depends on the material looseness, depth, thickness and area of the liquefied layer, the slope of the ground and the distribution of loads applied by other buildings and structures.

Liquefaction does not occur by chance, but is limited to environments that are geologically and hydrologically composed of fresh layers of sand (in areas with high aquifers). In general, the fresher and looser the sediment and the higher the water level, the more sensitive the soil is to liquefaction. More liquefaction-sensitive sediments include Holocene (less than 10,000 years old) in deltas, riverbed sediments, floodplain sediments, and sediments from wind and low-density fillers. Liquefaction is most likely to occur in areas where the groundwater aquifer is less than 10 meters below ground level. Several examples of liquefaction have been observed in areas with an aquifer surface greater than 20 m. Compacted soil, that is, well-compacted soil, has little sensitivity to liquefaction.

The effect of liquefaction on man-made environment

The phenomenon of liquefaction in itself may not be destructive or dangerous. Only when liquefaction leads to some kind of ground displacement or ground failure will its destructive effects on the environment be observed. The occurrence of liquefaction is not very important from an engineering point of view, but its severity or its potential for damage is very important. Side effects of liquefaction can take many forms. These forms are: ground failure (soil displacement), lateral expansion; Ground oscillation, loss of bearing power; subsidence; and increase lateral pressure on retaining walls.

Failure on the ground

Failure on the ground is the most catastrophic consequence of liquefaction. This fracture usually moves large masses of soil laterally tens of meters, and in some cases, large masses of soil move tens of kilometers down the slope at speeds of up to tens of kilometers per hour. This flow may be from fully liquefied soil or from healthy masses on a layer of liquefied soil. Saturation in loose sand or silt on a relatively steep slope usually extends more than 3 degrees.

Lateral expansion

Lateral expansion involves the lateral displacement of large rock masses of soil as a result of liquefaction in a subsurface layer. Displacement occurs as a result of a combination of gravitational forces and inertial forces generated by an earthquake. Lateral expansion generally occurs on a gentle slope (often less than 3 degrees) and moves toward a free side like a dug river channel. Horizontal displacement usually reaches several meters. The displaced ground usually breaks internally, causing cracks, extra ground, and subsidence on the fractured surface. Lateral expansion often causes problems in the foundation of buildings built on or across the fracture, the cutting of pipelines and other installations in the fracture mass, and the compression or buckling of engineering structures, such as bridges built on the toe of the fracture.

Earth oscillation

Where flat ground or slopes are too gentle to create lateral displacement, deep liquefaction may separate the overlying soil layers from the underlying layers, that This causes the topsoil to oscillate forward, backward, up and down with the ground waves. These oscillations are usually accompanied by the opening and closing of cracks and fractures of rigid structures, such as asphalt and pipelines.

Loss of bearing strength (bearing)

When the soil that supports a building or structure becomes liquefied and loses its strength, there is a possibility of large deformation inside the soil, causing the structure to either tilt or settle. In contrast, tanks and piles buried in the soil may come out of the liquefied soil. For example, many buildings collapsed and tilted during the 1964 Niigata earthquake in Japan. The largest such failure occurred during the event at the Kawangishicho Apartment Complex, where several four-story buildings were tilted up to 60 degrees. Apparently, liquefaction was first created in a layer of sand several meters below the ground and then spread upwards through the upper sand layers. The rising wave of liquefaction weakens the soil beneath the structures, causing the structures to slowly settle and tilt.

Subsidence

In many cases the weight of the structure to create a large subsidence associated with the failure of the soil bearing capacity described above, It will not be big enough. However, smaller subsidence may be dispersed due to pore water pressure in the soil. This subsidence can be destructive. Sand boiling eruption is a common symptom of liquefaction, which can also lead to localized differential deposition.

Increased lateral pressure on retaining walls

If the soil behind a retaining wall becomes liquefied, the lateral pressure on the wall may greatly increase. As a result, retaining walls may be displaced laterally, skewed, or structurally damaged.

Can liquefaction be predicted?

Although areas with liquefaction potential can be identified, their occurrence is not as predictable as an earthquake (with the time, place, and degree of confidence assigned to it).

The regional potential liquefaction map has greatly enhanced our knowledge of this hazard. These maps are now available for many parts of the United States, Japan, and other parts of the world. The liquefaction potential map is generally created by combining the liquefaction sensitivity map with a liquefaction possibility map. Liquidity sensitivity refers to the capacity of the soil to resist liquefaction, the main factors controlling its sensitivity are soil type, density and water depth. The possibility of liquefaction is a function of the magnitude of the earthquake or the force applied to the soil. The frequency of earthquakes and the intensity of earthquakes are effective factors in the occurrence of liquefaction.

What are the risk reduction options?

There are several ways to reduce the risk of potential liquefaction:

1. Strengthening structures to withstand projected ground movements.

2. Select the appropriate type and depth of foundation (including foundation modifications in the case of existing buildings), so that ground movements do not adversely affect the structure (for example, wide foundations to increase the strength of the foundation; piles or deep columns under a The area is spread out of liquefied soil).

3. Soil stabilization to eliminate the potential for liquefaction or to control its effects (for example, removal and replacement of liquefied soil; on-site stabilization by grout injection,

compaction or dewatering; strengthening lateral expansion areas).

How are reduction options selected?

The choice of reduction options strongly depends on the specific features of the site. If there is no significant risk of lateral movement, the reduction for a new building will largely depend on finding the most cost-effective solution for providing vertical support and subsidence control. For existing buildings, due to the presence of the structure, the way to reduce the probability of occurrence is generally more difficult and more expensive. Soil compaction techniques are prohibited for an existing building as they cause the structure to collapse.