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THE EFFECT OF THE EARTHQUAKE ON THE WATER DISTRIBUTION NETWORK

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ABSTRACT

When a large earthquake occurs in urban or rural area it natural damages the water foundations too. Network of water distribution are the Lifeline of civil society and their damage suffered significant economic losses in one hand, and on the other hand can result widespread damage, since the pipelines are widely spread, and in some areas they pass necessarily from areas with fault lines. Thus studying the pipelines in earthquake-prone areas is of utmost importance. In this paper, the effect of the earthquake on the water distribution network has been discussed.

Keywords: Water Foundations, Earthquake, Vibrations, Connections, Pipes

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INTRODUCTION

Earthquake is a natural disaster which is always ambushing structures and facilities used by humans. So it is necessary in any position depending on the type and geographical location, geological structures and facilities consider a reasonable safety factor. Lifelines are infrastructure, which are interconnected with life and peace of human society today. In

earthquakes lifelines including power lines, water, gas and sewage transmission channels are suffered main damages, followed by irreversible harm to survivors of the earthquake, at a time when we face growing incidence of natural disasters in the world and an earthquake with an intensity of 9 Richter scale in Japan, concerns about Iran which is a accident-prone country is increased.

The importance of water and its role in the life of living beings is no secret, most people feel the effects of dehydration after 36 hours, and the human body can withstand hunger better than thirst, even by water the issue of severe hunger can be delayed for a long time.

The earthquake may cause serious damage to water utilities of city. Many statistics and reports from around the world to make several severe damages caused by accidents on lifelines of various facilities, including water, gas, electricity and telecommunications installations after a high-intensity earthquake.

Reports from 1906 earthquake in San Francisco, America are available. The earthquake damaged the water treatment plants and city pipelines. The lack of supplying drinking water and multiple fires in the city after the earthquake happened. In fact, as a result of the city of San Francisco in an area with high seismic intensity, the main cause of the fire has been destroyed.

Another report has been raised issues of massive earthquake in Mexico City in September 1985. The earthquake resulted in the displacement range of lands. The destruction of water reservoirs and treatment plants, the water main pipelines were also broken and therefore more than 4 million people did not have safe drinking water for three weeks.

In 1994 Northridge earthquake in California, facilities including supplying drinking water treatment plants and water distribution main transmission pipelines were fractured due to permanent destruction of the earth.

In 1995 Kobe earthquake in Japan in tanks, ponds, water purification and distribution network, due to the destruction of the earth and under the earth shake and rising humidity in the pits near the bay that was artificially filled, more than 2,000 cases of fracture damage, repair and restoration of water storage tanks, pipes and drinking water facilities have been reported.

Due to the fact that our country is located on an earthquake belt, the history of our country

shows that almost every 5 years or more the 6 Richter scale earthquakes occurred in the country. In such circumstances, the possibility of an earthquake is past and likely it has become a reality. Studies in Tehran shows those severe losses in public and residential buildings in the earthquake, about one million housing units, public and service, as well as half of the training centers will be faced with damage.

When the earthquake damages water networks

Today, mainly in urban areas for safety reasons and beautification they use buried pipelines. Since a buried pipeline system mainly passes through a vast geographical area it deal with seismic events is very diverse soil conditions. Especially if underground pipes make the intersection with fault zones it will be very vulnerable. On the other hand pipes buried underground or seismic movements respond for movement along the ground in a way that is almost the same curvature of the Earth's axial stresses. During earthquakes, ground deformation by earthquake waves and buckling may have buried pipelines or break. So the basic principle in a free plan for earthquake seismic design of buried pipelines. This means that the pipes expansion and contraction and also be given the flexibility to reduce seismic forces.

At the time of earthquake, the abutments and maintenance of pipes fell due to earthquake loads or lose their stability. Destruction and damage to the facility after the crisis caused serious problems associated with the health situation of crisis, causing serious problems associated with the health status of the affected incidence area and cause many problems. Cutout in the water transmission pipes fracture endangers the lives of survivors after the earthquake. One of the problems that occur during an earthquake is the risk of infectious diseases. The risk of infectious diseases after the crisis affected the levels of disease, changes in domestic and residence. Cutout of public facilities, including lifelines, water networks and sewage spread the localized disease. Because of damage to lifelines, suspension in basic health services is occurring. The effect of lifelines, suspension in basic health services is occurring. The impact of the crisis management is important on the facility.

Based on past experience and statistics plumbing damage observed in earthquakes are divided into the following categories:

A - Damage the pipeline body: earthquake cause three types of damage in pipes; cracking, pipeline rupture and local buckling (folding pressure). The failure of the pipe body, including damage to water pipelines in Niigata earthquake, entered the city.

(B) Damage to connections: Most of the losses caused to the pipeline on joints and connections such as bends, tees and valves are two blocks circuit protection. High local stresses in piping with key building blocks of pipeline, such as tanks, buildings and bridges, especially at a time when sufficient flexibility to withstand the relative displacement between the pipes and fittings, cause considerable damage to the pipeline and facility creates configuration. In connection with changing of difficulty it caused damage. These damages include: cracking and bond failure, strain out the joints, fracture screws in steel pipe fittings, failure at the junction of the T-shaped or multi-branch and stretch out connections, followed by the protrusion of the pipe due to liquefaction of the earth or sand flow in pipes due to connection failure. Examples damages in connection are stretched out fittings, pipe failure, and irregular and failure hub in Niigata earthquake (1964).

The earthquake caused the ground fissures and cracking roads, junctions drawn and the failure of the compression and liquefaction coming up the pipes and taking them out of the land. In another experiment, damage fittings in Ni-Hen-Kay earthquake (1993). The earthquake rupture in the pipe body less steel pipes and other pipes was observed, however, failure in bolted joints and other parts of welded pipes was higher. The damage in parts of the T-shaped irregularly like links or parts bent pipes with small diameter was a clear example of the failure mode. In the cast-iron outside pipe fittings there is too much strain and relaxation. It should be noted that by reducing the diameter of the pipe connections has also increased the number of rupture.

In addition to the above mentioned are another case in vulnerability of transmission lines are important that might by mitigating these problems we can decrease earthquake disaster:

- Leaking pipes: tubing leak, causing damage to the tube and a high session of pipe supports which increase the damages.
- The quality of welded pipes: If welding is not handled properly, in an earthquake and damage to critical points and destroy the lines.

- Bends and splits status: According to past earthquakes, it has been found that most injuries occurred in place of bent tube. The location of bent pipes is a vulnerable spot. Therefore, the number of eggs less and angles of the bends a little smoother, decreases the vulnerability of an earthquake.
- Corrosion: aging and corrosion increase damages, especially in the steel and cast iron pipes with threaded connection which are unconsolidated. Old pipes to new pipes are more likely to damage and failure.

The possibility of damage to the pipes from the 1987 Los Angeles earthquake has shown an increasing trend. Similarly in Luma Prita earthquake of 1989, this trend has been observed for steel pipe. The weakening of the pipe corrosion by reducing material thickness of the pipe stresses and increases the wall concentration. The failure rate in steel pipes threaded steel pipe is higher than others. Chi Chi earthquake in Taiwan in 1999, 50% of steel pipe is broken, before the earthquake had been weakened due to corrosion.

The presented models for buried pipes

- Candy presented a new approach by taking a passive soil pressure evenly and the use of a large drop. In this way, it is assumed that the pipeline treats in the form of a soft cable considering the compatibility of the tubing into a curve with constant curvature changes shape. For balance applied only at the point of curvature using a tensile axial force and regardless tube was gently resistance. This it is necessary to remove the bending rigidity is assumed in this model did not satisfy the conditions of equilibrium and creates pressure in the pipelines. Another Candy assumption is distant parts of the curved area for tangential are connected to non-deformation lines pipes which is similar to the behavior of a beam on elastic foundation.
- Niemann has done numerous experiments on the subject of soil resistance movement against the horizontal tube. The results revealed that the resistance patio soil around the tube's circumference is not uniform and is much greater than the static pressure and also showed that the relationship between soil pressure and the shift is nonlinear and in greater quantities ground pressure, a further increase of the shift can be seen.

- Wang Vieira has developed an analytical model in which the influence of big moves faults on buried pipelines as static analysis and is based on the theory of large deformations. Unlike previous models that broke the pipe for axial tensile at failure contact fault in the pipeline was considered, in this model, the failure for the interaction of axial force and bending moment is in order. They also have constant radius of curvature of the pipeline. The results show that most cases of failure the interaction of axial force and bending moment is in a state of failure.

Factors affecting the vulnerability of pipes

1- Corrosion: corrosion in the pipes reduces the effective cross-sectional area of the pipe and critical juncture in the area caused by corrosion or rust. According to published reports, the 1999 Taiwan earthquake, 50 percent broken pipes were already weak due to corrosion which indicates that the corrosion is a major factor in the increasing damage caused by earthquake and to restrain; it is needed to replace pipes and possibly change the material.

2- Leakage of the pipe contents: leaking pipes from two aspects is considered. First of creating havoc in the pipe and second in terms of the pipes and pillars surrounding the leak to rust and corrosion.

3- Weld Quality: If the welding points are not of good quality welding points are critical and will become vulnerable during an earthquake.

4- Bad Conditions: past experience of earthquakes has shown that most failures occurred in pipes in bends areas, which can be due to many factors, so the curves is a vulnerable area. So whatever the numbers of bends are less and change in curves and angles is milder will be less vulnerable.

5- Isolation: the covering or insulation pipes it is desired direction that in steel pipes the cover damage caused corrosion and the pipes and thus creates the critical section.

6- Restraints: The most important factor for reducing the vulnerability of the pipes is their restrain condition. Restraints pipes can be divided into two vertical and lateral. The vertical restrain is to control the vertical displacement and the lateral restrain is

provided to control the lateral displacement. It is noteworthy that supports the laterally unstable situation fall the pipes from the edge of the console at the time of an earthquake. Restraints have different types which are determined due to the placement of braces, specifications and boundary conditions.

7- Branch relative diameter

8- Fatigue: is the effect of vibration pipe or other pipe perpetual motion is affected by different factors.

9- Proximity and Impact: failure to observe proper distance between the pipes with each other or other equipment stays in the objective assessment is examined, if the position of the pipes due to lateral movements caused by earthquakes is inadequate, the impact of collision forces on the tube is added to the body and sensitive parts which can cause damage to pipes, accordingly the number of cases is likely to impact assessment.

10- Connection to Unanchored Component: Pipe connection to unanchored component actually during an earthquake and a change of lot of places in equipment due to insufficient restrain may make changing places more than it is expected in pipes attached to the equipment.

11- Differential Displacement: There are high fixed end in a great location at the other end of the pipe and tube making changes is caused when the fixed end.

12- Aboveground: Pipes with a large diameter and short length, which naturally has hardness are susceptible to shear failures in plumbing systems.

Conducted studies about the effects of past earthquakes

In summary, the studies on the effect of past earthquakes achieved the following results:

- Small diameter had more damage
- Pipes with less depth had more losses.
- Flexural failure occurred in pipes of 50-100 mm diameter
- Liquefaction caused to pipes driven into the ground
- The amount of body damage in asbestos pipes and cast iron pipe is more than the other.
- The amount of damage in steel pipes was less than other pipes

- Old pipe had more damages
- Asbestos and concrete pipes and tubes have been very weak in the body.
- Year of construction and corrosion of pipes has influenced on body damage.

The studies conducted on the effects of past earthquakes on connections obtained the following results:

- 450-300 mm diameter pipes have the highest failure at the junction.
- Welded joints in steel pipes that are highly vulnerable due to frailty.
- Connections that have endured displacement and deformation (flange) were less damaged.
- Connections during deformation of liquefaction have been extracted from the earth.
- PVC pipe connections have been broken.
- failure and cracking occurred at T-shaped junction and screw
- The projection of joints in steel pipes was a main reason of failure
- Steel pipe and iron pipe in bolted joints were weak.
- Connections have been corrupted due to rotation

Earthquake effects on buried pipes

Iran is a country that is prone to earthquakes that more than seventy percent of its area is exposed to earthquakes. Earthquake effects on structures can be classified into two groups: dynamic and static effects.

Due to these two properties, structures and buried pipes are affected and the potential vulnerabilities exist, but static earthquake effects on buried pipes is much stronger than its dynamic effects. But the static effects are locally and in specific areas so with software and hardware methods we can control possible damage and repair.

Overall damages caused by the earthquake pipe network can be divided into three general categories that include:

- Loss of operational capability: when the network does not have the ability to transmit fluid even without leakage or breakage occurs.
- Losing sufficient pressure; that can be caused by leakage, breakage, crack or rupture the pipe walls during an earthquake.

- Losing abutments and maintainers: pipes of the mainstays, pendants and maintenance has fallen or may fall off the mainstays of the inside walls of pipes on the ground.

Correct and acceptable behavior of piping systems during an earthquake depends on the health and quality of key factors as:

- Used materials, mechanical design pipeline, wall thickness, composition and preservatives.
- Construction (welding, soldering, shackles and fasteners, NDT repair and maintenance)
- Monitoring and dealing with corrosion, regular inspections and periodically during operation
- Buildings and structures and soil conditions under and around buildings

Seismic waves can be classified in multiple categories each of them has unique properties and they have a certain impact also on underground constructions. Replying underground structures in the face of seismic waves have distortions that generally axial deformation on three floors, curving and bending deformation ring and fall.

Compressional waves crashing axial deformation of underground structures arise, by creating compressive and tensile stresses caused by deformation of the structure. Pressure waves caused by earthquakes in the form of increased tensions enough is designed to endure beyond the concrete and they can create walled underground structure and shell of their crunch and stresses that can cause cracking and loss of elasticity of the outer layers of the structures within it. Checking pressure waves helps to better understand the mechanism of this process.

Pressure wave (PW) is the fastest wave of earthquake waves and that's why the first wave of earthquakes that affected the structure that pressure waves, since the earthquake vibrations of elastic waves in tension and compression are dealing with the production constructions, for better visualization consider a spring that produced a wave along its length; this shock wave is spreading and collects a part of its length that can pull the adjacent section, this cycle will continue until the complete pass of wave from the spring.

By compressing springs compressed mode (pressure) and in effect being caused tension mode the structures for compressive and tensile stresses appear and if the intensity of these stress is out of the bearing structures can have devastating effects and affect adversely. These waves

(pressure waves) caused axial deformations of underground constructions and fall in the category of volumetric waves as it can be seen, the wavelength is dealing with more structure. Curving and bending over a structure in which is called S waves shear waves can be achieved. If the waves in the longitudinal direction diffuse structure with shear stresses noticed damage to structures, the waves that are perpendicular to the length of the structure and direction is unlike P-type waves is in vertical direction even if it is unwilling or perpendicular to the longitudinal axis of the structures to be released are still susceptible to deformation and destruction. Curvature of the waves on structures of the positive curvature concave upward direction and negative curvature that is concave downward direction is divided. According to the curvature of the lower and upper parts of the structure and intensity of the strain, for example a negative curvature in the upper part and the lower strain is experiencing congestion and if it is only out of tolerance structures will cause serious damage in structures. In the design of tunnels and underground structures lengthy analysis of the deformation caused by the recent wave depends on the frequency axis to expand its structures. A certain thing is a wavelength of the earthquake on the impact of the waves on the underground constructions noticeable effects.

Change ring shape occurs when seismic waves are perpendicular or almost perpendicular to the long axis deal structures. This will only occur when the wavelength is smaller than the radius of the earthquake's underground space this shear stress is created waves with structures.

DISCUSSION AND CONCLUSION

Although the vulnerability of water and wastewater facilities is lower than other service facilities, but in addition to direct damage, in combination with other facilities, potential hazards and damages its secondary. The risk of changes in water quality, effects and consequences of cutting off water for fire-fighting, water supply problems for sensitive centers and emergency and the like, is including concerns after the earthquake.

Plumbing vulnerability to earthquakes is important from several aspects; first, for example, cut water pipes could endanger the lives of earthquake survivors. The failure of natural gas pipeline can cause large fires and explosions, in the event of damage to the pipes and sewage

networks stench engulfed the affected area and there is a possibility of outbreaks of infectious diseases after the earthquake.

Seismic waves have certain parameters such as frequency, earthquakes, intensity, etc. The review of each structure against earthquakes is effective in determining behavior.

Pipe junction with faults, where the risk of slippery ground, liquefaction, lateral movement or impossible collapse is being pre-marked and the case for any appropriate preventive and corrective action is anticipated. In total, according to the distribution, stresses and strains of buried pipelines earthquake, lack of continuity in the line of pipe parts can lead to separation of the pipes at the junction.

While the fixed end connections through various means such as welding (in steel pipes and polyethylene), bolt are the fixed mechanical connection or create other ways cause the integrity of the pipeline and distribution of stresses and strains between different parts of the line. Axial and angular flexibility, decrease stress and strain on the joints play an important role in the body of the tube.

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