JOURNAL OF MULTIDISCIPLINARY SCIENCES AND INNOVATIONS

VOLUME 5, ISSUE 06
MONTHLY JOURNALS

ISSN NUMBER: 2751-4390
IMPACT FACTOR: 9,08

TECHNOLOGIES FOR PREVENTING ACCIDENTS IN WATER SUPPLY SYSTEMS DURING EARTHQUAKES

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https://doi.org/10.5281/zenodo.20541636

Abstract

Earthquakes cause significant damage to urban infrastructure, particularly water supply systems that are essential for public safety and emergency response. Failures in pipelines, pumping stations, reservoirs, and distribution networks can lead to water shortages, flooding, contamination, and secondary disasters. This study analyzes modern technologies and engineering approaches used to prevent accidents in water supply systems during seismic events. The research focuses on seismic-resistant pipeline materials, automatic shutoff valves, IoT-based monitoring systems, pressure control technologies, and smart emergency management systems. The study also evaluates international practices from seismically active countries such as Japan and United States. The results indicate that integrating smart sensors, seismic monitoring devices, and automated control systems significantly improves the resilience and operational reliability of urban water supply networks. The proposed recommendations can be applied in seismic regions to reduce infrastructure losses and enhance public safety.

Keywords: earthquake, water supply system, seismic safety, IoT, smart monitoring, pipeline protection, emergency shutoff system, engineering communications

Introduction

Earthquakes are among the most destructive natural disasters affecting engineering infrastructure worldwide. Water supply sy stems are particularly vulnerable because underground pipelines, pumping stations, and storage facilities are exposed to seismic ground motion, soil liquefaction, and structural displacement [1]. Damage to water networks during earthquakes may interrupt firefighting operations, domestic water supply, and emergency medical services.

Historical earthquakes such as the 1995 Kobe Earthquake in Japan and the 2011 Tōhoku Earthquake demonstrated that failures in water infrastructure can produce severe economic and environmental consequences [2]. In many seismic regions, outdated pipeline systems and insufficient monitoring technologies increase the probability of accidents.

Modern engineering solutions now incorporate intelligent monitoring systems, seismic-resistant materials, automatic isolation valves, and Internet of Things (IoT) technologies to improve infrastructure resilience [3]. These innovations enable rapid detection of leaks, pressure anomalies, and structural failures during seismic activity.

The objective of this study is to investigate technologies that reduce accidents in water supply systems during earthquakes and evaluate their effectiveness in seismic regions.

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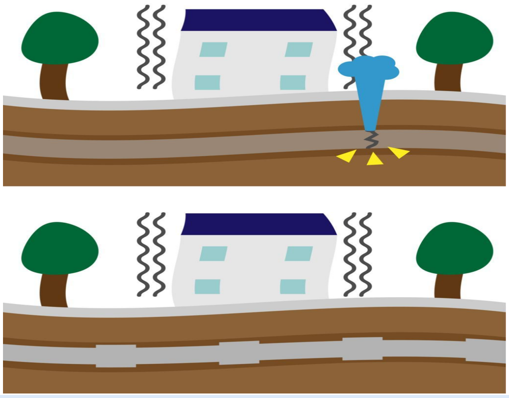
Materials and methods

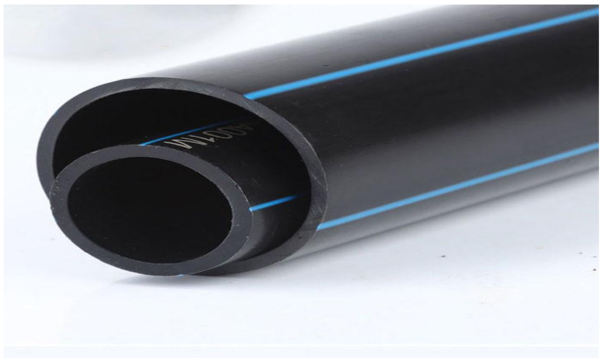
This study used analytical and comparative research methods to investigate technologies for preventing accidents in water supply systems during earthquakes. Scientific articles, seismic engineering standards, and international case studies related to earthquake-resistant water infrastructure were reviewed [1], [2].

The research focused on:

- Analysis of earthquake damage in water supply networks;
- Evaluation of seismic-resistant pipeline materials;
- Investigation of IoT-based monitoring systems;
- Assessment of automatic shutoff valves and pressure control technologies.

Different pipe materials such as cast iron, steel, PVC, and HDPE were comparatively analyzed according to their flexibility, durability, and seismic resistance properties.





The study also examined smart monitoring technologies based on sensors, microcontrollers, and wireless communication systems. IoT-based devices were analyzed for their ability to detect vibration, leakage, and pressure changes during seismic activity.

Comparative engineering analysis was used to evaluate the effectiveness of modern protection technologies in reducing water losses and infrastructure damage in seismic regions.

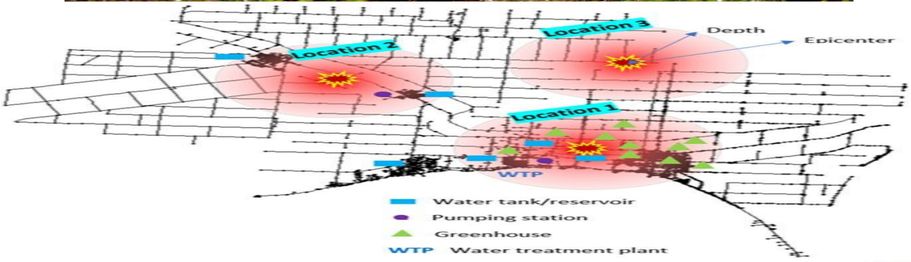
Results and discussion

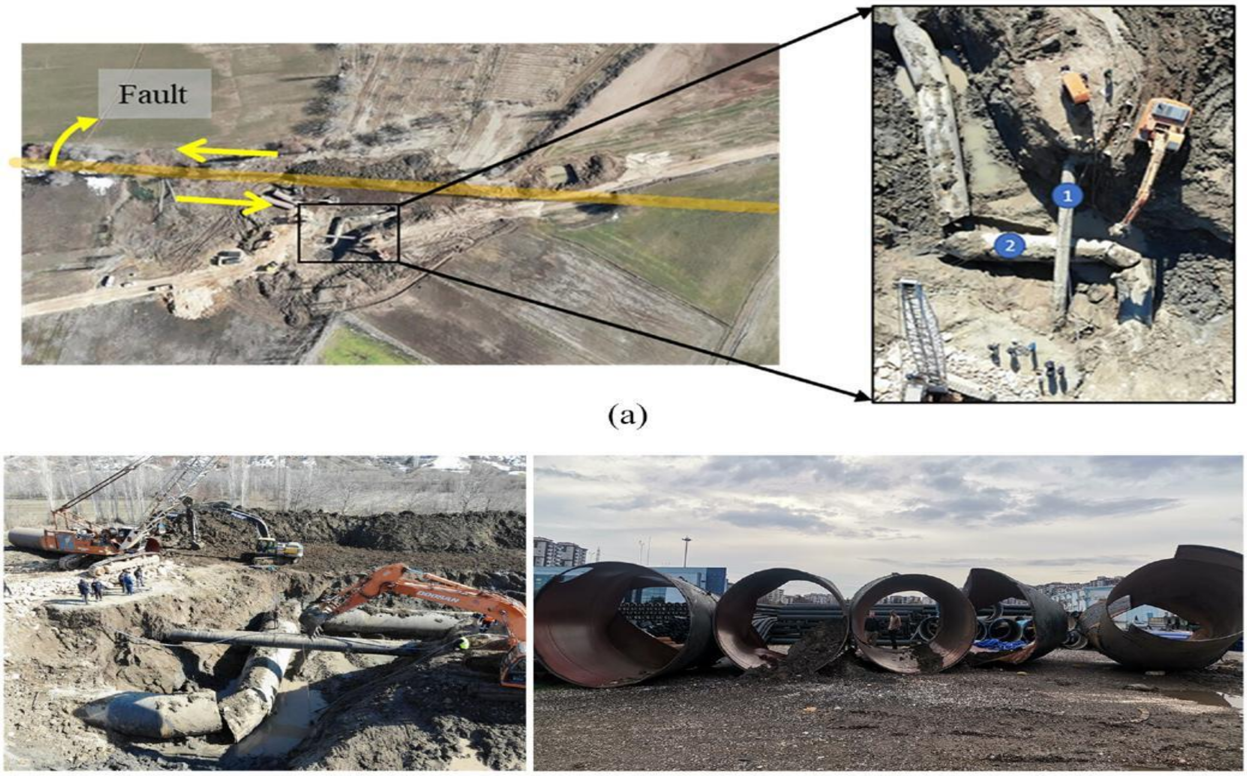
Earthquake Damage in Water Supply Systems

Seismic activity generates dynamic forces that damage underground pipelines and hydraulic structures. Common failures include:

- Pipe rupture;
- Joint separation;
- Reservoir cracking;

- Pump station malfunction;
- Water leakage and pressure loss.





(a)

(b) (c)

Ground displacement and soil liquefaction are major causes of underground pipe deformation [4]. Rigid pipeline materials such as cast iron are more vulnerable than flexible materials like high-density polyethylene (HDPE).

Seismic-resistant pipeline technologies

Modern seismic engineering recommends flexible and corrosion-resistant materials for water networks. HDPE and ductile iron pipes with flexible joints demonstrate higher seismic resistance compared to traditional rigid systems [5].

Advantages of seismic-resistant pipelines include:

- Increased flexibility;
- Reduced rupture probability;

- Improved vibration absorption;
- Longer operational lifespan.

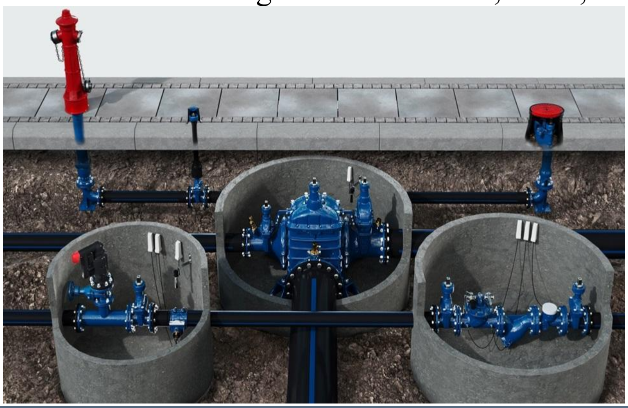
Flexible joints allow controlled movement during seismic displacement and minimize structural stress concentration.

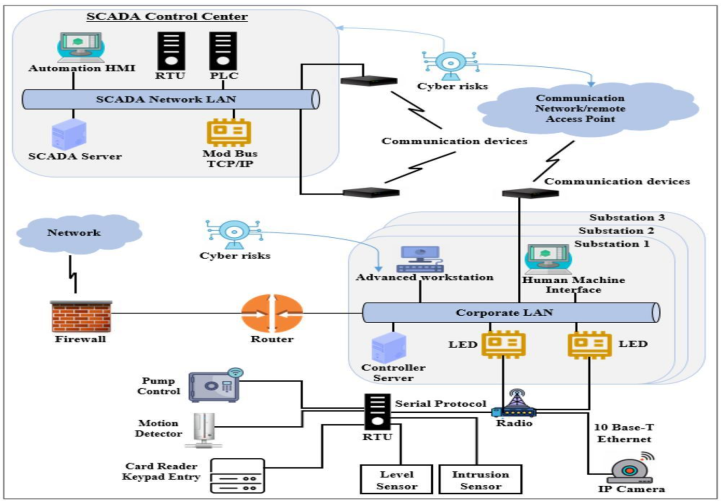
IoT-based monitoring systems

IoT technologies improve the real-time monitoring of engineering communication systems. Smart sensors installed within water networks can detect:

- Pressure fluctuations;
- Leakage;
- Pipe vibration;
- Abnormal flow conditions;
- Structural displacement.

The sensor data are transmitted to central monitoring systems through wireless communication technologies such as Wi-Fi, GSM, or LoRaWAN [6].





During earthquakes, seismic sensors can automatically activate emergency protocols and isolate damaged sections of the network.

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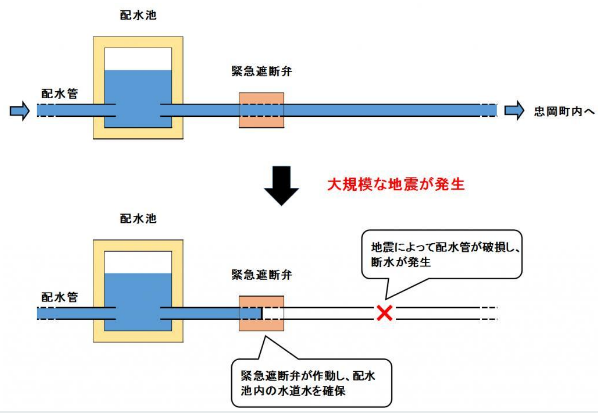
Automatic shutoff and pressure control systems

Automatic shutoff valves are among the most effective technologies for preventing catastrophic water losses during earthquakes. These systems use seismic sensors and pressure controllers to rapidly close pipeline sections when abnormal movement or leakage is detected [7].

The operating principle can be summarized as follows:

1. Seismic sensor detects ground motion;
2. Control unit analyzes vibration intensity;
3. Automatic valve closes affected pipeline segment;
4. Emergency monitoring system sends alerts.



Pressure regulation systems also reduce hydraulic shock effects caused by sudden pipeline damage.

Smart emergency management systems

Smart emergency management integrates IoT sensors, geographic information systems (GIS), and artificial intelligence technologies for rapid disaster response [8]. These systems help utility operators identify damaged zones, estimate leakage volume, and coordinate repair operations.

Countries such as Japan employ integrated seismic monitoring platforms connected to municipal engineering networks. Such systems significantly reduce emergency response time and infrastructure losses.

Conclusion

Earthquakes present serious risks to water supply systems and urban engineering infrastructure. Traditional pipeline networks are highly vulnerable to seismic forces, especially in densely populated regions.

The study demonstrated that modern technologies such as seismic-resistant pipes, IoT monitoring systems, automatic shutoff valves, and smart emergency management platforms substantially improve infrastructure resilience. Flexible pipeline materials and automated control systems reduce rupture probability and minimize water losses during earthquakes.

Implementation of intelligent monitoring technologies in residential and municipal engineering communication systems can significantly enhance public safety and emergency preparedness in seismic regions. Future research should focus on integrating artificial intelligence and predictive analytics into smart water supply protection systems.

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