Technical Note 13 – Improving seismic resilience in buried pipeline systems

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Technical Note 13 – Improving Seismic Resilience in Buried Systems

1 Background

This paper provides an overview of how to improve the seismic resilience of new and existing buried pipeline systems in a cost-effective manner.

2 General Principles of Seismic Resilience

Damage to buried systems is caused by ground movements.

Resilient systems are either resistant to damage or they can be readily restored to normal service. Some general principles for minimising seismic risk in a buried system are:

- Locate the system away from the hazard;
- Improve the ground to reduce or eliminate the hazard;
- Use more resilient materials and components;
- Use a more resilient design philosophy or system configuration;
- Build redundancy into an existing system;
- Provide a means of managing the system to minimise the impact of seismic damage and to assist in restoration and recovery.

The first four options are only applicable for new or replacement systems and are covered in more detail in the main guidelines document. However, for an existing pipeline system, unless renewal or replacement are viable options, only the last two of these are applicable.

3 Minimising the Impact of Seismic Damage

If the risk of seismic damage is considered unacceptable but it is not practical or cost effective to replace the pipeline, it may be possible to reduce the impact of damage. For example, if seismic surges are predicted in a system, surge suppression may help minimise any additional risk of failure resulting from the transient pressure. In some cases it may be more cost effective to make repair and recovery easier or faster, for example by adopting standard system components and sizes, by avoiding deep installations and by ensuring location plans are reliable and current.

The following approaches can improve seismic resilience. While the focus is on improving the resilience of existing systems, some of these approaches can also be incorporated into new designs and renewals works. Often the problem can be addressed in a new system at the design, system selection or construction stages more effectively than through a retro-fitted option.

3.1 System Redundancy

Redundancy in a system means creating alternative means of providing service. Everyday examples include provision of ring mains for water supply so that if there is a failure, service can be provided by an alternative route, and building multiple pipelines so that one can be maintained or repaired while the others remain in service.

For seismic redundancy, it is important to ensure that where possible, secondary supply routes are not exposed to the same hazards as the primary route. For example, if a pipeline is considered vulnerable because it crosses a fault, a secondary pipeline should ideally be located so that it does not cross the same fault.

3.2 Isolation Points

Isolation valves can be used to isolate vulnerable sections of water supply pipeline so that if they are damaged, loss of water can be minimised. Isolation valves for seismic resilience should be located in stable ground. They should also be easily identified, readily accessed and with clear operating instructions. Even where robust and reliable sensors and telemetry systems allow a check on the status and remote operation, it is worthwhile ensuring that manual operation is a practical option.

Identification systems should be robust and clear, and should ideally secondary systems so that if one marker is obscured or damaged, an alternative system can be used. Simple systems such as paint markings on valve chamber covers are good, but may be obscured by liquefaction silt, local flooding or soil movements. Marker posts or labels on trees and buildings could be displaced or destroyed by earthquake damage. Local markers can be complemented by plans and by the knowledge of local operators and contractors as well as through more sophisticated systems such as electronic tags and transponders.

Where possible, critical isolation valves should be located where they can be readily accessed. The ideal location would be on reasonably stable ground away from hazards such as traffic, slips or falling debris. If the controls are located inside a building the building needs to be sufficiently robust to allow safe entry to operate the controls. If the controls are located in a chamber, the chamber should itself be adequately robust to ensure the controls remain undamaged and accessible. It is also important to avoid the need for special procedures such as confined space entry since these will hinder the ability to operate the valves.

It is also helpful to ensure that operation of the isolation valves is straightforward, clear and unambiguous, as after a major earthquake specialist staff are unlikely to be available in all locations and it may be necessary to use whoever is available and contactable in the area. Simple instructions on the valve itself or on an information panel may help non-specialists to operate the system correctly and reduce the risk that a stressed operator will make an error. This could be as simple as an arrow showing which direction closes the valve, or a more detailed list of actions for a more complex response such as implementing a manual over-ride.

In some cases, it may be worth ensuring that a basic toolkit is available- for example ensuring there is a label and marker available to record that a valve has been shut, and a torch so that the instruction panel can be read at night or in bad weather.

3.3 Aids to Restoration

Connection points for temporary supply can be used to help restore partial service at locations where damage is expected. For example, isolation valves and a DN50 or DN100 offtake or hose connection can be installed across a vulnerable pipe bridge to allow a partial temporary supply to be restored with a hose or a PE pipeline. This is especially useful where full restoration is likely to take a considerable time and where alternative supply options are limited.

Connection points for temporary service can also be located at storage reservoirs or on trunk mains to allow local supply to be provided, whether directly at the connection or through a temporary pipeline. These temporary connection points should normally be sized to allow connection to standard hoses or to coiled PE pipes, since both of these require only minimal preparation and can be quickly deployed. PE pipes coils are relatively easy to transport by truck to relatively inaccessible locations and if a stub flange is fitted before delivery to site, they can be bolted onto a flanged offtake without need for a power supply.

Emergency depots should include essential tools and PPE as well as critical supplies, components and materials.

3.4 System Improvements

Retrofitting can include installation of valves and fittings, and replacement of components with more resilient alternatives (for example a flexible joint at an area likely to experience relative movement, or retrofitted devices to minimise seismic effects such as anti-flotation valves in chambers).

Anti-flotation devices are pressure actuated valves installed into existing manholes. They are intended to bleed off excess pore water pressure from the surrounding soil. This reduces the risk of liquefaction immediately around the manhole itself thereby reducing the risk of flotation. Since only a small amount of water has to be drained off into the manhole to reduce the pore water pressure, this has little impact on the flow in the system.

Not all manholes are suitable for retrofitting, but initial investigations (Morris, 2014) has shown that suitability for installation can be checked while gathering information required in the design process. As at 2017, there is only one approved contractor in New Zealand for anti-flotation devices. While the anti-flotation devices can be installed in new manholes, there is little benefit in doing this since the design and construction stages provide opportunities to minimise flotation risks for a new manhole by other means.

3.5 Automated Control Systems

Telemetry can provide an effective means of determining the status of a system after an earthquake (Lester Abbey, 2015) and of operating controls rapidly and without need to send operators and contractors to remote sites in difficult or uncertain conditions.

A range of options are available. These include sophisticated sensor and control systems such as automatic shut-off valves for reservoirs as well as more basic options. The one feature they share is that they rely on power and working communications links to be effective. Backup power and secure links that can operate with limited bandwidth are desirable features.

Automatic shut-off valves for reservoirs are potentially useful for avoiding uncontrolled loss of water through damaged pipelines. This can be useful in normal service, but is especially helpful after an earthquake where extensive damage and disruption can be expected. The valves need careful set up to avoid operation when flows are high for legitimate reasons such as firefighting, and determining effective trigger levels for shut off can be difficult in areas with high flow.

Control systems that combine information relating to flow and to recent seismic history can be used to minimise the risk of unjustified closure (infrastructurenews.co.nz). Manual operation of controls should always be possible in the event that power or telemetry systems are lost or where there is some other fault.

4 Planning

"The perfect plan is the enemy of a good plan" – Von Clausewitz.

While it is important to look at ways to make a system more physically robust, non-asset solutions involving planning and organisational factors are an essential aid to understanding the scale of the problem and providing a well-structured response.

Damage predictions such as those described in Technical Note 9 provide an indication of the likely scale and distribution of damage in an individual system for a predicted seismic event. Even a simplified sensitivity check of 2 x the predicted damage and ½ the predicted damage can provide a valuable test of the ability of an organisation to cope with a predicted event.

There are always some limitations to prediction accuracy even where known faults are considered. The Canterbury earthquake sequence and the Seddon earthquakes of 2013 indicate that not all active faults have been reliably identified. This means that while planning is useful, the actual outcome of an event will usually be different from what was initially expected. Even if a wide range of plausible scenarios have been considered, it will be necessary to find out what has happened and where so that the appropriate response can be implemented.

A convenient way of understanding the likely impact of a seismic event is to compare the predicted number of breaks with typical annual figures. If the predicted number of failures is within the typical monthly variability, it is unlikely to have more than a minor impact on customers and operations, but an event that causes two or five years' worth of damage is likely to have a major impact on service and exceed the ability of the normal maintenance team to manage.

The transition point between being able to cope and requiring external assistance is likely to be a few months' worth of breaks, but will be influenced strongly by local factors. These local factors could include the likely impact on road access – so a peninsular settlement is likely to have more access issues than a settlement in the middle of plains that is surrounded by potential alternative routes. Location will also influence the number of neighbouring communities that may be able to assist with supplies, manpower and other support.

The make up of the system will also have an influence. If a wide range of different sizes and systems is in use, spares availability and system compatibility may be harder to manage than in a homogenous network.

A community with long-serving staff and a good physical archive of drawings and plans may be able to get repair and restoration works underway even without access to electronic data stores, but a cloud based service may provide better overall resilience provided wireless data services are available. Descriptions of the processes used in Rangiora following the 2010 earthquake indicate that they were probably close to the maximum community size that can manage its own recovery. The importance of the statement “Know your system and know your friends” (Boot, 2010) illustrates that it is important to review both internal and external resources and knowledge when planning.

Policy is important as well. Lifelines planning is an important starting point for more critical systems, and most accounts of post-earthquake recovery focus on the repairs to major trunk lines and transmission services. But alternative approaches can be considered, especially once the more critical systems have been addressed. For example:

- Is it better to focus on the more badly damaged systems because they need most work or to preferentially target systems that show only minimal damage, which could allow faster restoration of services to more people?
- Is it worthwhile to work by sub-systems or supply zones to avoid dissipating recovery efforts but at the risk of leaving some communities with no service for a prolonged period?
- Are there benefits in restoring service to community distribution centres rather than individual householders?

None of these questions have easy answers but by thinking ahead, it is possible to test out approaches that are practical and resilient. In the worst case, a pre-planned approach that can be implemented quickly will provide at least some improvement to service. More often, the fact that several options have been considered in advance allows emergency management coordinators to select an appropriate response to the situation as it is seen and understood at the time, with the ability to review and consider alternative scenarios as the situation changes.

These approaches could also be modified by the ability to provide temporary services. In the months after the Christchurch events, images of portaloos and above ground water supplies provided a graphic reminder of the scale of disruption as well as showing that some level of normal life had been restored.

What all these approaches have in common is that none of them is useful until you know what problem you are dealing with.

5 Conclusions

New and replacement buried infrastructure systems can be designed and constructed to incorporate materials, fittings and installation practices that offer improved seismic resilience.

While opportunities for improving seismic resilience of existing systems are more limited, practical and cost-effective options are available that can improve resilience in a cost effective manner.

6 References

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