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SUSTAINABLE REHABILITATION AND UPGRADE TO UNDERGROUND TELECOMMUNICATION STRUCTURES

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ABSTRACT: Underground telecommunication structures (UTS) are considered to be a substantial component of public infrastructure and therefore have become an essential part in any scheme that involves the design/construction of new infrastructure projects or the rehabilitation, upgrading, and/or renewal of existing infrastructure including relocation of any adversely impacted UTS to comply and accommodate specific project requirements. The existence of UTS is as old as the infrastructure containing or housing them, such as roadways, bridges, tunnels, culverts, waterways, railways, etc. and in some cases even older than the infrastructure (e.g. road widening encroaching existing UTS).

An aged underground telecommunication structure means old material in varying states of deterioration, and non-compliance with current standards/requirements. This in turn means a potential interruption in the provided services and a potential hazard to the structures and the housing infrastructure. Therefore, any rehabilitation or addition to the main housing structure should include rehabilitation and upgrade of the UTS contained therein. Building a resilient underground telecommunication structure provides a safe haven for the telecommunication industry which is becoming vital for the development of information technology and social communication that urban centers, with a growing spread to sub-urban and rural communities, should be equipped with, especially under the pressure of the rapid community expansions underway supported by the high volume housing industry. Upgrades to existing UTS in older urban areas carry another set of challenges both in design and construction where congestion of existing utilities and road allowances impose major constraints to any rehabilitation project.

This paper provides an overview of the types of UTS, some methods, and processes required to investigate and assess the conditions of existing UTS as well as determine recommendations on rehabilitation approaches.

Keywords: Underground Utility Structures, Dry Utilities Maintenance, Rehabilitation, Telecommunication Structures, Resilient Underground Structures.

1. INTRODUCTION

Underground structures are completely encased and housed within the existing host ground medium (Sinha R.S). In Underground structures, unlike surface and aerial structures such as poles, towers, monopoles, etc., the interaction of the soil characteristics with the underground structure plays an exceptional role in affecting the sustainable characteristics of the structure. Underground systems are designed and constructed to provide adequate reliability and safety. Also, with contemporary social and political developments, along with the subsequent information technology evolution on one side, and growing environmental concerns on the other side, it has become essential to ensure that all infrastructure is built without compromising any of these aspects. Moreover, the vulnerability of the aging infrastructure is raising many issues with respect to its decline in performance and functionality as intended at the time of its original design and construction. From this perspective, it has become an exigency to perform rehabilitation design that is both sustainable and reliable, in order to meet operational and maintenance requirements while at the same time serving, as well as protecting, public health and safety. In case of the UTS, it is significantly important to raise awareness to the recent relevant requirements of sustainability issues when building new structures, or repairing existing structures, and assessing their current conditions. Several factors will affect the process of the planning, designing, and constructing of UTS since it is usually a component of larger infrastructure projects such as bridge replacements, roadway construction/widening/extensions, railway extensions/track line additions, new developments, etc.

2. TYPES OF UTS

There has been a significant evolution in the telecommunication industry since the telegraph was introduced in Canada in 1846. For the following fifty years, systems of wires were constructed across the US, Canada, and internationally, bringing a revolution in the speed of communication over distance (History Canada http://www.thecanadianencyclopedia.ca/en/article/telecommunications/). The materials used in the construction of UTS had gone through tremendous development over the same timeframe. Field inspections have revealed old conduits built of clay, timber, and asbestos based material. These materials have proven to be detrimental to the housing structure and to the surrounding soil upon deterioration and degradation causing pollution and ultimately placing the environment and public health at risk. New materials have since been developed including introduction of the polyethylene and fiberglass products such as; PVC, HDPE and FRE conduits, therefore, the type of the existing UTS is very much related to the year of its construction and type of the structure. Generally, the UTS can fall into one of the following categories*:

1. Underground duct structures which provide a continuous path to telecommunication cables (e.g. direct buried ducts, concrete encased ducts, steel encased ducts/cables, etc.) through various conveying medians.

2. Direct buried cables for direct services to property.

3. Manholes and Grade Level Boxes (GLB's), which house splices, terminals, repeaters and other equipment in addition to the cables or are simply used as pull-boxes.

4. Ducts hanger systems attached to bridges, overpasses, or tunnels at road separations.

UTS could be found in bridges; in/under roads and highways, under railways, and under waterways and canals, which can be affected in any project that involves the housing infrastructure such as:

1. Bridge construction e.g. rehabilitation, widening, extending, etc.
2. Road construction, including road resurfacing, widening, repairs.
3. Street tracks replacement and improvements.
4. New buildings and land developments.
5. New, replacement, upgrade of any other dry or wet utilities.
6. Transit solutions e.g. LRT systems.
7. Railway, road and waterway crossings

See appendix (1) for common types and material of underground and attached telecommunication structures.

** This categorization may apply to hydro structures as well.*

3. UTS – INVESTIGATION & ASSESSMENT OF DAMAGES & DETERIORATION

The aging phenomena, natural hazards, and project construction exhibit tremendous threats to the durable functionality of structures and infrastructures. The deterioration due to environmental stressors causes progressive reductions in the safety and reliability of existing UTS, and potential disruptions in the functionality of the structure and its containment, such as telecommunication cables, splices and apparatus. On the other hand, damage caused by other constructions (e.g. bridge or road rehabilitation work affecting existing telecommunication structure), will cause a similar level of disruption to service and have significant high repair costs. Generally, factors that contribute to UTS deterioration and damage can be physical, environmental, and/or operational causing service risk to the owner utility, and its customers. Types of risks to underground structures may be categorized as follows:

- Inherent risks (from within): mainly caused by consumptive characters of the utility, such as an internal deterioration of the utility or the compartment that houses it (e.g. deterioration of a concrete duct bank that encases ducts and cables).
- Acquired risks (from without): mainly caused by intrusive actions that lead to damage or termination of a service or structure such as a construction process that ignores sufficient protection to an adjacent utility.

The deteriorated UTS can be repaired and rehabilitated depending on the level of damage and its severity. The type of action required will be determined through structural investigation, and assessment, by following various methods ranging from visual inspection, physical inspection (using an assortment of tools such as hammer and chisel to check severity of concrete surface spalling), non-destructive testing (such as x-ray, ultrasound, etc. to determine some characteristics of the structure), and destructive testing (such as concrete core samples for manhole walls to be tested in the lab for more accurate specs). Nevertheless, this may require exposing the buried UTS in order to perform any or all of these tests through subsurface investigation efforts (e.g. test pitting). For ducts hanger systems attached to bridges, the damage could be a result of natural causes, faulty design, accidents, vandalism, etc. The maintenance, rehabilitation, or rebuild would depend as well on the level of damage and/or deterioration.

When investigating the structural integrity of an existing UTS, the following data is essential to the process:

- The type of the structure (e.g. manhole, concrete duct bank, direct buries cable or duct, etc.)
- Type of the conduit (e.g. clay, timber, Bitumenous based material, asbestos based material, PVC, etc.)
- Year of construction/installation, and records of previous work to the structure or in the vicinity of the structure.

The investigation process shall require data collection to assist in the completion of the rehabilitation design such as:

1. Obtaining various records from project stakeholders to assess, and determine the next level of details required to evolve the rehabilitation design.
2. Completing a topographical investigation to determine the existence of facilities that may be in conflict with the proposed work. Determine any municipal constraints and limitations (e.g. property lines, upcoming land appropriation, easements, short term and long term road closures, moratoriums, right of ways, etc.)
3. Conducting subsurface investigation in order to determine all relevant aspects such as soil conditions, existence of subsurface structures and utilities, as well as concealed conflicts such as high ground water conditions.
4. Using standard materials and techniques in the repair of the UTS, and have the capacity to make adjustments due to unforeseen conditions during construction. Such as injecting cracks in manhole walls using epoxy, replace damaged ducts with new split ducts, restore damaged concrete with new.
5. Determining a set of preventive actions, and remedies to address any critical issues resulting from the implementation of the project, or specific task.

Collected data from the inspection of existing UTS shall assist in:

1. Assessing overall condition of the structure and specifying unreliability concerns (e.g. old manhole located in boulevard might not sustain road loading condition in a road widening project due to incompliance with current reinforced concrete specification requirements).
2. Designing the appropriate method of repair for the structure taking into consideration all constraints (such as capping duct bank with concrete shell as a protection layer instead of repairing deteriorated sections).
3. Determining any deviations from the standard design and specification that may adversely lead to future destabilization (e.g. installing a duct hanger system under a bridge without accommodating expansion/contraction behavior of the ducts resulting in severe damage to the conduits and telecommunication cables).
4. Detecting information on inaccuracies in the original design/construction and pursue corrective actions in the design and construction of new structures (standard soil shoring design for manholes cannot be used for depths exceeding 3.2 meters in non-monolithic construction)
5. Predicting the life cycle of the structure and its reliability due to new conditions such as major construction in the vicinity of the structure (assessing structure to provide recommendation(s) for rebuild or major rehabilitation for reinvesting purposes).
6. Exploring other remedial approaches such as providing mechanical protection in compliance with CSA C22.3 No. 7 to the existing UTS where rebuilding, lowering, relocating and/or repairing is not feasible.

4. UTS – REHABILITATION & REPAIRS

Rehabilitation of UTS's are in the general prospect, a work to rebuild or replace parts or components of the structure, including applying some modification to restore it to a required operational condition and extend its life-cycle performance. The rehabilitation and upgrade of UTS's is aimed to maintain and manage the asset of the telecommunication service. Asset management has been described as "a systematic process of maintaining, upgrading, and operating physical assets cost-effectively. It combines engineering principles with sound business practices and economic theory, and it provides tools to facilitate a more organized, logical approach to decision-making" (National Guide to Sustainable Municipal Infrastructure NRC-CNRC. & ISO 55000). Rehabilitated and/or upgraded design of existing UTS may consider the following performance indicators as guidelines to preserve the integrity and reliability of the provided service to meet customers' expectations and be resilient for future expansions and growth (Structure and Infrastructure Engineering Vol. 8, No. 1, January 2012)

- **4.1 Sustainability**

Is a comprehensive concept to protect our quality of life for the future (Denise Nelson, P.E., ENV SP, LEED AP), therefore the rehabilitation design of an existing UTS should accommodate the environmental, social, resource allocation, and service improvement for the utility structure and its housing structure e.g. road, bridge, landscape area, etc.

New UTS should be built with new materials that meet current standards and address future predictions such as grade elevation changes, and changes in the load status (moving the structure from boulevard to road due to road widening). Design of UTS in joint use trenches and adjacent to wet utilities should consider precautionary measures to sustain any damage or collapse to those utilities. Periodic inspection of the UTS is recommended to address any urgent issues and avoid deterioration and damage escalation situations. Rehabilitation and/or upgrade to existing UTS should address various concerns related to sustainability such as replacing conduits made of outdated material (e.g. clay ducts, timber ducts and ducts containing harmful ingredients) with new CSA approved conduits, or rebuilding underground manholes with reinforced concrete that can withstand current loading as per standard (CAN/CSA – S6 Canadian Highway Bridges Design Code).

4.2 Redundancy

Design rehabilitation may allow downgrading the specifications of existing UTS if it is evident that such a downgrade is synchronized and harmonized with new conditions to the housing structure (e.g. reducing the number of ducts in a structure due to area downsizing, compromising depth of cover if the structure is moved to no traffic zone, reducing separation to adjacent utility by adding additional protection measures, etc.)

4.3 Reliability

The magnitude of infrastructure use is an indication of its importance, and considering telecommunications as a vital requirement to daily life in urban cities, it becomes extremely necessary to design, repair, and install this infrastructure in most reliable way. The consequences to improper rehabilitation design of existing UTS may undermine its reliability and impose drastic devastation to the public health and economy through network malfunction and the cost of restoration.

4.4 Resiliency

Is the ability to recover the functionality of an infrastructure system, subject to an extreme event of any kind, in a fast and efficient manner. The rehabilitation design for existing UTS should take into account the importance of the resiliency factor. In the face of a changing climate, the increasing frequency and severity of extreme events, it is important to ensure that existing infrastructures including UTS could survive such events. Solutions would include increasing the depth of cover for structures under canals and rivers, or alternatively providing adequate protection, and utilizing FRE ducts for exterior application such as structure attached to a bridge instead of PVC conduits.

4.5 Risk

Is a performance measure, which includes the probability of an event and its consequences. The rehabilitation design to existing UTS should consider risk factors that may exist such as risks generated from the operation of the housing structure (partial bridge failure causing severe damage to the attached telecommunication structure), risks generated from adjacent utilities (such as placing telecommunication cables along with high voltage hydro cable in the same joint trench without sufficient protection), risks generated from environmental impacts such as seismic effects to the housing structure, and risks associated with limited options to immediate repairs due to certain constraints such as road moratoriums, etc.

4.6 Robustness

Is the ability of the structure to withstand the action of an extreme event without being damaged to an extent disproportionate to the original cause (UK Building Regulations, Eurocode EN). In the assessment of deteriorated or damaged existing UTS, the rehabilitation design should be consistent with the robustness of the structure. For example, an existing duct system can be maintained with sufficient repair to local damages to its encasing structure such as replacing corroded steel beams in a racking system in telecommunication chamber.

4.7 Vulnerability

A large number of existing UTS's are designed and constructed based on standards and codes developed decades ago, based on outdated data and materials that do not have the potential capacity to withstand current conditions (such as old underground chambers that were designed to old traffic loading conditions, or ducts designed with materials that do not meet current standards and eventually are considered hazard to public health). In rehabilitation design of such structures, substantial consideration should be made to the vulnerable characteristics of the structure due to climate change and global warming issues such as using proper contractions and expansions due to rapid fluctuations in temperature for conduits in an exterior application.

5. CONCLUSION

It is essential to pursue any required repair and/or rehabilitation work to existing UTS whether the cause of its deterioration is due to usage, or damage caused by other construction activity, to achieve the following qualities:

1. Building an environment friendly structure.
2. Building a structure that meets current specifications and standards.
3. Rebuilding a structure that was originally designed/built with outdated material and currently considered non-compliant standards.
4. Making the underground structure more compatible with the housing structure.
5. Providing an upgraded plenum for competitive systems (e.g. fiber optic)
6. Reinvesting in the utility structures, to extend the life cycle of the utility and reduce maintenance costs.
7. Providing mitigating measures for structural failure in roads, bridges, and other housing structures.
8. Replacing multi-tile ducts, wood ducts, and other out of use material with new materials that meet current standards.
9. Repairing damaged conduits and cable paths to restore structure capacity.
10. Repairing and rehabilitating concrete manholes.

11. Mitigating detrimental coexistence with other adjacent utilities (e.g. closeness to vibrating facilities such as underground transit, closeness to high voltage hydro cables/vaults, closeness to main gas lines, and the potential resulting hazardous consequences).

6. REFERENCES

CAN/CSA – C 22.3 No.7 Underground Structures

CAN/CSA – S6 Canadian Highway Bridges Design Code

History Canada (http://www.thecanadianencyclopedia.ca/en/article/telecommunications/)

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Appendix (1)

Common underground and attached telecommunication structures

Figure 1: Underground telecom manhole	*Figure 2: Underground structures*

Figure 3: FRE Ducts on hanger system attached to bridge structure	*Figure 4: Horizontal Directional Drilling-HDPE ducts*

Figure 5: OPI & CPS equipment on concrete foundation

Figure 6: Clay tile ducts structure

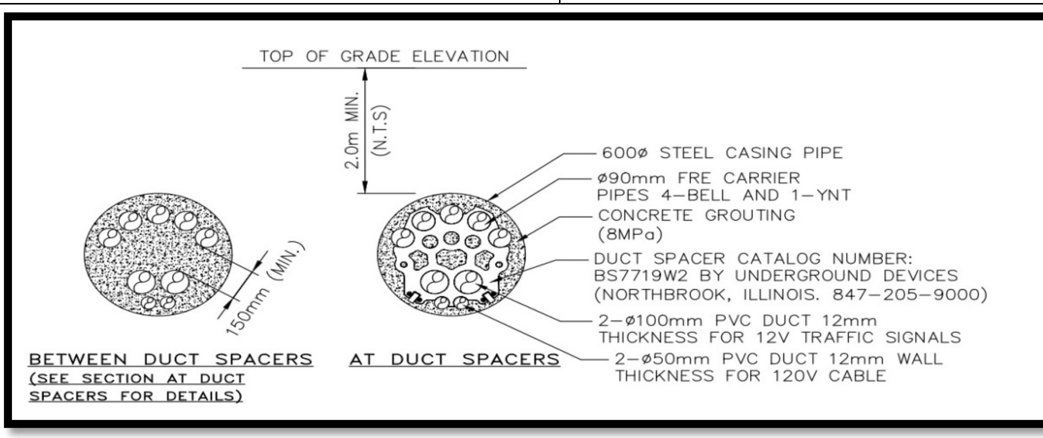

Figure 7: Design sketch for steel casing pipe

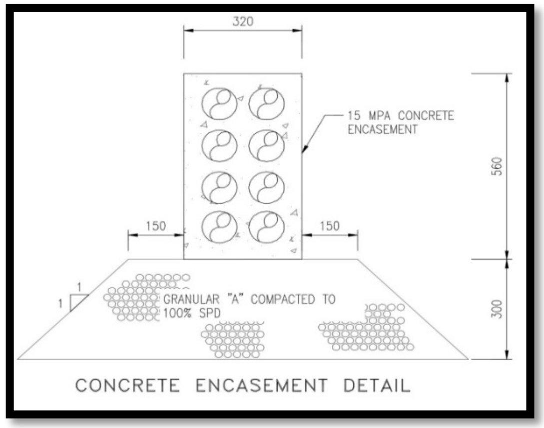

Figure 8: Design sketch for ducts concrete encasement