SELECTION CRITERIA FOR MATERIALS AND METHODS TO REHABILITATE UNDERGROUND INFRASTRUCTURES FOR THE SUSTAINABILITY OF FUTURE HEALTHY GENERATIONS

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SELECTION CRITERIA FOR MATERIALS AND METHODS TO REHABILITATE UNDERGROUND INFRASTRUCTURES FOR THE SUSTAINABILITY OF FUTURE HEALTHY GENERATIONS

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ABSTRACT

Drinking water in the United States contains trace elements of pharmaceuticals drugs, antidepressants, illicit drugs, and other dangerous chemicals. A source of these chemicals is the poor condition of our sewer infrastructure which allows large quantities of clean water to enter the sewer collection system which can overwhelming the water treatment facilities.

Municipalities must recognize that drinking water resources and sewer infrastructure are key and vital capital assets, just as its buildings, historical sites, transportation infrastructure, parks and landmarks. Thus, appropriate capital expenditures should then be allocated to maintain and rehabilitate this infrastructure. Our steadily increasing population growth, coupled by diminishing clean water sources could lead to unsustainable cities if no corrective action is taken now. By not allowing clean ground water to enter the sewer collection system, todays generation can preserve clean water supplies for future generations. This paper covers the premise that by selecting proper rehabilitation and lining materials and proper installation methods, we can further sustain future generations health.

1.0 INTRODUCTION

The ancient City of Rome depended on abundant clean water sources to provide its citizenry the highest quality of life possible. Some of that infrastructure still exists today. These clean water sources were clearly separated from their sewer disposal. Today, our modern city sewer infrastructure is not only old, outdated and deteriorating rapidly, but also is helping deplete our clean water sources.

Since the infrastructure is typically underground it becomes an “out of sight, out of mind” issue. This poor condition of the infrastructure has become the culprit for allowing large quantities of clean water to enter it in the form of inflow and infiltration and that water is unnecessarily contaminated. Once the clean water mixes with sewer effluent, not only is it difficult to re-clean it but is also very expensive. During major rain events, water treatment plants become overwhelmed and can not effectively clean the water so untreated water is prematurely released to our streams, creeks, and lakes. These same watersheds then become the drinking water source for other communities downstream.

Sustainability of healthy populations and nature must coexist. Humans depend on it. Unlike the ancient cites like Rome where there was an abundant water sources, today we depend on technology to clean our water that may have been used a multitude of times before we consume it. In the past there was plenty of room for error for humans and ecosystems to coexist, today due to the ever increasing demand for goods by our increasing populations, our margin of error is decreasing. We can no longer take our clean water sources for granted. We can survive without our parks, buildings and landmarks, however, we can not live without clean water. Untold number of deaths occur yearly in central Africa’s communities where the line of clean water and sewer effluent is often blurred.

It is imperative that we recognize that allowing our sewer infrastructure to simply wear itself out, or to haphazardly patch it is no longer an option. Municipalities must assess the existing condition, record the major problems and prioritize the rehabilitation. Municipal authorities at all levels must recognize that the cost of digging up and replacing underground infrastructure is insurmountable. Thus, when we recognize it as an Asset versus a Liability, we all tune into rehabilitation for the long term.

2.0 DISCUSSION

In the United States numerous studies conclude that of all ground water entering the sewer collection system unintentionally, approximately 50% to 65 % enters though its structures such as manholes, pump stations, lift stations, and junction boxes. The other percentage infiltrates through its piping systems. I would suspect that the similar estimates would be expected in other countries including Australia.

The base material of construction for these underground structures is primarily masonry such as cement, brick and mortar, and some block. Some of these structures are cast in place, some are cast in a factory, some are hand built in place. There is a large degree of variation in the quality of materials and quality of work. In the United States municipal work is openly bided and the low bidder usually gets the work. The highest level of construction quality is not typically used. Therefore, Infrastructures intended to last 50 years, may not be feasible. In addition there are other materials involved in lesser quantities, such as aluminum, steel, pvc, thermoplastics, rubber and steel.

2.1 Exposure to Underground Structures

These structures are dynamic not static. They are exposed to shock, vibration, cyclic thermal changes, seismic movements, ground movements due to dry and wet weather, sewerage loading cycles, abrasion wear, and the highly corrosive hydrogen sulfide gas.

The hydrogen sulfide is a byproduct of microbiological activity on the walls, ceiling and crown area of pipes. The hydrogen sulfide gas combines with moisture and creates sulfuric acid. The level of acidity or ph levels on the surface of walls is difficult to measure. Microscopic biological colonies grow inside the capillaries created by the inherent in the concrete hydration process where excess water used to place or cast the concrete escapes and leaves large quantities of growth sites. The ph levels could be in the zero to 1 range. This very corrosive process severely deteriorates the basic components of underground infrastructures and compromises the entire sewerage systems.

Hydrostatic pressure is always present in underground structures. The deeper the structure the higher the pressure head. This force is always present and can not be stopped. Since the majority of the rehabilitation process occurs inside the structure, the weight of the ground compresses soils and water table so that they are pressurized. If you would to drill a hole in the sidewall of a manhole located near a stream or lake, you would get a stream of water infiltrating into the structure. Since concrete is porous and permeable, you always have moisture seeping in to the underground structure. This is important because whatever material you are going to apply inside the structure, it will always have this continuous moisture transmission migrating into the structure. It is typically in the form of liquid water and water vapor gases.

This brings us to the fact that underground structures are always wet.

Regardless of the ground surface moisture levels, there is always moisture deeper in to the ground. Since there is always sewer effluent traveling through the pipelines and structures, the interior surface of underground structures are always wet, therefore, all materials used to rehabilitate manholes, pump stations, lift stations, holding tanks and tunnels must be applied where moisture is present.

3.0 INFLOW and INFILTRATION

Inflow is extra water entering the sewer collection system from above ground due to a wet weather cycles through manhole covers and manhole chimneys or faulty sealants close to the surface.

Infiltration is extra ground water that enters the collection systems from the surrounding ground through faulty joints, deteriorate concrete or mortar, breaks and cracks in the walls, pipe penetrations, faulty pipe connections, and general seepage of water through the porous and permeable concrete. Hairline cracks that develop overtime will allow tree roots to enter the sewer systems and further provide entry points for ground water.

All the water that enters the collection system unnecessarily depletes and contaminates future clean water sources.

4.0 MATERIALS USED TO REHABILITATE UNDERGROUND STRUCTURES

Any and all rehabilitation inspections, and application processes require trained and experienced technicians trained to work in Confined Spaces where there may be poisonous, explosive atmospheres, and limited openings and rescue potential.

It is important to note that there are a myriad of problems associated with the rehabilitation of sewer infrastructure. There is Not one single product or process that will resolve all the problems. The solution typically involves more than one product and process. Some solutions are short term, some are longer term.

4.1 Chemical Grouts and Water Plugs

Chemical grouts can be used to stop large volumes of water infiltrating the structures and is typically used where the underground structure is relatively sound. Typically a series of holes have to be drilled through the structure adjacent to the defect. The grout can be injected behind the structure where it chemically reacts with the incoming water. The chemical grout could be of a urethane, acrylate, or polyurethane composition. Environmental conditions will be a factor in determining the type, set time, and the application method. Grouts can also be utilized to stabilize the soil surrounding the underground structures.

Fast reacting cement water plug can also be used to stop active leaks. These cements are typically considered temporary solutions until reinforced liners or polymers can be used to keep these plugs in place.

Both chemical grouts and very rapid setting cements require experienced installers. Both systems stop leaks are however they are not designed to reinforce the structure nor do they stop the corrosive effects of hydrogen sulfide gasses.

4.2 Cementitious Coatings

Cement based materials are used as patching mortars or as over layments. These coatings can be applied once the infiltration of the underground structure has been stopped and proper surface preparations are complete. The composition of the cement materials may be portland based, some contain varying amounts of calcium aluminates, micro-silica or fumed silica, fly ash, curing admixtures, synthetic or glass fibre, and other proprietary admixtures to increase compressive strengths and water proofing qualities.

These cement coatings can be used as stand alone or can be used as under layments where they will be subsequently coated with more chemical resistant polymeric coatings or fiber reinforced liners.

Repair mortars are designed to correct large voids, fill in holes where there are missing brick and block, and to smooth out transitions in dimension changes, curvatures, and other defects and for general resurfacing.

As coatings, these cements are designed to protect the structures where the pH surface levels are above 2. Below that level, they may become a short term sacrificial coating. This material can be spin-casted, hand troweled, or applied with a low pressure rotor stator pump.

Most underground structures are composed of mostly cementitious materials. Cements will bond well to other cements, but may not bond well to other materials found in the structures. If the structures are exposed to a lot of shock and vibration, or expansive soils, these coatings are brittle and may crack. In some applications, they can be used as an under-layment for polymeric coatings. Calcium aluminate cements may exhibit a marginally more corrosion protection versus portland cement, however, they are a bit more complex installation.

4.3 Polymeric Coatings

Polymers such as epoxy, urethanes, polyurethanes, hybrids, and other coatings can be applied over existing structures or over cementitious coatings. Polymeric coatings are typically water proof, can be sprayed-on, hand troweled, and spin cast. The formulation of these materials must be such that they can be applied in freshly applied concrete patching, and directly over concrete under-layments. They must overcome the ever-present hydrostatic moisture pressure. Epoxies typically have a higher degree of forgiveness when applied on moist concrete than urethanes or polyurethanes. When exposed to water or moisture, urethanes or polyurethanes chemically combine with water and create foam. Special care is needed to thoroughly attempt to dry the underground structures before a urethane type product is used as a coating.

The thickness of the coating applied is plays a significant in the life of the coating. Depending on the flexural modulus or stiffness of the material, the depth of the underground structure, the surface profile, and other factors the thickness a key component to long term success. Polymeric coating are much more chemical resistant to sulfuric acid and other chemicals that is present in sewer systems than cementitious coatings. Most polymeric coatings will can resist pH levels of 1, some may handle lower pH levels.

Some coatings are made to be flexible, or elastomeric, some are made to be stiff and brittle. The more flexible and elastomeric, the less the chemical resistance, the more hard and brittle the more chemical resistant, however, hard coatings may break during ground movements, or via normal maintenance routines where workmen may drop tools, or hose ends, nozzles, during cleaning. Therefore, the mechanical properties of polymeric coating must be custom designed to endure the dynamics of the structure, chemical resistant, be subjected to the cyclic loading of the structure, and be designed for long term endurance. Polymers are usually waterproof, however, they easily develop pinholes and holidays. This pin holing must be corrected otherwise in the presence of high H2S, the bacteria will degrade the concrete behind the polymeric coating. Since the concrete substrate of the underground structure is subject to hydrostatic pressure, water vapour permeates through the top coats and may overpower the cohesive cross-linking process of polymers.

Polymeric coatings as do cementitious coatings also have limitations. They are dependent on the substrate they are attached to. If the substrate or host structure continues to deteriorate, then these top coats will also eventually fail.

4.4 Fiber Reinforced Cured-in Place Liners

In order to achieve a true monolithic composite liner, a continuous glass-fibre cloth has to be sandwiched in between layers of epoxy and custom fitted to the underground structure. Hand layup- composite liners can achieve this. An assessment of the structural deficiencies need to be noted after a thorough cleaning and leak stoppage. Then, the structure has to be surface prepared as for the cement coating and epoxy coatings. A cementitious underlayment can be applied where needed such as joints, major defects, and to smooth out transitions between chase and benches, in corners of walls, or around pipe entries.

The key concept is to custom design and create a stand alone liner inside of the structure. This is a similar process as to building a boat inside your underground structure and using the host structure as your mould. Wherever, structural defects, leaks, etc were noted during the initial condition assessment, they can be first patched with a layer if epoxy and fiberglass cloth. The entire structure can then be lined with a thick layer of epoxy at about 100 mils of an inch or 1.5 millimeters thick. A layer of fiberglass cloth is then embedded into the soft pliable epoxy, wetted out, and an addition thick layer of epoxy is applied to encapsulate the fiberglass cloth. In areas where a lot of concentrated stresses can be located such as corners, chimney areas or bench to wall sections, or pipe penetrations,additional reinforcement can be installed.

This type of system creates a structural long term rehabilitation process. This type of system is corrosion proof, waterproof, provides addition structural enhancement and is custom built to fill the needs of a dynamic underground structure.

After the lining of over 50,000 structures over the past 25 years and this method of lining with a glass-fibre epoxy matrix has proven to be of much longer life than the other methods of simply lining with only cement and just lining with epoxy over cement. Although the cost is typically 30% more, we have found that there is very little to no repairs needed for at least 20 years in harsh service.

5.0 LONG TERM OBSERVATIONS AND CONCLUSIONS

One objective of sewer rehabilitation is to reduce the infiltration of ground water into the sewer effluent. As more infiltration is stopped, it is noted that the sewer effluent becomes more septic and therefore corrosive over time. This observation also indicates that the rehabilitation materials used must not only be corrosion resistant to today's sewer atmospheres but must also be resistant to future more corrosive environments that may result from less and less clean water diluting the sewer effluent.

This paper did not cover the lining of sewer piping and pipe laterals, however, the lining of underground structures is one way of helping save our clean water sources for the future sustainability of healthy generations. The selection of materials and processes is critical for long term life of our decaying sewer infrastructure.