Sustainability in precast concrete manholes

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The sustainability of built structures has been one of the main concerns in the last decade. In order to evaluate the sustainability of precast concrete manholes, a life cycle assessment scheme for precast concrete manholes is discussed in this paper. The sustainability efforts associated with precast concrete manholes is also briefly explained in this paper. Accounting for the soil structure interaction effect, in the design of different types of precast concrete manholes is proposed as an approach that may lead to a more sustainable design. This proposal is based on an extensive experimental and numerical investigation on precast concrete manholes that was conducted at Western University, Canada, in collaboration with the Ontario Concrete Pipe Association. The results of this investigation show that the manhole base design procedure can be altered to reduce the required reinforcement in the manhole base, which in turn would lead to a more sustainable manhole production.

Manholes are the main access points to the sewer and storm water systems for checking and maintenance. The fact that the codes governing the sewer and storm water systems require the presence of a manhole at each junction, change in grade, change in direction of the system and at certain maximum distances along the pipe lines, illustrates the importance of manholes as a main component of these systems. In this paper, the discussion concentrates on precast concrete manholes which are very strong when installed in the ground. One of the main advantages of these types of manholes over other types is that they have a service life exceeding 100 years if properly designed as they don't rust, burn or rot. Precast concrete manholes can help in earning the infrastructure project LEED points as described in Table 1.

Precast concrete manholes life cycle assessment scheme

The environment, economic and social aspects should be equally considered when evaluating the sustainability of a structure or a system, which refers to the triple bottom line concept as shown in Figure 1 [2]. All three factors should be analyzed over the full life cycle of the structure by using what is referred to as the life cycle assessment (LCA).

Table 1: Proposed LEED points to be gained on an infrastructure project [1].

Credit	SS Credit 5.1	SS Credit 6.1 & 6.2	MR Credits 2.1 & 2.2	MR Credits 4.1 & 4.2	MR Credits 5.1 & 5.2
Description	Site development: Protect or restore habitat	Storm water design: quantity and quality control	Construction waste management: divert from disposal (50 % = 1 pt.; 75 % = 2 pts.)	Recycled content: post-consumer plus half pre-consumer (10 % = 1 pt.; 20% ,= 2 pts.)	Regional materials: processed and manufactured regionally (10% = 1 pt.; 20% = 2 pts.)
Credits available	1	2	2	2	2
Comments	Due to precast concrete manholes being plant cast and are delivered to the site ready to set so they require very minimal site disturbance to install.	Most storm water management plans will require manholes in the design to properly handle the storm water runoff. Precast concrete manholes are the superior choice.	Precast concrete manholes are plant cast and delivered to the site ready to set and create minimal to zero amounts of onsite waste material.	Precast concrete manholes may contain supplementary cementitious materials such as fly ash and blast furnace slag which will add to the project's recycled content goals.	The vast majority of materials that go into the construction of precast concrete manholes are within a 500-mile radius of the precast plant.

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A proposed life cycle assessment scheme for precast concrete manholes, which divides the life cycle of the manhole into five phases [3] entails:

1. Materials production
2. Manhole components manufacturing
3. Manhole installation and construction
4. Manhole usage
5. Manhole end of life

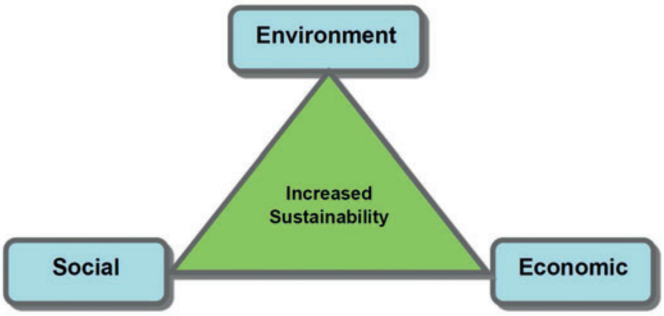

Fig. 1: The trip bottom line sustainability concept

A schematic diagram showing these phases along with a brief description of each of these phases is shown in Figure 2.

Precast concrete manholes sustainability efforts

Precast concrete manufacturers have put a good amount of effort into improving the sustainability of precast concrete manholes. These efforts are among the overall procedures to increase the sustainability of the whole sewer or storm water systems; and they can be grouped into three core areas: the manhole's concrete mix design, the manhole's casting and production procedures and the treatment of the manhole's surface. The main points related to the efforts in each of the three groups are summarized below.

The manhole's concrete mix design

Altering the concrete mix design to increase the sustainability of the precast concrete manhole can be done to achieve three main goals:

1. Reduce the amount of cement – which has a high CO_2 emission associated with its manufacturing – used in the mix and replace it with materials that have less CO_2 emission related to its manufacturing.
2. Alter the concrete mix design by adding additives and/or admixtures to enhance the durability performance of the manhole. This will:
    1. Increase the service life of the structure
    2. Reduce the required maintenance and replacements
    3. Lead to a more sustainable manhole
3. Produce lighter weight manholes which will reduce the energy and CO_2 emissions associated with their transportation and installation.

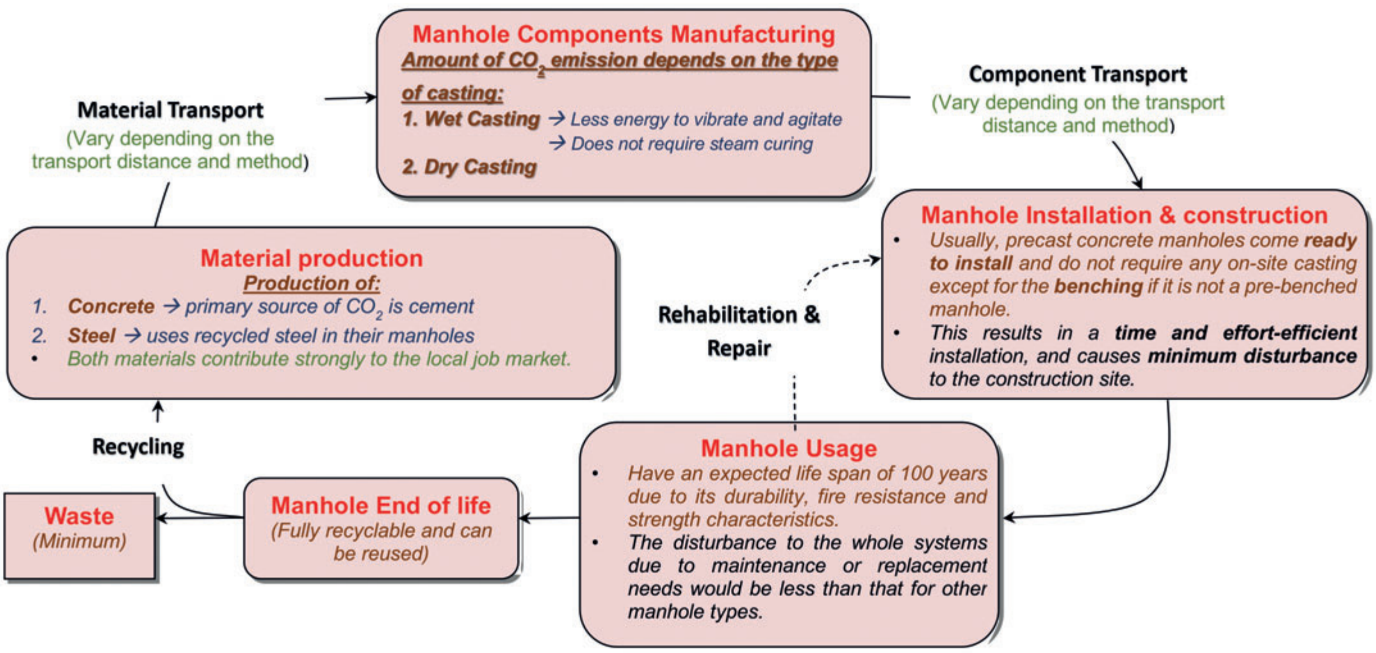

Fig. 2: Precast concrete manholes life cycle assessment scheme.

Achieving the three goals is the ultimate aim of the efforts done on altering the mix design if applicable [3-7].

The manhole's casting and production procedures

One of the main directions that manhole manufacturers follow to produce a more sustainable manholes, is to alter the manufacturing processes in order to reduce the energy consumption and CO_2 emission associated with manholes production. These efforts can be summarized as below for each of the two types of available casting procedures.

Wet casting

- Conventional concrete or self-compacting concrete is usually used. The use of self-compacting concrete in the wet casting method will save the energy required to agitate the concrete in the dry casting method.
- This method gives space for the modified mixes mentioned in the previous heading to be utilized.
- Also, the wet casting method saves the energy associated with the steam curing due to the overnight drying technique adopted.

Dry casting

- The foremost advantage of the dry casting method is the fast formwork removal which accelerates the production process.
- This is due to the use of zero slump concrete that usually requires intensive energy to agitate and vibrate and then steam cure the produced concrete manhole.
- The main sustainability efforts for this casting method concentrate on developing less energy intensive equipment for agitating and vibrating the concrete.

To reduce the onsite installation time other manufacturers went in the direction of trying to eliminate onsite concrete casting during the instillation process by producing prebenched manholes in the factory [3, 8].

The treatment of the manhole's surface

When highly corrosive environments are expected, the surface of the manhole and pipes are treated by coating or lining their inner surface. This increases their durability and in turn increases their sustainability. The coating or spraying of the concrete sewer system is mainly aiming at deactivating or reducing the bacteria causing the generation of the concrete corroding agents [3, 9,10].

Accounting for soil structure interaction effect for a more sustainable manhole design

Soil Structure Interaction (SSI) analysis involves the evaluation of the interactive behavior between the structures or their foundations, and the supporting soil media. Most building codes stipulate that SSI decreases the seismic force and thus neglecting its effect provides more conservative design. The provisions of most codes recommend performing SSI analysis for critical structures only. This leads to a common practice by civil engineers of ignoring the SSI effect when designing several types of structures. When dealing with underground structures, accounting for the SSI effect will alter the response of the structure and it will lead to a more realistic design than that done when not accounting for its effect.

In this paper accounting for the SSI effect in the design of precast concrete manholes is recommended as a procedure that leads to a more sustainable manhole design. This recommendation is based on a study conducted by the author and other researchers at Western University, Canada, in collaboration with the Ontario Concrete Pipe Association (OCPA) [11 - 13]. This study consisted of two parts: conducting full-scale testing of circular precast concrete manholes and an extensive finite element numerical investigation on the same type of manholes. The first part of the study involved 27 full scale tests on three circular precast concrete manholes in the Large-Scale Geotechnical Testing Facility (LSGTF) at Western University under loads representing the Ontario truck loads incorporated in the Canadian Highway Bridge Code. Two of the tested manhole bases were unreinforced. The main aim of this part of the study was to evaluate the state of strains in the precast concrete manhole and the state of stresses in the soil surrounding the manhole and beneath the base. The main finding of this part of the study is that no steel reinforcement is required in the manhole base for structural purposes as none of the tested manholes, including those with unreinforced bases, have shown any signs of cracking. The details of this part of the study and the testing results can be found in [11, 13].

The second part of the study consisted of an extensive finite element numerical investigation using Plaxis 3D. The tests performed in the experimental part of the study were used to calibrate the finite element analysis models. The aim of this numerical investigation is to extend the results of the study to cover all the possible manhole lengths and different soil conditions. This part's results indicated that the moment in the base are far from the cracking moment for all studied conditions. The details of this part of the study and all the pertinent results can be found in [12, 13]. The results of both parts of the study [11 - 13] indicated that the current design procedure for circular precast concrete manholes, that did not fully account for the SSI effect, resulted in a very conservative design of the manhole base including a very heavily reinforced base section. Altering the design of the circular precast concrete manhole base accounting for SSI would largely reduce the required base reinforcement, which in turn will result in a more sustainable precast concrete manhole design. Studies similar to the above e can be made on different types and shapes of precast concrete manholes to alter their design procedure to account for the SSI effect, which may result in more sustainable manhole designs.

Conclusions

Sewer systems are exposed to one of the harshest environments for concrete materials. These systems are usually accessed for maintenance and inspection, using access provided through precast concrete manholes. In this paper, a life cycle assessment scheme for precast concrete manholes was discussed in order to evaluate their sustainability. A brief explanation of the sustainability efforts associated with precast concrete manholes was presented, followed by a proposed approach that may lead to a more sustainable design. Accounting for SSI in the precast concrete manhole design was proposed. This approach is based on extensive experimental and numerical investigations carried out on full-scale tested manholes in Canada. This study showed that the manhole base design procedure can be altered to reduce the required reinforcement in the manhole base, which in turn will produce a more sustainable manhole. ■

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