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CASE STUDY: DEMONSTRATING USE OF TIRE DERIVED AGGREGATE (TDA) IN BACKFILLING HOME BASEMENT WALLS IN MANITOBA

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1 Project Overview

This project is a collaboration among Manitoba Hydro (MH), tire recycling industry in Manitoba and Red River College. The focus of the project, began in 2013, has been on exploring the effective use of tire derived aggregate (**TDA**) underneath and around home basement slabs and walls, as replacement for natural fill material (NM). Manitoba Hydro had an interest to support the investigation because of the potential energy saving resulting from enhancing the insulation value of the basement foundation. Tire recycling industry, represented by Tire Stewardship Manitoba (TSMB) and Off-The-Road (OTR) Tire Recycling Corp., were interested in the project as their mandate is to promote economically viable end use and market applications for scrap tires, thus diverting used tires from simply ending up in landfills.

Work on the project was divided into three Phases. In Phases I & II of the project; work included determining the physical and mechanical properties of **TDA**. All tests conducted during Phases I & II were small scale laboratory type of experiments. Results of the laboratory tests are summarized in Figure 1

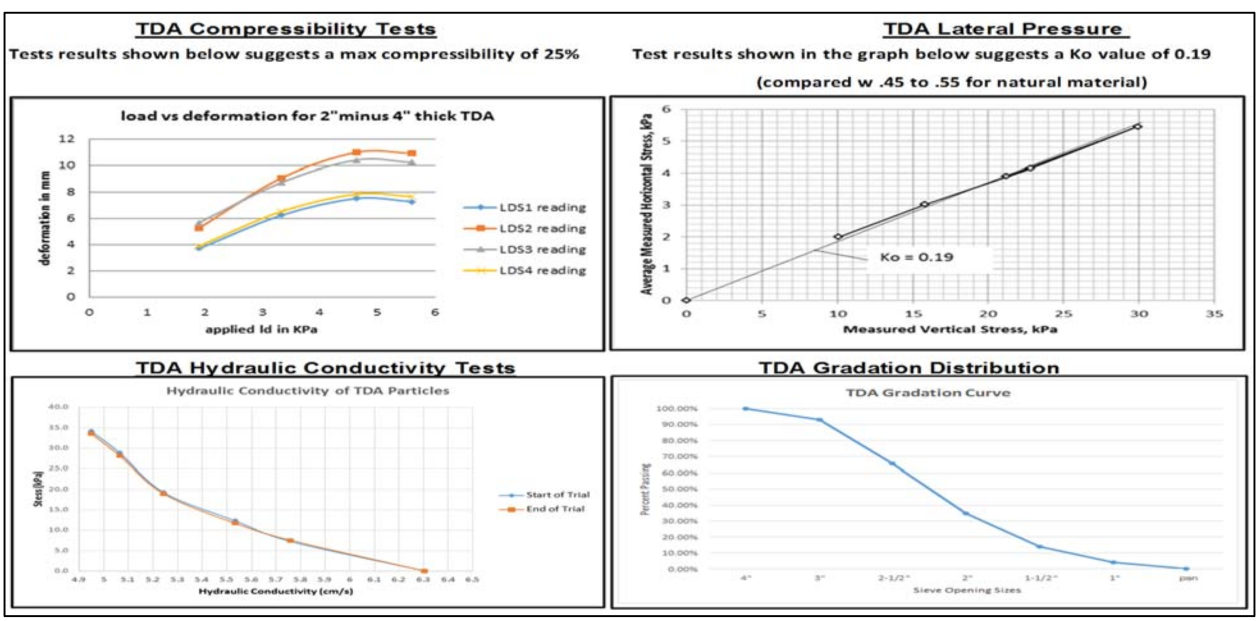

Figure 1: Summary results of the TDA small scale tests during Phases I & II of the project

Based on the test results in Phases I & II, the project progressed into Phase III, a full scale demonstration, where the focus has been on determining the long term performance of **TDA** when used in this particular application. The building used for the full scale demonstration included a typical 24 ft by 36 ft (7.5m X 11m approx.) full basement with a makeshift top for weather protection. The basement was divided into two identical parts, where **TDA** was used as backfill and underneath the slab on one side and natural material (NM) was used on the other side. Figure 2 shows the building, called the "Experimental House" during construction and placement of **TDA** and locations of sensors.

Figure 2: the Experimental House during and after construction

2 Innovations

Although **TDA** has been used in other civil engineering applications; e.g. road construction and retaining walls, this is the first complete investigation that focuses on its use in home basements construction. The investigation entailed extensive measurements and analysis of both short and long term performance of **TDA**. While specific values describing the physical and short term properties for **TDA** were determined during small scale tests (e.g. hydraulic conductivity and lateral pressure), in this demonstration, Phase III of the project, analysis are based on comparing measured performance between both sides of the basement, the **TDA** and natural material (NM) sides. As shown in Figure 3, sensors stations were distributed evenly between the two sides. Each station included: temperature, moisture and lateral pressure sensors.

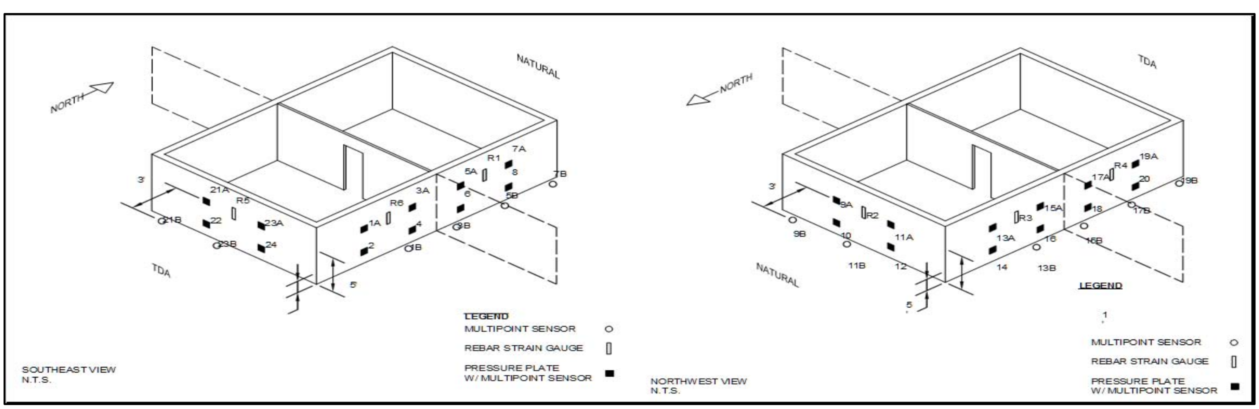

Figure 3: the performance measuring sensors distributed evenly at both sides of the basement

While commercial multi-point sensors were used for measuring the moisture and temperatures of the backfill; in this project a simple device was developed that allowed researchers to compare between the lateral pressure induced by **TDA** vs that by NM on basement walls. The device, shown in Figure 4, includes strain gauges connected to a cantilever that bends as the lateral pressure is induced by the backfill. The device was developed mainly due to the high cost of commercial available pressure cells.

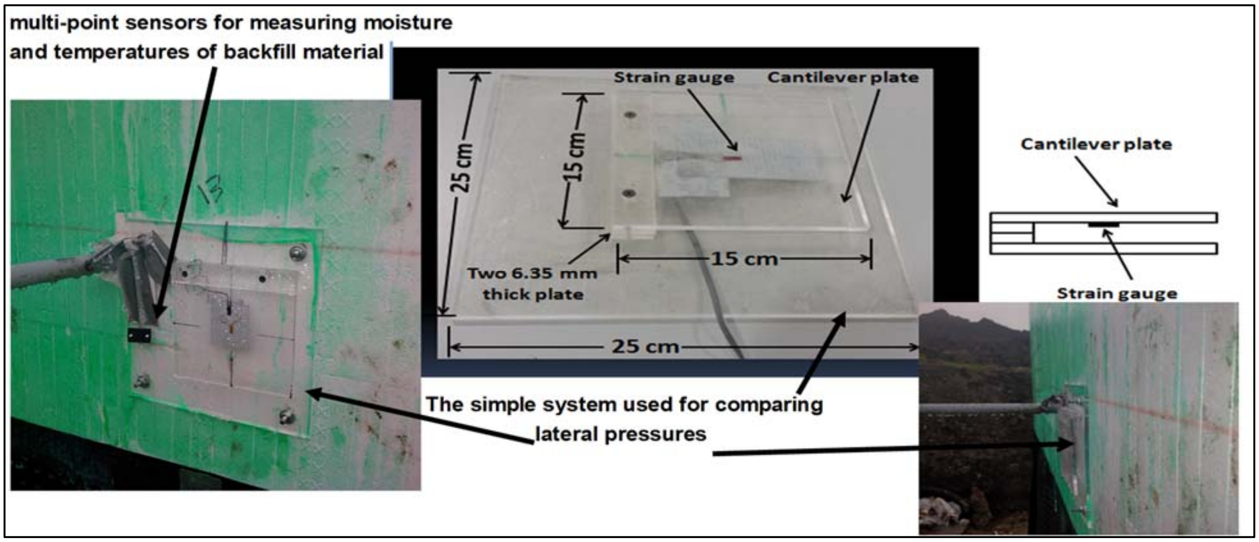

Figure 4: Cantilever plate & strain gauge used for measuring pressure

Although was not the primary focus, but another innovative aspects of this project was the integration of performance sensors' data into the building information model (BIM) of the facility. A digital platform was developed that hosted both the BIM model and live data and was used to demonstrate the possible extension of BIM use beyond design and construction stages into facility management.

3 Lessons Learned

The experimental and analytical methodology followed in this project; i.e. comparing between two sets of parameters, allowed making effective use of prior laboratory tests' results and enabled including many of those parameters in assessing the performance of **TDA** in comparison to NM as summarized below:

- **Heat Losses:** Analysis of the differences in backfill temperatures between **TDA** and NM sides have shown that **TDA** has more ability to retain higher temperature than NM. The measured differences may lead to 4-8 times higher walls' thermal conductivity on NM side than on **TDA** side. However, this advantage, which contributes to heat losses through the walls particularly during winter months, may be lost if proper construction practice are not followed, e.g. mechanical compaction to reduce voids ratio, use of geotextile material between **TDA** and top soil… etc.

- **Moisture Retention & Drainage Ability:** Two years of analysis have shown that this is probably the largest benefit for using **TDA** instead of NM in backfilling basement walls. While the average moisture was approximately 40% for **TDA** and 80% for NM, drainage speed of surface water (e.g. rain and melting snow) was twice as fast on **TDA** side as was on NM side. Of course this particular property of **TDA** has a significant effect on reducing moisture leakage through basement walls, a common problem in many Manitoba homes, particularly older ones.

- **Lateral Pressure on Basement Walls:** Data analysis showed that lateral pressure of NM on basement walls is higher than that for **TDA**. Using early laboratory results for K_o = 0.19 (K_o is the ratio between horizontal and vertical forces for at-rest-condition), simple calculations show that the value of the horizontal pressure resulting from NM is 8 to 9 times as much as that resulting from **TDA**. This significant difference would potentially translate into structurally thinner and less reinforced wall sections and in turn lower cost for basement walls backfilled with **TDA** compared with those using natural fill material.

- **Differential Movements of the Basement Concrete Floor:** Analysis of floor elevations over 18 month period showed that, generally, floor levels on both sides have experienced very little and insignificant movements, all within 4 mm. However, an interesting observations may be noted from reviewing the profiles of the floor on both sides. While the floor levels on the **TDA** side indicated settlement or sagging, the levels on the natural material side indicated rising or heaving. Even though the values are insignificant, but this observation may refer to the expected soil swelling that normally occur and causes the concrete basement slab to crack over time.

- **Radon Emissions Levels:** Radon emission data analysis showed slight lower values appearing on the **TDA** side during any of the three stages of ventilation; active, passive and no ventilation when compared with the emission levels on NM side. This may be attributed to the lower pressure difference and dryer conditions on the **TDA** side.

- **Ground Water Qualities:** Series of tests were conducted from January to September 2016 to determine levels of ground water qualities following the construction of the Experimental House and use of **TDA** in backfilling the basement walls. Results indicated no “out of the norm” effects due to use of **TDA** as compared with the results from water samples collected from the natural material side.

- **Indoor Environmental Qualities:** Results showed no significant differences between the two sides of the basement with respect to parameters such as: levels of CO, CO_2, relative humidity, air contaminants such as dust particles and volatile organic compounds (VOC). However, measurements for the moisture contents of the indoor drywalls showed that average moisture on the NM side of the basement is higher than that for the drywall on the **TDA** side. These were 10% on the NM side vs 7% on the **TDA** side. Normally, a drywall moisture content above 10% may signal a “mold” problem.

- **Flash Point:** In addition to the comparative analysis done which is based on measuring the different performance characteristics on both sides of the basement, flash point test was conducted on **TDA** material to determine at what level of temperature **TDA** my ignite on its own. The test was conducted at independent laboratory and results showed that the flash point is above 75 C^{o}, which is considered a safe limit for this application.

- **Economic Analysis:** A preliminary analysis of current market cost shows that while clean fills’ cost ranges from $600 to $3,600 for a typical (24’ by 36’) basement construction, **TDA** cost ranges from $450 to $900, depending on size gradation.

- **Commercialization Prospects:** Throughout the project, many stakeholders including designers, architects and City of Winnipeg Building Authorities, were continuously kept informed of the work progress and results of the analysis. This “sharing” of information has significantly helped in mobilizing the gained knowledge and in turn in preparing for the introduction of this material into construction industry, as a green material. A number of residential and commercial projects in Manitoba are currently being discussed with TSMB for possible collaboration in the coming construction season.

Acknowledgements

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