Recycling Pavement for Highway 401 Expansion Project from Mississauga to Milton

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Abstract

West Corridor Constructors (WCC) was selected to design and build the Highway 401 Expansion Project. The project widened 18km of Highway 401 from Credit River in Mississauga to Regional Road 25 in Milton, from the 3 lanes in each direction, to 5 lane sections and 6 lane (collector/express) sections. Highway 401 is the busiest and most congested highway in North America; therefore, WCC required a strategy to maintain traffic during construction while reconstructing the median portion of the highway and keeping the project on schedule. Removing existing road material and transporting it off-site was not feasible due to the volume of traffic. Instead, a recycling concept was used to eliminate the need for trucking off-site. Asphalt and concrete were recycled on-site to produce granular material that could be used in the pavement structure, resulting in the conservation of materials and less fuel consumption.

Introduction

The Highway 401 Expansion project is a Design Build project to widen 18km from Credit River in Mississauga to Regional Road 25 in Milton, from the 3 lanes in each direction to 5 lane sections and 6 lane (collector/express) sections. The Ministry of Transportation (MTO) and Infrastructure Ontario (IO) selected West Corridor Constructors (WCC) to design, build, and finance the Highway 401 Expansion Project under a Public Private Partnership. WCC is an integrated Joint Venture comprised of Aecon Infrastructure Management Inc., Parsons Inc., and Amico Design Build Inc. The Highway 401 Expansion was a $650M project that was built under a very aggressive schedule to be constructed in under 4 years, with the project awarded in April 2019 and the completion in 2023. Highway 401 has a large volume of traffic and carries approximately 180,000 vehicles on average per weekday from Credit River to Regional Road 25.

One of the most complicated aspects of the project was to maintain traffic during construction. The staging approach involved widening the highway to the outside, then shifting traffic to the widened portion and then reconstructing the median portion of the highway. The traditional method for reconstruction in the median would be to remove the existing road (asphalt, concrete base, aggregate & concrete barrier walls) and transporting them in trucks off-site, then process, followed by transporting granular material from off-site to build the road base and sub-base. However, this approach would require trucking an extremely large quantity of material off-site for disposal and inversely transporting a large amount of material to the site from aggregate sources. There is also the added complication of trucks having to cross 3 lanes of live traffic to leave the site, resulting in greater fuel consumption for transporting all the material.

This paper will discuss the challenges of highway infrastructure expansion in an urban environment, and the benefit of recycling methods. In traditional applications, this may not be cost effective, but after a review and analysis of our situation, it was deemed to be practical.

Recycling Concept Approach and Methodology

The project requirements specified either a flexible or rigid pavement structure as from the Preliminary Design Report (Golder Associates Ltd., 2012) which is as follows:

Flexible
- 40 mm Stone Matrix Asphalt (SMA) 12.5
- 50 mm Superpave 19.0
- 70 mm Superpave 19.0
- 100 mm Superpave 25.0
- 100 mm Open Graded Drainage Layer (OGDL)
- 200 mm Granular 'A'
- 500 mm Granular 'B', Type 1

Rigid
- 270 mm Jointed Plain Concrete Pavement (JPCP)
- 100 mm Open Graded Drainage Layer (OGDL)
- 300 mm Granular 'A'

WCC selected the Flexible option and developed a pavement design using the American Association of State Highway and Transportation Officials (AASHTO) Design (AASHTO, 1993), which was developed by the design team. One modification was made to the flexible pavement structure specifications to use 700mm Granular A instead of 200mm Granular A and 500mm of Granular B, as there was a readily available source of Granular A. For Stage 1 of the project (widening to the outside), the work was done in a traditional manner to bring in native material for the 700mm of Granular A. However, for Stage 2 work (reconstruction in the median) it was going to be significantly more costly due to the work zone being in the middle of Highway 401.

As such, the project team reviewed options and alternatives to the traditional methods of staging and reconstruction of the median to determine whether there was a better approach. This included a review of the boreholes and geotechnical reports to understand the quality of the existing Granular Base and Asphalt Surface. Material samples were taken to confirm whether the concrete, asphalt, granular base, along with some new material could be blended to meet the *Ontario Provincial Specification Standard (OPSS) 1010: Material Specification for Granular A Base* (OPSS, 2013). Based on the quantities, it was determined that it would be feasible to bring crushers on-site to recycle the asphalt and concrete to produce granular material that would meet the requirements for Granular A to be used in the pavement structure. Four of these crushers were brought to the work zone to continuously crush the material, which was transported and placed on-site, eliminating the need for off-site trucking. Not only did this recycle a lot of material, but it also had the added benefits of reducing the amount of truck traffic and interface with trucks on Highway 401, thus improving safety for the travelling public and reducing the amount of congestion on Highway 401.

Recycling Concept Implementation

Initial steps in development were to validate whether mobile crushing could be efficiently executed onsite within a long, narrow, working corridor. Could these machines meet project demands from a durability and production standpoint? To help with the vetting process, four manufacturers of crushing equipment had the opportunity to participate in a performance run at a mock-up facility to test endurance, maintenance, production, and usability. Endurance and maintenance criteria required that machine servicing was limited to 2 hours at the end of each shift with zero down-time during a 10-hour period. Production performance was measured hourly and upon completion of the shift, with all machines processing raw material similar to what would be encountered on the Highway 401 Expansion Project. Usability was heavily weighted with crushing equipment requiring ease of operation. Project teams for the most part would not have a lot of experience using the equipment, so operator machine interface was important to maximize production. Complicated machines would result in frustration and limited use. Upon completion of trials, Keestrack R6 was selected from Frontline Equipment, which ranked highest in all categories and excelled in production targets.

Samples were collected and processed, which were analyzed to determine the optimum mix ratios from a varying range of source materials onsite with random cross sections which made it challenging to get a consistent gradation and composition for the crushed material.

Having access to 250 bore holes, WCC charted this data to clarify and detail out all sections of the existing highway. Having cross sectional thicknesses every 100 to 200 meters made way for computing mix ratios targeting OPSS 1010 Granular A with 30% Recycle Asphalt Pavement (RAP) can be used. Programing spread to adjust for varying thickness and target rap content gave a work plan for all operations during recycling. Initial milling offsite was controlled, having maximum mill depths with minimum depth of asphalt to remain. The remaining make up 70% granular and concrete was a guide for operation to plan grading activities and movement of surplus materials. This was following the specifications under OPSS 1010 and MTO's Pavement Design and Rehabilitation Manual (MTO, 2013). Understanding the theoretical volumes, crews could anticipate the need for additional resources to move process aggregate to other sections of the project. Gradation tests and Physical Properties tests were conducted on the Granular A produced from the recycled material to ensure that it met requirements (as shown in one of the example Quality Assurance (QA) test results in **Figure 1**). Of additional importance was the verification that the Asphalted Coated Particles did not exceed the maximum allowable 30%, which was also tested as shown in **Figure 2.**

Project HWY 401 Contract Number: 401-AFO-01 Date: 27-Apr-22

Sample ID: Project: Central - HWY 401 Expansion in GTA

Material Type: Granular A -Recycled LOT **709** Sublot **2**

Sample Weight, g: 24500 Seal **4715** Date Received: 21-Apr-22

Source Name: Crusher 1 Location: -

MTO LS 601 **Renamed to Lot 708 - Sublot 1**

	Sample	1	2
Dry mass before washing, g		12136	411.9
Dry mass after washing, g			357.8

Sieve Size	Cumulative Mass Retained, g	% Passing	Cumulative Mass Retained, g	% Passing	OPSS 1010 Specification	
					Min	Max
26.5 mm	0	100.0			100	100
19 mm	609.8	95.0			85	100
13.2 mm	2143.3	82.3			65	90
9.5 mm	3568.6	70.6			50	73
4.75 mm	5980.1	50.7			35	55
1.18 mm		25.4	205.7		15	40
300 µm		13.6	301.1		5	22
150 µm		10.3	328.4			
75 µm		7.3	352.7		2	8
PAN		6.7	357.8			

Comments: Gradation meets Granular A OPSS Specification.

Figure 1: Granular A gradation test and physical properties test

% Asphalt Coated Particles					
	Asphalt Coated Particles	Asphalt Coated (g)	Total Mass (g)	Percentage asphalt coated	Maximum %
		102.3	1984.5	5.2	30.0

Figure 2: Example of % Asphalt Coated Particles verification

Given that the crushers were crushing asphalt and concrete, as well as native granular material, there were many variables in the blend. This could easily affect the gradation and composition of the material. Quality Control (QC) results were done regularly to ensure the material was within the allowable limits, which also required regular adjustments to the crushing operation.

Construction Working Groups further refined planning and development of recycling operation from logistics, approach, and maintenance. A scaled down 1:50 scale drawings and diecast were used to help assist with refining positions of equipment and staging plan for removals as shown in **Figure 3**. The scaled concept provided a visual reference for staff to process and refine challenges. This step sped up the process in finalizing the location of stockpiles, direction of crushing and how process material will be placed. The actual production layout is shown in **Figure 4**.

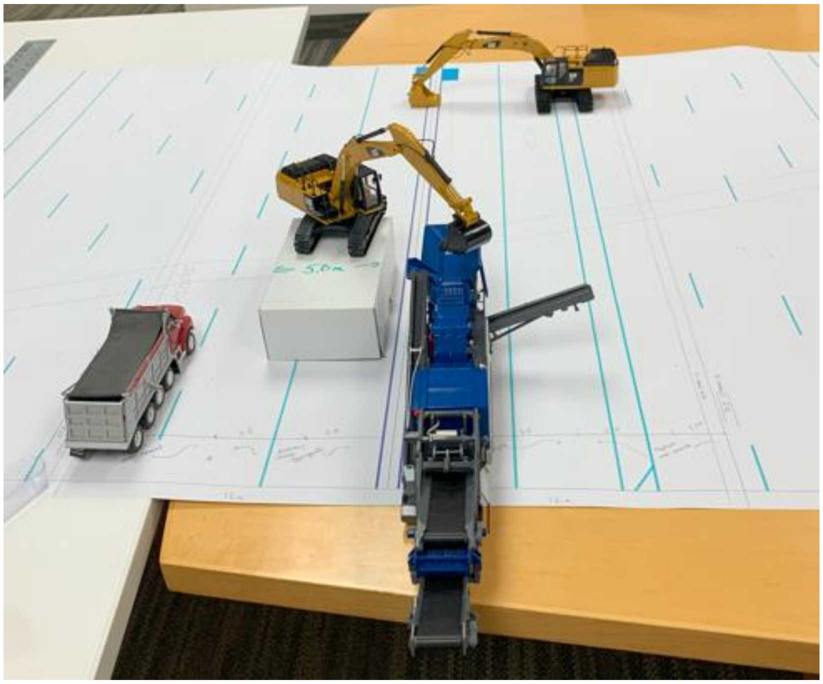
Figure 3: Planning concept scale 1:50

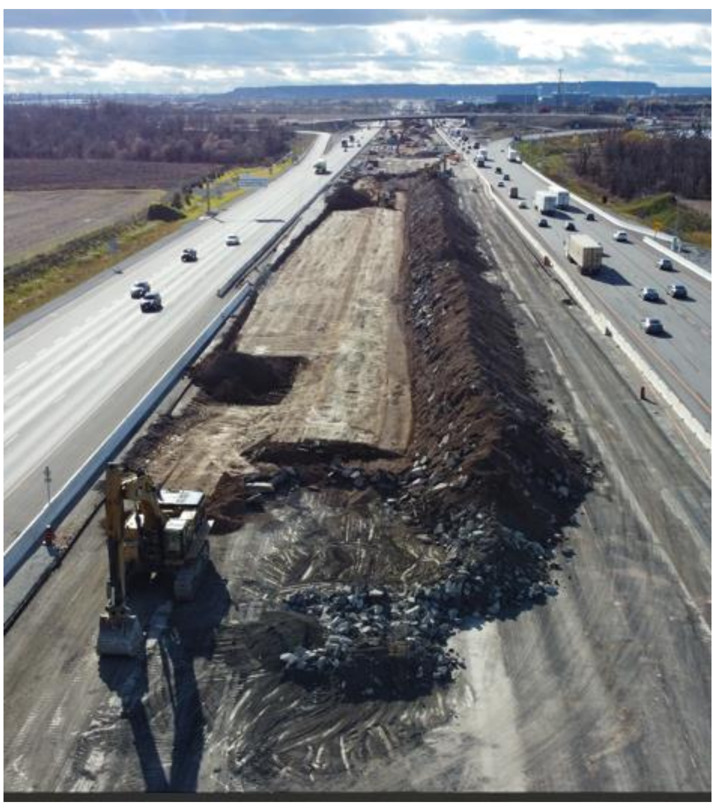
Figure 4: Actual production layout

Challenges and Opportunities

The Construction team established working groups to identify anticipated challenges while completing proposed works. Sessions revealed a number of pinch points to maintain budget and schedule during Stage 2 of the expansion project. Construction teams identified the following concerns in the execution of the works:

- Access to work zone;
- Traffic impact as result of traffic patterns and accidents;
- Volume & quality of material availability; and,
- Resourcing in hiring trucking companies to deliver materials and remove.

Accessing the work zone during daytime hours was limited to non-peak hours (peak hours being 6am to 6 pm). These hours restricted truck traffic into the work zone, forcing large volume access into work zone to occur in after hours. Additionally, Highway 401's high volume of traffic with mainline in construction stage reduced traveling speeds. Lower speeds coupled with accidents regularly caused traffic gridlock to occur, having a further impact to truck traffic into the work zone. As shown in **Figure 5**, traffic flow generated an adverse impact to travel time, increasing fuel and time consumption.

Figure 5: Traffic volume impact by direction

Another challenge was managing trucking vendors and their ability to deliver a target of 20,000 tons of material daily to site and remove 10,000 cubic meters of existing road materials, forecasting a need for 300 triaxles each shift. Managing this large volume of vehicles, logistics, disposal sites, and quarries would have required significant resources to control cost and schedule. Teams estimated that 4 people would be required to manage logistics, with at least 8 people onsite site managing vehicle traffic passing through site. This led to another concern with heavy loads passing over works in progress causing subgrade failures and rework. To mitigate this, a section would be over built with aggregate to accommodate the high traffic within the construction site. Traffic teams would then manage all traffic onsite including client vehicles, concrete trucks, and deliveries to ensure traffic operated efficiently with no adverse impacts to other operations.

Necessity to meet demands and delivery project on time led to a recycling concept that changed the traditional approach to recycling and eliminating a large variable (trucking) as an operational concern. Spin-off opportunities to complete concurrent works while removal and crushing progressed were identified which benefitted the project schedule, including drilling high mast foundations, Overhead Sign Structure foundations, Form and Pour Caps, and storm sewer installations. Since WCC could control pile locations and size, gaps were provided in locations where planned works were required. Crushing operations were primarily completed first, which provided a granular pad to complete the other proposed works. Site cleanliness was significantly improved as a result of crews operating from a granular surface rather than a clay surface.

WCC's schedule was improved, as we had full control of recycling operations that formed a key piece of the critical path, with little to no impact from third parties. Operations within the zone were not impacted and isolated from external influences, with crews focusing on production. On average the recycling project in 24 hours generated 16,000 tons of material, eliminating 450 loads or equivalent traffic onsite. The completed widening of Highway 401 is shown below in **Figure 6**.

Figure 6: Completed widening of Highway 401

Lessons Learned and Conclusions

The Highway 401 Expansion was a very challenging project, particularly from a schedule perspective, with a large amount of work to be completed in only 4 years. Lessons learned, from a pavement design and construction perspective included:

- Look at opportunities for innovation and recycling at the project inception. Specifically on Design-Build Projects, where the design is effectively taken to 30% at the bid stage, it is important to incorporate those opportunities and aspects. The project was bid and planned based on the importance of the Granular Base material and commenced that way. While the nature of the work made the recycling of the material feasible in Stage 2, this could have been incorporated earlier, and with more advanced planning. The recycling from Stage 2 alone reused 650,000 tons of Granular Material and 750,000 tons of Asphalt.
- Collaborate with all disciplines of the construction and design team to identify where the surplus from one operation may be used in another operation and review for efficiencies when doing the work. Keeping the design team engaged during the construction process allows for quick pivoting, making use of opportunities as they are identified, rather than there being resistance to modify the design after it has been completed.
- The more you recycle, the more you can save. Even when there is a large upfront effort, cost and mobilization, through proper planning this risk can be mitigated.
- Dedicate a high level of oversight to the recycling operation. The recycling process, while feasible, was very difficult. It is harsh on the equipment, and there is variability to the material production. Continuous QC testing and equipment maintenance ensures the operation continues without equipment failures or rejected material results.

In conclusion, the recycling operation was a success from a project delivery point of view and an environmental point of view in reusing a very large quantity of material. Specifications were followed to ensure that the recycled product still produced the same quality product. Despite the challenges and lessons learned through the process, it was a worthwhile endeavor.

References

1. American Association of State Highway and Transportation Officials. 1993. “Guide for the Design of Pavement Structures”.

2. Golder Associates Ltd. January 5, 2012. “Final Preliminary Pavement Design Report, W.O. 07-20024, Highway 401 Widening from Trafalgar Road to Regional Rd 25”.

3. Ontario Provincial Specification Standard 1010. April 2013. “Material Specification for Aggregates - Base, Subbase, Select Subgrade, And Backfill Material”.

4. Ministry of Transportation Ontario. 2013. “Pavement Design and Rehabilitation Manual”. *Materials Engineering and Research Office.*