AMERICA RIDES ON US

Asphalt.

CARBON FOOTPRINT

How does asphalt stack up?

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HOW DOES ASPHALT STACK UP?

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Environmental consciousness is on the rise and many transportation officials are striving to make their practices and policies greener or more sustainable. But how do you measure the greenness of a pavement? It's all about the carbon — how, when, and whether it is counted.

A useful guide is ISO 14040 — Environmental Management — Lifecycle Assessment — Principles and Framework [2006(E)], which outlines the basic definitions and procedures that should be used in looking at the environmental impact of a product throughout its life. It has two important principles: make sure you **count everything** and make sure you **don't count anything twice**.

To analyze the carbon footprint of a pavement, one must look at the greenhouse gas (GHG) emissions associated with the construction and maintenance of a pavement. Greenhouse gases include carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and hydrofluorocarbon (HFC) leakage from air conditioning systems. Although not usually included, water vapor is the most abundant greenhouse gas. Greenhouse gas emissions are typically measured in terms of carbon dioxide equivalents (CO_2e).

The analysis for asphalt pavements is complicated by the fact that the cementing material, the asphalt cement or bitumen, has high carbon content. The average carbon content of asphalt cement is about 82 percent, and asphalt cement makes up about 5 percent of an asphalt pavement, with the rest being aggregates — stone, sand, and gravel. Currently in North America, at least 95 percent of the asphalt pavement removed from the road is either reused in new asphalt pavements or recycled as base or shoulder material. The material not reused or recycled is still not burned and thus the embodied carbon is never released into the atmosphere. **In essence, when we pave with asphalt, we put the aggregate and the asphalt cement in the bank for future generations.**

Carbon Footprint of HMA and PCC Pavements [1], a paper presented at the 2009 International Conference on Perpetual Pavements, examined the carbon footprint of asphalt and concrete pavements for typical residential, collector, and freeway pavements constructed in Ontario, Canada. In addition, the paper looked at the carbon footprint of an equivalent asphalt freeway pavement built as a Perpetual Pavement. Both the carbon footprint of the initial construction and the carbon footprint of the maintenance activities over a 50-year life cycle were evaluated and compared.

The paper used an analysis method designed by VicRoads, a state authority in Australia, to carry out a trial carbon-neutral project. In this case, VicRoads chose to plant 7,463 trees at the completion of the project to achieve carbon neutrality. The trees will absorb carbon from the atmosphere over their life to remove the carbon generated by the extraction, manufacturing, and placement of the material used, as well as the transportation of the materials to and on the site [2]. To carry out the calculation, VicRoads developed a table of typical carbon dioxide equivalent values for the various materials used on the site. Table 1 gives the values used by VicRoads in their analysis.

The most striking feature of this table is the difference in the values for the asphalt and concrete pavements. One reason for the divergence is the chemical processes that occur in the production of Portland cement, the cementing material that binds concrete pavements together. For every 1,000 kg of Portland cement, approximately 730 kg of carbon dioxide is produced [3]. Heating the aggregate and clay used to produce Portland cement to a temperature of around 1,450°C in the kiln causes the disassociation of the limestone and the production of about 60 percent of the carbon dioxide, which is released to the atmosphere. The remaining carbon dioxide comes from the combustion of the fuel used to heat the raw materials.

[1] BROWN, ALEXANDER. **CARBON FOOTPRINT OF HMA AND PCC PAVEMENTS.** PROCEEDINGS, INTERNATIONAL CONFERENCE ON PERPETUAL PAVEMENTS, COLUMBUS, OHIO, 2009. http://asphaltroads.org/images/documents/ghg-carbon_footprint_of_various_pavement_types.pdf

[2] VICROADS. http://www.vicroads.vic.gov.au/Home/NewsRoom/News+Archive/Jan-Mar+2008/MicklehamRoad.htm

[3] CEMENT INDUSTRY OF CANADA. **CEMENT INDUSTRY SUSTAINABILITY REPORT 2010.** http://www.cement.ca/images/stories/ENGLISH%20FINAL%202010%20SD%20Report%20Mar17.pdf

TABLE 1 — CO_2 EQUIVALENT CONVERSION VALUES

Material	CO_2eEmissions (Tonnes / Tonne)
Asphalt Pavement (at 5.0 percent asphalt cement)	0.0103
Granular A (crushed, screened and washed aggregate)	0.0080
Granular B (screened and washed aggregate)	0.0053
Concrete Pavement (at 32 MPa [4640 psi])	0.1073
OGDL*	0.0090

* Asphalt-stabilized open-graded drainage layer at 1.8 percent asphalt cement

It should be noted that VicRoads chose not to include the carbon content of asphalt cement in the calculation because the purpose of the carbon footprint calculation is to calculate the actual emissions of greenhouse gases into the atmosphere. The carbon in the asphalt cement will never be released into the atmosphere. It is neither consumed nor wasted in the process. In a way, the carbon has been sequestered in the form of an asphalt pavement. In addition, 100 percent of the asphalt cement can be reused in new asphalt pavement at the end of its life by simply reheating the material, thus reusing the energy invested in the initial production of the material.

The pavement sections used for the analysis are given in Tables 2 and 3. The asphalt sections for residential and collector pavements are taken from typical asphalt pavements constructed in Ontario. The concrete pavement sections for the same road class are taken from the Streetpave program published by the Portland Cement Association. Due to environmental conditions in Ontario (i.e. wet freeze/thaw), the concrete pavement sections may be considered to be thinner than required.

TABLE 2 — ASPHALT PAVEMENTS ANALYZED

Material	Residential	Collector	Freeway
Asphalt Pavement	90 mm / 3.5 in	130 mm / 5.1 in	240 mm / 9.5 in
OGDL*			100 mm / 3.9 in
Granular Base	150 mm / 5.9 in	150 mm / 5.9 in	150 mm / 5.9 in
Granular Subbase	300 mm / 11.8 in	450 mm / 17.7 in	450 mm / 17.7 in

* Asphalt-stabilized open-graded drainage layer at 1.8 percent asphalt cement

TABLE 3 — CONCRETE PAVEMENTS ANALYZED

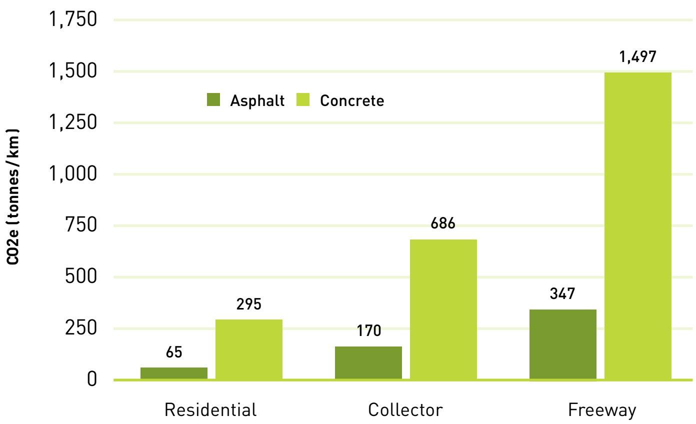
Material	Residential	Collector	Freeway
Concrete Pavement	145 mm / 5.7 in	170 mm / 6.7 in	240 mm / 9.4 in
OGDL*			100 mm / 3.9 in
Granular Base	100 mm / 3.9 in	100 mm / 3.9 in	300 mm / 11.8 in

* Asphalt-stabilized open-graded drainage layer at 1.8 percent asphalt cement

The freeway pavement sections were taken from the Life Cycle Cost Analysis tool which the Ministry of Transportation for Ontario developed to allow for comparison of alternate-bid contracts.

To carry out the analysis of typical pavements, the tonnes/tonne CO_2e factors given in Table 1 were applied to initial construction of one kilometer of standard concrete and asphalt pavements for residential, collector, and freeway pavements constructed in Ontario. The following graph shows that the greenhouse gases emitted for an asphalt pavement, measured in terms of carbon dioxide equivalents, is only 22 percent to 25 percent of the greenhouse gases of a typical concrete pavement.

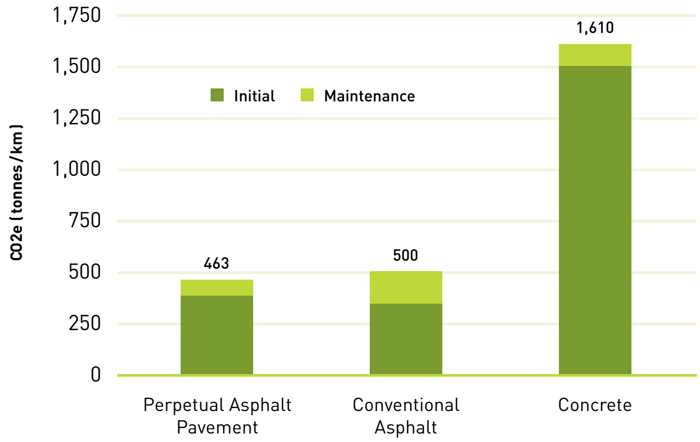
FIGURE 1 — GREENHOUSE GASES FROM INITIAL CONSTRUCTION



It should be noted that all the calculations in this paper are based on using 100 percent virgin materials for both the asphalt and concrete pavement options. In addition, only hot-mix asphalt pavements were analyzed consistent with the VicRoads project. If recycling and warm-mix asphalt were considered, the carbon footprint of the asphalt pavement would be further reduced.

The effect on life cycle for the greenhouse gases for concrete and asphalt pavements was also examined, but only for the freeway case. The maintenance schedule followed for various agencies depends on priorities and budget constraints. A fair analysis would be difficult. In order to make a realistic and fair comparison, the 50-year life-cycle maintenance

FIGURE 2 — 50-YEAR LIFE-CYCLE GREENHOUSE GAS PRODUCTION



schedule used in the Ontario Life Cycle Cost Analysis model was analyzed. The details of the model are available in the paper. In addition, the life-cycle greenhouse gas emissions for all three options are shown in Figure 2.

Although the greenhouse gas emissions from initial construction are greater for the Perpetual Pavement option than for conventional asphalt, it still has lower greenhouse gas emissions over the 50-year life cycle. Regardless of which asphalt option is chosen, the asphalt pavement options only produce about 30 percent of the greenhouse gas emissions of comparable concrete pavements.

Conclusion

This paper has examined greenhouse gas production of asphalt and concrete pavements. The tools employed in these analyses are based on published materials from ISO 14040, VicRoads, and the Ministry of Transportation for Ontario. In every case, the analyses show clearly that asphalt has a far lower carbon footprint. This means that asphalt pavements are the more sustainable choice. When it comes to roads, black is green, now and for the future.

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