Clearing the Air

Quantifying the Air Pollution Emissions Associated with Material Recycling in Road Reconstruction Projects

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As a member of the faculty of the Civil and Environmental Engineering Department at Rice University, Professor Matt Fraser directs several air quality research projects. Most of Dr. Fraser's research focuses on using organic speciation and receptor modeling to apportion ambient pollutants to their original source. To tackle this complex problem, Dr. Fraser's research group has been involved in field monitoring programs, source characterization studies, emission inventory preparation, and analytical method and instrument development projects. Dr. Fraser's research is focused on being directly relevant to environmental policy. Dr. Fraser serves in several roles to bring scientific understanding of air pollution into the regulatory process including the Science Coordinating Committee of the Texas Commission on Environmental Quality. Dr. Fraser teaches courses on air pollution control and atmospheric chemistry.

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Abstract:

The impact of material recycling in road reconstruction projects was quantified using examples of local industry practices. For this study, only CO2 emissions were quantified but emissions of other pollutants will scale directly with CO2.

Centralized Recycling Depots

The first industry practice studied is the recycling of material in centralized recycling depots where waste concrete is hauled to a central site, processed into road base stabilization aggregate and returned to the construction site (central depot recycling). The second practice is the on-site recycling of waste concrete into road base aggregate (on site recycling). The third practice is the hauling of waste concrete to a local landfill and supply of virgin road base aggregate from a local supply depot (no recycling). For each of the two recycling options, three recent road construction processes were studied and the emissions associated with material hauling compared to what would be expected if material recycling was not done.

Central Depot Recycling = 0.8kg vs 2.2kg CO2

For central depot recycling, CO2 emissions averaged 0.8 kg CO2 per ton material compared to 2.2 kg CO2 per ton material if no material was recycled. For on site recycling, CO2 emissions averaged 1.0 kg CO2 per ton material compared to 3.5 kg CO2 per ton material if no material was recycled. Since CO2 emissions are directly related to fuel consumption, fuel use would also be lower for the recycling alternatives compared to not recycling material. The depot recycling yielded lower emissions than on-site recycling mainly because some of the on-site recycling projects involved long hauls to the feedstock pile. However, both recycling options yielded significant regional CO2 emissions reductions compared to land filling of waste combined with virgin aggregate supply. On an absolute basis, the recycling of 4,182,000 tons of material in the Houston area in 2006 resulted in a decrease of CO2 emissions of more than 6,900 tons of CO2. That is equivalent to taking more than 1100 cars off the road (assuming the average car travels 12,000 miles per year and gets 20 miles to the gallon).

Background

TxDOT Statewide Recycling Program

In 1992 the Texas Department of Transportation (TxDOT) initiated a major shift in materials and construction policy by allowing and encouraging the use of recycled aggregates at Houston's Hobby Airport. This project converted 575,000 tons of project debris (concrete and soil) into TxDOT specification aggregates utilized in sub-base for runways, taxiways and ramps. Today this recycling program combines the efforts of three state agencies working across 15 Texas counties, with several notable accomplishments since 1992:

- Diversion of more than 20 million tons of debris from landfills [1]
- Creation of more than $55 million in taxpayer savings [1]
- Conservation of over 20 million tons of native aggregate and habitat
- Significant Regional NOx and CO2 emissions reductions

The success of the program today is related to key events in 1994 that included (a) legislation requiring increases in statewide recycling through legislated planning and goals[2], and (b) research sponsored by the Federal Highway Administration, the Center for Transportation Research, Texas Natural Resource Conservation Commission, and others. TxDOT began a statewide program in 1994 encouraging the use of recycled roadway materials and also implemented a Special Provision[3] to allow the use of crushed concrete as a direct replacement for natural aggregates.

Since that time, regulatory agencies working in partnership with TxDOT have developed consensus on reducing regulatory barriers to recycling. Statewide specification for recycled road construction components has been implemented [4] which ensures engineering and environmental quality of end products.

Central Depot Recycling

On-Site Recycling

Landfilling

Hauling waste concrete from construction sites and supply of road base aggregate to sites are necessary functions in the construction industry. Several approaches can be used to fill this need. Central depot recycling of concrete material removes waste pavement material to a centralized location for processing into base aggregate for ground stabilization. On-site recycling hauls waste concrete to an on-site material mound where material is processed into road base aggregate and reused. Another approach is hauling waste material to distant landfills for permanent disposal and supply of virgin aggregate material from remote locations. The emissions of air pollutants associated with materials hauling from these three alternative approaches have not been assessed or used in conjunction with environmental mitigation plans. This study uses local

experience to quantify the air pollution impacts associated with these alternative methods of waste pavement removal and supply of base aggregate.

Emissions associated with materials hauling for the three alternative approaches (central depot recycling, on-site recycling and landfilling and virgin aggregate supply) were calculated using data on recent road reconstruction projects in the greater Houston area. Emissions for materials hauling were calculated for three representative construction projects which employed central depot recycling plus three construction projects that used on-site recycling. For all recycling cases, the emissions that would have been generated if the waste material was hauled to a local landfill and virgin aggregate supplied for road base stabilization were also determined. While this study quantified emissions of carbon dioxide, similar emissions reductions would be expected for other important air pollutants. Also, since carbon dioxide emissions are directly linked to fuel consumption, the results can also be used to estimate fuel savings from central depot recycling or on-site recycling.

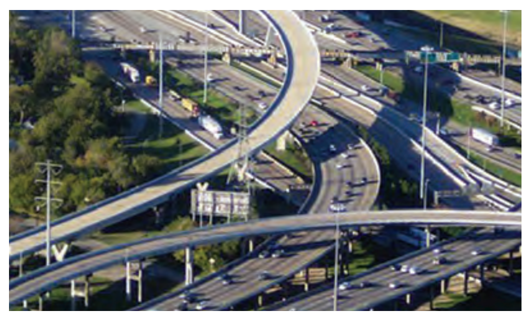
Representative Projects

Centralized: Intercontinental Runway

US 59 Reconstruction

Houston Street Reconstruction

For the local construction projects employing material recycling in a centralized depot, three recent projects where material was hauled to a yard operated by Southern Crushed Concrete were chosen to quantify the emissions of material hauling for this approach. These included a runway and apron reconstruction project at Intercontinental Airport, the reconstruction of US 59 in Montgomery County and the reconstruction of urban streets in downtown Houston. For all cases, the waste concrete hauling and base aggregate supply were determined from the bidding documents released by the contracting authority including:



- IAH project, Dannenberg Engineering for the City of Houston
- US 59, Texas Department of Transportation
- Downtown street reconstruction Metropolitan Transit Authority.

The haul distance for waste removal and base aggregate supply was determined as the road distance from the project site to the nearest depot operated by Southern Crushed Concrete.

On-Site: Bennington Plant Winfield Plant Airtex Plant

For local projects that utilized on-site material recycling, three examples of industry practices from Williams Brothers Construction projects were studied based on information provided by the Texas Department of Transportation. Specifically, the Bennington plant on W. Hardy Road in Houston, the Winfield plant on Winfield Road in Houston, and the Airtex plant on Airtex Road in Houston were all investigated. The distance from the job site to the material mound for each project was taken as the average value for all construction projects that used that specific material mound.

Comparisons to Nearest Local Landfill

For comparison purposes, the air pollution emissions that would have been expected for these six projects if the waste material was disposed at a local landfill and virgin material supplied for base stabilization was calculated. In all cases, the truck emissions associated with material hauling to the nearest operating landfill and separately hauling base stabilization aggregate were calculated in the same manner as the emissions expected for material hauling for the two recycling options. For this comparison, hauling distance was determined as the road distance from the job site to the closest local landfill selected from five operating facilities including Ft. Bend, Cougar, BFI Fresno, Waste Management Fairbanks, or BFI McCarty. For material supply, the haul distance to the job site from one of three local supply depots was determined. The three aggregate supply yards included one in the vicinity of the Houston Ship Channel, one in Humble, and one in Jersey Village. The selection of these facility locations was based on discussions with industry professionals and are meant to represent current industry practices.

Calculating Emissions From Material Hauling

Truck Calculations

For all three scenarios investigated, the air pollution emissions from truck traffic for material hauling were determined assuming a truck load of 22 tons per truck, fuel efficiency of 6 miles per gallon, a density of diesel of 7.0 pounds per gallon and an 85% carbon content for diesel fuel. An assumption that any carbon from the diesel fuel combusted in material hauling was converted to CO_2 was made.

While this study focused on the CO_2 emissions associated with material hauling, the expected emissions of other air pollutants, such as nitrogen oxides or diesel soot, would be directly proportional to the emissions for CO_2. Also, since CO_2 emissions are directly proportional to fuel consumption, the results can also be scaled to quantify fuel consumption rates for the three alternative scenarios.

Results

For material recycling in a centralized depot, emissions of CO2 per ton of material processes ranged from 0.4 to 1.2 kg CO2 per ton material and averaged 0.8 kg CO2 per ton processed. If, however, for the three representative construction projects investigated for central depot recycling, material was hauled to a local landfill and virgin material supplied for stabilization base aggregate, the CO2 emissions would have ranged from 1.8 to 2.8 kg CO2 per ton and averaged 2.2 kg CO2 per ton material processed. These results are shown graphically in Figure 1.

The findings are mainly a result of two factors. First, multiple centralized depots for materials processing result in shorter overall haul distances for recycling compared to hauling material to an operating landfill and supplying virgin material. Second, the fact that a truck can haul waste to the central recycling depot and return filled with base aggregate to supply the construction site means trucks are never traveling empty.

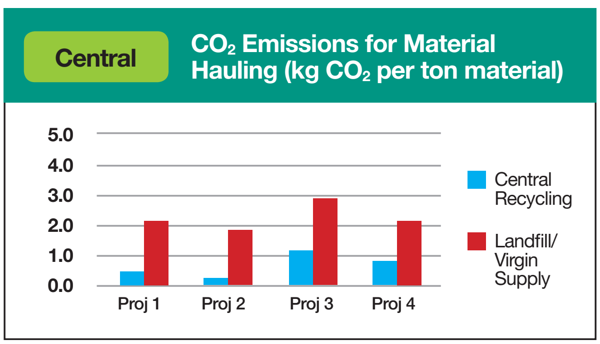


Figure 1: Comparison of CO2 emissions in kg CO2 per ton of material processed using central depot recycling compared to landfilling waste material and virgin aggregate supply for base stabilization.

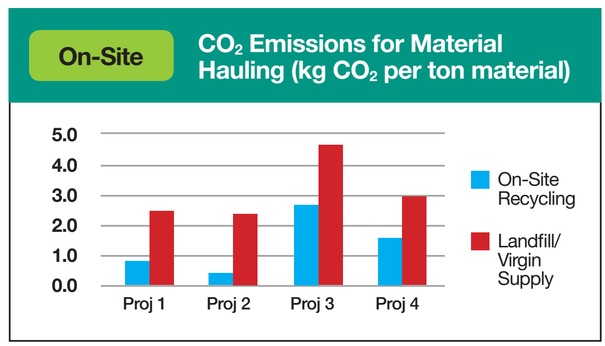


Figure 2: Comparison of CO2 emissions in kg CO2 per ton of material processed using on-site material recycling compared to landfilling waste material and virgin aggregate supply for base stabilization.

Average 63% Reduction in CO2

For material recycling on the construction site, emissions of CO2 per ton of material processes ranged from 0.05 to 2.6 kg CO2 per ton material and averaged 1.0 kg CO2 per ton processed. If, however, for the three representative construction projects investigated for on-site material recycling, waste concrete material was hauled to a local landfill and virgin aggregate supplied for base stabilization, the CO2 emissions would have ranged from 1.6 to 5.0 kg CO2 per ton and averaged 3.5 kg CO2 per ton material processed. These results for the three representative projects are shown graphically in Figure 2 (next page).

The average emission reductions for material recycling compared to landfilling waste material and supply of virgin aggregate is 1.4 kg CO2 per ton material for central depot recycling and 2.5 kg CO2 per ton material for on-site recycling. That greater emissions reductions from on-site recycling are a function of reduced travel from the construction site to the processing plant compared to a centralized recycling depot.

Regional Impacts

2006 Reductions = 1,100 + Cars Removed from Roads

The Texas Department of Transportation catalogs the regional volume of recycled aggregate production. In the Houston region in 2006, a total of 4,182,000 tons of recycled aggregate were produced. Using the CO2 emissions estimated from the representative projects, the reduced CO2 emissions from on-site and central depot recycling compared to landfilling and virgin aggregate supply can be estimated. Based on the annual recycling volume of 4,182,000 tons in TxDOT Houston region and using the more conservative emissions reductions of 1.5 kg CO2 per ton material, regional CO2 emissions were decreased by 6,900 tons of CO2 in 2006. By comparison, these emissions reductions equate to removing more than 1,100 cars from the road (assuming a representative vehicle average of 20 miles per gallon and 12,000 miles driven annually).

Acknowledgements

The author gratefully acknowledges data from Ms. Deborah Lively of the Texas Department of Transportation and Mr. Mark Briggs of HPP.

References

1 – HPP Corp estimates for TxDOT Regional Recycling Study, May 2007, provided to TxDOT Recycling & Recycled Products Program, General Services Division.

2 – Texas Legislature S.B. 1519 codified into Section 363.061 of Health and Safety Code.

3 – TxDOT Special Provision to Specification Item 247 – Houston District.

4 – TxDOT Department Material Specification, DMS-11000, “Evaluating and Using Nonhazardous Recyclable Materials Guidelines”.