Teaching Sustainable Design in Construction:

A Module on the Recycling and Re-use of Urban Soil, Stone, Fill and Related Construction Material

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This paper presents a module on the recycling and re-use of urban soil, stone, fill and related construction material at the job site to demonstrate that such practices are consistent with progressive sustainable design and construction practices for this industry. While the displacement of excavate material is often inevitable in site preparation due to grading, foundation design and contaminant removal, the value of these materials can often be realized in re-use applications both on and off-site. Such opportunities include use of soil as grading material, re-use of stone aggregate as a raw material for concrete and re-use of crushed concrete material as sub-base material for roadways and parking lots. Recycling and re-use rather than off-site disposal of these materials saves on transportation expenses and tipping charges. Reducing the need to bring virgin soil and stone on-site protects natural resources, lowers transportation costs and reduces air emissions. These practices may also provide credit opportunities for projects seeking LEED certification. Despite the growth in recycling and re-use of on-site soil materials, the topic is rarely addressed in any detail in standard sustainable construction texts. This paper both reviews current practices as well as emerging trends in the reuse and recycling of these materials in construction and describes how the general topic has been included in civil and construction course-work.

Keywords: sustainable construction; recycling and re-use; urban fill; asphalt, brick and concrete; green construction.

The Case for Sustainable Design and Construction

Green building principles, means and methods have emerged to become an established and necessary component for construction in the built environment. Energy, environmental and economic forces have led the building industry to seek innovative alternatives to conventional building and infrastructure design and construction. Forces on the industry towards becoming more green include the interests of owners, governments and the general public. In many respects, the green approach is not an option but a necessity in order to compete in this ever evolving industry.
Students in construction programs of study must understand these concepts and applications in order to stand out in a very competitive job marketplace. Despite our current recession, national trends reveal that the future construction market will continue to increase its focus on green, building. Students entering the construction field must be familiar with sustainable design and construction principles and practices to be competitive.

**Soil, Stone, Fill and Related Construction Materials**

![Image of Boston, MA](image)

**Figure 1. A satellite view of Boston, MA.** Most of Boston is filled land, making it necessary for any construction project involving earth moving to incorporate management of fill material.

Like many cities along the eastern seaboard, Boston is built mostly on filled land. Atop this manmade surface is concrete, brick, stone and soil imported from surrounding uplands. Today, construction in metropolitan areas typically encounters fill as well as asphalt, brick and concrete
(ABC) debris that must be managed. Environmental, regulatory and economic forces are changing the methods used to manage these materials. Off-site transport is expensive. Disposal options are disappearing as permitted demolition debris and solid waste landfills reach capacity and fewer new facilities are created. Fortunately, there are recycling and re-use opportunities for most soil and ABC in construction. These opportunities may be on the site of generation or off-site for another construction project.

For many applications, urban fill and ABC can be a substitute for virgin building materials such as sand and aggregate. Provided strength requirements can be met, crushed stone, brick and concrete can be used as aggregate for concrete and asphalt formulations. These materials can also be used as sub-base materials for roadways and parking lots in many settings. Urban soils and mixed fill materials often present challenges to re-use and recycling options. However, on-site treatment to modify their physical properties (such as sieving to modify particle size distribution and compactability) may be performed to make these materials suitable for grading and landscaping.

Figure 2. Site redevelopment of concrete structures often performs on-site concrete processing. Here on-site generated crushed concrete will be used as sub-base material for a shopping plaza parking lot.
Many recycling/re-use applications require off-site processing. For example, asphalt re-processing, which requires grinding asphalt into appropriately sized aggregate and remixing with emulsion, is performed at the asphalt plant. Stone crushing of excavated boulders to make crushed stone for asphalt and concrete formulations and for sub-base material is also commonly performed by an off-site vendor. As the cost for virgin materials increases, the value of recycled construction debris increases, creating a market for recycled ABC as a commodity.

Figure 3. Fill as a commodity. Markets for local soil, stone and ABC are developing as purchase and transportation costs of virgin materials continue to rise.

Depending on the size of the project and available space, on-site processing of ABC may be feasible. It is becoming increasingly common for demolition contractors to crush concrete on-site. The process often includes source separation of metal from reinforced concrete. In such cases, the crushed concrete may be used on-site as sub-base material for roadways and parking areas. Other examples of on-site materials treatment includes soil screening, such as screening of loam for on-site use as top-dressing. Realizing the full potential of on-site re-use of construction materials such as ABC and soil can be achieved with a preliminary inventory of ABC quantities, an assessment of their quality, and carefully planned construction sequencing.

*Regulatory Reform*
Building code, subdivision requirements and state and local highway regulations present a hurdle to greater use of recycled ABC and urban soils in construction. In many instances, these regulations specify virgin material and the prohibited use of recycled materials is either implied or explicitly forbidden. Code reform to permit the reuse of ABC, provided it exhibits the performance characteristics of virgin material, needs to be performed to encourage more sustainable construction. Some states, including Minnesota have adopted aggregate specifications that allowed some use of recycled concrete for highways. This had led to reduced costs without compromising performance. Reforms of this nature typically result in municipal highway departments adopting similar allowances in a trickle-down effect of regulatory acceptance.

![Diagram of a road section](image)

**Figure 4.** Municipal code routinely requires the use of virgin material for sub-base material. Here, recycled crushed concrete would easily meet the performance specifications of sidewalk sub-base material, but its use is not permitted.

**Material Characteristics**

Preliminary assessment of the amount of available ABC and soil from a construction site must consider the quality of the material. Material characteristics include the presence of
contamination and other physical/chemical properties that may affect structural strength, compatibility and resistance to weathering of the material.

In all circumstances, but particularly in Brownfield redevelopments, the presence of contamination must be considered. The nature of contamination varies with the recycled material and its prior use and history. For example, while structural concrete may be relatively free of impurities, painted concrete walls may be contaminated with lead-base paint. Similarly, urban soils may contain metals, petroleum, asbestos and/or other chemicals that may limit its potential for reuse. Source segregation of materials of differing environmental quality is a viable strategy to manage contaminated soils and ABC.

Figure 5. Brownfield redevelopment sites frequently must deal with fill material contaminated with a wide spectrum of regulated material including asbestos, heavy metals and petroleum products.

Teaching Opportunities

Like many evolving topics in construction, re-use and recycling of urban fill and related construction materials could be taught in a stand-alone course. Short of that, design and construction issues that relate
to this topic can be taught as a component to several different standard courses. At Wentworth, parts of the material described in this paper have been included in 3 courses.

CCEV417 – Sustainability in the Built Environment. This elective course is offered to Civil Engineering Technology, Construction Management, Facilities Management and Environmental Science majors. The course reviews several sustainability concepts and practices, including green building. The re-use and recycling of urban fill and ABC is addressed in this course under the broader theme of LEED certified buildings.

CCEV575 – Municipal Planning. This elective course is offered to civil engineering technology students. The course reviews municipal planning on a broad scale as well as development details and design concepts relative to local zoning code. The regulatory requirements with the re-use and recycling of ABC are addressed in this course.

CCEV660 – Civil Senior Capstone Design. This course is taught to senior civil engineering technology students in their final semester. As a design challenge, student design groups were required to integrate recycling and re-use of urban fill and/or ABC into their design project.

A text book that provides a comprehensive review of the topics described in this paper does not exist. In presenting this material, the author has developed lecture material and real-life engineering, design and management exercises and assignments based on his experience in this field over the past 25+ years. Excellent supplementary information is also available from on-line resources provided by government regulatory agencies and related professional organizations.

has been used to accompany and reinforce many of the topics presented in the course. As is the nature of sustainable design, no one text can adequately cover the breadth of topics and necessary detail covered in such a course. This course was developed to address the specific needs of undergraduate students from several sub-disciplines in the built environment and unfortunately most texts present sustainable design from a single professional’s perspective (such as architecture, construction management or interior design). For this reason, approximately half of course material presented was compiled from a variety of sources including, instructor material and experience, web-based resources and reference material.

This material is sought out and very well received by students. The above mentioned elective courses have high enrollments. In many instances, students returning from Coop (i.e., internships) recognize the importance and relevance of sustainability in the industry and take these courses as a response. This material also lends itself to the experiential model of learning, which Wentworth students are very comfortable with.

**Conclusion**
The topic of re-use and recycling of urban fill and related construction materials is an important component to most, if not all, construction projects seeking to follow sustainability practices. The topic can be viewed from several perspectives including construction means and methods, design, regulatory compliance, green building, scheduling and economics. The topic can also be introduced as a stand-alone course or as a module in numerous standard courses in construction or civil engineering curricula.