Life cycle assessment and life cycle costing for demolition waste management

Mingming Hu[1], Brenda Miranda-Xicotencat[1], Diana Ita-Nagy[1], Valentina Prado[1], Jeroen Guinée[1], Eric van Roekel[2], Renate Huismans[2], Frank Rens[2], Somayeh Lotfi[3], Francesco Di Maio[3]

[1] CML – Institute of Environmental Science , Leiden University, Einsteinweg 2, 2333 CC Leiden, Netherlands, Phone (+31) 71 527 1497; E-mail: hu@cml.leidenuniv.nl
[2] GBN - Grondbank Nederland & Afvalbank Nederland, Strukton B.V., Westkanaaldijk 2, 3542 DA Utrecht, Netherlands
[3] Faculty of Civil Engineering and Geosciences, Delft University of Technology, Stevinweg 1, 2628 CN Delft, Netherlands

Abstract

Ninety five percent of the construction and demolition waste is recycled in the Netherlands. Most of it is used for low value applications such as road base materials; the use of secondary material in buildings is still less than 3%[7]. In order to recover waste for higher value applications, enhancing selective demolition and waste management practices is of crucial importance. In this study Life Cycle Assessment and Life Cycle Costing of a demolition project in Almere was carried out to identify the environmental and financial hotspots in the selective demolition and waste management in the Dutch context.
Results suggest that (1) the best practice selective demolition and (2) the substitution of virgin concrete aggregate with secondary aggregate processed by Advanced Dry Recovery (ADR) system, will lead to environmental and financial improvements compared to the business as usual practice. On the building level, the advantage is mainly due to connecting the demolition and the re-development projects, which maximizes local reuse of old building components in the new building. The key of success for selective demolition is pre-audit to identify and connect to the market for material reuse. This is a direction that BIM (building information modeling) technology can contribute. With regards to the ADR concrete aggregate manufacturing, it was found that the transport distance for aggregate supply was the largest contributor to the environmental impacts and costs. Therefore it is important to locate ADR facilities next to concrete manufactures and/or provide ADR service on- site.

Keywords: LCA, LCC, selective demolition, hotspot analysis, cost-effectiveness

Introduction

Construction and demolition waste (CDW) is the largest waste stream in the Netherlands; about 25 million tons of it is annually generated in the Netherlands. Although 95% of the CDW is already recycled (mainly as road base material), the use of secondary material in buildings is still less than 3%. In order to recover waste for higher value applications, enhancing selective demolition and waste management practices is of crucial importance.

[7] RIVM, 2016, Circular economy in the Dutch construction sector. Available at: http://www.rivm.nl/bibliotheek/rapporten/2016-0024.pdf.

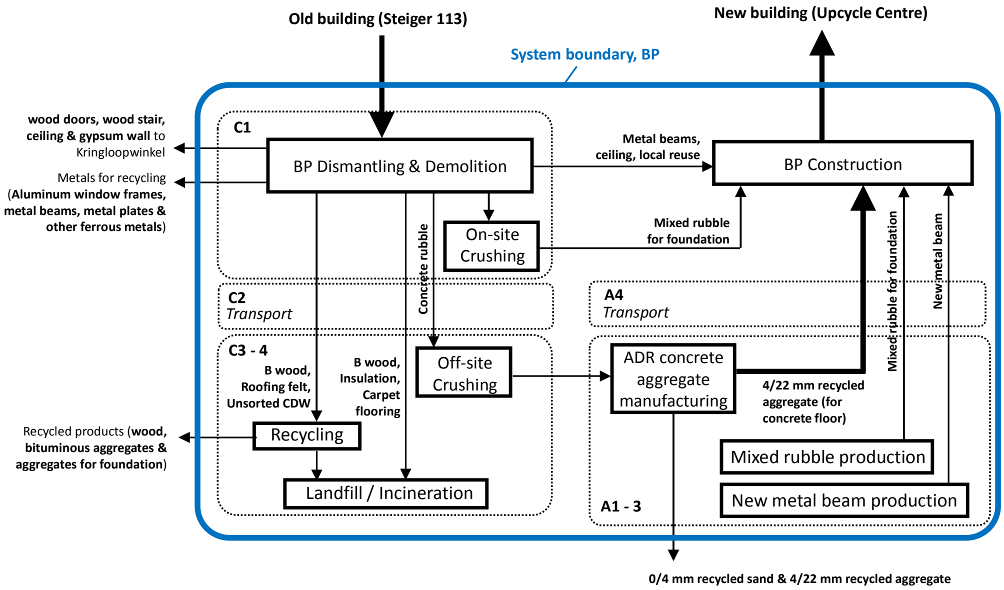
Within the HISER project, technological and non-technological solutions are developed in order to guarantee a higher efficiency in the recovery of the complex demolition waste streams. This paper presents the screening results of the environmental life cycle assessment (LCA) and life cycle costing (LCC) for (1) a monitored best-practice selective demolition and waste management of an office storage building in Almere in 2016 (BP) and (2) a virtual business-as-usual selective demolition and waste management of the same building (BAU).

Methodology

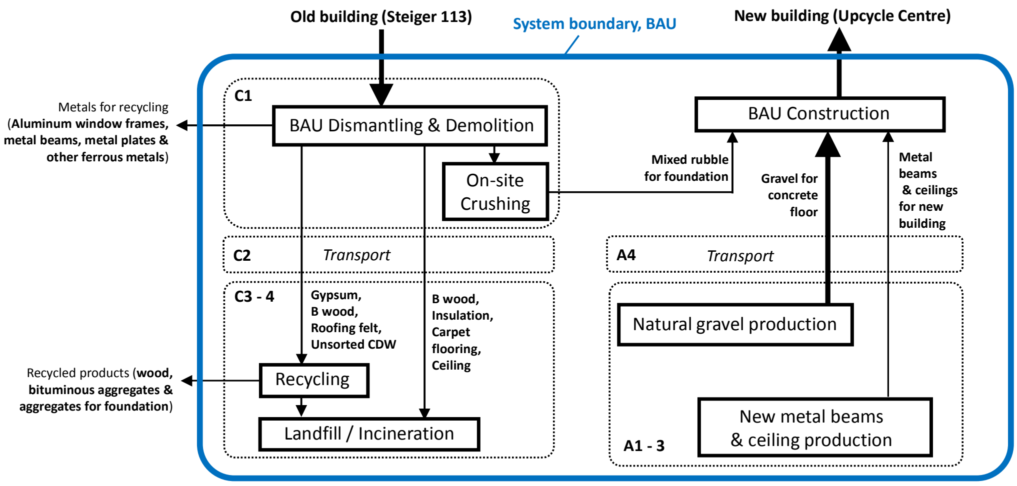
Life cycle assessment (LCA) and life cycle costing (LCC) have been carried out in parallel. For the environmental assessment fourteen impact categories are calculated, according to the European PEF Guide [2]. Within the economic assessment, financial costs are divided into two major groups: capital expenditures (CAPEX) and operational costs (OPEX). For both comparative assessment studies the same functional unit has been used: i.e. the selective demolition of the old Steiger 113 building in Almere (The Netherlands) in 2016 and the related disposal and recovery of 2,323 ton of demolition waste coming out of the building, and the provision of 36 ton of metal beams, 360 ton of concrete aggregate, 1800 ton of foundation aggregate and 50 m^2 of ceiling materials for the construction of new Upcycle Centre building at the demolition site. System boundaries for the BP and BAU selective demolition case are shown in the block flow diagram in *Figure 1*.

Results

Hotspots in BP demolition. From an environmental perspective, ‘C1: Demolition’ and ‘A1-3: Product stage’ are the dominant stages responsible for 52% - 90% burden of the investigated impact categories. The processes contributing most to the environmental burden are ‘metal beam production’ and ‘dismantling and demolition’. The former is responsible for 88% impact of ‘Eutrophication – fresh water’ and more than 75% impact on other 5 categories, including ‘Human toxicity’. While the latter is responsible for 90% of particular matter emission, and has significant impact (24% - 45%) on other 6 categories. Therefore, connecting new construction with demolition projects to maximize the reuse potentials, especially metals, is most important to improve the environmental profile of the demolition and related material treatment. From a financial perspective, ‘C1: Demolition’ stage dominates the life cycle cost. It is responsible for 57% of the gross cost, and 39% of the net cost, compensated with the proceeds received for the recovered valuable building components and materials. Table 7 shows the ‘Dismantling and demolition’ process at C1 stage, generates 100% of the proceeds, and is responsible for 90% of the personnel cost, 80% of the equipment cost and 77% of the utility cost. The second important cost is at ‘A1-3: Product stage’, due to the purchase of metal beams for new construction. Therefore, connecting new construction with demolition projects to maximize the reuse potentials, especially metals, is most important to improve both the environmental and economic profiles of the demolition and related material treatment.



a) System boundaries and life cycle stages for BP scenario



b) System boundaries and life cycle stages for BAU scenario

C1: De-construction/demolition; C2: Transport to waste processing and disposal facilities; C3 - 4: Waste processing and disposal; A1 - 3: Product stage; A4: Transport to building site; BAU – Business as usual; BP – Best practice; ADR – Advanced dry recovery.

Figure 20. Simplified flow diagrams of the monitored evaluated BP (best practice) and virtual BAU (business-as-usual) scenarios. Blue lines indicate the boundaries of the comparative Selective demolition cases on building level. Thick arrows denote the compared functional flows.

BP and BAU Comparison. From an environmental perspective, BP is preferred over BAU for all environmental impact categories. Depending on the type of category, BP has potential to reduce 19 – 78% of the environmental impacts. From previous hotspot analysis, we know most of the BP improvement is due to the reduced production of metal beams for new construction. There are 78% reduction of water depletion impact, which is due to the saved gravel mining process, by using ADR recycled concrete aggregate. From a financial perspective, BP can reduce the life cycle cost from €61,328 to €47,427. The biggest saving is at 'Product stage' due to the reuse of metal beams from demolition and the saved gravel purchase for concrete aggregate. The second saving is at 'Demolition' stage. It is due to the free dismantling offered by the Kringloopwinkel for the recovered usable and resalable items (showing as larger proceeds), and the reduced on-site crushing (showing as lower cost), as 671 ton concrete rubble was separated for off-site recycling. At 'Waste processing and disposal' stage, BP scenario has lower processing fee for the light and unsorted fractions, but this advantage is hidden by the off-site crushing cost for the concrete rubble. Due to the long distance movement of concrete rubble, BP scenario shows disadvantage at both transport stages. This disadvantage is covered by the saved purchase cost for gravel and new metal beams, resulting in a general saving of 23% for the life cycle cost of Steiger 113 demolition and related material treatment. Mass based indicators show both BP and BAU demolition plans can realize 100% mass recovery, but value based indicators show BP plan can recover 25% more potential value than BAU one.

Conclusion

For the selective demolition, the evaluations on building level show that environmental success can go along with financial success if market for material reuse can be identified and connected before the demolition. Across environmental impact categories, BP demolition has the potential to reduce 19 – 78% of the environmental impacts as compared to BAU. The hotspot analysis shows that most of the BP environmental improvement is due to the reduced production of metal beams for new construction. From an economic point of view, BP has the potential to reduce the life cycle cost by 23%, from €61,328 to €47,427. The management of the metal fraction was an important parameter as it represents the highest economic value (despite representing 6% of total recovered material by weight). The use of recycled aggregate in the new building was proven to be environmentally preferable due to the avoidance of raw material extraction and the reduced transport for aggregate supply.

Acknowledgement

This research is part of the HISER project (www.hiserproject.eu). The HISER project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 642085.

Reference

Di Maio, F. and P.C. Rem. 2015. A Robust Indicator for Promoting Circular Economy through Recycling. Journal of Environmental Protection 6(October): 1095–1104.

EN 15804:A1 (2013), Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products

European Commission (EC) (2013). Annex II: Product Environmental Footprint (PEF) Guide to the Commission recommendation (2013/179/EU) on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations.

Guinée, J.B. et al. 2002. Handbook on Life Cycle Assessment: Operational Guide to the ISO Standards. Ed. by Jeroen B. Guinée. Dordrecht: Kluwer Academic Publishers.

ISO 14044 (2006). Environmental management -- Life cycle assessment – Requirements and guidelines.