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# LCA Modeling of Cement Concrete Waste Management

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*Abstract. Valorization of construction and demolition wastes (CDW) has become a fundamental issue in Europe, due to the huge amounts generated every year. Choosing an appropriate destination among several destinations for such wastes requires a global environmental assessment that can be provided by Life Cycle Assessment (LCA). Recycling is one of the waste handling practices whose environmental performances can be assessed by several methods in LCA. Among those methods, system expansion and cut-off methods are currently the most used methods, which were investigated in this paper to handle recycling of cement concrete demolition waste (CCDW) in LCA. Therefore, a case study was defined as waste management of a specific amount of CCDW for landfilling or for producing aggregates for road pavement construction. Results of the analysis showed that methods provide different results for the same problem.*

*Overcoming this methodological problem of identifying actual environmental consequences requires developing a waste management model by taking into account the economic demands for the main co-product of the quarry process in the markets.*

*Résumé. La valorisation des déchets de construction et de démolition (DCD) est devenue une préoccupation fondamentale en Europe, en raison des énormes quantités générées chaque année. Le choix approprié d'une destination parmi plusieurs pour de tels déchets nécessite une évaluation environnementale globale qui peut être fournie par l'Analyse du Cycle de Vie (ACV). Le recyclage est l'une des voies de gestion des déchets dont les performances environnementales peuvent être évaluées par plusieurs méthodes en ACV. Parmi ces méthodes, deux sont les plus utilisées actuellement à savoir «system expansion» et «cut-off method», et qui sont comparées dans le présent document pour traiter du cas d'application du recyclage des bétons de démolition (BDD). Notre étude de cas porte plus précisément sur la gestion d'une quantité spécifique de BDD vers deux destinations possibles : la mise en décharge ou la production d'agrégats pour la construction de sous-couches de chaussées routières. Les résultats de l'analyse ont montré que les méthodes ACV fournissent des résultats différents pour le même problème. Pour faire face à ces divergences méthodologiques, dans notre étude de cas, l'identification des conséquences environnementales réelles nécessite d'élaborer un modèle de gestion des déchets en tenant compte des exigences économiques du principal coproduit de carrière disponible sur le marché. ....*

*KEY WORDS: construction and demolition waste, life cycle assessment, recycling, allocation, system expansion, cut-off method.*

*MOTS-CLÉS : déchets de construction et de démolition, Analyse de cycle de vie, recyclage, allocation, System expansion, cut-off method.*

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## 1. Introduction

Constant and rapid increase in construction and demolition waste (CDW) generation and consumption of natural resources has become one of the biggest environmental problems in the construction sector. Yearly about 970 million tons of CDW are produced in Europe. Concrete waste is the main constituent of CDW, about 40% [SON 2013]. In 2012 the total CDW generated from public works and buildings in Loire-Atlantique, France was about 3.9 million tons, among which inert waste such as concrete accounted for 97% of the total waste generated [CER 2013]. Hence, it is important to investigate possibilities of using concrete waste as an alternative to natural resources in order to avoid disposing huge amounts of waste into the landfills. Though, besides natural resource depletion, all environmental impacts of concrete waste management should be also considered. For this reason, assessing all environmental impacts is a key issue, and thus we need to investigate various waste handling practices for concrete waste using LCA. However, various methods can be used in LCA to model waste management systems representing transformation of a waste into a new product.

The main objectives of this article are to analyze different aspects of two current methods in LCA for handling multi-functionality problem of recycling, assess their influence on the LCA results, and discuss the further need for research to fill the knowledge gaps associated with concrete waste management. We based our approach on a case study regarding management of a specific amount of cement concrete demolition waste (CCDW) that could be either landfilled or recycled to produce aggregates for constructing 1 m<sup>2</sup> of road pavement. The chosen case study represents a common situation in France, especially in the region of Loire-Atlantique.

## 2. Method

In order to compare two allocation methods, system expansion and cut-off methods, with the reference model, in which CCDW is sent to an inert landfill and road pavement is exclusively constructed with natural materials, two cases are considered, Case A and Case B.

### 2.1. Case A: Modelling using the system expansion method to assess recycling

Case A contains case 1A and Case 2A. Case 1A includes landfilling of CCDW, and case 2A contains recycling of CCDW into recycled cement concrete (RCC) to be used as aggregates in road pavement, in system model case 2A the system expansion method is used to assess recycling.

Case 1A is considered as the reference case. This model considers that the pavement is exclusively constructed by natural aggregates, whereas CCDW is disposed into an inert waste landfill. The quarry process produces natural aggregates required for constructing 1m<sup>2</sup> of pavement. Natural aggregates are used in both bound and unbound layers. Aggregates for bound layer are sent to the asphalt plant. Besides, the reference case includes inert landfilling process of CCDW.

System expansion which is applied to case 2A corresponds to rule number 3 which is discussed in detail by Weidema, [WEI 2001]. Under conditions of rule number 3, the total environmental burdens from constructing 1 m<sup>2</sup> of pavement, which is partly made with recycled cement concrete (RCC), includes environmental burdens from the production process of natural aggregates required for bound layers, asphalt production, and 1 m<sup>2</sup> of pavement construction as well as environmental burdens from the recycling process of CCDW. Besides receiving environmental burdens, the analyzed product system will also receive credits for the avoided disposal of waste. These credits should be applied by subtracting environmental burdens of landfilling of the waste from the total environmental burdens generated from the analyzed product system.

### 2.2. Case B: Modelling using the cut-off method to assess recycling

Case B contains case 1B and case 2B. Case 1B, in which CCDW is disposed into an inert landfill, and case 2B, in which the cut-off method is used to assess recycling of CCDW, are compared. In the cut-off method, the focus is put on the product system that uses recycled material. In our case, it is the road pavement construction.

In general, three main categories of aggregates are produced in the quarry process that can thus be considered as a multi-output process [MAR 2008]. The reference case (case 1B), without recycling, is then different from case 1A, as the quarry process should be modeled by considering three unitary processes that produces three different qualities of natural aggregates. The three qualities of aggregates are utilized in different layers of the pavement. Only tertiary aggregates are used inside bound layers, whereas primary and secondary aggregates are of lower quality compared to tertiary aggregates and mostly suitable to be used as unbound aggregates in

unbound layers of the road pavements. In this study it is considered that only secondary aggregates are used in the unbound layers and primary aggregates are stored in the quarry for further use.

The fact that for producing tertiary aggregates, primary and secondary aggregates are inevitably produced, should be also taken into account in conceptual model of case 2B.

Thus, by using RCC instead of natural secondary aggregates (natural unbound aggregates), the production process of natural unbound aggregates is not avoided nor displaced; only utilization of secondary aggregates is considered to be avoided.

### 3. Results

All results were calculated using indicators from the CML baseline 2001. Results show that the main contributor to almost all environmental impact categories for all four cases is asphalt production process. For both cases with recycling (2A and 2B), the recycling process is found not to have considerable impacts, because CCDW only requires one treatment line (one line is one crusher and several grids) compared to five treatment lines required for the quarry process.

Figure 1 shows that case 2A overestimates the environmental improvements resulted from recycling. In case 2A, a part of the quarry process is displaced due to the use of RCC in the unbound layers of the road pavement, whereas in scenario 2B, the quarry process will store natural unbound aggregates when they are replaced by RCC.

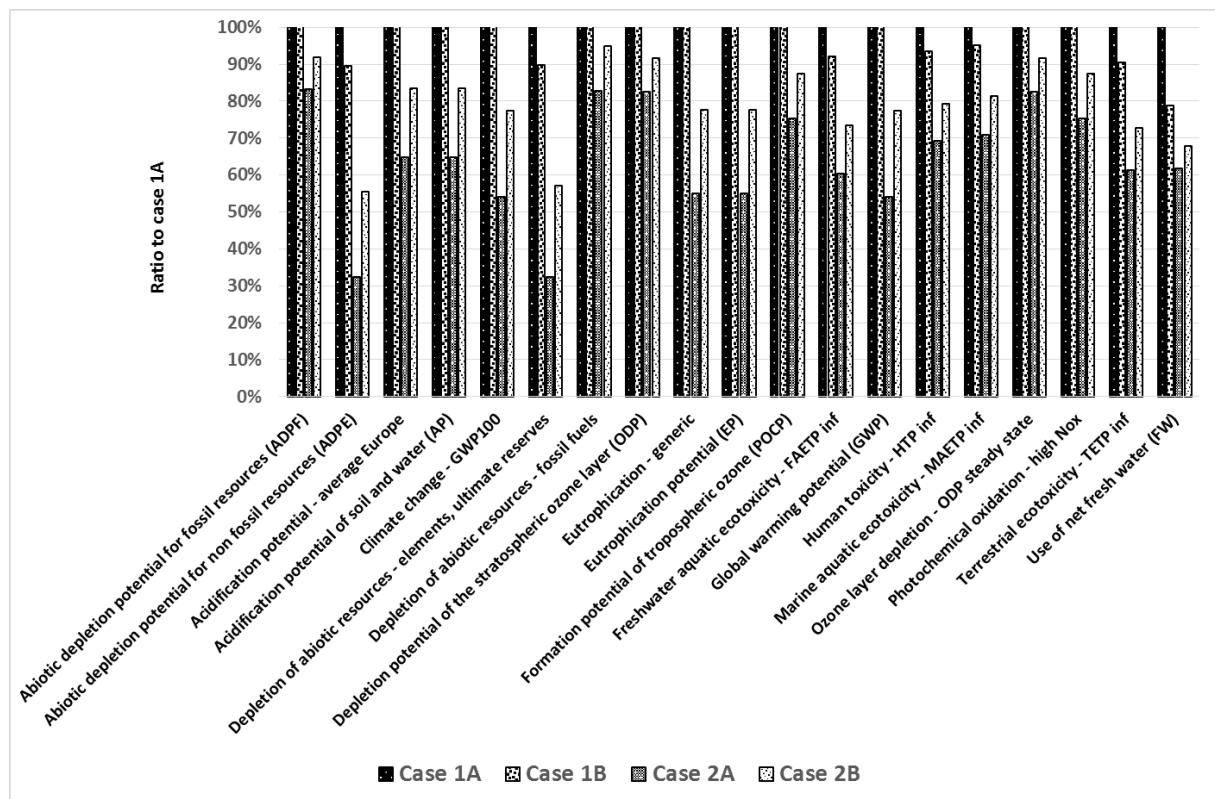


Figure 1. Synthesis of results from four cases.

### 4. Discussion and conclusion

Results mainly show that the choice of system model has a large influence on the final results. Choosing a suitable allocation method for assessing environmental impacts of recycling is one of the most debated and controversial issues in LCA. Since, gaining credits from the recycling process or recycled material highly

depends on the LCA practitioners' points of view and their responsibilities for receiving environmental credits, whether being a waste producer or a recycled material user. While, with an aim of improving waste management systems, it is required to take waste managers' points of view into consideration.

Reflecting actual environmental consequences from CCDW management requires including market mechanisms into analysis. This is mainly due to the fact that production process in the co-producing quarry process is not affected by the recycling process, whose product is in competition with lower quality natural aggregates, whereas is driven by the economic demand for high quality aggregates. Therefore, it is required to develop an economically oriented model to predict future environmental consequences. Furthermore, in order to reflect actual practices, estimate total demands for natural aggregates and the changes in demands for these materials, developing dynamic stock models are required. This is mainly because transportation costs of such heavy materials are too high to be exported and store of them might be an economically viable solution. The importance of stocks in the case of recycling has already been highlighted [STA 2016] and our case study shows they cannot be excluded from the analysis because of two main reasons: the importance of market mechanisms in the analysis and existence of the multi-output process, such as quarry.

Consequently, this study provides some basic assumptions to develop a more specific conceptual model for cement concrete demolition waste management at local level, which is based on LCA, MFA, market mechanisms, and quality of materials. The conceptual model provided in this article needs to be developed in terms of processes, stocks and markets using local economic and flow data. It will be developed and tested for the case study of Loire-Atlantique in France.

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