Carbon footprint of dredged sediments and virgin aggregates in a road case study

ABSTRACT Aggregates extraction and quarry operations is a major source of greenhouse emissions in construction work. The growing demand on virgin aggregates for road construction and other infrastructure works promote the use of alternative materials. Waste valorization is one of these strategies that substitute the need of virgin aggregates by reusing or recycling wastes. These wastes provide a suitable alternative in case they met the environmental and mechanical requirements in terms of their functionality. Dredged sediments are one of these materials that shown several abilities to be used in road construction. The focus of using such alternatives in order to avoid natural resources consumption doesn't disperse the attention to their carbon footprints. In this paper, a comparative assessment was conducted to address the carbon footprints beyond the production of virgin aggregates and their replacement by dredged sediments for the use in road construction. Carbon footprints were estimated based on a life cycle assessment approach.

Keywords Carbon Footprint, Dredged Sediments, Alternative material, Valorization, Road

I. INTRODUCTION

The increasing demand on raw material as aggregates induces additional environmental impacts. In France , the aggregates need increases from 435 million tons in 2017 to 445 million tons of aggregates in 2018 ,with (-2.2 million ton of aggregates) as a difference between imports and exports in 2018 (UNICEM, 2020).

This additional loads have been transmitted to the French regulations and plans .As in the order of June 4, 2021 (Arrêté du 4 juin 2021) that sets out the criteria for the removal of waste status for excavated soil and sediments that have been prepared for use in civil engineering or development under certain environmental conditions and requirements . In France between 40 and 50 million m^3 of sediments are dredged annually (Hayet et al., 2017) .Dredging is necessary in ports, canals and channels to facilitate the operation of ports infrastructures and improve their accessibility. According to the French and European regulations sediments is considered as waste once it is removed from its natural environment. (Directive 2008/98/EC).

Dredged sediments had shown several valorization possibilities in road construction, as its beneficial uses as a backfill, capping layer, or in other applications (Zentar et al., 2009).

Life cycle assessment (LCA) is a way of analysis of a system in order to calculate the environmental impacts beyond the functionality of this system. LCA comprise 4 main stages: goal and scope, inventory analysis, impact assessment, and interpretation. Where the emissions and flows are characterized into specific categories that represent an environmental problem as climate change, acidification, human toxicity, and others (Zentar and Almokdad, 2022). Meanwhile some issues have their own single-issue assessment, as carbon footprint or water footprint .That's due to their importance and popularity especially in this decade because of the increasing awareness about the climate change effect and water scarcity issues and their related regulations and decisions in the different governments.

The term Carbon footprint is a common term used to describe the impact of a product or a system beyond the greenhouse emissions and represented in CO_2 equivalent.

II. Materials and methods

Carbon footprint studies relies on the LCA approach in order to calculate the estimated values of the studied system effects. LCA studies are performed with respect to the standards (NF EN ISO 14040, NF EN ISO 14044), where these standards describe the principles framework guidelines and requirements for any LCA study that address different areas of concern. While carbon footprint studies as in this study it only addresses a single issue and it should be quantified according to the (NF EN ISO 14067) "Greenhouse gases-Carbon footprint of products-Requirements and guidelines for quantification". This study relies on Ecoinvent 3.7.1 database and IPCC 2013 impact method.

A. Case study

Sediments characteristics used in this study are based on several non-submersible sediments' characteristics taken from the dehydration basins in the harbor of Dunkirk. These sediments are environmentally acceptable according to the guide referring to the use of alternative material in road construction(SETRA ,CEREMA, 2011), and compatible with the mechanical characteristics requirements according to the French technical guide GTR for the use of material as a backfill (SETRA and LCPC, 2000).

B. Goal, scope, and System boundaries

The evaluated systems correspond to different material to be used as a backfill for road construction purpose, where in the first case the virgin aggregates are supplied by normal quarry operation, while in the second case the dredged sediments materials are supplied by the dehydration basins facility in the harbor area. Thus, the aim of this study is to evaluate the environmental potentials expressed as CO_2 equivalent emissions that corresponds to these different cases. Several assumptions and exclusions related to the comparative assessment purpose between these two cases were taken into account. Therefore, only processes that may cause differences between the compared cases are considered. (Table 1)

Table 1. Life Cycle Inventory

Scenarios	Processes	Amount
40 km	Transport, freight, lorry 16-32 metric ton, EURO5, RER / Transport, freight, lorry 32 metric ton, EURO5, RER	131200 ton.km
60 km		196800 ton.km
80 km		262400 ton.km
100 km		328000 ton.km
/	Sand {RoW}| gravel and quarry operation	3280 ton

As an example, construction processes or material handling processes in both cases by using excavators and others machines are excluded. Furthermore, the dehydration basins operations also were excluded as it will happen identically even in the case where virgin aggregates are used. (See Figure 1)

This study relies on attributional cut off by classification approach that represent the compared systems from stage of pre-construction stage and until the transport of material to the construction site. Including the different scenarios related to the distance between dredged sediments source and the road worksite. Assuming a distance of 40 km between construction site and virgin aggregates source that are much more common and available than alternative material. Also taking into account the effect of using different transportation truck capacities (16-32 metric ton and >32 metric ton) in these different scenarios.

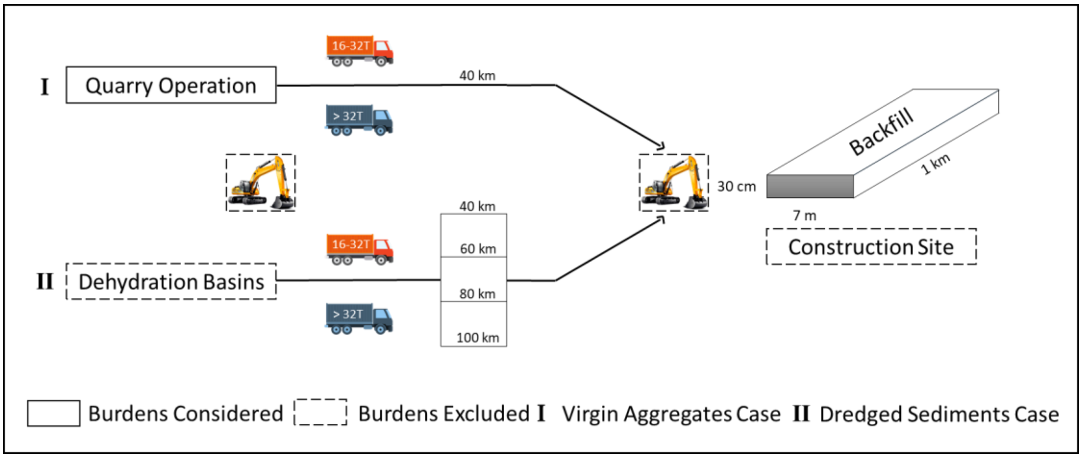

Figure 1. System Boundaries

C. Functional Unit

The functional unit is the system quantification reference in which several cases can be compared in different scenarios. In this case the functional unit where the material quantity that suits the mechanical functionality requirements of the backfill (SETRA and LCPC, 2000) for a distance of 1 kilometer, 7-meter width , and 30 cm thickness corresponding to 3280 tons for both materials .

III. Results

The results demonstrate two main findings: the importance of the truck capacity used in handling material, and the significance effect of site distance from aggregates source location in term of comparison between both sources. For virgin aggregates usage and in case the 16-32 T truck have been used, the transportation and production impacts are equal to 60% and 40% respectively. While if the bigger truck is used the transportation will be reduced to 45% of the total impacts .

Referring to results shown in Figure 2 it can be concluded that when the truck of capacity > 32 T is used the carbon footprint for both cases of usage: virgin aggregates (VA) and dredged sediments (SD) and for all distance scenarios (40, 60, 80,100) is less than that in the case where trucks with 16-32 T capacity are used .

In case the truck of > 32 T capacity has been used the scenario of using dredged sediments shows an environmental impact savings of CO2 equivalent until the distance of 80km, which equal 2 times the distance for virgin aggregates source (40km) . While if the smaller trucks were used that shows an environmental saving until 60 km (1.5 times the distance for virgin aggregates).

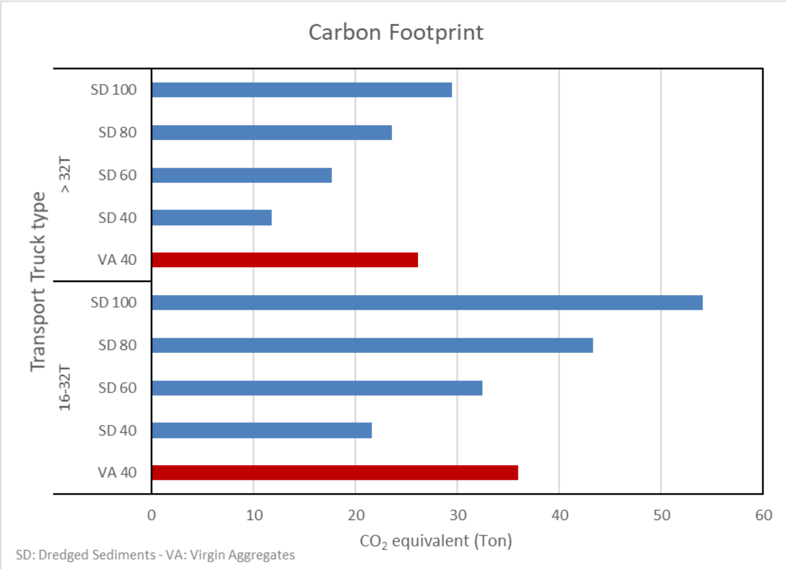

FIGURE 2. **Comparative Carbon Footprint between dredged sediments and virgin aggregates**

IV. Conclusion

The comparative assessment shows that an environmental saving in carbon footprint can be achieved by using dredged sediments as an alternative material in construction sites that are not so far from dehydration basins as in the coastal sites in the Nord department near Dunkirk port .

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