Material Inventory Analysis of Residential Buildings in Homs, Syria for Rehabilitation

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INTRODUCTION

In March 2011, a public revolution followed by a severe civil war broke out in Syria. The large-scale destruction in urban areas created a vast number of demolished building wastes (DBW) (REACH, 2019). The DBW will overwhelm the existing solid waste management facilities and give impacts on other emergency responses and recovery activities (Brown, et al., 2011). Homs city is the third largest city in Syria and the first city which exposed to damage due to the war. The number of damaged and destroyed structures reached to 13,778 buildings that make it the third largest affected city due to the war (REACH, 2019). In developing countries such as Syria, however, there are no well-developed guidelines and legal frameworks for estimating and managing disaster waste (Poudel, et al., 2018). The purpose of this study is to estimate the amount of building material stocks in Homs city and to define its components. Specifically, the study identifies the building inventory for two types of residential buildings in Homs, estimates the amount of building material stock, and then estimate the total amount of DBW due to the war with three different scenarios of reuse and recycling.

MATERIALS AND METHODS

In the light of the insecure situation, it was impossible to access the site to get the primary data, and the reliable data sources were minimal. Hence, this study was conducted primarily based on the secondary data. First, we identified the material inventory measured in kg/m^2 by using the reliable data (e.g., Central Bureau of Statistics., 2012) and the Syrian building code. Second, we obtained the necessary building floor area data by creating a digital map for the whole city at the block-level and classified the residential buildings into different categories. In the map, the block was defined as a group of buildings located side by side without any spaces, and the blocks were classified into different categories, depending on the following three factors: building type, building size, and the material use. Third, by using the database of the building floor area created in the previous phase, we defined the building material stock of the city. Forth, we quantified the DBW through multiplying the buildings' floor area by the latest damage data (percentages), and then defined its detailed components by using the material inventory. To fill the gaps between the damage data (building-level) and the building material data (block-level), first, we selected five representative residential blocks from each category. Then we conducted a more detailed investigation to obtain the necessary building information from each block. Then finally we defined the average values of building height, foot pint area, and floor area, which were used to represent all buildings of each category. Finally, we compared the quantities of damaged waste with three different reuse, recycling, and recover (3R) scenarios: zero 3R, applicable 3R, and optimum 3R scenarios.

RESULTS AND DISCUSSION

The results of the material inventory analysis showed that there were 17 types of building materials of which nine of them were cementitious materials. Building material stock in the Homs city was quantified for each block on the map. We obtained building material stock for the six major building material components (i.e., plain concrete, reinforced concrete, steel, cement brick, clay, and mortar) in each residential block. Then we obtained total amount of material stock in the whole city as shown in Table 1. The result shows that the largest component is the reinforced concrete, which is 20.7 million tons in total. This is because most of the buildings in Syria are concrete buildings

Table. 1. Material inventory, material stock and the damaged materials

Building Material	Material inventory (Kg/m²)	Materila stok (ton)	Damaged (ton)
Plain concrete	365.89	16588499	1141425
Reinforced Concrete	457.49	20741459	1427182
Steel	27.33	1239092	85260
Cement Bricks	377.37	17108740	1177222
Mortar	64.95	2944446	202602
Clay	122.76	5565473	382950

which depend mainly on reinforced concrete as an essential part in their structures.

The total amount of building material stock before the war is about 85.3 million ton. Meanwhile, DBW was calculated for each block on the map. We obtained the amount of DBW in each residential block and in the whole city as shown in Table 1. The result shows that the total amount of DBW of the aforementioned six components is 4.4 million tons in the whole city, which is equal to 6.9% of the total building material stocks. From the damage distribution map (Fig. 1), it was found that there are three areas with high damage densities, implying that these areas used to have a high material stock density and then exposed to high bombing rates during the war.

Figure 1. Distribution of damaged reinforced concrete in the residential buildings in Homs city. Red circles refer to the areas with high damage intensities.

The amount of the damaged material is 3.07 million ton. The building material flow of the city is analyzed in Fig. 2 with three different scenarios, namely zero rates of recycling and reusing, optimum recycling and reusing, and the use of DBW in producing new concrete.

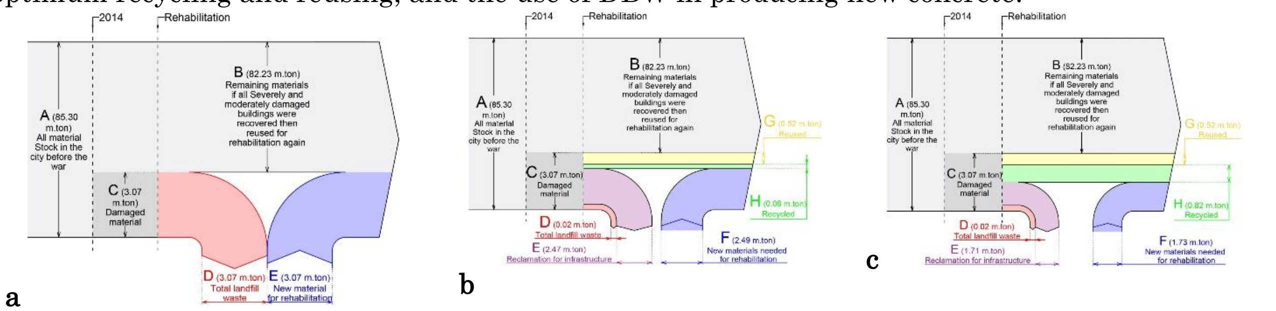

Figure 2. Flow of building materials before and after the war for the residential buildings in Homs. (a) Scenario 1 (Zero recycle and reuse) (b) Scenario 2 (Optimum recycling and reusing rates) (c) Scenario 3 (Using demolition waste in producing new concrete)

CONCLUSION

The results showed that there were 17 types of building materials in Homs city, Syria, of which nine of them were cementitious materials. The total amount of building material stock before the war was about 85.3 million ton. Meanwhile, the amount of the damaged material was estimated as 3.07 million ton. Then, the landfill size required in zero recycle and reuse rate scenario was estimated to be 2.34 km^2 which could be reduced to 0.02 million ton if an optimum recycle and reuse rate scenario was applied.

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