ENVIRONMENTAL ASSESSMENT OF MANAGEMENT OPTIONS OF THE URBAN MINERAL BUILDING MATERIAL STOCK

Renate Huber, MSc.
Institute for Water Quality and Waste Management, Vienna University of Technology
Vienna, Austria

1. Abstract

The building industry in Europe is causing a large consumption of natural resources and emissions to the environment. Hence, environmental impact assessment of building waste management options is necessary to assess the ecological best options. The paper gives a rough overview of the impacts on the environment caused by building processes and estimates the in- and output of building materials for the City of Vienna in Austria. The stock of building materials which are "stored" in buildings is determined. Concrete is one of the dominant building materials. Therefore, production emissions for concrete and recycling concrete are examined and their impacts on CO_2-equivalents and the consumption of natural resources are investigated.

2. Importance of the building industry

The building industry in Europe is responsible for a large consumption of areas and energy, for production of waste and for growing stocks. In the EU with the borders of 2003 3,200,000 km² of the land area are used by buildings. The daily growth is 10 km². Buildings claim 45 % of the primary energy consumption in the EU. 15 % (7.5 mill. t) of the yearly waste generation in Austria are building wastes. The buildings are responsible for the erection of a huge stock of materials in our society. In Austria the stock of buildings (volumes of existing constructions) is 200 to 500 t per capita. It doubles in 30 to 50 years if the growth of now is extrapolated. The domination of the building industry in the material flow of a state brings the need to deal with the question on how building wastes shall be managed and how environmental impacts can be assessed.

3. Goal and questions

The goal of the paper is to assess the stock of urban mineral building materials and compare the environmental impacts of the production of concrete and recycling concrete. The paper deals with the following questions:

- Of which materials consists the stock of buildings?
- Is scarcity expected for mineral building resources?
- Which potential for secondary resources represents the building stock?
- How much "nature" is consumed in production of secondary resources compared to primary resources?

4. The observed system and the stock of buildings

The city of Vienna serves as an example to calculate the urban stock of buildings. The observed system is shown in Figure 1. The examined processes are buildings of the structural engineering such as buildings for housing or office buildings and buildings for civil engineering (here only road buildings are investigated), landfills and the processing of building waste for recycling of building material. The system border in space is the buildings in Vienna, in time it is the year 2001. The arrows mark the yearly in- and output flows of goods like building materials or construction waste. Only mineral construction materials are investigated (no metal, wood etc.).

The stock of buildings is calculated using statistical data [1]: the number of existing buildings in Vienna, their age, the use (housing, office, industrial building) and the method of construction (main building material). Indicators (t material per m²) [2] are used for the calculation of the material input into buildings dependent on the construction method. Statistical data of the road areas and their construction is used for the calculation of road building masses.

The yearly in- and output calculation is based on statistical data as well [1] [3]. For the processes "buildings SE" and "buildings CE" together 12 mill. t of mineral construction materials are the input into the city of Vienna in the year 2001. The output is 1 mill. t (concrete waste, rumble, road building waste).

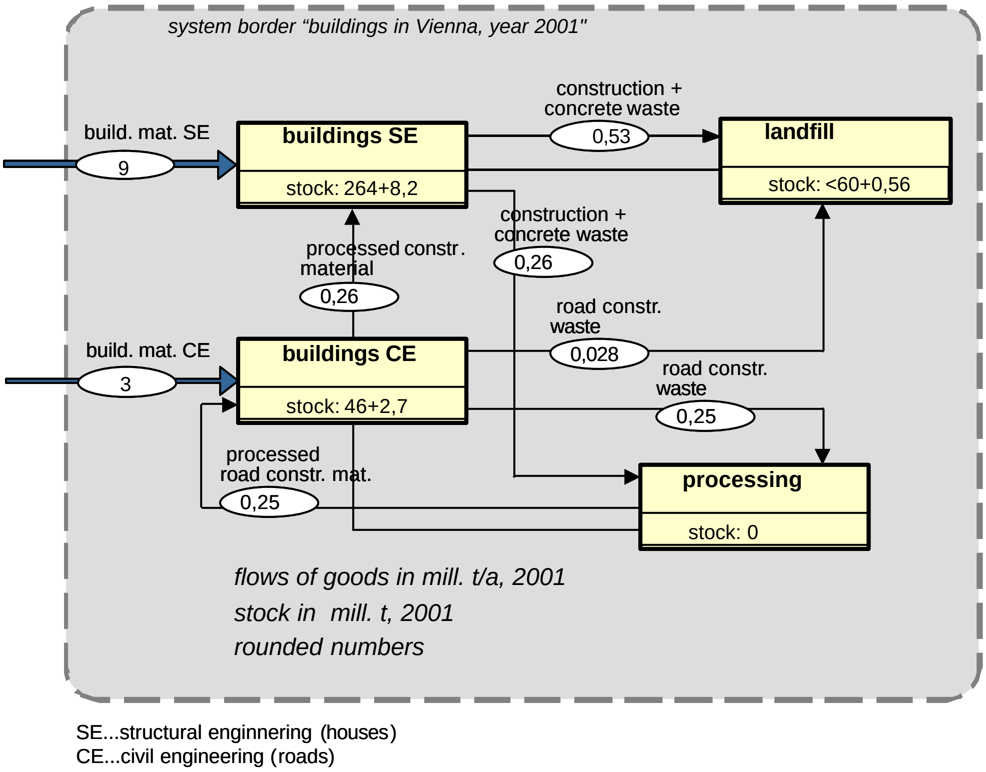

Figure 1: System „buildings in Vienna, year 2001"

The stock of mineral building materials in Vienna has a mass of 311 mill. t: 77 mill. t of concrete and 104 mill. t of brick. The rest is plaster, floor pavement, mortar, gravel, cement, granite, roofing and others (Figure 2).

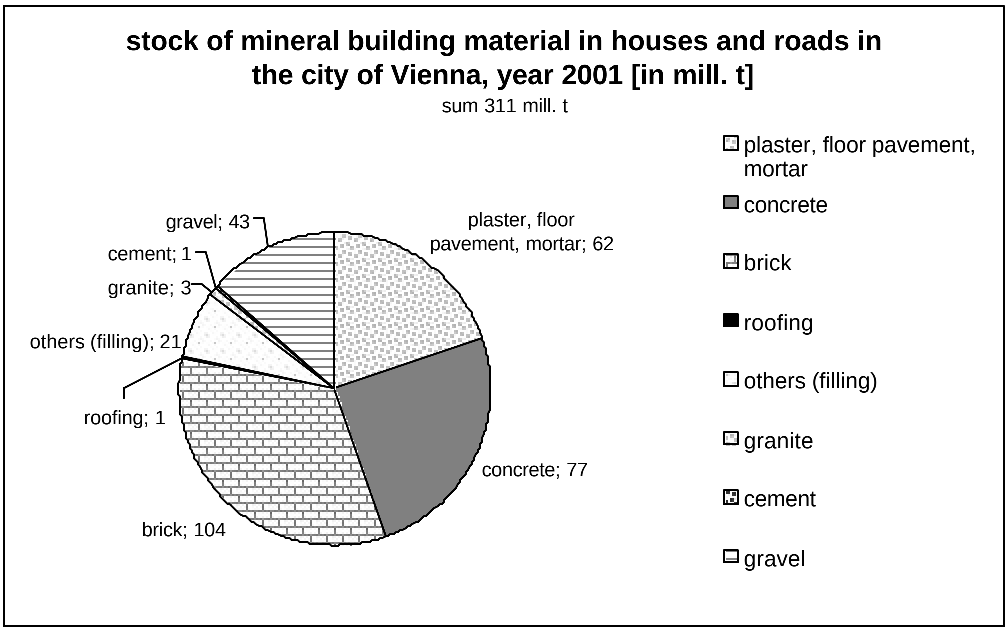

Figure 2: Stock of mineral building materials in houses and roads in the City of Vienna, year 2001. The stock defines the existing buildings which will become waste in the future.

The dominant building material before the 1940s used to be brick and stone (Figure 3). Nowadays concrete becomes the mainly used material. Therefore, the following investigations concerning the ecological impacts of processes will be performed for concrete.

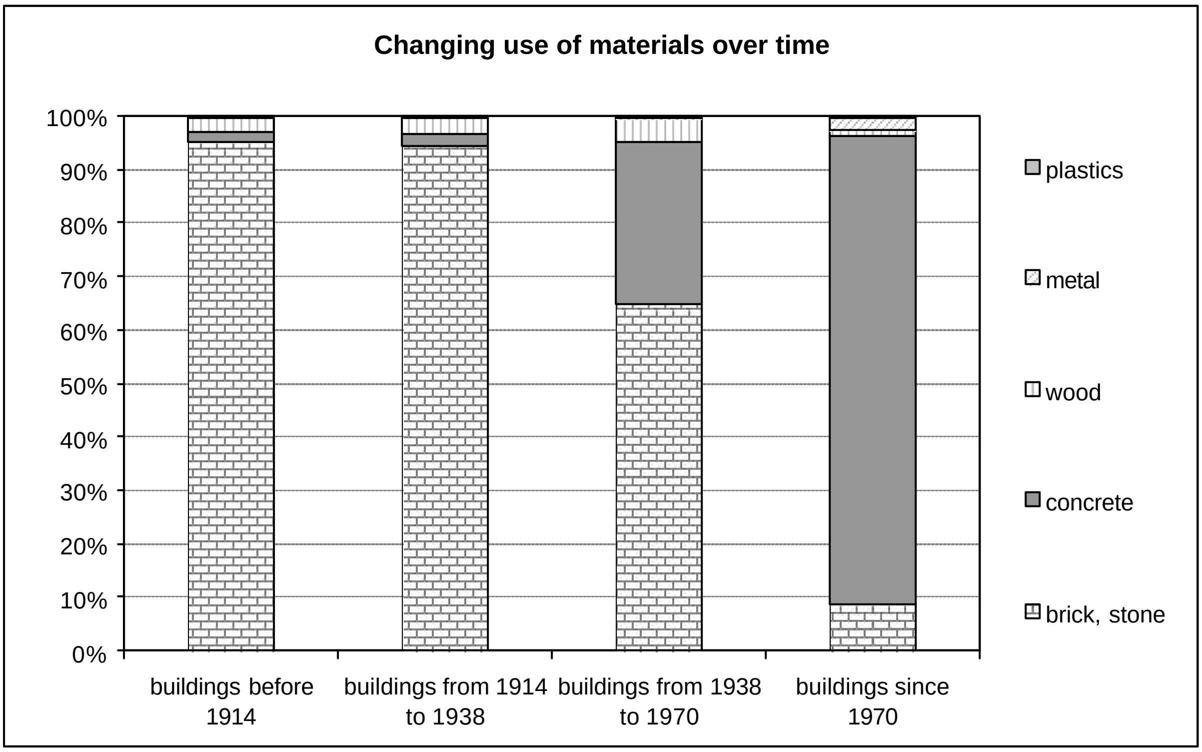

Figure 3: Changing use of materials over time [4].

5. Assessment of ecological impacts

Different building options and building waste management options have different impacts on the environment. Ecological assessment methods allow the estimation of environmental impacts. Environmental categories that can be observed are:

- the consumption of resources
- emissions to air, water and soil
- generation of waste (landfill volume)

Two of the mentioned categories will be discussed here. The focus of this paper is the emissions of CO_2 to air and the consumption of the resources gravel and sand.

<u>Emissions to air</u>

Selected impacts are presented here. The comparison of the yearly concrete production with recycling concrete (RC) production serves as an example. It was assumed that the concrete buildings which are built in one year in Vienna are made of concrete on one hand and of RC on the other hand. The environmental impacts of the concrete production per year for Vienna are calculated. For RC it was assumed that old concrete was crushed and used for aggregate. The fraction < 4 mm was exchanged by primary sand. The cement rate was assumed to be a little higher for RC (concrete: 16 kg cement /kg concrete; RC: 17 kg cement /kg). This higher cement rate does not have to be necessary in RC production but was applied to see the effects of increased cement on the impact categories.

The CO_2-equivalents are calculated to estimate greenhouse effect relevant emissions into air. The GWP coefficients from [5] were applied to calculate the CO_2-equivalents. Cement is the dominant factor for CO_2-emissions (Figure 4). This results from the high energy demand for cement production. The use of crushed concrete as aggregate in RC does not significantly reduce the emissions. The comparison of concrete with RC showed no significant difference. When RC is produced with little increased cement the CO_2-emissions of RC even overtop those of concrete. In the next step it was investigated if CO_2-emissions of concrete production are a relevant category to look at. The yearly CO_2-emissions of cars in Vienna amount about 1 bill. kg CO_2. The Viennese waste incineration plant Spittelau produces 1 mill. kg CO_2 per year. Hence, the emissions of the yearly concrete production (500 mill. kg) can not be neglected.

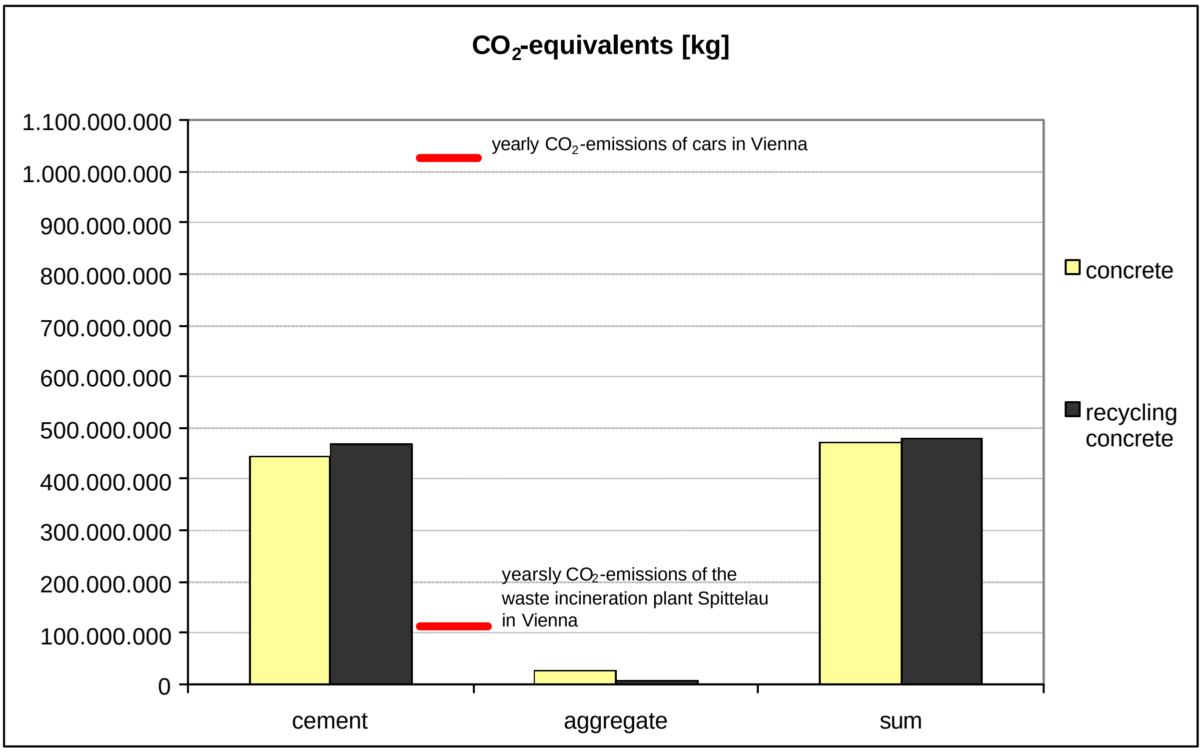

Figure 4: Comparison of the CO_2-equivalents of the yearly concrete production and recycling concrete production to CO_2-emissions by cars and a Viennese waste incineration plant.

Consumption of resources

To find out whether the use of a resource is critical it has to be assessed if it is scarce. The scarcity of the resources gravel and sand can be only made regionally. Gravel and sand are not limited by the volume of their occurrence in nature but by conflicts of interests of the regional policy (waterproofing areas, building land etc. [6]). Figure 5 shows a map of an important gravel deposit outside of Vienna. The authorized deposits around Vienna contain 310 mill. m^3 of gravel. As the yearly need of gravel and sand for buildings in Vienna is 1.4 mill. m^3 the deposits would last for 220 years if it is assumed that no other city consumes these resources.

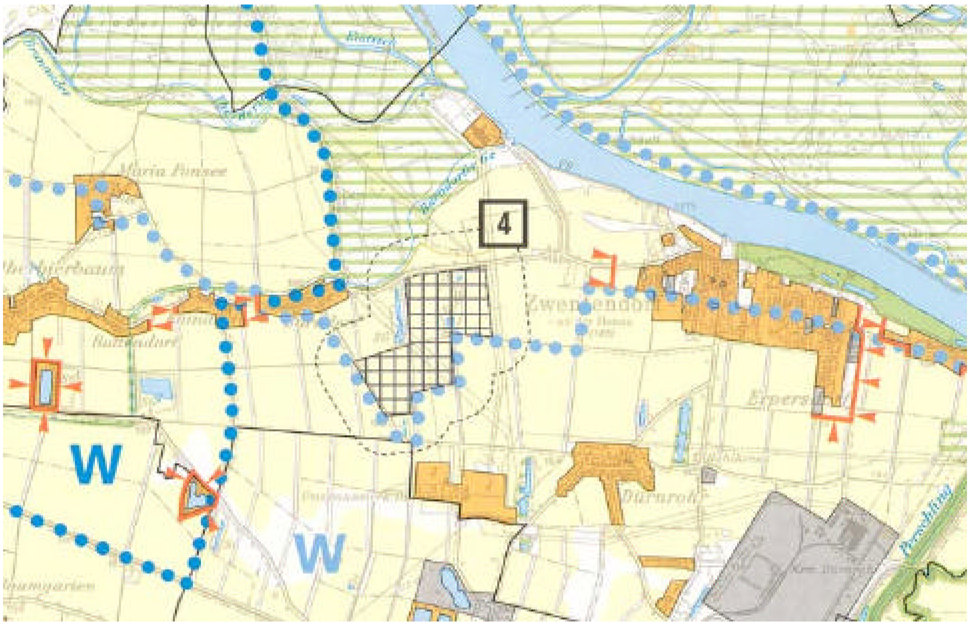

Figure 5: Map of an important gravel deposit (Tullnerfeld No. 4) near Vienna [7]

In case of the use of crushed concrete as aggregate for concrete the deposits would last for 250 years. The small difference of 30 years derives from the following conditions: The output "concrete waste" is only one tenth of the yearly needed concrete material (input into the system in Figure 1). From concrete waste only 50 % can be used for RC. Fractions < 4 mm are excluded. This is why only a small part of the needed gravel could be replaced by recycling aggregate and the natural deposits can be conserved just to a certain amount. Here it is assumed that crushed concrete is not used for road building but for RC in structural engineering.

6. Conclusions and outlook

Of which materials consists the stock of buildings?

The stock of mineral building materials in Vienna has a mass of 311 mill. t: 77 mill. t of concrete and 104 mill. t of brick. The rest consists of plaster, floor pavement, mortar, gravel, cement, granite, roofing and others. Brick and concrete are the dominant materials in the stock of buildings. The output of the process "buildings" is one tenth of the input. The data for the calculation of the stock is based on statistical data which is still not satisfying. Accountancy for the input materials into buildings should be established in Austria as the building industry is responsible for a large volume of goods.

When results of different studies concerning the ecological impact of processes are compared the different system borders have to be taken into account.

How much "nature" is consumed in production of secondary resources compared to primary resources?

The main factor to reduce CO_2 production emissions is cement. If a higher cement ratio is needed for the production of recycling concrete (RC) the impact on the environment of RC is even a little higher compared to normal concrete.

Is scarcity expected for mineral building resources? Which potential for secondary resources represents the building stock?

Gravel and sand can not be declared as scarce. They are not limited by the volume of their occurrence in nature but by conflicts of interests of the regional policy (waterproofing areas, building land etc.). The use of recycling aggregate in RC conserves the natural resources gravel and sand. The conservation is limited because the yearly production of concrete waste is only one tenth of the needed concrete for new buildings on one hand. In case of RC only 50 % of the concrete waste could be used on the other hand. Hence, the potential for concrete waste as a secondary resource is limited. The production of RC can help to reduce landfill areas for concrete waste.

The here presented assessment method will be expanded to other environmental impact categories to make a comprehensive assessment of concrete and RC possible.

7. References

[1] MA 66, „*Statistisches Jahrbuch der Stadt Wien 2002* (statistical yearbook for the City of Vienna)“, Magistrat der Stadt Wien, Vienna 2003.

[2] Gruhler, K., Böhm, R., Deilmann, C. & Schiller, G., „*Stofflich-energetische Gebäudesteckbriefe – Gebäudevergleiche und Hochrechnungen für Bebauungsstrukturen* (material-energetic building characteristics – comparison of buildings)“, IÖR-Schriften Band 38, Institut für ökologische Raumentwicklung e.V., Dresden 2002.

[3] MA 48 „*Wiener Abfallwirtschaftskonzepte* (waste management concepts for the City of Vienna)“, Magistratsabteilung 48, Wien, Vienna 2001.

[4] Glenck, E:, Lahner, T., Jereb, W., Leitner, E., Brunner, P.H., Schachermayer, E., „*Bauwesen – Abfallstrategien in der Steiermark (Projekt BASS)* (building industry – waste management strategies in styria).“ Band 3: Lageraufbau im Bauwesen (LAUF). Institute for Water Quality and Waste Management, Vienna University of Technology, Vienna 2000.

[5] IPCC - Intergovernmental Panel on Climate Change, “*Radiative Forcing of Climate Change. The 1994 Report of the Scientific Assessment Working Group of IPCC. Summary for Policy Makers.*“ WMO/UNEP 1994.

[6] Heinrich, M., „*Bundesweite Übersicht zum Forschungsstand der Massenrohstoffe Kies, Kiessand, Brecherprodukte und Bruchsteine für das Bauwesen hinsichtlich der Vorkommen, der Abbaubetriebe und der Produktion sowie des Verbrauchs. Zusammenfassung* (deposits of gravel, sand and other materials for the building industry in Austria, deposits and production)“ Berichte der geologischen Bundesanstalt. Heft 31. Vienna 1995.

[7] Niederösterreichische Landesregierung (Government of Lower Austria) “*Regionales Raumordnungsprogramm nördliches Umland Wien* (Regional policy north hinterland of Vienna)“ 8000/86-0, Stammverordnung 155/99, 1999.