博 士(工 学) モンテロ アルファロ ホセ アロンソ

学 位 論 文 題 名

Reduction and utilization of fine residue generated from mixed construction and demolition waste sorting facilities

(建設混合廃棄物の破砕選別施設から発生する残渣の削減と有効利用に関する研究)

学位論文内容の要旨

Construction and demolition waste (CDW) is one of the major solid wastes generated from industrial sectors in every country. In Japan, nearly 20% of industrial waste was generated from construction sectors in 2007. However, by enforcement of the Construction Material Recycling Law, several kinds of CDW such as concrete, asphalt, etc., has been recycled or reused at a high rate. On the contrary, as for mixed construction and demolition waste (MCDW), almost one third was disposed of into landfill. Based on the Japan's targets for establishing a sound material-cycle society, to reduce the amount of MCDW sent to landfills is significant. Sorting process of MCDW is clue for achieving it. Hence, in this study, sorting process of MCDW was investigated in terms of material recovery and how to improve its efficiency was discussed. A major issue of the sorting process was the generation of the fine residue, which was thought to have potential of hydrogen sulfide formation because it contains both gypsum and organic matter. Thus, separation methodology of gypsum and organic matter from fine residue generated from the process was also studied. Moreover, the risk of hydrogen sulfide formation in case of utilization in environment was assessed by examining leaching behavior of sulfate and organic matter from fine residue.

Chapter 1 provides a general introduction and description of the objectives of the whole research. It shows a background of the addressed problem, presents past studies in similar areas, and states the main objective of the overall research.

Chapter 2 describes a field research carried out at a facility located in Kanto Area that accepts MCDW. The most important activity carried out was a batch test where MCDW were used as input into the sorting process and after the process was over samples from all outputs were collected for analysis. The goal was to determine how the material was distributed through the process, in order to find where the gypsum, organic matter and heavy metals were concentrated the most. Then, the separation efficiency of the sorting process was evaluated. For this, flows of mass, of organic matter, Fe, Pb and gypsum were depicted. The flows of materials were also break down by contributing outputs. By this, the recycling rate of the facility, the disposal rate, where the most of the organic matter and metals were diverted to and which outputs contributed the most to each category were indicated. At the end, the original MCDW were compared against the material to be landfilled, to

evaluate if the sorting process was efficient enough to divert the most of the pollutants away from it. The findings from this chapter were communicated to the facility management in order to reduce the amount of residue generated and to improve its quality, and based on them, the sorting process was modified.

Chapter 3 describes a new field research carried out in the same MCDW sorting facility previously analyzed. The objective was to re-diagnose the sorting process to evaluate the effectiveness of the changes implemented. Three independent batches of MCDW were input into the process and once the process was concluded, samples were collected from all outputs to be analyzed. As the results, it was found that the recycling ratio increased, amount of material to be landfilled decreased and the quality of residue was also improved. Nevertheless, still some amounts of residue are inevitably generated. To deal with this, it was proposed to mix fine residue with other output containing very small amounts of organic carbon. The resulting mixture was estimated to contain a TOC of about 4% and could be recycled as aggregate, reducing the amount of material to be landfilled by increasing the recycling rate.

Chapter 4 describes a heavy liquid separation performed to the samples obtained at the MCDW facility in order to determine the specific density range containing the most of undesirable materials (gypsum and organic matter). It was found that the most of the gypsum contained in the samples was in a powder state, therefore having a high density unlike many of the organic matter that has low densities. As the result, 93% of the gypsum was concentrated in the density range of 1.59-2.28 g cm^{-3}, which contained 24% of the total mass. Organic matter was mainly contained in densities below 1.5. The above findings indicate that since gypsum is mainly distributed in the fine fraction and has a high density, the amount of gypsum going to landfills can be reduced by first separating the fine fraction from MCDW and then removing particles in the density range of 1.59–2.28 g cm^{-3}. These measures could remove 24% of the mass, containing 93% of the gypsum, resulting in a gypsum concentration of only 1.55 % in residual fine matter. By this quality improvement, the risk of H_2S generation after disposal in even non-controlled type landfill can be reduced.

Chapter 5 presents an evaluation of the environmental risk posed by MCDW residue if it gets in direct contact with a low-organic-carbon environment. As found before, the main targeted pollutants were SO_4^{-2} (provided mainly from gypsum) and organic matter. They are also found in materials regularly used in the environment as fertilizers, soil conditioners and materials for construction. Therefore, the objective was to elucidate if the leaching behavior of all those selected materials were different among them, and if so, what was that difference. In order to confirm this, serial batch leaching test was performed for all samples and leaching of sulfate and organic matter were analyzed. As the results, sulfate leaching was similar among several samples including residue because its leaching is dominated by solubility of gypsum. On the other hand, leaching behavior of organic matter was quite different among samples. Leaching of TOC from residues continued even at $L/S = 15$ although those from others were ceased. However, it was also confirmed that constituents of TOC was not suitable substrate available for sulfate reducing bacteria (SRB). One fertilizer indicated far high TOC leaching even though it is utilized in environment without care. Based on these findings, we conclude that impact of the utilization of residue is not so different compared with other materials which contained gypsum and organic matter such as fertilizer.

Chapter 6 summarizes the results obtained in the research and presents some recommendations.

学位論文審査の要旨

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学位論文題名

Reduction and utilization of fine residue generated from mixed construction and demolition waste sorting facilities

(建設混合廃棄物の破砕選別施設から発生する残渣の削減と有効利用に関する研究)

建設混合廃棄物の処理・処分の適正化のためには直接埋立を回避するだけでなく,主要な処理手段である破砕選別施設において効率的な資源回収,埋立量削減を実現することも重要である.本研究では,建設混合廃棄物の破砕選別プロセスに着目し,物質フローに関する詳細な調査を実施することで,その資源回収機能を明確にしている.また,選別残渣中から石膏と有機物を分離する手法についても検討し,これらが集中して存在する比重範囲を特定している.さらに,実際に残渣を一般環境中で利用した場合の硫化水素生成リスクについても,硫酸イオンと有機物の長期溶出特性から評価し,硫酸イオンを含有する肥料,土壌改良材等との比較を行い,硫化水素発生に他材料と大きな差がないことを見いだしている.

本論文は,6 章から構成されている.

第 1 章は,序論であり,本研究の背景,目的,および関連する既往の研究が示されている.

第 2 章では,建設混合廃棄物を処理している実施設において,破砕選別プロセスにおける物質の移行特性と資源の分離能を明らかにすることを目的に実施した調査について記述している.本章の最も重要な調査は,1.7t の建設混合廃棄物をラインに投入したバッチ試験である.試料をプロセスに投入して処理を通過させ,各排出物の重量を計測すると共に,排出物の有機炭素,熱灼減量,重金属類,石膏の分析を行っている.各排出量と分析結果を基に,各物質毎にマテリアルフローを描き,混合物中に含まれる各物質が,埋立地,再生利用,熱処理等のどの行き先に分配されるかを算出し,本プロセスの資源分離能を評価した.最後に,未処理の混合廃棄物が直接埋立処分される場合に比較して,本プロセスによって生成される埋立対象物を埋め立てることによる埋立負荷の削減効果が示されている.本調査で得られた知見に基づき,当該施設では破砕前の振動篩目の変更,風力選別の導入等のプロセス改変がなされた.

第 3 章では,プロセスの変更が資源分離と埋立量削減に及ぼす効果を明らかにすることを目的に再度バッチ投入試験を実施している.試験は約 12 トンの廃棄物を投入して 3 回実施し,前記した調査と同様の手法により,有機炭素,金属類,硫黄,発熱量の各排出物への移行率を求め,さらにそれを

搬出先別に整理し, 資源化, 燃料化, 埋立処分毎のフローを描いている. プロセス改変の結果, 再生砕石, 代替燃料への資源化率は向上し, 埋立に向かう残渣量は大幅に減少した. さらに各再生資源の質はそれぞれの用途 (砕石, 代替燃料等) に適した性状を有していた. さらに残渣の埋立量を削減するために, 再生砕石との混合についての検討を行い, 残渣と再生砕石を 1:1 で混合しても実際に再利用されている砕石と同等の品質にとどまることを示した.

第 4 章では, 選別残渣から有機物と石膏を分離するために, これらが濃縮している比重範囲を重液選別を用いて明らかにしている. 石膏は 93% が比重 1.59-2.28 の範囲に集中しており, この比重範囲は重量の 24% に相当した. したがってこの比重範囲で分離を行えば,93% の石膏を分離可能であり, 分離後の石膏含有量は 1.55% にまで低減する. 具体的に選別すべき範囲が特定されたことは, 今後乾式の選別を検討するにあたり極めて有用である.

第 5 章では, 破砕選別残渣, 硫酸イオンを含有する肥料・土壌改良材・建設系再生材を対象にシリアルバッチ試験を実施し, 試料からの硫酸イオンと有機物の長期溶出特性を追跡している. 有機物については TOC, グルコース, 有機酸の分析を行い, 硫酸塩還元菌に利用可能な有機物についての経時的な溶出パターンを示し, 硫化水素発生に関して議論している. 多くの試料で, 硫酸イオンの溶出は石膏の溶解度に支配された一方, 有機炭素の溶出は試料によって大きな差異が認められた.TOC は, 選別残渣において土壌改良材等と比較してやや高い溶出を示したが, グルコース,VFA では他材料との大きな解離は認められなかった. 硫酸イオンと TOC の長期溶出試験結果を基に, 硫化水素の生成を予測した結果, 肥料や土壌改良材と同等の使用量であれば, 危険な濃度の硫化水素生成は無いことを示した.

第 6 章は結論であり, 論文の主な内容がまとめられている.

これを要するに, 筆者は建設混合廃棄物の破砕選別施設が果たしている機能を物質フローから明らかにし, 石膏と有機物を分離する手法を提案している他, 硫化水素生成リスクが大きくないことも示している. これらの成果は, 建設混合廃棄物処理に重要な学術的知見を提供していると言える. 以上より, 筆者は北海道大学博士 (工学) の学位を授与される資格あるものと認める.