Characterization and Placement of Municipal Solid Waste as Engineered Fill

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ABSTRACT: Sixty-year-old municipal solid waste (MSW) at a partially closed landfill in southern California, USA, was excavated, processed, blended with soil, and placed as engineered fill to accommodate post-closure development. Processing involved waste screening followed by removal of objectionable materials (e.g., tires, large wooden planks) and shredding of large particles retained on the screen. Processed material was delivered to the fill site and blended with on-site soils. Prior to these field activities, an assessment of the material properties of the waste and its long-term settlement potential were conducted. This paper presents the results of detailed characterization of representative bulk samples of waste recovered from the area to be excavated and laboratory testing of these samples. The laboratory testing program included organic content measurement, grain size analysis, Atterberg limits testing, modified Proctor compaction testing, one-dimensional compression testing and analysis of the cellulose, hemicellulose, and lignin content. The results of the laboratory testing program were used to estimate the long-term settlement potential of the blended waste placed as engineered fill.

1. BACKGROUND

To accommodate a proposed freeway access ramp for post-closure development at an old landfill, it was deemed necessary to completely excavate and remove waste from beneath the ramp due to waste settlement concerns. For various reasons, transporting the excavated waste to an active landfill was not possible. It was, therefore, necessary to consolidate the excavated waste on-site, beneath the engineered cap in the post-closure development area.

The preferred area for waste reconsolidation was determined to be the parking lot portion of the redevelopment area. This area was considered to be more settlement tolerant than the balance of the site. Furthermore, sufficient air space was available in this area to accommodate the waste excavated from the highway area. Therefore, it

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was proposed that the waste excavated from the highway area be excavated, processed, blended with soil, and disposed of as engineered fill in the area proposed for the parking lot development and capped with a final cover. A schematic of the blended engineered fill placement and capping scheme is presented in Figure 1.

This paper presents our investigation of the waste properties of the materials to be excavated and placed as engineered fill. The purpose of this investigation was to ascertain the state of waste degradation and the waste mechanical properties necessary for developing recommendations for its processing, blending, placement, and performance as engineered fill. The project included the application of field and laboratory techniques to classify and characterize waste.

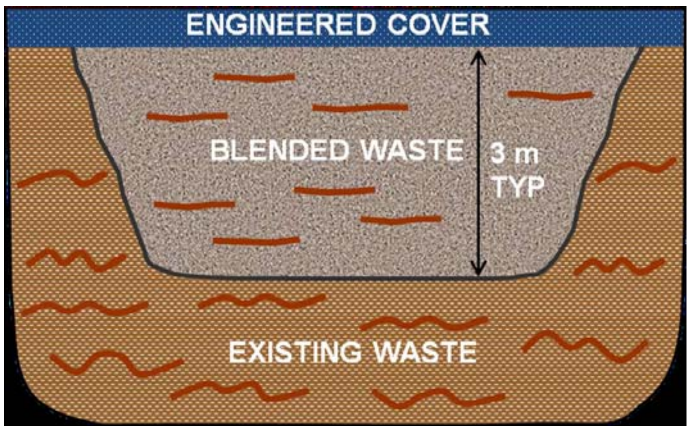

Fig. 1. Schematic of the intended final configuration of the existing and processed waste.

2. REVIEW OF BACKGROUND INFORMATION

Available information regarding the history of waste placement, the type of waste placed, daily cover practices, previous geotechnical investigations, and site history were gathered and analyzed for potential relevance to the investigation at hand. The available and relevant background information indicated that the waste is likely several decades old. Furthermore, landfill records indicated that both municipal solid waste and construction type waste were placed at the site. Based upon previous investigations, waste thickness in the areas to be excavated was reported to be on the order of 30 ft.

3. FIELD SAMPLING

Two trenches of the approximate dimensions shown in Figure 2 were excavated in the access ramp area with a backhoe to collect bulk samples of waste. These trenches were approximately 0.3 to 0.6 m wide. Bulk samples of waste from each trench were recovered and logged in accordance with the procedures described in Geosyntec (1995) and placed into 200-liter drums. Two samples were taken from different locations in each trench and placed in separate drums. During excavation, the age (from newspaper clippings), composition, homogeneity, and general moisture state of the waste were recorded on field logs. No attempt was made to evaluate the in-situ density or temperature of the waste.

Fig. 2. Typical investigation trench cross section.

The newsprint in all four trenches was in a state of degradation such that news articles could be read in their entirety. Excavated waste was dated to 1949 by newsprint (Figure 3). Pieces of wood and newsprint were found in a moist condition. The waste composition was described as household in nature (e.g., telephones, bottles, small pieces of wood).

Fig. 3. Excavated newsprint dating waste material to 1949.

4. WASTE CHARACTERIZATION

4.1 Initial characterization

An on-site laboratory was established at the landfill to characterize the sampled waste.

Representative samples were extracted from the 200-liter drums for characterization. At this stage, all particles with a dimension greater than 76-mm were removed from the samples. The plus 76-mm particles removed from the samples constituted approximately 5 to 20%, with an average of 11%, of the sample moist weight. Hence, all subsequent analysis and testing were conducted only on particles less than 76 mm in size.

The basic characterization procedure involved separating the waste by particle size and visually identifying the larger particles. The waste was separated with a 19-mm screen. Waste particles passing through the 19-mm screen were classified as "soil and soil-like". Particles retained on the 19-mm screen were classified as either mixed paper, newsprint, corrugated paper, plastic, yard waste, food waste, wood, other organics, ferrous metal, aluminum, glass, and other inorganics according to ASTM D 5231. This procedure is consistent with the waste characterization procedures originally proposed by Geosyntec (1996) and recently published in Zekkos et al. (2010). Figure 4 shows the waste that passed through the 19-mm screen (in the pan) and the waste retained on the 19-mm screen sorted into major constituents (in the bowls).

Fig. 4. Typical screened and sorted waste at the on-site laboratory

The "soil and soil-like" content in the waste samples removed from the 200-liter drums varied from 84 to 91% on a moist (or "as sampled") weight basis, with a mean of 87%. Approximately 6% of the waste was classified as "other – inorganic," 3% as newspaper, 0.9% as wood, 0.5 % as metal, 0.1% as plastic, 1.9% as glass, and 0.5% as "other – organic." The "other – inorganic" material was largely composed of rocks.

The combined total of degradable materials (newspaper, wood, and "other – organic") retained on the 19-mm screen (i.e., exclusive of the soil and soil-like material) was on the average 5%. This suggested that the waste was fairly well degraded.

5. LABORATORY TESTING

A suite of laboratory tests was conducted to characterize the properties of the fraction of the sampled waste that passed through the 76-mm sieve. Sieve analysis (ASTM D 422), Atterberg limits (ASTM D 4318), moisture and organic content (ASTM D 2974), one-dimensional consolidation (ASTM D 2435), and modified Proctor compaction (ASTM D 1557) tests were conducted on selected samples of this material. Moisture content was determined for each sample at both 55 and 105°C to evaluate the potential volatilization of organic material between 55 and 105°C. The cellulose (C), hemicelluloses (H), and lignin (L) content of the material (reported as the ratio of (C+H)/L) were measured in accordance with the procedure proposed by Hossain et al. (2003).

Results of the Atterberg limits, modified Proctor, cellulose, hemicellulose, lignin and grain size tests are presented in Figure 5 and Table 1. The measured moisture content varied between 7 and 25%. The observed difference in waste moisture content when determined at 55 and 105°C was, for practical purposes, minimal (between 0.6 and 1.4%, with an average difference of 0.8%). The organic content (measured as the mass loss between 105 and 440°C) varied from 5.6 to 12.4%. The tested waste exhibited (C+H)/L ratios characteristic of degraded waste (Hossain et al. 2003). Fresh waste typically has a (C+H)/L ratio of about 2.5 (Hossain et al. 2003).

A single one-dimensional consolidation test was conducted on a specimen reconstituted from the material with the highest organic content. Material passing the U.S. #4 (4.75-mm) sieve was used to reconstitute the test specimen. The specimen was compacted to 90% of the modified Proctor maximum dry unit weight at a moisture content of 32% (the as-sampled moisture content). The test yielded a modified compression index, $C_{\varepsilon c}$ (i.e., the strain-based compression index or the slope of the vertical strain versus log vertical-stress curve), of 0.04.

The modified Proctor compaction tests were conducted on the material passing the 76-mm screen. The results from the two samples from Trench 1 were relatively consistent while the results for the samples from Trench 2 were inconsistent. However, inspection of the test data indicates that higher organic contents correlate with lower maximum dry densities and higher optimum water contents, and that the two samples from Trench 2 had different organic contents.

6. BLENDED WASTE SETTLEMENT

Settlement predictions were made on the basis of the above waste characterization program and data available in the literature. The blending of soil with the waste was not explicitly considered in our settlement estimates because data were not available for the proposed soil–waste mixture. However, soil blending was considered to be beneficial to the fill from a stability and compressibility standpoint. Therefore, the settlement predictions were thought to be slightly conservative.

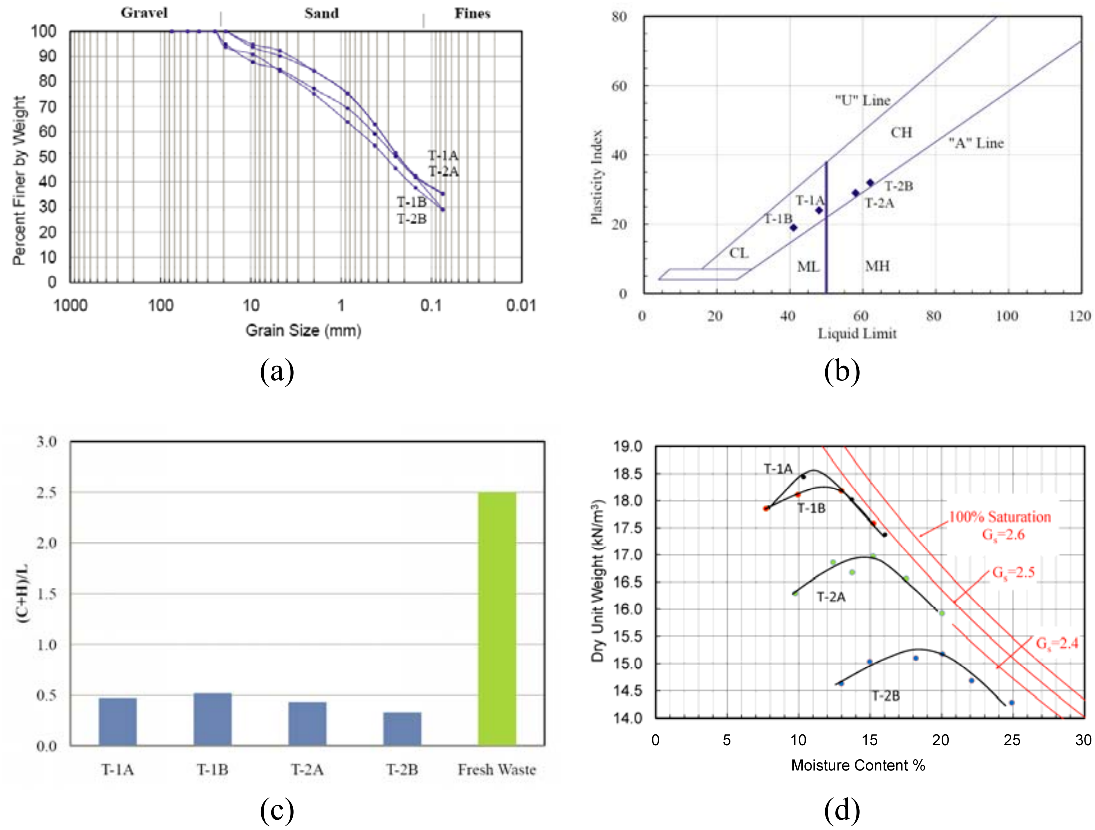

Fig. 5. Results of laboratory testing (minus 76-mm waste fraction): (a) grain-size distribution; (b) Atterberg limits; (c) (C+H)/L; and (d) modified Proctor compaction.

Table 1. Summary of laboratory testing results (minus 76-mm waste fraction).

ID	% O(1)	% F(2)	LL(3)	PI(4)	γ_{dmax} (5)	w_{opt} (6)	(C+H)/ L(7)	$C_{\varepsilon c}$ (8)
T-1A	6.3%	35.5%	48	24	18.5 kN/m^3	10.9%	0.72	-
T-1B	5.6%	29.2%	41	19	18.2 kN/m^3	11.8%	0.78	-
T-2A	8.5%	35.2%	58	29	16.9 kN/m^3	14.9%	0.47	-
T-2B	12.4%	28.9%	62	32	15.2 kN/m^3	18.8%	0.52	0.04

(1) Percent Organic Content
(2) Percent Fines Content
(3) Liquid Limit
- Not tested
(4) Plasticity Index
(5) Modified Proctor Maximum Dry Density
(6) Modified Proctor Optimum Moisture Content
(7) (Cellulose+Hemicellulose)/Lignin
(8) Virgin Compression Index

For the purposes of estimating the potential settlement of the waste placed as engineered fill, the waste was assumed to be in an advanced state of decomposition with a relatively low (less than 10%) degradable organic content. This assumption was substantiated by the results of the waste characterization program, including the waste classification data, the total organics content, and the measured (C+H)/L ratios as well as the absence of significant gas generation at the site.

It was therefore assumed that the compacted waste would settle at a rate representative of an organic silt or clay soil. Available data and correlations for organic silt or clay soil were used to estimate the compression behavior of the waste. Results of these estimates were similar to the results of the one-dimensional consolidation test. The resulting 30-year secondary compression settlement expected in the waste fill was estimated to be between 0.2 and 0.8% of the waste thickness.

7. PLACEMENT AS ENGINEERED FILL

7.1 Construction Process

A summary of the construction process is presented in Table 2. The construction process was started by excavating waste and transporting the excavated waste to a designated processing area. Very large (greater than 300-mm) particles (e.g., tires) were then removed from the waste. A Doppstadt SM720 Trommel with a 76-mm screen (Figure 6) was then used to separate the waste into plus 76-mm particles (i.e., particles having a diameter greater than 76 mm) and minus 76-mm particles. Plus 76-mm particles were inspected for Unexploded Ordinances (UXO) and large metal objects and then shredded (Figure 7).

Table 2. Construction process overview.

Construction Process Stage		**Description**
Excavation		Waste was excavated from the landfill
Processing	Removal of very large particles	Very large (greater than 300-mm) particles were visually identified and removed from the excavated waste
	Screening	Excavated waste was screened into plus and minus 76-mm fractions with a Doppstadt SM720 Trommel
	Removal of objectionable materials	Plus 76-mm fraction were inspected for UXO and large metal objects
	Shredding	Inspected plus 76-mm fraction was shredded
Blending		Both minus 76-mm waste fraction and shredded waste were blended with soil
Compaction		Blended material was compacted into place as engineered fill

The minus 76-mm and shredded waste material were then blended with "impacted" on-site soil at a 3:1 (waste:soil) ratio by volume (although additional soil was often added). The blending occurred as the waste and soil were placed in 200-mm loose lifts and compacted to at least 90% of the maximum dry unit weight (according to ASTM D 1557) with a 340 Rex sheepfoot compactor.

Upon completion of engineered fill placement, settlement plates and monuments were placed for future monitoring.

Fig. 6. Waste is screened by a trommel into "plus" and "minus" 76-mm particle stockpiles.

Fig. 7. "Plus 76-mm" waste is shredded.

7. CONCLUSIONS

This paper presents a case history of MSW characterization, excavation, processing, and placement as engineered fill to facilitate post-closure development of a landfill site. Sixty-year-old MSW at a partially closed landfill in Southern California, USA, was excavated from a freeway access ramp area, processed, blended with soil, and placed as engineered fill over existing waste to accommodate the proposed post-closure development. This paper presents details of the characterization, processing, and laboratory testing of representative bulk samples of waste recovered that may facilitate future work of this kind. The paper also describes processing, placement, and compaction of the excavated waste. The main lessons learned and the conclusions derived from this project include:

- The (C+H)/L ratio is a valuable index for assessment of the waste degradation stage.
- Samples of degraded waste were mostly composed of material that could be classified as "soil and soil-like" material.

- A maximum dry density of at least 15.2 kg/m^3 could be achieved when the waste material was compacted in accordance with ASTM D 1557 (the modified Proctor compaction test). The corresponding optimum moisture content ranged between 11 and 19%.

- Maximum dry density decreased and optimum moisture content increased with increasing organic content. Plasticity index and liquid limit also typically increased with increasing organic content.

- Waste with similar gradation had very different compaction characteristics, even though the Atterberg limits for the four different samples all plotted along the A-line. This was attributed to varying organic content.

- The observed difference in waste moisture content when determined at 55 and 105°C was, for practical purposes, minimal (0.8%).

- The 30-year secondary compression settlement estimated for the blended waste was low (0.2 to 0.8% of waste thickness).

This project provides an example of how old waste deposits can be effectively processed (including screening and shredding), blended with soil, and used as engineered fill in applications with moderate settlement tolerances. This technology may be useful worldwide where cleanup and redevelopment are necessary or desirable in aged waste deposits.

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