Waste Use in Highway Construction

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This paper discusses engineering and economic considerations of using solid waste in highway embankment construction. Both milled refuse and the residuals of various resource recovery systems are discussed as substitutes for costly highway building material. Included are an exploration of the problems and advantages of this concept and suggestions for further research.

In this paper, the following questions about the engineering and economic considerations of using solid waste in highway embankment construction are addressed:

1. Can refuse perform adequately as an embankment construction material?
2. Is the use of refuse economically justified when compared to the availability of other materials?
3. What role does resource recovery play in the economic and engineering evaluations?
4. What research activities should be undertaken to further investigate the use of refuse as an embankment construction material?

REFUSE

Disposal of waste materials has always been an unpleasant problem. From the distant to the recent past, the only concern has been disposal at the lowest possible cost. Concerned individuals have from time to time pointed out the damage done to air and water quality by open and sometimes burning dumps. Increased environmental awareness during the 1960s and 1970s, however, stimulated waste managers to clean up landfill operations and thereby decrease the objectionable effects of landfills.

Just as decisions were made and funds committed to improve the situation, shortages of every kind occurred and had a significant effect on waste management. Added to the costs of complying with new environmental regulations are increased fuel prices and skyrocketing land costs. Hence, the cost of getting garbage to landfills and disposing of it properly is increasing.

ROADS

Although the era of massive road-building projects is over, new highways to further serve transportation needs are continually being built. Many of these projects occur around large cities where the source of embankment material is usually far away and may also be in short supply. Therefore, obtaining and transporting this material back to the city are also becoming more and more expensive.

REFUSE ROADS

A reasonable course of action then would be to try to lower the total cost of each project by combining refuse and roads. The use of municipal refuse in local road embankment construction would unquestionably increase the life of the landfill dramatically and, therefore, reduce the cost of disposal.

Depending on the percentage of refuse by volume in an embankment, road-building costs would likewise be reduced. Of course, the first consideration in the use of refuse in embankments is its engineering suitability and not its economy.

ENGINEERING CAPABILITIES OF REFUSE AS CONSTRUCTION MATERIAL

Raw refuse directly after collection certainly is not a desirable building material. It is not uniform; therefore, it is difficult to handle and to compact. Larger particles tend to bridge when attempts are made to compact the material. When further loading is applied, this bridging effect causes uneven and unpredictable settlement. Organic fractions of the refuse are subject to decay, and this causes further settlement. As decay continues and water infiltrates, contaminating leachate is formed that pollutes ground and surface water. Flammable and noxious gases also build up in the fill and

Publication of this paper sponsored by Committee on Earthwork Construction.

present the possibility of explosion or health hazards.

For all of the seemingly insurmountable problems associated with using this material in embankment construction, it is surprising that refuse is currently being used successfully in a highway realignment project in California (1, 2), where garbage from an existing landfill, through which the highway must pass, is used in construction of the embankment. The refuse is laid down in thin lifts, mixed with dirt, and compacted. Then two lifts of traditional embankment material are laid down and compacted over the refuse. This sandwiching of garbage and traditional embankment material proceeds to within 1.2 m (4 ft) of the finished elevation.

The contractor on the job is saving money because the volume occupied by refuse carries only a transportation and placement cost. Traditional material, if it were not available from cuts, would have to be purchased as well. Logistically the project is a success; however, performance of the embankment has not yet been evaluated.

From an engineering standpoint at this time, only recommendations about methods of placement can be made. Extremely limited data have been collected on this subject. Even data on the settlement and load bearing performance of sanitary landfills are lacking because, until recently, there has been no need to use landfill sites for any type of construction and because few completed landfills have been operated according to current strict specifications. As a result, data from these covered dumps are useless (3, 4, 5).

Recommendations for placement of waste material in embankments are given below.

1. Because of the high probability of leaching and the unrealistic measures necessary to collect and treat leachate along a roadway, refuse embankments should only be constructed in areas where the water table is low and where the underlying soil is capable of naturally attenuating leachate to an acceptable condition before it reaches groundwater.
2. Care should be taken to ensure that daily refuse is covered with compacted material to prevent excessive infiltration of precipitation during construction. Familiarity with standard sanitary landfill operation procedures will be helpful when one is attempting to use refuse as a construction material.
3. Refuse should be milled or shredded before placement. Settlement will be unavoidable, but it can at least be predictably uniform. Densities of 830 to 950 kg/m^3 (1400 to 1600 lb/yd^3) may be expected. Milled refuse is inert; hence, it will not attract annoying and unsanitary flies and rodents during construction or after placement (6).
4. Refuse is extremely active biologically and chemically. Daily production should be compacted and covered. It will be impossible to stockpile refuse material for even short periods of time (days). Piles of refuse begin to decompose quickly and create a health hazard. This is a severe limitation in areas where seasonal inclement weather completely halts road construction activity.
5. Placement of refuse should occur in about 0.3-m (1-ft) compacted lifts, and suitable embankment material should be mixed into the refuse as it is compacted and covered by two layers of compacted earth material.
6. Refuse should be placed at least 1.2 m (4 ft) away from the profile of the embankment.
7. A period of settlement should be allowed before subsequent layers are placed.

In relation to recommendations 5, 6, and 7, specifications for the MacArthur Boulevard project in California are as follows (1):

1. Mix one part trash with five parts suitable material from excavation other than type A;
2. Cover each layer of mix with two layers of embankment material;
3. Do not use more than 15.2 cm (6 in) of biodegradable material;
4. Allow the first 2.7 m (9 ft) of fill to settle for 60 days;
5. Allow the second stage (also with a 60-day settlement) to go from 2.7 to 5.4 m (9 to 18 ft) high, but not at a rate of more than 0.4 m (1.3 ft) per week;
6. After the second stage, do not allow placement to exceed 0.9 m (3 ft) per week; and
7. At a bridge abutment excavation, allow the fill to settle for 365 days.

It is the position of this paper that refuse should not be used within 30.5 m (100 ft) of bridge abutments and then the refuse embankment should not end abruptly. Rather, over the next 30.5 to 61 m (100 to 200 ft) from the bridge abutment, the use of refuse should be decreased gradually to zero at 30.5 m (100 ft). These recommendations are general; however, until some practical experience is gained (as in the MacArthur Boulevard project) and more research is completed, general recommendations are the best that can be offered.

ECONOMICS OF PLACING MILLED REFUSE IN HIGHWAY EMBANKMENTS

In a typical situation today, a municipality pays for waste disposal services of the solid waste authority. Based on a city with a population of 300 000, refuse disposal costs are as follows ($1/Mg = $0.907/ton):

Item	Cost ($/Mg)
Milling	4.40
Transportation to landfill, assuming round-trip distance of 40 km (25 miles) from shredder station	2.63
Landfill operation	3.31
Total	10.34

A contractor enters the scene with a highway embankment project to supplement a completed municipal bypass. The average distance between the mill and the road project is the same as that between the shredder and the landfill.

A logical pattern to follow should the refuse be acceptable within the specifications of the highway project would be for the waste authority to deposit milled refuse at the road site rather than at the landfill. There would be no charge to the contractor for this material.

The city, at this point, would still be paying exactly the same fee per megagram to the waste authority, less landfilling costs. Net cost to the city would then be $7.04/Mg ($6.39/ton).

With this arrangement, each interest benefits. The contractor may avoid purchase and transportation costs of as much as 30 percent of the necessary fill material. The resultant lower cost per kilometer of highway is a direct benefit to the municipality. This is in addition to the aforementioned 30 percent reduction in total refuse disposal costs. The capacity of the landfill site is extended because it will be used primarily for bulky materials rejected from the mill and special industrial wastes.

Sanitary landfill sites are extremely difficult to find. When the property is purchased, extensive engineering studies are required for approval. Expensive site preparation is necessary before operations may begin. Hence it is in the owner's best interest to extend the life of an established site for as long as possible.

It is appropriate to mention at this time that, although shredding nearly doubles the cost of refuse disposal, the benefits and potential value of this process make the expenditure worthwhile; the small, even particle size makes it easy to handle with little blowing. Shredded refuse does not attract flies or rodents. With the advent of resource recovery, shredding is a necessary first step in all phases, such as in the use of refuse as a construction material.

A hidden cost in the shredding of gargage is the cost of transferring the garbage to the landfill because the shredder station also acts as a transfer station. In moderate to large cities, these facilities are an essential part of the waste disposal system.

IMPACT OF RESOURCE RECOVERY ON CONCEPT OF SOLID WASTE IN HIGHWAY EMBANKMENT CONSTRUCTION

Resource recovery involves the removal of specific materials from refuse. From an engineering standpoint, the residual product would generally be of higher quality as an embankment material but would have significantly less volume.

Until the recent shortages of fuel materials, resource recovery could not compete economically with landfills as a means for refuse disposal, nor were products of recovery competitive with products manufactured from virgin materials. However, as the prospect of long-term shortages increases and as the costs of finding and operating landfills go up, the value of recovered resources is quickly reaching a break-even point and will soon become profitable (7, 8, 9).

The cost of embankment construction was decreased by the use of refuse; therefore, the cost to the municipality was proportionately reduced. The city also had lowered the cost of refuse disposal by eliminating much of the landfill operational costs.

If a resource recovery plant is used, the most economical programs at this time are material recovery (fiber, metal, and glass) or pyrolysis to produce fuel oil.

Both systems reduce the volume of residual waste substantially. In the case of total materials recovery, in which a wet process is used, the residual product is a sludge that would be unsuitable for use in the embankment and would necessarily have to be disposed of in a sanitary landfill. The financial benefits of the materials recovery system would then have to be balanced with the losses, namely, landfill costs and a more expensive roadway.

Pyrolysis reduces the organic fraction of refuse to a No. 6 grade fuel oil and gases. The remaining char is a glassy aggregate called frit. The gases given off during the process are burned to provide energy for the plant, and the oil is sold commercially. The remaining char, although it has not been studied formally, would seem to be an adequate material for earth construction. Certainly it is superior to pure refuse that is subject to substantial settlement. The physical properties of this char are probably similar to bottom ash, which is a product of coal combustion. Bottom ash is used successfully in secondary and utility road construction (10, p. 108). Again, however, the financial rewards gained from the sale of oil would need to be compared with the greater expense of constructing embankments without the contribution of no-cost refuse.

An important property of these two residual materials is their biological inactivity. Unlike raw refuse, this material can be stored or stockpiled during periods of surges or when working conditions are impossible. Therefore, even if resource recovery can lower the total cost of refuse disposal, an alternative use for the refuse such as embankment fill may still be more economical. In such an application, refuse may be considered a resource in and of itself.

Other resource recovery processes include incineration. The residuals are fly ash, bottom ash, and glass and metals if they have not been removed. The bottom ash itself would suffice as an embankment material. Metal and glass included would contribute to volume and overall mechanical properties. Fly ash itself has been used as a component in the making of certain types of concrete.

Fuel recovery, similar to pyrolysis, segregates the refuse via air classification into fibrous energy-rich materials and heavy material, consisting of large amounts of glass and metal, that would be suitable embankment material with little differential settlement when placed properly.

Currently a severe problem with resource recovery is the unpredictability of markets. A municipality may invest heavily in a particular resource recovery concept based on temporarily high values of the product. Extended periods of low demand are not unusual, however, in current markets, and this is especially true of recycled resources. Generally, recycled materials, such as wood fiber, glass cullet, and scrap metal, can only be used in a small proportion to virgin materials. Therefore, when the demand for a finished product slips slightly, the effect on the recycled components is more severe (11).

CONCLUSION

The concept of combining refuse disposal and highway construction is attractive enough to merit further research. Under present circumstances, refuse in embankment construction would always be less expensive than any other material, simply because there is no charge for it. The only costs that may be incurred are temporary storage in a sanitary landfill situation and transportation costs greater than those already paid for by the municipality for transport of refuse to the landfill.

The following areas need to be investigated.

1. Completed refuse embankments should be researched to determine how total settlement is affected by lift thickness, mixtures of soil and refuse, settlement intervals, and total embankment thickness.
2. Leachate production should be monitored to determine whether the asphalt or concrete roadway is impervious to excessive infiltration of water.
3. Costs of spreading and compacting refuse material should be compared with the costs of preparing traditional road-building material. In this paper, these costs are assumed to be the same. This assumption should be investigated.

Resource recovery residues in many cases appear to have excellent road-building qualities. In view of the growing economic incentives for resource recovery, high-quality residue materials will be increasingly available. The disposal of these in road embankments would effectively complete the recycling process. Therefore, it would be wise to initiate research in the use of these materials.

Cost studies should be performed to answer the following questions:

1. Assuming that a municipality donates the refuse at a mill for no charge and likewise agrees to transport the material distances less than or equal to the landfill distance, for what additional distance would the cost of transport still be less than the cost of procuring conventional embankment material?

2. Assuming that a particular resource recovery system becomes a legitimate competitor for the refuse, what price would the contractor be willing to pay for the shredded refuse versus allowing it to be processed through resource recovery? What value should be placed on the residues of recovery as highway embankment materials?

The political implications of refuse embankments must also be considered in highway projects where environmental impact statements are required. It is already difficult enough to win approval for certain highway construction projects without the issue of an additional environmental threat. The possibility of a refuse embankment becoming a polluter could easily become a serious political issue. This consideration again stresses the importance of research in the area of leachate production in the embankment.

These are some of the areas that offer research possibilities for the future. However, until more data are evaluated, it would be unwise to embark on widescale refuse embankment construction. Performance data simply are not yet available to prove that refuse embankments provide a stable foundation for highways.

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