The Benefits of an Encapsulated Mechanically Stabilized Earthen (eMSE) Berm

An eMSE berm presents potential new sources of material beneficial to the owner. These not only offset the costs of berm construction, but they also do not consume valuable airspace that can be used for waste streams that generate a higher gate rate.

By Katherine Warwick, P.E., Scott Sheridan, P.E. and Jeff Crate P.G.

In February 2019, an article entitled "Using a Mechanically Stabilized Earth Berm to Expand Existing Landfill Space" was published in *Waste Advantage Magazine* by Hullings, Piedmont-Fleischmann, and Schurie.[1] This article addressed the continuing need for landfills in the U.S. as a means for managing non-recoverable (non-recyclable) wastes. After explaining the obstacles of siting new landfills, the article recommended the use of Mechanically Stabilized Earthen (MSE) berm technology as a viable alternative for expanding existing landfills.

As stated, MSE berms are a practical and common technique for expanding the capacity of existing landfills. The benefits of an MSE berm landfill expansion, along with other non-capacity related site benefits, have been well documented; it goes without saying however, that these benefits cannot be realized without their safe design and deployment. The general design of MSE berms was discussed in the referenced paper, and design components to be considered were listed as follows: global stability, internal reinforcement, external limiting eccentricity, external sliding, external bearing resistance and compound surfaces.

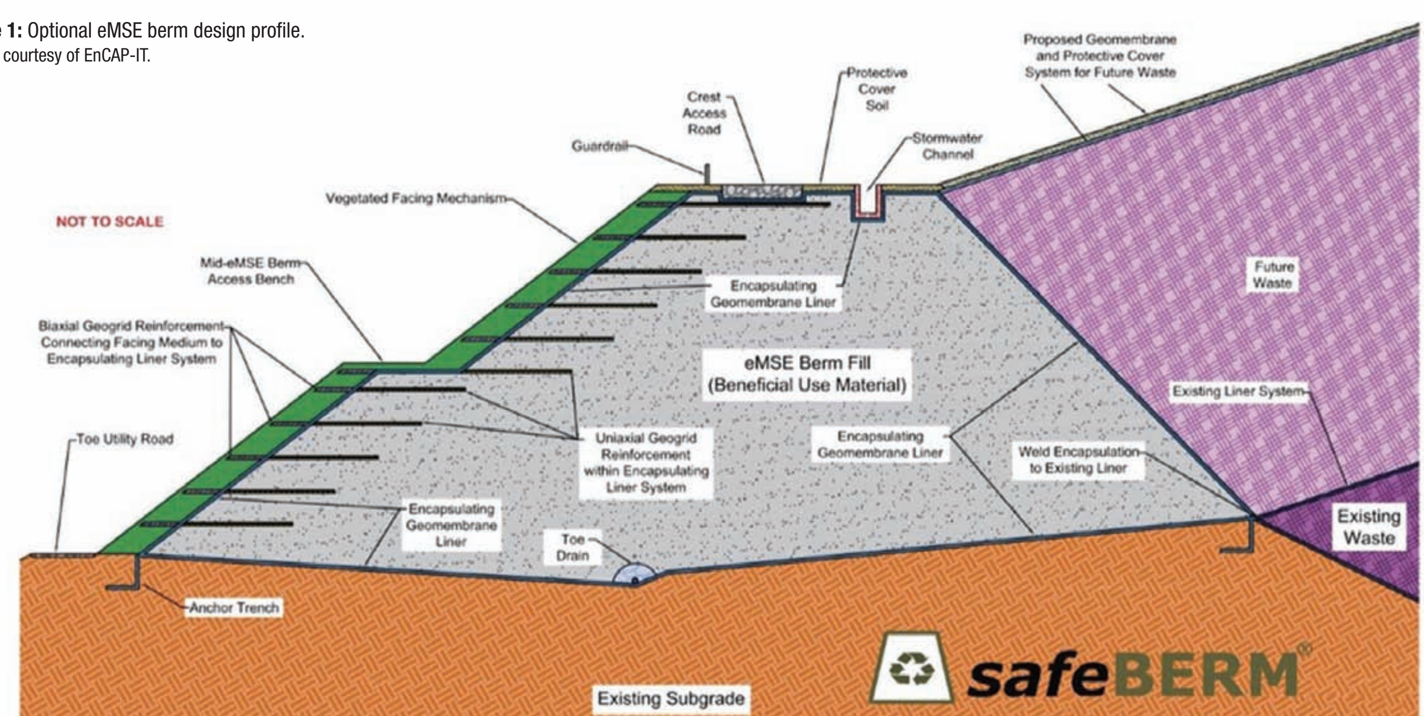
The purpose of this article is to introduce the reader to the Encapsulated Mechanically Stabilized Earthen (eMSE) berm, an innovation that improves upon the design of traditional MSE berms used in landfill applications.

Primary Risk Associated with MSE Berms—Control of Water

A traditional MSE berm is constructed by compacting select fill materials (also referred to as berm fill) in layers, or lifts. Each lift is underlain by a reinforcing medium, typically a geosynthetic geogrid. The alternating layers of compacted fill and reinforcement create a stable earthen berm with exterior slopes that are steeper than non-reinforced fills. Designing the reinforcement follows standard design techniques, and specification of the reinforcement is relatively straightforward. The design and specification of the berm fill can be less straightforward and represents a greater risk to the project.

In 2013, Robert M. Koerner and George R. Koerner of the Geosynthetic Institute published a white paper entitled, *A Data Base,*

Figure 1: Optional eMSE berm design profile.
Images courtesy of EnCAP-IT.



Statistics and Recommendations Regarding 171 Failed Geosynthetic Reinforced Mechanically Stabilized Earth (MSE) Walls.[2] One of the conclusions of the paper was that the selection of fill materials with appropriate drainage characteristics is crucial to help avoid the common failure modes of MSE berms. As stated, “When fill materials that exhibit low hydraulic conductivity are utilized without proper drainage relief or accommodation in the design, the risk of the buildup of pore pressures within the berm fill is elevated along with the risk of failure.” Koerner, 2013 was further updated in Koerner, 2018[3] in which the conclusions of the original paper were strengthened with additional case studies. The authors identified a growing trend in using fine-grained materials that exhibit low hydraulic conductivity in MSE Berm fill; thus, the management of pore pressures is becoming an increasingly important design priority.

Preventing the introduction of water into the berm fill is a design strategy that can minimize failure risks. Stormwater controls at the top of the berm can be used to prevent stormwater run-on and to control stormwater run-off. The importance of the stormwater control design for managing water before it enters the berm fill was referenced in the white paper, also authored by Koerner, *Improper Surface Water Control*.[4]

Construction of an eMSE berm using coal combustion residuals with geogrid reinforcement.

The eMSE Berm in Landfill Expansions

Proactive Control of Moisture

The MSE berm design innovation presented in this article uses “macro-encapsulation”, in which the berm fill is fully encapsulated using a geomembrane liner system to proactively control the infiltration

Figure 2: eMSE berm construction using CCR and impacted soils as fill material.

of water. In an eMSE berm application, the geomembrane liner system fully encapsulates the berm, including the berm fill material, preventing the migration of stormwater run-on or run-off into the fill material. In addition to the encapsulation system, a toe drain collector at the bottom of the eMSE berm collects water that enters the fill during construction. If the collector is designed to remain functional after construction, it provides continued removal of water that may remain in the eMSE berm after construction.

Stability by Design

Traditional MSE berms require free-draining sands and gravels because potential infiltration of stormwater or leachate may increase the pore pressures within the berm. However, finer grained materials may potentially be used as fill materials in an eMSE berm since pore pressure surcharge is not expected to be a problem during the lifetime of the berm, provided the angles of interface friction and/or adhesion meet the specifications for internal and global stability. The encapsulation not only maximizes moisture control, but it also offers the owner more flexibility in the fill materials that can be specified for the project.

MSE berms are typically costly to implement due to the source, quantity and preparation of the select fill used. Thus, economizing the berm design is important to reduce these costs while satisfying the appropriate design standard of care. In this process consultants and owners must weigh the costs of design with the practicality of those costs. Encapsulation of the berm fill offers the designer and owner increased flexibility with regards to fill selection, reinforcement and configuration in their effort to economize the design.

As noted in Hullings et al, 2019, using less fill results in lower costs, leading to narrower and steeper berm designs. In contrast, an eMSE berm design allows the use of more economical fill materials as well as greater flexibility with regards to berm configuration. In fact, the right selection of backfill material can result in a more cost-effective project. Many beneficial use materials (discussed in more detail later in this article) have value, and when used as fill can offset construction costs; thus, specifying a wider berm profile that uses more fill material represents an opportunity to maximize the economics of the eMSE berm. For example, low impacted soils are often defined as beneficial use material (as well as other sources) and can be used as fill in an eMSE berm. Its use can dramatically change the economics of the expansion project. Using beneficial use material, the eMSE berm innovation allows the owner to configure the berm as deemed most technically and economically appropriate (**Figure 1, page 42**).

Other Design Benefits of an eMSE Berm

There are other benefits to designing and constructing an eMSE berm versus a traditional MSE berm for the purposes of landfill expansion.

1. Resilient Design: The use of an encapsulation system allows for a more resilient design that can lower the risk of failure during extreme weather conditions. For example, in an extreme weather event that generates localized flooding, the encapsulation system of the eMSE berm prevents the infiltration of water into the berm fill. By preventing infiltration, the berm fill does not become over saturated and pore pressures do not build up when the flood waters recede. As an added benefit, the eMSE berm isolates the waste mass of the landfill from the floodwaters preventing the potential for contamination or migration of waste. Stormwater control features on MSE berms are typically designed to satisfy design storm events such as a 25-year, 24-hour storm event. The actual design storm will depend on the local and state regulations for the landfill; however, it appears that the intensity and duration of storms have been increasing. An eMSE design with encapsulation of the fill material provides an added element of conservatism to the stormwater control design. If a storm intensity overwhelms the capacity of the stormwater control system or creates flow velocities that cause ditch or channel treatments to fail, the encapsulation may prevent the runoff from entering the berm fill and causing a greater failure.

2. Efficient Use of Airspace: The use of an eMSE berm can also provide a more efficient use of valuable landfill airspace. Materials used as eMSE berm fill material can be material that would typically be managed as capacity-depleting municipal solid waste, such as low-impacted soils, certain processed construction demolition debris, or captive industrial landfill materials provided the materials satisfy project specifications. By using materials that typically consume airspace as berm fill material the landfill's airspace is used more efficiently.

3. Aesthetics: Hullings, Piedmont-Fleischmann, and Schurie stated in their article that aesthetics is not usually a concern at landfills. This may be true for many facilities, but in the authors' experience visual objections to landfills are increasing in concert with sprawling commercial and residential development, even when the landfill pre-

dates the development. The eMSE Berm addresses this problem in a three-fold manner: (1) the liner encapsulation protects the fill from unsightly erosion, (2) the outer face is protected from erosion with one of several facing options that can even enhance the aesthetics of outer slopes, and (3) the berm can be used as a visual screen for daily operations.

A Good By-Product of the eMSE Berm in Landfill Expansions

Beneficial Use Materials

The EPA defines beneficial use materials as non-hazardous by-products of manufacturing or industrial processes that can be substituted for a virgin or analogous material "in a way that provides a functional benefit, meets product specifications, and does not present concerns to human health or the environment".[5] Many states have their own beneficial use programs that adhere to, at a minimum, the EPA definition.

To date, multiple eMSE projects have been completed by the authors of this article, and several are currently under analysis. During the project development stage, the EPA-beneficial use material qualifiers are used to identify candidate materials as potential sources of eMSE berm fill including: (i) must effectively substitute the use of a virgin or commercial material, (ii) must provide a functional benefit, (iii) must meet the structural fill product specifications, and (iv) must not pose a threat to human health or the environment. Examples of the wide variety of non-hazardous by-products that have the potential to be classified as beneficial use material in the application of eMSE berms are low-impacted soils, coal combustion residuals (CCRs), municipal solid waste incinerator ash, and mixtures of materials such as crushed glass and dredge material, etc. **(Figure 2)**.

Source of Economic Benefit

Much of the potential berm fill material classified as beneficial use material already comes to the same landfills seeking expansion for disposal. They may already be used within the waste management boundary as alternate daily cover or access road surface material on the landfill area. In addition, a formalized beneficial use material acceptance program offers an owner the opportunity to significantly decrease their project construction costs.

In recent years, some municipalities have added supplemental fees to accommodate the siting of new landfills once capacity is exhausted.[6] Vertical expansions are sometimes also laden with additional fees by their host municipalities.[7] In cases where the vertical expansion employs a traditional MSE berm, the cost to construct plus these host fees may eclipse the value of the additional capacity.

A traditional MSE berm is inherently expensive particularly if the expanding facility must pay to source natural soil fill material for construction. This may represent the single-greatest economic challenge for the justification of a traditional MSE berm for landfill expansion. Material markets that could not be previously pursued (in both cases representing non-capacity diminishing revenue) can become a new source benefitting the owner. While there are multiple factors that come into play on a site-specific basis, a technical and economic evaluation can help determine where an eMSE berm application is appropriate. The availability of beneficial use material that satisfies the specific project requirements may tilt the economic justification of landfill expansion away from the implementation of a traditional MSE berm towards that of an eMSE berm.

Considerations

There are several reasons to consider the implementation of an eMSE berm along with a traditional MSE berm for landfill expansion, these being: (1) the eMSE berm innovation lowers the risk of berm failure resulting from the infiltration of water into the berm fill material; (2) encapsulation provides the designer and owner with greater flexibility in the type of berm fill material specified for the project; (3) an eMSE berm presents potential new sources of material beneficial to the owner; these not only offset the costs of berm construction, but they do not consume valuable airspace that can be used for waste streams that generate a higher gate rate; and (4) valuable capacity is gained by leveraging existing facility permits, and eliminating the need to expand laterally or to identify and develop other properties. | **WA**

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Notes

1. Hullings, Don, Bodhi Piedmont-Flieschman, and Kirstie Shurie. "Using a Mechanically Stabilized Earth Berm to Expand Existing Landfill Space." *Waste Advantage Magazine*. February 1, 2019.

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3. Robert M. Koerner, George R. Koerner. "A data base, statistics and recommendations regarding 171 failed geosynthetic reinforced mechanically stabilized earth (MSE) walls." Geosynthetic Institute. January 7, 2012

4. ibid, Koerner page 25

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