Compaction versus the value of airspace:
Solid Waste Compaction in Sanitary Landfills

Author:
Stéphane BERTRAND – CATERPILLAR Europe, Africa and the Middle East.
Industrial and Waste applications specialist
E-mail: bertrand_stephane@cat.com

ABSTRACT

There are numerous waste processing methods, including incineration, composting, grinding, baling and recycling. All of these methods can help reduce the amount of waste, but ultimately whatever is left over will go to a landfill. Additionally landfills serve as a backup to every other component of an integrated waste management.

Today, landfills remain the most cost effective & secure way of disposing of non-recyclable municipal and industrial waste.

Over the last few years sorting & recycling as grown in importance. However the landfill business still represents a significant percentage of the total waste volume handled.

The new generation of sanitary landfills have to comply with a certain level of standards and regulation in order to make sure the environment & ground water are fully protected from the contamination generated by the storage of our own solid waste.

Therefore the construction of a landfill is a lengthy, complex and costly process. Considering the level of investment, it is critical for its operator to insure the longest possible life of each cell in the landfill.

The only thing a landfill has to "sell" is Airspace. Simply said: Airspace = density = compaction

There never has been more pressure on the equipment to produce more controlled compaction and capacity to efficiently manage the continuous flow of MSW "all day every day".

There are 3 ways to gain compaction:

- Compression
- Shredding
- Moisture

The way of making those goals possible is through the utilization of dedicated pieces of equipment combine with disciplined processes & personnel training.
When it comes to mobile equipment operation in sanitary landfills, there are multiple choices in terms of machine types, sizes and options. The purpose of this paper is to provide guidance to landfill site managers in these critical choices, by explaining how they can influence the final density of solid waste, and lifetime of the landfill site. This will be achieved not only when selecting his fleet, but also by applying different machine operation techniques.

This document will provide guidance on what additional compaction brings to a landfill site, which machines are better suited for each task, and how they perform when working as a team. As a result, landfill sites managers will know how to optimize solid waste compaction, further reduce the impact on the environment, and lower the costs of handling waste for the community while improving returns.

1. INTRODUCTION

The proper technique of solid waste compaction consists of shredding it in small pieces, pushing waste to mix it and place it to fill the voids, and finally compact it in order to maximize the tonnage of waste using a minimum amount of space in the landfill.

Figure 1: Landfill compactor in operation

2. OTHER AVANTAGES OF SOLID WASTE COMPACTION

2.1 Minimize fire starts

Oxygen is essential to combustion. If you control the presence of air in contact with combustible waste at the surface of the landfill, you reduce risks of fire. In the absence of compaction, waste is more in contact with air. In the case of a fire start, wind will increase combustion. Once a fire has started on a landfill, it is extremely difficult to stop combustion entirely. Smoke may contain toxic gases. Digging out the combusting material and covering it with dirt best control fires within the waste.

2.2 Minimize leachate generation

Figure 2: Leachate leak

The more compaction, the less infiltration of rain water inside the cell. Water will remain close to the surface and a higher percent will evaporate, instead of percolate through the landfill. This in turn reduces the amount of leachate generated, reduces risks of ground pollution, and lowers costs of leachate treatment.

3. SOLID WASTE PLACEMENT ON A LANDFILL

So, how do we get from a pile of waste dumped from the collection truck, to a well-compacted waste layer? Most landfill cell dimensions should be kept to approximately 30 to 60 meters wide, by 20 to 25 meters long on slopes around 5 (H) to 1 (V) (lift height would be approximately 4 to 5 meters) during working hours and brought in to 4(H):1(V) or 3(H):1(V) by end of day for use of less cover soil. A daily slope of 5 to1 gives faster cycles, less fuel, less maintenance; and by moving the slope in to a 4 to1 or 3 to 1 by day's end, you reduce exposure of rainwater to the waste and machine operators are working in a manageable area of compaction.

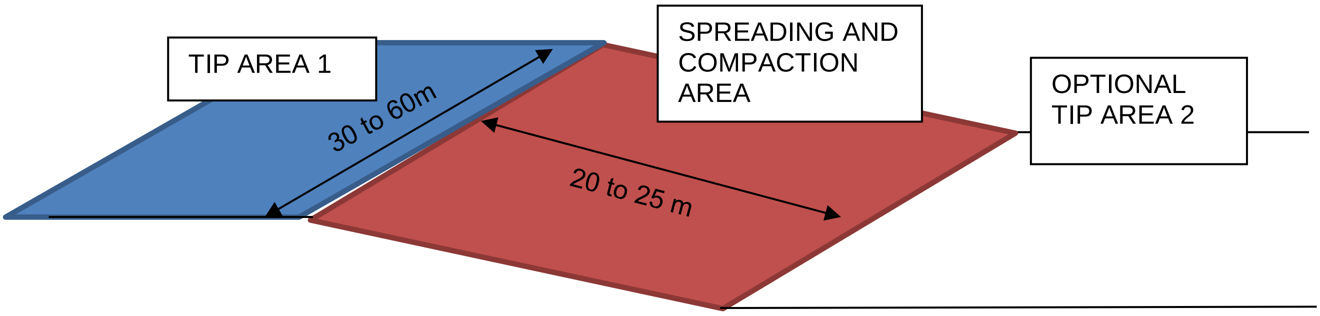

Figure 3 and 4: Proper size and slope of an active cell

3.1 Control of tipping area

The active face of a landfill is busy with the daily traffic of collection trucks and transfer trucks. First of all, it is important to control the collection truck traffic, i.e. the landfill site spotter has control over the collection truck drivers and allows them to dump in designated areas. This way, you

-Keep the landfill cell to the above dimensions,
-Reduce time to push waste from the dumping spot to the cell
-Improve safety on the site by allowing truck drivers only on a dedicated access road.

Figure 5: Line of collection trucks at the tipping area.

3.2 Assessing the current situation

This list of question helps you assess where your landfill site stand in term of compaction capability

What is the current waste compaction **equipment fleet**? How many machines a readily available for a compaction task?
How many **tonnes / day** do you currently treat? As a first estimate, calculate how many tonnes of waste need to be landfilled per day. There may be variations in the week or seasonality in the year:
Peak period times – tonnages / vehicles. Within a day, there will also be variations of tonnage. Make sure you know the peak tonnage, in order to size your fleet accordingly.
What **type of waste** (MSW, C&D, Industrial / Commercial, Sludge, other). Different types of waste carry different densities
Equipment: Hours of **operation**
Working **face dimensions**:
Slope?
Width?
Length?
Layer height: (height of layered material before compaction)
Type of daily **cover** (s). How do you handle your cover material?
Type of **delivery vehicles.** This may impact for instance the size of a dozer pushing waste from the tipping area to the cell
Uptime: How do you do the machine maintenance and repair?

3.3 Pushing waste to the landfill cell

Once waste has been dumped, it needs to be pushed to the landfill cell.
Question: "As municipal and industrial solid waste comes in various shapes and sizes, and is often enclosed in plastic bags, should it be shredded, compressed and chopped during landfilling?
The answer is yes. When waste is compressed, reduced in size, and shredded properly, it will find more easily its place, (bind together), and reduce voids. Good compaction promotes mixing and blending of materials creating a more even surface.

On modern landfills, you tend to use dedicated equipment for each task required. Although mobile equipment is often designed to increase their versatility, it is important to take a closer look at each machine configuration:

Figure 6: Variety in sizes and shapes among solid waste

In order to effectively chop and shred waste, it is recommended to use track type tractors (dozers) or track loaders, to spread waste. These machines are fitted with steel tracks. Track grousers will act as blades to chop and shred material.

A track type tractor is ideal to spread waste on a slope. Its ability to push a load while controlling precisely the position of the blade ensures consistent layer thickness better than any other machine.

Figure 7: Track type tractor.

Figure 8: Track type loader

Landfill compactors are equipped with a large capacity blade, enabling the machine to push large quantities of waste. However when it comes to pushing and spreading waste, it is important to consider that a track type tractor will have a better traction force, thanks to its track design, providing a better grip on the loose refuse.

Also note that the more time pushing and spreading with a compactor, the less time for what it is designed for, compacting.

3.4 Thickness of the waste layer

Proper layering consists of pushing and spreading the waste in thin layers. Thin layers bind, compress, and shred easier than thicker layers. Machines use less fuel, gain higher densities, and have less maintenance issues with thinner layers. Thicker layers take away all of the above gains and only compacts the top of the layer leaving a spongy non compacted area beneath it that increase rolling resistance during compaction runs.

The layer thickness will depend on the weight of the equipment used for compaction. See Table 1 for layer thickness recommendations.

Table 1. Recommended layer thickness by compactor weight

Compactor weight	**Layer thickness**
25 Tons 816K	30 cm
41 Tons 826K	40 cm
55 Tons 836K	60 cm

If the layer gets thicker than these recommended values, the lower part of the layer will not receive enough pressure to reduce voids in the waste. The layer will act like a spring, and once the compactor has made a pass over the layer, it would return to its initial volume.

Figure 9. Left: Track type tractor spreading in thin layers. Right: Landfill compactor does straight passes

Dozers equipped with large capacity blades increase the site productivity. The tracks provide a good balance and floatation on loose waste, and will facilitate an efficient spread. Alternatively, sites not equipped with dozers can use landfill compactors. Small sites can use track loaders equipped with large capacity buckets.

3.5 Compression

Now that waste has been laid on the cell, it is ready to be compacted.

How much compression will the equipment apply on the waste?
Mobile equipment will apply a vertical force on the waste, which will compress waste and reduce voids. This force is linked to the pressure applied by the equipment

$$\text{Pressure} = \text{Weight} / \text{Contact surface}$$

A dozer has a large surface of contact with waste (4 to 6 m^2 for a 240 HP dozer), therefore by default, its compaction capability is far less than a landfill compactor equipped with steel wheels.

It is not obvious to evaluate the contact surface of a machine equipped with wheels, working on a loose surface, however a good estimate is the linear pressure, where instead of using the contact surface, you take into account the width of each wheel.

By further reducing the wheel width, you increase pressure and compaction on waste. It is therefore not recommended to utilize mobile equipment equipped with 2 drums instead of 4 wheels, as they increase the contact surface with ground and decrease pressure, when it comes to compaction.

CATERPILLAR has carefully chosen the steel wheel size, as reducing wheel size does increase pressure but not necessarily compaction. For example, too narrow wheels break free easier and spin easier: the shear force of that wheel might be higher than the compacted waste causing wheel spin.

Figure 10: Steel wheels equipped with specific landfill tips on a landfill compactor

3.6 Influence of number of passes on solid waste layer on final compaction

Each pass increases final compaction. Experience shows that the economical balance between number of passes and operating cost of a landfill compactor is to make 4 passes on the layer, for typical household waste. For industrial waste, more passes are required due to the different nature of the material. Industrial waste is generally dryer, and items have a larger size, requiring more shredding before compaction.

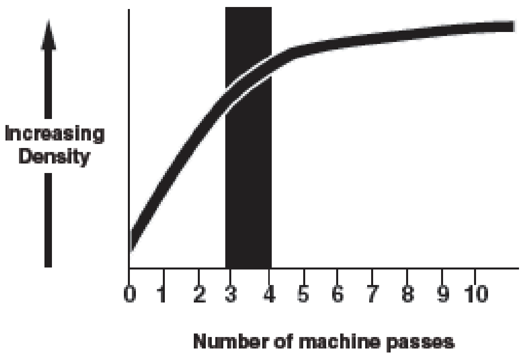

Figure 11: Influence of number of passes on final density

A pass is a travel in one direction of the compactor all across the active cell. According to the tests we realized, once you have done 4 passes on solid waste, the gain in density is minimal, compared to the time and fuel spent.

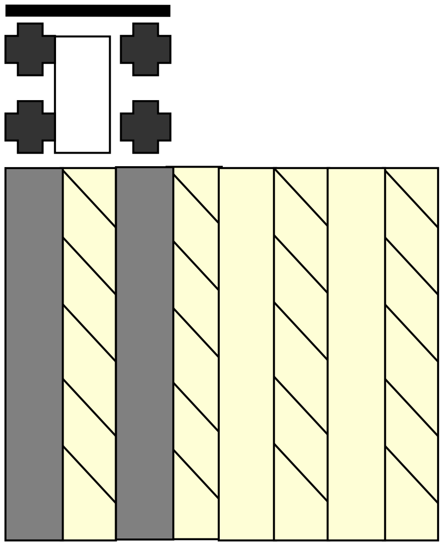

Figure 12: Schematic of a one-pass movement

Following a logical pattern – left to right or right to left.
The compactor operator will make one pass forward and a second pass in the same track in reverse.
He then moves over one wheel, makes two more passes (forward / reverse in same tracks)
Moving over 1 more wheel width while making forward / reverse passes, will gain him 4 passes as he logically moves in this patter across the waste.

The machine operator needs to make sure that:
1 - machine travels straight on the face to keep waste in place and compact forward and reverse in the same tracks.
2 - both axles front and rear will compact waste on the active cell
The compactor operator makes sure that he completes the passes forward and reverse till the wheel or wheels are completely off of the waste insuring that the layer is completely compressed and shredded
3 - he follows a pattern to ensure the whole face is uniformly compacted, following a pattern across the waste, shreds, compacts, and covers all the area uniformly.

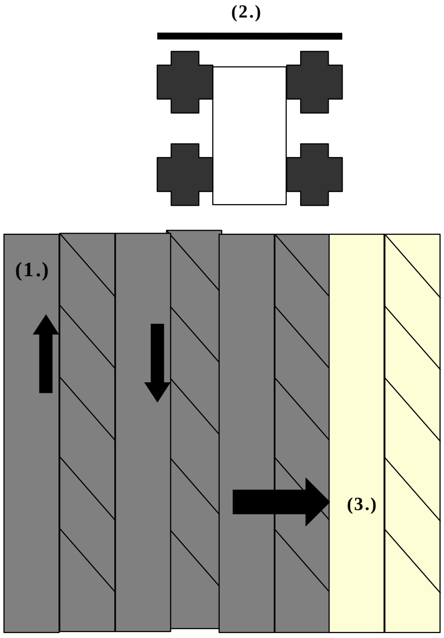

Figure 13: Sequence of 4 passes

By working without pattern, the machine tends to roam on the face, and not be used efficiently. It may run on some areas more than 4 passes, without significantly increasing compacting, and in the opposite, it may not have done 4 passes in some areas.

This will cause differential compaction on the face. A uniform compaction helps also save fuel on the fleet operation, as it reduces rolling resistance on the surface.

Once 4 passes have been done on the working face, it is recommended that you perform a final passé 45 degrees from your pattern direction.

3. CONCLUSIONS

As technology evolves, there are more and more tools to improve compaction.

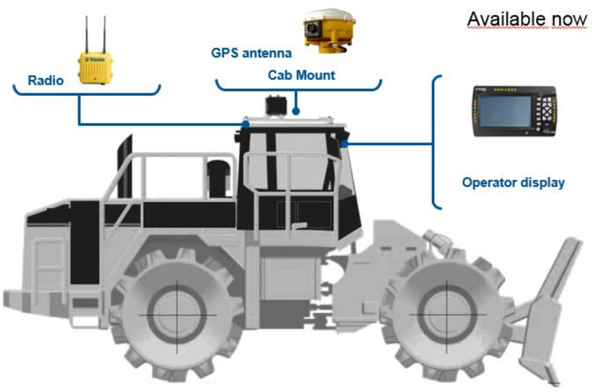

Figure 14: New guiding systems

However, it is important to establish first the current situation in terms of compaction capacity, and determine what your compaction objectives are.

There are operational improvements such as layer thicknesses and number of passes that can first bring compaction enhancements.

Then, in terms of compaction equipment, make sure you select the right size of equipment for the peak time production requirement of your landfill. By dedicating landfill compactors to compaction, and dozers to pushing and spreading, you will also increase the overall production of the fleet.

The fleet organization as a team of machines, landfill compactors and track type tractors, will also bring a more complete involvement of the fleet personnel, including spotters.

Even if the site has a large reserve of airspace, improving density of solid waste, will improve safety on site and for the neighborhood, by reducing the risk of fire, odors and rodents.