FACTORS TO CONSIDER WHEN PLANNING LANDFILL CONSTRUCTION [1]

David J. Kerkes, Ph.D., P.E.
Consulting Geotechnical (Civil) Engineer
1311 Mustang Trail • Kingwood, Texas 77339 USA
dkerkes@geotechconsultant.com • http://www.geotechconsultant.com

ABSTRACT

The complexity of composite liner systems required to meet Subtitle D regulations and the difficulties inherent in constructing the liner systems have definite implications on the time necessary to complete construction. When planning the construction or expansion of a landfill the failure to properly consider the various factors involved in actual construction can have serious consequences in terms of project delays and additional costs. For many landfills the loss of air space is the ultimate cost of missing a construction completion date. This paper offers some practical suggestions, based on actual construction experience, to assist owners in developing realistic construction schedules. The paper is intended to make the reader aware of certain aspects that frequently seem to be ignored and to alert owners to potential problems as well as possible courses of action to avert problems. The points outlined in the paper will also assist owners in evaluating the qualifications of potential contractors who may propose on landfill construction projects.

INTRODUCTION

The author's experience has been that a great many problems frequently encountered in landfill construction can be avoided, or at least minimized, if proper consideration is given to what can and cannot be done by earthworks and geosynthetics installation contractors. It would seem obvious that contractors cannot do the impossible, but it is surprising how frequently they are expected to do just that. The reason appears to be that a number of factors which should be considered when developing a construction schedule frequently seem to be ignored. This paper discusses several of those factors and offers some suggestions for developing a reasonable construction schedule, based on the author's experience of what earthworks contractors and geosynthetics installers can actually do. Remember, few contractors are likely to win a contract by telling the owner that they will not be able to meet the schedule; therefore, do not assume that the schedule is reasonable simply because the contractors do not object to it.

---

[1] Proceedings of the Eighth Annual Texas Municipal Solid Waste Management Conference, Austin, TX, January 25-27, 1995, pp 115-122. Reprinted by the author with the permission of The Texas Natural Resource Conservation Commission (TNRCC).

PRODUCTION RATES

To develop an estimate of how long it should take to construct a composite liner and leachate collection system to Subtitle D standards, it is necessary to have an idea of how much production a contractor can realistically achieve. Based on the author's experience on the construction of over fifteen composite liner systems, a reasonable estimate for placement and compaction of clay liner is approximately 1,250 cubic yards per day, which equates to 2½ days per acre for a 2 feet thick compacted clay liner. A reasonable estimate for the installation of geomembrane would be approximately 1½ to 2 days per acre, which includes deployment and production seaming of the material as well as typical repairs that are an inevitable part of the installation. Geosynthetics installers will often estimate 1 acre per day, but the author has found this to be optimistic under the best of circumstances. The final operations are the installation of the drains for the leachate collection system and placement of the protective soil cover, which are typically performed simultaneously, and experience has shown that these operations typically require approximately 2 days per acre for completion. There will always be contractors who will state that they are capable of better production rates, and there are some contractors who are; however, more often than not it is simply an idle boast intended to win work. This does not mean that earthworks contractors are incapable of higher production rates; however, high production rates are generally achieved on large earth moving projects where the contractor has both a large equipment fleet and a large area over which to operate that fleet. Landfill cells are not large by earth moving project standards.

Delays are an inevitable part of any construction project; therefore, provision should be made in the schedule for reasonable delays. The basic question is, "What constitutes a reasonable delay?" The causes for many delays are avoidable, or at least predictable, and an understanding of these causes can be helpful to an owner. There are basically three major reasons for delays during construction, and these are: delays due to weather, delays due to equipment problems, and delays due to material problems.

WEATHER AND CLIMATE

It should come as no surprise to anyone that it rains in many parts of Texas, yet it remains one of the major causes for cost and schedule overruns. Climatologic data for many locations in Texas can be obtained at a reasonable cost from the Louisiana State University Southern Regional Climate Center (tel. 504/388-5021). This information will enable you to formulate reasonable estimates of the amount of time likely to be lost due to rainfall, and it will also be valuable in developing an estimate of the potential volume of stormwater that will have to be handled. Depending on the amount of rainfall, the contractor not only loses a day's production for each day that it rains, but also at least one day's production is typically lost after the rain stops for dewatering operations and any other work necessary to restore the cell and borrow area to a level where productive work can again be achieved. It is unwise to ignore the potential effects of climate, and rainfall is not the only possible problem. In arid environments the lack of moisture in the air and ground can be just as serious a problem as too much water, the implications of which will be discussed in a subsequent paragraph.

CONSTRUCTION EQUIPMENT

To construct a compacted clay liner it is essential that the contractor have the proper equipment to do the job. The following pieces of construction equipment are considered by the author to be an absolute minimum:

- one (1) CAT 815 compactor, or equivalent;
- one (1) track mounted excavator;
- one (1) bulldozer (D-7, minimum);
- one (1) harrow disc or roan plow;
- three (3) dump trucks;
- one (1) 10,000 gallon water truck, with water canon;
- one (1) motor grader;
- one (1) smooth drum roller;
- diesel fuel storage tank sufficient to maintain the equipment (estimate an average of 10 gallons per hour, per machine);
- pumps (typically 6 inch minimum) and hose sufficient to dewater the cell and borrow area(s).

The list of equipment above is an absolute minimum; however, it is adequate to achieve a production rate of approximately 1,250 cubic yards per day. You should seriously question the experience and abilities of a contractor who proposes to do the work with less equipment. Obviously, a contractor is potentially at risk if he provides the minimum amount of equipment without provision for backup. The contractor may be able to operate without one of his dump trucks; however, his operation will terminate if his excavator breaks down. Consequently, the age of the equipment is a factor if the contractor proposes to supply only the minimum number of pieces necessary to do the job. Conversely, if the contractor brings in more dump trucks, but only has a single compactor or a single excavator to load the trucks, his rate of production will remain the same.

MATERIAL

Two of the most important considerations in the project are the materials for construction, which are basically soil and geosynthetics. Of the two, the geosynthetic component is the more straight forward to deal with because geosynthetics are man-made and as such, some level of quality control can be exercised by the manufacturer. The soil, however, is a naturally occurring material that is a bit more complicated than most people realize, and a basic understanding of the nature of clay is valuable in recognizing the potential effects that the material can have on the construction schedule.

Clay is the term given to the soil group made up of particles smaller than two (2) microns (0.002 millimeters or approximately 1/10,000 inch). The unique characteristics of clay are attributable to the size and chemical properties of the particles that make up the soil. The particular property of clay soils that make them desirable for application to landfill construction is their hydraulic conductivity, which is essentially the velocity of fluid passing through the soil and is typically expressed as centimeters per second (cm/s) or feet per minute (ft/min). As a measure to ensure that the desired hydraulic conductivity is achieved during construction, the stipulation is made that the clay be compacted to a certain standard. Achieving that standard is where problems arise. There exists a specific relationship between the density that can be achieved during compaction and the amount of moisture present in the soil. The density is commonly expressed in terms of the dry weight (pounds) of soil in a unit volume (cubic foot), or pounds per cubic foot (pcf). The moisture is expressed as the ratio of the weight of water in a unit volume of soil to the weight of dry soil in that same unit volume, typically expressed as a percentage. Figure 1 illustrates a typical moisture/density relationship. For a given compactive effort, say six passes with a CAT 815 compactor, the maximum dry density will be achieved at a specific moisture content, which is referred to as the optimum moisture content. The lowest hydraulic conductivity will normally be achieved when the soil is compacted slightly above the optimum moisture content. This relationship is very sensitive to the type of soil; therefore, the moisture/density relationship must be established for each soil type proposed for use in construction of the clay liner. Once this relationship is established it is very important to determine the moisture content of the clay at the proposed material source. If the soil is too dry, the moisture content will have to be increased, and if it is too wet it will have to be dried back.

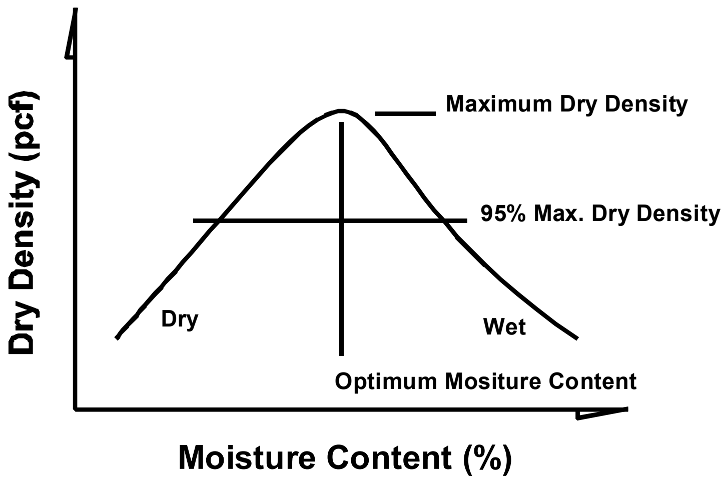

Figure 1: Typical relationship between soil density and moisture.

Unfortunately, the characteristic of clay soils that makes clay desirable as a natural liner material (i.e., the rate at which fluids pass through clay) also makes them difficult to work with from a construction standpoint. Clays do not easily take on or give up water, which makes it difficult to increase or decrease their moisture content. What is typically required is time and a considerable amount of effort in repeatedly mixing the material, which is why the water truck and the harrow disc are essential pieces of equipment. Consequently, the closer the material is to the desired moisture content, the less time required for clay liner construction. Therefore, it is very important to know the characteristics of the clay material source so that the time necessary for moisture conditioning can be factored into the schedule. It is relevant to note that repeatedly running over the soil with a compactor will not achieve the desired product; however, this is a suggestion that is frequently offered by contractors as an alternative to the use of a harrow disc.

There are several points to keep in mind regarding the matter of moisture conditioning. As a general rule it is not practical to moisture condition material in the cell when the change in moisture content is greater than about 3 percent because of the time and amount of effort necessary. Rushing the process can result in an unacceptable product in terms of the engineering properties of the soil, and the consequences of this will be discussed in a subsequent paragraph. Therefore, the soil should either be moisture conditioned in the borrow area or an area on site specifically designated for this purpose. This may require an additional bulldozer to tow the harrow disc, which may pose a problem for the contractor if this operation was not anticipated during the bid process. If the material is extremely dry it is best to moisture condition the soil in the borrow area. One method is to open the ground with a ripper, water the area, then cover it back up and allow some time for the soil to absorb the moisture. A significant improvement in the material can be achieved over a period of days, but the process is slow and the effective depth is limited to the size of the ripper. Another extremely effective method is the use of a pulva-mixer, which simultaneously breaks up dry soil clods and mixes the material. The combined use of a water truck and pulva-mixer typically produces an excellent product, but the process translates into time and expense. Consequently, the owner must be aware of what will be required to achieve the required product in place.

OTHER CONSIDERATIONS

The physical size of the proposed landfill cell should also be taken into account when developing a construction schedule. A contractor cannot work his equipment effectively in too small an area, or in areas with difficult or limited access. Heavy equipment needs room to maneuver in order to efficiently achieve production. Equally important is the proximity of the clay material source to the landfill cell. If the material is coming from off site, where will the material be stockpiled? Stockpiling material is often dismissed as a bad idea because of the need to double handle the material, and contractors will often suggest that the material be hauled and dumped directly into the cell. The logic of this suggestion seems too strong to argue with; however, more often than not this becomes a real logistics problem for the contractor. First, the process of spreading the material into uniform lifts and compacting it cannot be done as quickly as material can be hauled into the cell. If one piece of equipment necessary for placement and compaction breaks down, the hauling operation must shut down as well, whereas hauling and stockpiling could continue if the two operations were independent. Secondly, a potential traffic problem arises when the contractor's hauling operation has to be performed around his placement and compaction operation. The process is complicated even further if there is a need to moisture condition the material, which will be discussed in a subsequent paragraph. As a general rule it is best to have more material available at any given time than the contractor can place and compact; therefore, the schedule should provide for some time at the start of the project for material hauling and stockpiling when the source of the clay is off site. Even if it is decided to allow the contractor to bring material from off site directly into the cell, provisions should be made for stockpiling somewhere on site if it becomes necessary.

Regardless of whether the source of material is on or off site, it is essential that the location of the material source be established and the quantity and quality of material necessary for construction be verified <u>prior</u> to the start of construction. Do not assume that a contractor will be able to maintain a reasonable rate of production if he has to look for suitable material at the same time he is constructing a compacted clay liner. Considerable planning needs to be done before the start of construction regarding the source of clay liner material for the project. Factors to consider include the uniformity of the material (naturally occurring geologic deposits can be highly variable), proximity to the site, accessibility (particularly in wet weather), available quantities, and amount of preparatory work necessary to obtain the material (clearing and removal of overburden). As a general rule it is best to identify a source that has twice as much material as will be needed because it is frequently difficult to make accurate quantity estimates in naturally occurring geologic deposits, and it is common to find that not all of the material encountered will be of acceptable quality. Also keep in mind that current regulations limit the quantity of rock present in the clay liner to less than 10 percent by weight and the maximum particle size to 1 inch. Screening clay or removing rocks by manual labor are neither practical nor cost effective.

Equally important to the earthworks and geosynthetics contractors is a well defined set of contract documents, which should include a detailed set of construction drawings. Do not assume that the drawings provided in the permit will be sufficient for actual construction of the cell and installation of the geomembrane. A good set of construction drawings will minimize the potential for confusion, errors and delays. When information provided to the contractor is insufficient or ambiguous the contractor will frequently make assumptions involving the least expense on his part, and extra payment will be sought if the owner's requirements during construction result in greater costs to the contractor than were assumed. Furthermore, it is not uncommon for conditions encountered during construction to deviate from those anticipated during preparation of the permit, and the best time to resolve any such deviations with the Texas Natural Resource Conservation Commission is during preparation of the contract documents, rather than introducing a delay during construction. Of particular importance in the construction drawings are a final grading plan, horizontal and vertical survey control points, liner cross sections, details for construction of the sump, anchor trench details for the geosynthetics, details of the leachate collection system, details of tie-ins to existing cells, and details for the construction of stormwater and waste containment berms. Whenever possible, the contract documents should also indicate if and at what depth groundwater may be encountered. Accurate hydrogeologic data, as well as geotechnical data, in the contract documents will help reduce the risk of construction claims during the project. As a general rule, efforts to save money by dispensing with good construction drawings for the project result in potentially greater expense during construction, as well as unnecessary delays.

In regard to the installation of the flexible membrane liner, it is preferable to schedule the installation of the geomembrane after completion of the compacted clay liner, which allows the geosynthetics installer to proceed with the work in an optimal manner. For example, geosynthetics are generally installed from the highest point in the cell toward the lowest in order to minimize the potential for rain getting under the geomembrane liner during installation. However, if the earthworks contractor is burdened with an unreasonable schedule it may become necessary to begin the geomembrane installation in one location of the cell while clay liner construction is simultaneously underway in another location. More often than not, the result is a slower production rate for both operations because each contractor has to work his operation around the other. Limiting accessibility to the cell often slows earthwork production, and since geomembrane can be deployed relatively quickly, the geosynthetics installer ends up waiting for the earthworks contractor to get out of his way. Add bad weather to the picture and a difficult situation becomes impossible, with both contractors brought to a standstill.

The final operations consist of the installation of the drains for the leachate collection system and placement of the protective soil cover, and a tight construction schedule will inevitably require that these operations be started before completion of the geomembrane liner. Once again the geosynthetics installer and earthworks contractor are working in each other's way. If at this point in the project the geomembrane is being installed at the lowest portion of the cell as protective cover is being placed at the highest point, a rainstorm can have a devastating effect by washing protective cover down into the geomembrane installer's work area. The situation that has been outlined here is frequently written off as "bad luck." Who can control the weather? No one can control the weather; however, good planning and a reasonable construction schedule can lessen the negative impact of bad weather. As a general rule each of the major construction operations should be scheduled so that each contractor can perform his work unencumbered by the presence of another contractor. The objection to this (and it is a poor one) is that there may be wasted time between the completion of one operation and the start of the next. I have yet to see this happen. Inevitably there will be delays, and any apparent extra time in the schedule will more than likely disappear. In the highly unlikely event that your project should proceed without any problems you will find yourself in the most enviable position of completing ahead of schedule. Remember that the consequences of missing a completion date may not only be additional construction costs; the ultimate cost for many landfills is the temporary loss of air space.

One other thing to keep in mind is the cost associated with third party construction quality assurance (CQA). The CQA contractor is there to represent the interests of the general public by providing an independent verification that the project was constructed in compliance with the permit, plans and specifications. The criteria applied by the CQA contractor are <u>minimum</u> criteria, and all components of the project must meet these minimum criteria. Consequently, each test <u>must</u> pass and close is not good enough. Areas that do not meet the specification must be reworked until an acceptable product is achieved or the material must be removed. Criticism is sometimes voiced that the CQA contractor looks for the worst areas rather than the average; however, this is exactly what the CQA contractor is expected to do. Therefore, the consequences of using marginally acceptable construction materials can be extreme. For example, when a hydraulic conductivity test fails the question becomes, "How much material must be reworked or removed?" The answer to this question frequently requires that additional tests be performed in an effort to identify the limits of the unacceptable material. Additional testing incurs additional costs, a delay in construction while the tests are being performed, and a further delay when the area is ultimately reworked or replaced. Therefore, if you are not fortunate enough to have a high quality source of material for the compacted clay liner, anticipate delays and additional costs during construction. Do not assume an optimistic position; keep in mind that Mother Nature has consistently demonstrated a total lack of respect for the owner's schedules and budgets.

Assume that the contractor will work six (6) days per week, ten (10) hours per day. This leaves the last day of the week open in the event that the contractor loses a day's production to the weather or equipment problems. Therefore, an estimate for the time required to construct ten (10) acres of composite liner and leachate collection system would be: 25 working days for the compacted clay, 20 working days for the geomembrane, and 20 working days for the leachate collection system, for a total of 75 calendar days or approximately 11 weeks for the project. This allows for 11 Sundays that the contractors can use to either complete ahead of schedule or make up for delays. However, for the purpose of third party CQA it is best to assume twelve (12) hour work days and at least a few (7) day work weeks, which will reduce the potential for cost overruns for CQA associated with construction delays.

Two other factors that should also be considered are the amount of time it takes a contractor to mobilize equipment and the time necessary to complete initial site preparation. The contractor should be allowed a reasonable amount of time to move the necessary equipment to site. Additional time should also be allowed for preparation of the subgrade prior to clay liner placement because it is not possible to achieve the degree of compaction required for a Subtitle D clay liner if the subgrade is too soft. Similarly, additional time should be allowed for the contractor to develop the clay borrow area, build haul roads, etc.

CONCLUSION

While no construction project is immune to problems and delays, many problems are avoidable if the project is properly planned. The failure to plan the project properly, or the idea that money can be saved if the contractor is forced to comply with a tight construction schedule, will usually result in construction delays and additional costs over and above those that would have been incurred if a realistic construction schedule had been developed. Projects typically go sour when the contractor begins to lose money, and when projects go sour all parties lose, not just the contractor. This is avoidable! There is a certain minimum cost associated with each project, and that cost will ultimately be paid; however, the project will go better if the money goes to the contractor rather than the lawyers for the owner and contractor. The best way for the owner to save money is to provide the contractor(s) with both a reasonable construction schedule and the information necessary to formulate a bid that will allow a reasonable profit. Much of the information needed by the contractor(s) to prepare the bid can and should be provided by the engineer hired to do the design, and it is a poor designer who defers important matters until construction with such arguments as "That's the contractor's problem." Problems for the contractor ultimately become problems for the owner. Therefore, identification and testing of potential clay material sources, estimates of both the quantity and quality of materials, location of stockpiles, proper specification of the geosynthetic components, development of well defined construction specifications, preparation of construction drawings, etc., should all be performed by the designer. As a final point, always keep in mind that the lowest bidder may simply be unaware of what the project actually involves, and all parties involved with the project will have to deal with the consequences.