This chapter is devoted toward ancillary materials used within a waste containment facility, various appurtenances which are necessary for proper functioning of the system and other important details. Ancillary materials such as plastic pipe for leachate transmission, sumps for collection of leachate, manholes and pipe risers for removal of leachate will be covered in this chapter. Appurtenances, such as penetrations made through various barrier materials, will be covered. Lastly, other important details requiring careful inspection, such as anchor trenches, internal dikes and berms, and access ramps, will also be addressed.

8.1 Plastic Pipe (aka "Geopipe")

Whenever the primary or secondary leachate collection system at the bottom of a waste containment facility is a natural soil material, such as sand or gravel, a perforated piping system should be located within it to rapidly transmit the leachate to a sump and removal system. Figure 8.1 illustrates the cross section of such a pipe system which is generally located directly on top of the geomembrane or geotextile to 225 mm (9.0 in.) above the primary liner material. This is a design issue and the plans and specifications must be clear and detailed regarding these dimensions.

Figure 8.1 - Cross Section of a Possible Removal Pipe Scheme in a Primary Leachate Collection and Removal System (for illustration purposes only).

The pipes are sometimes placed in a manifold configuration with feeder lines framing into a larger main trunk line thus covering the entire footprint of the landfill unit or cell, see Fig. 8.2. The entire pipe network flows gravitationally to a low point where the sump and removal system
consisting of either a manhole or pipe riser is located. The diagonal feeder pipes, if included, are always perforated to allow the leachate to enter into them. The central trunk lines may or may not be perforated depending on the site specific design. It must be recognized, however, that there is a large variety of schemes that are possible and it is clearly a design issue which must be unequivocally presented in the plans and specifications.

Leachate collection and transmission lines in most waste containment facilities are plastic pipe, with polyvinyl chloride (PVC) and high density polyethylene (HDPE) being the two major material types in current use. Furthermore, there are two types of HDPE pipe in current use, solid wall and corrugated types. Each of these types of plastic pipes will be described.

8.1.1 Polyvinyl Chloride (PVC) Pipe

Polyvinyl chloride (PVC) pipe has been used in waste containment systems for leachate collection and removal in a number of different locations and configurations. The pipes can be perforated or not depending on the site specific design. The pipes are often supplied in 6.1 m (20 ft) lengths which are joined by couplings or utilize bell and spigot ends. The PVC material typically consists of resin, fillers, carbon black/pigment and additives. PVC pipe does not contain any liquid plasticizers, see Fig. 8.3.

Regarding a specification or a MQA document for PVC pipe and fittings the following items should be considered.
1. The basic resin should be made from PVC as defined in ASTM D-1755. Details are contained therein.

2. Other materials in the formulation, such as fillers, carbon black/pigment and additives should be stipulated and certified as to the extent of their prior use in plastic pipe.

3. Clean rework material, generated from the manufacturer’s own pipe or fitting production may be used by the same manufacturer providing that the rework material meets the above requirements. See section 3.2.2 for a description of possible use of reworked and/or recycled material.

4. Pipe tolerances and properties must meet the applicable standards for the particular grade required by the plans and specifications. For PVC pipe specified as Schedule 40, 80 and 120, the appropriate specification is ASTM D-1785. For PVC pipe in the standard dimension ratio (SDR) series, the applicable specification is ASTM D-2241.

Figure 8.3 - Photograph of PVC Pipe to be Used in a Landfill Leachate Collection System.
5. Both of the above referenced ASTM Standards have sections on product marking and identification which should be followed as well as requiring the manufacturer to provide a certification statement stating that the applicable standard has been followed.

6. PVC pipe fittings should be in accordance with ASTM D-3034. This standard includes comments on solvent cement and elastomeric gasket joints as well as a section on product marking and certification.

8.1.2 High Density Polyethylene (HDPE) Smooth Wall Pipe

High density polyethylene (HDPE) smooth wall pipe has been used in waste containment systems for leachate collection and removal in a number of different locations and configurations. The pipe can be perforated or not depending on the site specific design. The pipes are often supplied in 6.1 m (20 ft) lengths which are generally joined together using butt-end fusion using a hot plate as per the gas pipe construction industry. Other joining variations such as bell and spigot, male-to-female and threading are also available. The HDPE material itself consists of 97-98% resin, approximately 2% carbon black and up to 1% additives. Figure 8.4 illustrates the use of HDPE smooth pipe.

Figure 8.4 - Photograph of HDPE Smooth Wall Pipe Risers Used as Primary and Secondary Removal Systems from Sump Area to Pump and Monitoring Station.
The following items should be considered regarding the contract specification or MQA document on HDPE solid wall pipe and fittings:

1. The basic material should be made of HDPE resin and should conform to the requirements of ASTM D-1248. Details are contained therein.

2. Quality control tests on the resin are typically density and melt flow index. The appropriate designations are ASTM D-1505 or D-792 and D-1238, respectively. Other in-house quality control tests should be encouraged and followed by the manufacturer.

3. Typical densities for HDPE pipe resins are 0.950 to 0.960 g/cc. This is a Type III HDPE resin according to ASTM D-1248 and is higher than the density of the resin used in HDPE geomembranes and geonets.

4. Carbon black can be added as a concentrate, as it customarily is, or as a powder. The type and amount of carbon black, as well as the type of carrier resin if concentrated pellets are used, should be stated and certified by the manufacturer.

5. The amount of additives used should be stated by the manufacturer. If certification is required it would typically not state the type of additive, since they are usually proprietary, but should state that the additive package has successfully been used in the past and to what extent.

8.1.3 High Density Polyethylene (HDPE) Corrugated Pipe

Corrugated high density polyethylene (HDPE), also called “profiled” pipe, has been used in waste containment systems for leachate collection and removal in a number of different locations and configurations. The pipe can be perforated or slotted depending on the site specific design. The inside can be smooth lined or not depending on the site specific design. The pipes are often supplied in 6.1 m (20 ft) lengths which are joined together by couplings made by the same manufacturer as the pipe itself. This is important since the couplings are generally not interchangeable among different pipe manufacturer’s products. The HDPE material itself consists of 97-98% resin, approximately 2% carbon black and up to 1% additives. Figure 8.5 illustrates HDPE corrugated pipe.

Regarding the contract specification or MQA document on HDPE corrugated pipe and fittings, the following items should be considered:

1. The basic material should be made of HDPE resin and should conform to the requirements of ASTM D-1248. Details are contained therein.

2. Quality control tests are typically density and melt flow index. Their designations are ASTM D-1505 or D-792 and D-1238, respectively. Other in-house quality control tests are to be encouraged and followed by the manufacturer.

3. Typical densities for HDPE pipe resins are 0.950 to 0.960 g/cc. This is a Type III HDPE resin according to ASTM D-1248 and is higher than the resin density used in HDPE geomembranes.

4. Carbon black can be added as a concentrate as it customarily is, or as a powder. The type and amount of carbon black, as well as the type of carrier resin if concentrated pellets are used, should be stated and certified by the manufacturer.
5. The amount of additives used should be stated by the manufacturer. If certification is required it would typically not state the type of additive, since they are usually proprietary, but should state that the additive package has successfully been used in the past.

6. The lack of ASTM documents for HDPE corrugated pipe should be noted. There is an AASHTO Specification available for corrugated polyethylene pipe in the 300 to 900 mm (12 to 36 in.) diameter range under the designation M294-90 and another for 75 to 250 mm (3 to 10 in.) diameter pipe under the designation of M252-90.

![Figure 8.5 - Photograph of HDPE Corrugated Pipe Being Coupled and After Installed.](image)

8.1.4 Handling of Plastic Pipe

As with all other geosynthetic materials a number of activities occur between the manufacturing of the pipe and its final positioning in the waste facility. These activities include packaging, storage at the manufacturers facility, shipment, storage at the field site, conformance testing and the actual placement.
8.1.4.1 Packaging

Both PVC pipe and HDPE pipe are manufactured in long lengths of approximately 6.1 m (20 ft) with varying wall thicknesses and configurations. They are placed on wooden pallets and bundled together with plastic straps for bulk handling and shipment. The packaging is such that either fork lifts or cranes using slings can be used for handling and movement. As the diameter and wall thickness increases, however, this may not be the case and above 610 mm (24 in.) diameter the pipes are generally handled individually.

8.1.4.2 Storage at Manufacturing Facility

Bundles of plastic pipe can be stored at the manufacturing facility for relatively long periods of time with respect to other geosynthetics. However, if stored outdoors for over 12 months duration, a temporary enclosure should be used to cover the pipe from ultraviolet exposure and high temperatures. Indoors, there is no defined storage time limitation. Pipe fittings are usually stored in a container or plastic net.

8.1.4.3 Shipment

Bundled pallets of plastic pipe are shipped from the manufacturer's or their representative's storage facility to the job site via common carrier. Ships, railroads and trucks have all been used depending upon the locations of the origin and final destination. The usual carrier from within the USA, is truck. When using flatbed trucks, the pallated pipe is usually loaded by means of a fork lift or a crane with slings wrapped around the entire unit. When the truck bed is closed, i.e., an enclosed trailer, the units are usually loaded by fork lift. Large size pipes above 610 mm (24 in.) in diameter are handled individually.

8.1.4.4 Storage at Field Site

Offloading of palleted plastic pipe at the site and temporary storage is a necessary follow-up task which must be done in an acceptable manner.

Items to be considered for the contract specification or CQA document are the following:

1. Handling of pallets of plastic pipe should be done in a competent manner such that damage does not occur to the pipe.

2. The location of field storage should not be in areas where water can accumulate. The pallets should be on level ground and oriented so as not to form a dam creating the ponding of water.

3. The pallets should not be stacked more than three high. Furthermore, they should be stacked in such a way that access for conformance testing is possible.

4. Outdoor storage of plastic pipe should not be longer than 12 months. For storage periods longer than 12 months a temporary covering should be placed over the pipes, or they should be moved to within an enclosed facility.

8.1.5 Conformance Testing and Acceptance

Upon delivery of the plastic pipe to the project site, and temporary storage thereof, the CQA engineer should see that conformance test samples are obtained. These samples are then sent to the
CQA laboratory for testing to ensure that the pipe supplied conforms to the project plans and specifications.

Items to consider for the contract specification or CQA document in this regard are the following:

1. The pipe should be identified according to its proper ASTM standard:
   (a) for PVC Schedule 40, 80 and 120: see ASTM D-1785
   (b) for PVC SDR Series: see ASTM D-2241
   (c) for PVC pipe fittings: see ASTM D-3034
   (d) for HDPE SDR Series: see ASTM D-1248 and ASTM F-714
   (e) for HDPE corrugated pipe and fittings: see AASHTO M294-90 and M252-90.

2. The conformance test samples should make use of the same identification system as the appropriate ASTM standard, if one is available.

3. A lot should be defined as a group of consecutively numbered pipe sections from the same manufacturing line. Other definitions are also possible and should be clearly stated in the CQA documents.

4. Sampling should be done according to the contract specification and/or CQA documents. Unless otherwise stated, sampling should be based on one sample per lot, not to exceed one sample per 300 m (1000 ft) of pipe.

5. Conformance tests at the CQA Laboratory should include the following:
   (a) for PVC pipe and fitting: physical dimensions according to ASTM D-2122, density according to ASTM D-792, plate bearing test according to ASTM D-2412, and impact resistance according to ASTM D-2444.
   (b) for HDPE solid-wall and corrugated pipe: physical dimensions according to ASTM D-2122, density according to ASTM D-1505, plate bearing test according to ASTM D-2412 and impact resistance according to ASTM D-2444.
   (c) for HDPE corrugated pipe in the 300 to 900 mm (12 to 36 in.) range see AASHTO M294-90 and in the 75 to 250 mm (3 to 10 in.) range see AASHTO M252-90.

6. Conformance test results should be sent to the CQA engineer prior to deployment of any pipe from the lot under review.

7. The CQA engineer should review the results and should report any non-conformance to the Project Manager.

8. The resolution of failing conformance tests should be clearly stipulated in the specifications or CQA documents.
8.1.6 Placement

Plastic pipe is usually placed in a prepared trench or within other prepared subgrade materials. If the pipe is to be placed on or near to a geomembrane, as in the leachate collection system shown in Fig. 8.1, the drainage sand or stone should be placed first. There may be a requirement to lightly compact sand to 90% relative density according to ASTM D-4254. Small excavations of slightly greater than the diameter of the pipe are then made, and the pipe is placed in these shallow excavations. Thus a trench, albeit a shallow one, is constructed in all cases of pipe placement in leachate collection sand or stone.

Where plastic pipe is placed at other locations adjacent to the containment facility and the soil is cohesive, compaction is critical if high stresses are to be encountered. Compaction control is necessary, e.g., 95% of standard Proctor compaction ASTM D-698 is recommended so as to prevent subsidence of the pipe while in service.

The importance of the density of the material beneath, adjacent and immediately above a plastic pipe insofar as its load-carrying capability is concerned cannot be overstated. Figure 8.6 shows the usual configuration and soil backfill terminology related to the various materials and their locations.

Regarding a specification or CQA document for plastic pipe placement, ASTM D-2321 should be referenced. For waste containment facilities the following should be considered:

1. The soil beneath, around and above the pipe shall be Class IA, IB or II according to ASTM D-2321.
2. The backfill soil should extend a minimum of one pipe diameter above the pipe, or 300 mm (12 in.) which ever is smaller.
3. Other conditions should be taken directly according to ASTM D-2321.
4. Pipe fittings should be in accordance with the specific pipe manufacturer’s recommendations.

8.2 Sumps, Manholes and Risers

Leachate which migrates along the bottom of landfills and waste piles flows gravitationally to a low point in the facility or cell where it is collected in a sump. Two general variations exist; one is a prefabricated sump, made either in-situ or off-site, with a manhole extension rising vertically through the waste and final cover, the other is a low area formed in the liner itself with a solid wall pipe riser coming up the side slope where it eventually penetrates the final cover. Both variations are shown schematically in the sketches of Fig. 8.7. In addition, the sump and sidwall riser of a secondary leachate collection system typically used in double lined facilities is shown in the right sketch of Fig. 8.7(b), i.e., a leak detection system. Each type of system will be briefly described.

Many existing landfills have been constructed with primary leachate collection and removal sumps and manholes constructed to the site specific plans and specifications as shown in the left hand sketch of Fig. 8.7(a). The vertical riser is either a concrete or plastic standpipe placed in 3 m (10 ft) sections. It is extended as the waste is placed in the facility and eventually it must penetrate the final cover. Leachate is removed from this manhole, on an as demanded basis, by a submersible pump which is permanently located in the sump.
A more recent variation of the above removal system is an off-site factory fabricated sump and manhole system wherein the leachate collection pipe network frames directly into the sump, see the right hand sketch of Fig. 8.7(a). Various standardized sump capacities are available. This type of system requires the least amount of field fabrication. The riser is extended in sections as the waste is placed in the facility and eventually it must penetrate the final cover. Leachate is removed from the manhole by a submersible pump which is permanently located in the sump.

Quite a different variation for primary leachate removal is a well defined low area in the primary geomembrane into which the leachate collection pipe network flows. This low area creates a sump which is then filled with crushed stone and from which a pipe riser extends up the side slope. The pipe riser is usually a solid wall pipe with no perforations. When the facility is eventually filled with solid waste, the riser must penetrate the cover as shown in the left hand sketch of Fig. 8.7(b). The leachate is withdrawn using a submersible pump which is lowered down the pipe riser on a sled and left in place except for maintenance and/or replacement, recall Fig. 8.4.
(a) Types of Primary Leachate Collection Sumps and Manholes with Vertical Standpipe Going through the Waste and Cover

(b) Types of Primary (Left) and Secondary (Right) Leachate Collection Sumps and Pipe Risers Going Up the Side Slopes

Figure 8.7 - Various Possible Schemes for Leachate Removal
In a similar manner as above, but now for secondary leachate removal, a sump can be formed in the secondary liner system which is filled with gravel as shown in the right hand sketch of Fig. 8.7(b). A solid wall pipe riser, perforated in its lower section, extends up the sidewall between the primary and secondary liner where it must penetrate both the primary liner, and eventually the cover system liner, see the right hand sketch of Fig. 8.7(b). This pipe riser is often a solid wall pipe in the 100-200 (4 to 8 in.) diameter range with no perforations. The leachate is withdrawn and/or monitored using a small diameter sampling pump which is lowered down the riser and left in place except for maintenance and/or replacement, recall Fig. 8.4.

Some specification and CQA document considerations for the various sump, manhole and riser schemes just described are as follows. Note, however, that there are other possible design schemes that are available in addition to those mentioned above.

1. In-situ fabrication of sumps requires a considerable amount of hand labor in the field. Seams for HDPE and VLDPE geomembranes are extrusion fillet welded, while PVC and CSPE-R geomembranes are usually bodied chemical seams (EPA, 1991). Careful visual inspection is necessary.

2. The soil support beneath the sumps and around the manhole risers of plastic pipes is critically important. The specification should reference ASTM D-2321 with only backfill types IA, IB and II being considered.

3. Riser pipes for primary and secondary leachate removal are generally not perforated, except for the lowest section of pipe which accepts the leachate.

4. Riser pipe joints for primary and secondary leachate removal require special visual attention since neither destructive nor nondestructive tests can usually be accommodated.

5. The sump, manholes and risers must be documented by the CQA engineer before acceptance and placement of solid waste.

8.3 Liner System Penetrations

Although the intention of most designers of waste containment facilities is to avoid liner penetrations, leachate removal is inevitably required at some location(s) of the barrier system. Recall Fig. 8.7 where the cover is necessarily penetrated for primary leachate removal. For leak detection both the primary liner and the cover liner must be penetrated. It should also be recognized that the penetrations will include geomembranes, compacted clay liners and/or geosynthetic clay liners. Figure 8.8 illustrates some details of pipe penetrations through all three types of barrier materials.

The following recommendations are made for a specification or CQA document:

1. Geomembrane pipe boots are usually factory fabricated to a size which tightly fits the outside diameter of the penetrating pipe. Unique situations, however, will require field fabrication, e.g., when pipe penetration angles are unknown until final installation.

2. The skirt of the pipe boot which flares away from the pipe penetration should have at least 300 mm (12 in.) of geomembrane on all sides of the pipe.

3. The skirt of the pipe boot should be seamed to the base geomembrane by extrusion fillet or bodied chemical seaming depending on the type of geomembrane (EPA, 1991).
Figure 8.8 - Pipe Penetrations through Various Types of Barrier Materials
4. The nondestructive testing of the skirt of the pipe boot should be by vacuum box or air lance depending on the type of geomembrane. Refer to Section 3.6.2.

5. The pipe boot should be of the same type of geomembrane as that of the liner through which the penetration is being made.

6. Pipe penetrations should be positioned with sufficient clearance to allow for proper welding and inspection.

7. Stainless steel pipe clamps used to attach pipe boots to the penetrating pipes should be of an adequate size to allow for a cushion of compressible material to be placed between the inside surface of the clamp and that of the geomembrane portion of the pipe boot.

8. Location of pipe clamps should be as directed on the plans and specifications.

9. Pipe penetrations through compacted clay liners and geosynthetic clay liners should use an excess of hand placed dry bentonite clay as directed in the plans and specifications.

8.4 Anchor Trenches

Generally, the geosynthetics used to line or cover a waste facility end in an anchor trench around the individual cell or around the entire site.

8.4.1 Geomembranes

The termination of a geomembrane at the perimeter of landfill cells or at the perimeter of the entire facility generally ends in an anchor trench. As shown in Fig. 8.9, the variations are numerous. Such details should be specifically addressed in the construction plans and specifications.

Some general items that should be addressed in the specification or CQA documents regarding geomembrane termination in anchor trenches are as follows:

1. The seams of adjacent sheets of geomembranes should be continuous into the anchor trench to the full extent indicated in the plans and specifications.

2. Seaming of geomembranes within the anchor trench can be accomplished by temporarily supporting the adjacent sheets to be seamed on a wooden support platform in order that horizontal seaming can be accomplished continuously to the end of the geomembrane sheets. The temporary support is removed after the seam is complete and the geomembrane is then allowed to drop into the anchor trench.

3. Destructive seam samples can be taken while the seamed geomembrane is temporarily supported in the horizontal position.

4. Nondestructive tests can also be performed while the seamed geomembrane is temporarily supported in the horizontal position.

5. The anchor trench is generally backfilled after the geomembrane has been documented by the CQA engineer, but may be at a later date depending upon the site specific plans and specifications.
Figure 8.9 - Various Types of Geomembrane Anchors Trenches (Dimensions are Typical and for Example Only).
6. The anchor trench itself should be made with slightly rounded corners so as to avoid sharp bends in the geomembrane. Loose soil should not be allowed to underlie the geomembrane in the anchor trench.

7. The anchor trench should be adequately drained to prevent ponding of water or softening of the adjacent soils while the trench is open.

8. Backfilling in the anchor trench should be accomplished with approved backfill soils placed at their required moisture content and compacted to the required density.

9. The plans and specifications should provide detailed construction requirements for anchor trenches regardless if soils or other backfill materials are used.

8.4.2 Other Geosynthetics

Since all geosynthetics, not only geomembranes, need adequate termination, some additional comments are offered for plans, specifications or CQA documents.

1. Geotextiles, either beneath or above geomembranes, usually follow their associated geomembrane into the same type of anchor trenches as shown in Fig. 8.9.

2. Geonets may or may not terminate in the anchor trench. Water transmission from beyond the waste containment may be a concern when requiring termination of the geonet within the geomembrane's anchor trench or in a separate trench by itself. Thus termination of a geonet may be short of the associated geomembrane's anchor trench. This is obviously a design issue and must be clearly detailed in the contract plans and specifications.

3. When used by themselves, geosynthetic clay liners (GCLs) will generally terminate in a anchor trench in soil of the type shown in Fig. 8.9. When GCLs are with an associated geomembrane, as in a composite liner, each component will sometimes end in a separate anchor trench. These are design decisions.

4. Double liner systems will generally have separate anchor trenches for primary and secondary liner systems. This is a design decision.

5. In all of the above cases, the plans and specifications should provide detailed dimensions and construction requirements for anchor trenches of all geosynthetic components.

6. The plans and specifications should also show details of how natural soil components, e.g., compacted clay liners and sand or gravel drainage layers, terminate with respect to one another and with respect to the geosynthetic components.

8.5 Access Ramps

Heavily loaded vehicles must enter the landfill facility during construction activities and during placement of the solid waste. Typical access ramps will be up to 5.5 m (18 ft.) in width and have grades up to 12%. The general geometry of an access ramp is shown in Fig. 8.10(a).
Figure 8.10 - Typical Access Ramp Geometry and Cross Section
The traffic loads on such a ramp can be extremely large and generally involve some degree of dynamic force due to the constant breaking action which drivers use when descending the steep grades. Note that the entire liner cross section must extend uninterrupted from the upper slope to the lower slope and in doing so must necessarily pass beneath the roadway base course. When working with a double lined facility this can involve numerous geosynthetic and natural soil layers. Further complicating the design issues is that drainage from the upper side slopes must communicate beneath the roadway base course layer or travel parallel to it and be contained accordingly. A reinforcing element (geotextile or geogrid) can be incorporated in the roadway base course material. This can serve several purposes; i.e., to protect long-term integrity of underlying systems, to minimize potential sliding failures, and to minimize potential rutting and bearing capacity failures. These are critical design issues and must be well defined in the plans and specifications.

Regarding recommendations for the contract specifications or CQA document, the following items apply:

1. Many facilities will limit the number of vehicles on the access ramp at a given time. Such stipulations should be strictly enforced.
2. Vehicle speeds on access ramps should be strictly enforced.
3. Regular inspection should be required to observe if tension cracks open in the roadway base coarse soils. This may indicate some degree of slippage of the soil and possible damage to the liner system.
4. Ponding of upper slope runoff water against the roadway profile should be observed for possible erosion effects and loss of base course material. If a drainage ditch or pipe system is indicated on the plans, it should be constructed as soon as possible after completion of the roadway subbase soils.
5. The roadway base course profile should be fully maintained for the active lifetime of the facility.

8.6 Geosynthetic Reinforcement Materials

For landfill and waste pile covers with slopes greater than 3 horizontal to 1 vertical (3H:1V), stability issues regarding downgradient sliding begin to be important. Additionally, the stability of primary leachate collection systems for landfill and waste pile liners with slopes greater than 3H : 1V is suspect at least until the solid waste material within the unit raises to a stabilizing level. Such issues, of course, must be considered during the design phase and the contract plans and specifications must be very clear on the method of reinforcement, if any. If reinforcement is necessary it can be accomplished by using geotextiles or geogrids within the layer contributing to the instability to offset some, or even all, of the gravitational stresses. Refer to Fig. 8.11(a) and (b) for the general orientation of such reinforcement, which is sometimes called “veneer reinforcement”.

The concept of using geogrid or geotextile reinforcement to support a liner or liner system when a new landfill is built above, or adjacent to, an existing landfill has recently been developed. The technique has been referred to as “piggybacking” when vertical expansions are involved, see Fig. 8.11(c). The main focus of the reinforcement is to provide stability against differential settlement which can occur in the existing landfill.
Figure 8.11 - Geogrid or Geotextile Reinforcement of (a) Cover Soil above Waste, (b) Leachate Collection Layer beneath Waste, and (c) Liner System Placed above Existing Waste ("Piggybacking")
Since geotextiles were described previously from a manufacturing standpoint and for separation and filtration applications, they will be discussed here only from their reinforcement perspective. Geogrids will be described from both their manufacturing and reinforcement perspectives.

8.6.1 Geotextiles for Reinforcement

The manufacturing of geotextiles was described in section 6.2 along with recommendations for MQC and MQA documents. Regarding CQC and CQA, the focus was on separation and filtration applications. Some specific recommendations regarding reinforcement geotextiles for a specification or CQA document are as follows:

1. A manufacturer's certification should be provided that the geotextile meets the property criteria specified for the geotextile that was approved for use on the project via the plans and specifications.

2. CQA personnel should check that the geotextile delivered to the job site is the proper and intended material. This is done by verifying the identification label and its coding and by visual identification of the product, its construction and other visual details.

3. Conformance samples of the geotextile supplied to the job site should be obtained as per ASTM D-4759. Typically, the outer wrap of the rolls are used for such sampling.

4. Conformance tests should be the following. Wide width tensile strength per ASTM D-4595, trapezoidal tear strength per ASTM D-4533 and puncture strength per ASTM D-4833. Additional conformance tests which may be considered are polymer identification via thermogravimetric analysis (TGA) and grab tensile strength, via ASTM D-4632.

5. Field placement of geotextiles should be at the locations indicated on the contract plans and in the specifications. Details of overlapping or seaming should be included.

6. Geotextile deployment is usually from the top of slope downward, so that the geotextile is taut before soil backfilling proceeds.

7. If the upper end of the geotextile should be anchored in an anchor trench, the details shown in the contract plans should be fulfilled.

8. Soil backfilling should proceed from the bottom of the slope upward, with a minimum backfill thickness of 220 mm (9 in.) of cover using light ground contact construction equipment of 40 kPa (6 lb/in²) contact pressure or less.

9. Seams in geotextiles on side slopes are generally not allowed. If permitted, they should be located as close to the bottom of the slope as possible. Seams should be as approved by the CQA engineer. Test strips of seams should be requested for conformance tests in the CQA laboratory following ASTM D-4884.
8.6.2 Geogrids

Geogrids are reinforcement geosynthetics formed by intersecting and joining sets of longitudinal and transverse ribs with resulting open spaces called "apertures". Two different classes of geogrids are currently available, see Fig. 8.12(a). They are the following: (a) stiff, unitized, geogrids made from polyethylene or polypropylene sheet material which is cold worked into a post-yield state, and (b) flexible, textile-like geogrids made from high tenacity polyester yarns which are joined at their intersections and coated with a polymer or bitumen. Figure 8.12 (b) shows geogrids being used as veneer reinforcement.

Some recommended contract specification or CQA document items that should be addressed when using geogrids as reinforcement materials are as follows:

1. A manufacturer's certification should be provided that the geogrid meets the property criteria specified for the geogrid that was approved for use on the project per the plans and specifications.

2. CQA personnel should check that the geogrid delivered to the job site is the proper and intended material. This is done by verifying the identification label and its coding and by visual identification of the product, its rib joining, thickness and aperture size. If the geogrid has a primary strength direction it must be so indicated.

3. Conformance samples of the geogrid supplied to the job site should be obtained as per ASTM D-4759. Typically, the outer wrap of the rolls are used for such sampling.

4. Conformance tests should be the following. Aperture size by micrometer or caliper measurement, rib thickness and junction thickness by ASTM D-1777, and wide width tensile strength by ASTM D-4595 suitably modified for geogrids. Additional conformance tests which may be considered are polymer identification via thermal analysis methods and single rib tensile strength, via GRI GG 1.

5. Field placement of geogrids should be at the locations indicated on the contract plans and in the specifications. Details of overlapping or seaming should be included.

6. Geogrid deployment is usually from the top of slope downward, so that the geogrid is taut before soil backfilling proceeds.

7. If the upper end of the geogrids are to be anchored in an anchor trench, the details shown in the contract plans should be fulfilled.

8. Soil backfilling should proceed from the bottom of the slope upward, with a minimum backfill thickness of 22 cm (9.0 in.) of cover using light ground contact construction equipment of 40 kPa (6 lb/in²) contact pressure or less.

9. Connections of geogrid rolls on side slopes should generally be avoided. If permitted, they should be located as close to the bottom of the slope as possible. Connections should be as approved by the CQA engineer. Test strips of connections should be requested for conformance tests in the CQA laboratory following ASTM D-4884 (mod.) test method.
(a) Various Types of Geogrids

(b) Geogrids Used as Veneer Reinforcement

Figure 8.12 - Photographs of Geogrids Used as Soil (or Waste) Reinforcement Materials
Often on sloping solid waste landfill covers soil loss in the form of rill, gully or sheet erosion occurs in the topsoil and sometimes extends down into the cover soil. This requires continuous maintenance until the phenomenon is halted and the long-term vegetative growth is established. Alternatively, the design may call for a temporary, or permanent, erosion control system to be deployed within or on top of the topsoil layer. Additional concerns regarding erosion control are on perimeter trenches, drainage ditches, and other surface water control structures associated with waste containment facilities. Listed below are a number of alternative erosion control systems ranging from the traditional hand distributed mulching to fully paved cover systems. They fall into two major groups; temporary degradable and permanent nondegradable.

**Temporary Erosion Control and Revegetation Mats (TERMs)**

- Mulches (hand or machine applied straw or hay)
- Mulches (hydraulically applied wood fibers or recycled paper)
- Jute Meshes
- Fiber Filled Containment Meshes
- Woven Geotextile Erosion Control Meshes
- Fiber Roving systems (continuous fiber systems)

**Permanent Erosion Control and Revegetation Mats (PERMs)**

- Geosynthetic Systems
  - turf reinforcement and revegetation mats (TRMs)
  - erosion control and revegetation mats (ECRMs)
  - geomatting systems
  - geocellular containment systems
- Hard Armor Systems
  - cobbles, with or without geotextiles
  - rip-rap, with or without geotextiles
  - articulated concrete blocks, with or without geotextiles
  - grout injected between geotextiles
  - partially or fully paved systems

Temporary degradable systems are used to enhance the establishment of vegetation and then degrade leaving the vegetation to provide the erosion protection required. Challenging sites
that require protection above and beyond what vegetation can provide need to use a permanent nondegradation system, i.e., high flow channels, over steepened slopes etc. Of these various alternatives, jute meshes, containment meshes and geosynthetic systems are used regularly on landfill and waste pile cover systems, see Fig. 8.13.

Some items which are recommended for contract specifications or CQA document for these particular systems are as follows:

1. The CQA personnel should check the erosion control material upon delivery to see that the proper materials have been received.

2. Water and ultraviolet sensitive materials should be stored in dry conditions and protected from sunlight.

3. If the erosion control material has defects, tears, punctures, flaws, deterioration or damage incurred during manufacture, transportation or storage it should be rejected or suitably repaired to the satisfaction of the CQA personnel.

4. If the material is to be repaired, torn or punctured sections should be removed by cutting a cross section of the material out and replacing it with a section of undamaged material. The ends of the new section should overlap the damaged section by 30 cm (12 in.) and should be secured with ground anchors.

5. All ground surfaces should be prepared so that the material lies in complete contact with the underlying soil.

6. Ground anchors, called “pins”, should be at least 30 cm (12 in.) long with an attached oversized washer 50 mm (2.0 in.) in diameter, or “staples” number 8 gauge “U” shaped wire at least 20 cm (8.0 in.) long. For less severe temporary applications e.g., TERMS’s, one may consider 15 cm (6 in.) number 11 gauge “U” shaped wire staples.

7. Adjacent rolls of erosion control material shall be overlapped a minimum of 75 mm (3.0 in.). Staples should secure the overlaps at 75 cm (2.5 ft) intervals. The roll ends should overlap a minimum of 45 cm (18 in.) and be shingled downgradient. The end overlaps should be stapled at 45 cm (1.5 ft) intervals, or closer, or as recommended by the manufacturer.

8. If required on the plans and specifications, the erosion control material should be filled with topsoil, lightly raked or brushed into the mat to either fill it completely or to a maximum depth of 25 mm (1.0 in.).

9. For geosynthetic materials used in drainage ditches, their overlaps should always be shingled downgradient with overlaps as recommended by the manufacturer or plans and specifications whichever is the greatest.

10. If required by the plans and specifications, the manufacturer of the erosion control or drainage ditch material should provide a qualified and experienced representative on site to assist the installation contractor at the start of construction. After an acceptable routine is established, the representative should be available on an as-needed basis, at the CQA engineer’s request.
Figure 8.13 - Examples of Geosynthetic Erosion Control Systems
8.8 Floating Geomembrane Covers for Surface Impoundments

In concluding this Chapter, it was felt that a short section on geomembrane floating covers for liquid wastes contained in surface impoundments is appropriate. These floating covers are geomembranes of the types discussed in Chapter 3. Hence all details such as polymer type, production, conformance testing, etc., are applicable here as well. The uniqueness of the application is that the geomembrane is always exposed to the atmosphere, thus subject to sunlight, heat, damage, etc., and furthermore it must be rigidly anchored to a concrete anchor trench or other similar structure, surrounding the perimeter of the facility, see Fig. 8.14.

Some items in addition to those mentioned in Chapter 3 on geomembranes that are recommended for a contract specification or a CQA document are as follows:

1. Acceptance of the geomembrane should have some verification as to its weatherability characteristics. The tests most frequently referenced are ASTM D-4355 and ASTM G-26. There is also a growing body of data being developed under the ASTM G-53 test method.

2. Other conformance tests, e.g., physical and mechanical property tests, are product specific and have been described in Chapter 3.
Figure 8.14 - Surface Impoundments with Geomembrane Floating Covers along with Typical Details of the Support System and/or Anchor Trench and Batten Strips
3. The anchorage detail for floating covers is critically important. Construction plans and specifications must be followed explicitly. To be noted is that there are very different anchorage schemes that are currently available. Some use concrete anchor blocks with embedded bolts which attach the geomembrane under a batten strip. Other anchorages are patented systems consisting of tensioned geomembranes attached to movable dead weights riding inside of stationary columns. Additional schemes are also possible. In each case the manufacturer’s recommendations should be cited in the contract documents and must be followed completely.

4. The manufacturer/fabricator of the floating cover should provide a qualified and experienced representative on site to assist the installation contractor at the start of construction. After an initial start-up point, the representative should be available on an as needed basis, at the CQA engineer’s request.

8.9 References

AASHTO M252-90, “Corrugated Polyethylene Drainage Tubing”
AASHTO M294-90, “Corrugated Polyethylene Pipe, 12- to 36-in. Diameter”
ASTM D-698, “Moisture Density Relations of Soils and Soil/Aggregate Mixtures”
ASTM D-792, “Specific Gravity and Density of Plastics by Displacement”
ASTM D-1238, “Flow Rates of Thermoplastics by Extrusion Plastomer”
ASTM D-1248, “Polyethylene Plastics and Extrusion Materials”
ASTM D-1505, “Density of Plastics by the Density-Gradient Technique”
ASTM D-1755, “Poly (Vinyl Chloride) (PVC) Resins”
ASTM D-1777, “Measuring Thickness of Textile Materials”
ASTM D-1785, “Poly (Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80 and 120”
ASTM D-2122, “Determining Dimensions of Thermoplastic Pipe and Fittings”
ASTM D-2241, “Poly (Vinyl Chloride) (PVC) Pressure Rated Pipe (SDR-Series)”
ASTM D-2321, “Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications”
ASTM D-2412, “External Loading Properties of Plastic Pipe by Parallel Plate Loading”
ASTM D-2444, “Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)”
ASTM D-3034, “Type PSM Poly (Vinyl Chloride) (PVC) Sewer Pipe and Fittings”
ASTM D-4254, “Maximum Index Density of Soils and Calculation of Relative Density”
ASTM D-4355, “Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus)"

ASTM D-4533, “Trapezoidal Tearing Strength of Geotextiles”

ASTM D-4595, “Tensile Properties of Geotextiles by Wide Width Strip Method”

ASTM D-4632, “Breaking Load and Elongation of Geotextiles (Grab Method)”


ASTM D-4833, “Index Puncture Resistance of Geotextiles, Geomembranes and Related Products”

ASTM D-4884, “Seam Strength of Sewn Geotextiles”

ASTM F-714, “Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter”


ASTM G-53, “Operating Light- and Water-Exposure Apparatus (Fluorescent UV - Condensation Type) for Exposure of Nonmetallic Materials”

GRI GG1, “Geogrid Rib Tensile Strength”