Review of specification and regulation of geomembranes for waste landfill application

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ABSTRACT: Geomembrane is a continuous membrane type barrier/liner composed of materials of low permeability to control fluid migration. The raw materials of geomembranes may be a polymeric or asphaltic or a combination thereof. The barrier applies when the geomembrane is used inside a soil mass and the liner is generally reserved for the cases where the geomembrane is used as an interface or a surface revetment. Also, geomembranes are made from various thermoplastic resins and are manufactured and distributed throughout the world, making all types of products readily available. In here, it is introduced that the overall concepts of geomembranes e.g., raw materials and manufacturing process, welding, performance and regulation etc. to applied to the lining and capping system of waste landfills.

Keywords: geomembrane, barrier/liner, waste landfills

1 INTRODUCTION

Geomembranes are generally used as water barrier materials in earth dams, canals, tunnels, artificial ponds constructions etc. Especially, geomembrane is the most important material for waste landfills and to be installed to capping, lining and slope systems. It was introduced that geomembranes in lining and capping applications. Especially, the case of waste landfill application as shown in Figure 1 was considered as main application and raw materials, manufacturing process and performance evaluation both index and field performance tests were mentioned. Most of this article is related to the general concepts of geomembranes. Figure 1 represents an example scheme of the geosynthetics composition of waste landfill capping system.

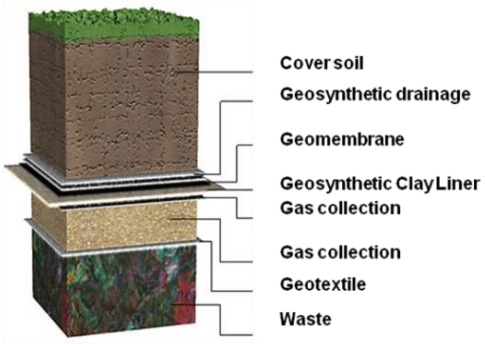


Figure 1. Schematic of geosynthetics composition of waste landfill capping system.

2 RAW MATERIALS AND MANUFACTURING OF GEOMEMBRANES

All General raw materials of geomembranes are high density polyethylene(HDPE), chlorosulphonated polyethylene(CSPE), polyvinyl chloride(PVC), polypropylene(PP), ethylene propylene diene monomer(EPDM), ethylene vinyl acetate(EVA) etc. Table 1 shows the classification of geomembranes and shows the composition of geomembranes with raw materials.

Table 1. Composition of geomembranes

Type	Resin	Plasticizer	Fillers	Carbon Black	Additives
HDPE	95-98	0	0	2-3	0.25-1
LLDPE	94-96	0	0	1-3	0.25-4
fPP	85-98	0	0-13	2-4	0.25-2
PVC	50-70	25-35	0-10	2-5	2-5
CSPE	40-60	0	30-40	5-10	5-15
EPDM	25-30	0	20-40	20-40	1-5

HDPE = high density polyethylene
LLDPE = linear low density polyethylene
fPP = flexible propylene
PVC = polyvinyl chloride (plasticized)
CSPE = chlorosulfonated polyethylene
EPDM = ethylene propylene diene terpolymer

Otherwise, some additives such as carbon black, anti-oxidant, filled agent, plasticizers etc. should be compounded for modification and improvement of performance of geomembranes. For example, polyethylene made geomembranes could be degraded by sunlight attack and show the strength decrease. To prevent this from degradation for HDPE geomembranes, anti-oxidants as HALS(hindered amine as light stabilizers) should be added to increase the weatherability performance. Also, long-term performance and durability of geomembranes could be improved due to the longer oxidation induction time when the surface of HDPE geomembrane would be damaged during service life. Some kinds of manufacturing methods are introduced to make geomembranes with different raw materials and manufacturing process. In here, we would like to classify two main products namely, smooth and textured type geomembranes and then their manufacturing processes as following. Raw materials of these manufacturing processes are HDPE, PP, PVC etc. and special control should be needed for rubberlike geomembranes manufacturing.

1) Smooth and blown type geomembranes

Geomembranes are extruded through flat and circular dies with sheet form and then engineering performance are determined by roll drawing. Smooth type geomembranes are from flat die extrusion and blown type geomembranes are from circular die extrusion in Figure 2 (a) and (b), respectively. For these geomembranes, clear difference of thickness in MD(Mechanical Direction) and CMD(Cross Mechanical Direction) between these may be occurred as shown in Figure 3. This thickness difference could influence the welding efficiency and mechanical properties of geomembranes and therefore, this must be carefully controlled by winding and drawing process under optimum temperature and roll speed.

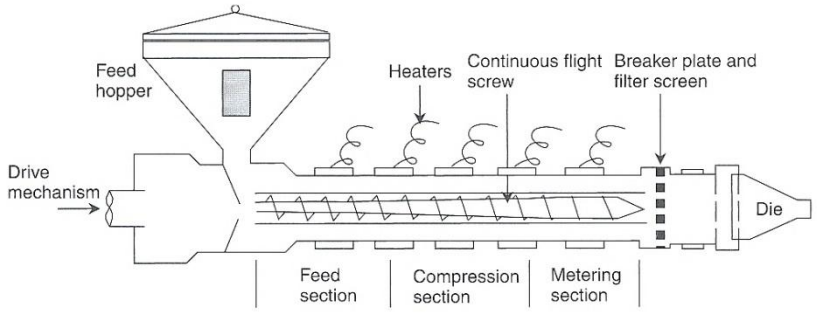
2) Textured type geomembranes

To improve the frictional property of geomembrane, surface of geomembrane should be modified and some special treatment could be done by using spray-on, coating and co-extrusion processes etc. This is very important to modify the surface frictional property between or among geomembrane and filled soils, geosynthetics in waste landfills. Figure 4 shows the textured geomembranes manufacturing process.

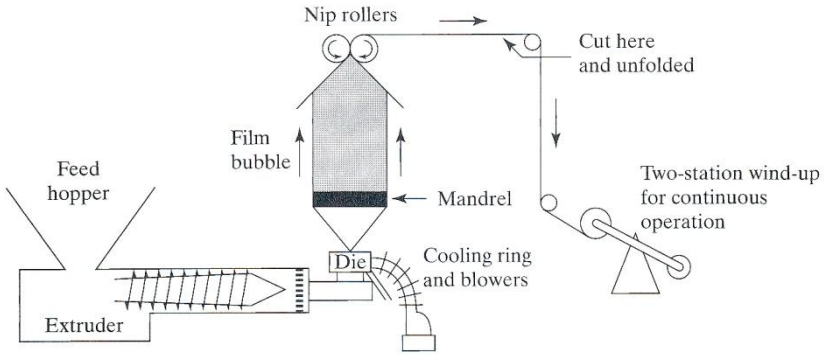
① Blown coextrusion type geomembranes
* 3 layer composed coextrusion die and blowing agents for bubble formation are used.
* Advantages - low manufacturing costs needed due to uniform manufacturing process.
- Very strong bonding between interlayer of geomembranes.
* Disadvantages - Difficult to make differential surface structure geomembrane.
- Decrease of welding efficiency due to the textured surface structure.

② Spray on type geomembranes
* To spray extrusion polymer to surface of smooth type geomembranes.
* Processing parameters
- spray temperature, distance between geomembrane and spray nozzle, sprayed coating foam size etc.
* Advantages - To make the uniform textured surface of geomembranes
- Little weight increase of geomembranes by coating.

* Disadvantages - Higher manufacturing cost is needed to setup the spray coating system.
- Slow production rate.



(a) Flat die extruder



(b) Circular die extruder

Figure 2. Geomembrane manufacturing extruder.

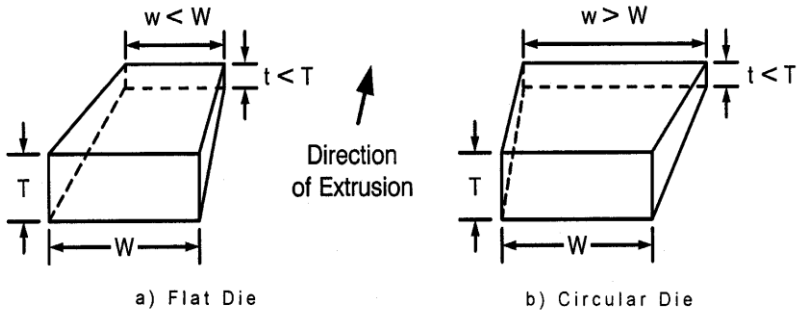


Figure 3. Draw-down of geomembranes at extrusion die exit.

③ Hot embossing type geomembranes
* Convex and concave structure calendar are adapted to the extrusion die.
* Different structure of both surface sides of geomembranes is manufactured.
* Advantages - Manufacturing both different surface geomembranes is available.
- Possible to make geomembranes having uniform friction angle.
* Disadvantages - Higher manufacturing cost needed to install facilities.
- Limit of geomembrane width.

④ Extrusion coating type geomembranes
* Extrusion coating to the surface of smooth geomembranes and same manufacturing process as blown coextrusion process.
* Advantages - Easy to quality control of geomembranes.
- No intrusion of blowing agent into inner side of geomembranes.
* Disadvantages - Difficult to operation of continuous manufacturing geomembranes.
- Low reproducibility of same geomembrane manufacturing.

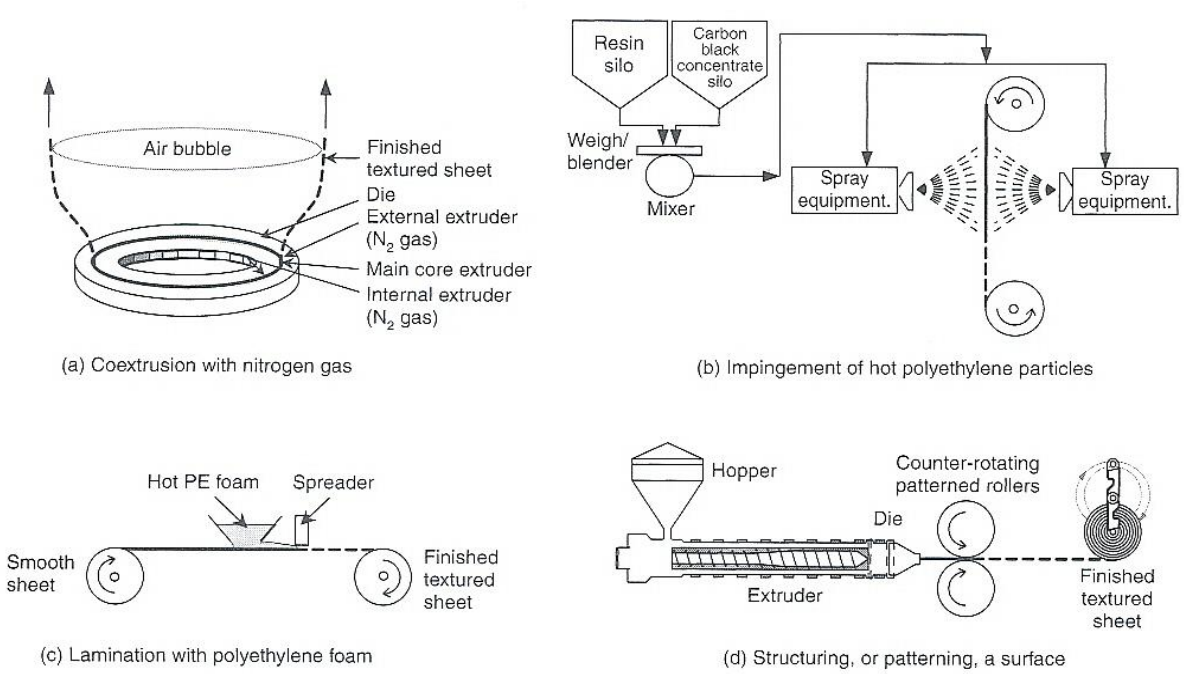


Figure 4. Textured geomembranes manufacturing processes.

3 ADVANCED TECHNOLOGY OF GEOMEMBRANES

Hybrid type geomembranes which have combination of reinforcement and separation functions besides typical barrier function would be needed and the following is only its research trend by geomembrane type.

1) Smooth type geomembranes
   ① Thickness variation
   ② Improvement of OIT(Oxidation Induction Time) and stress cracking resistance etc.
   ③ Applications of new materials- PU, PVA etc.
   ④ Modification of welding technology etc.
2) Textured type geomembranes
   ① Development of one or both side textured geomembranes
   ② Modification of welding technology etc.
3) Reinforced Type geomembranes
   ① Development of hybrid manufacturing process
   ② Creation of specialty end-uses
   ③ Manufacturing multi-functional geomembranes etc.

4 MQC/MQA AND CQC FOR GEOMEMBRANES

MQC/MQA and CQC/CQA are very important system to manage and keep the geomembranes performance during installation period through prepared analysis of index and field tests of geomembranes. It is very serious and dangerous if geomembrane manufacturing process has the unsolvable problem not to keep the optimum performance constantly. This is a main cause of installation failure and will not provide the reliability of construction structure. From the effective MQC/CQC and MQA/CQA management, the best construction condition will be prepared. Therefore, the requirements of soil structure and geomembranes are essential for waste landfill construction. The following is this related content of CQA of geomembranes.

5 WELDING OF GEOMEMBRANES

Geomembrane welding is very important to maintain the barrier function during service period in waste landfills and this can provide the protection barrier from the environmental pollution by leakages. If the failure of welded part of geomembranes is occurred, this means the serious ground pollution and therefore, the most effective welding of geomembranes should be needed. Stress concentration of geomembranes on welded part could be the main cause of failure and this is due to welding method and condition, geometrical structure of welded part etc. Extrusion welding, wedge welding, hot air welding, ultrasonic welding, solvent welding, bonding agent welding etc. are generally used as welding of geomembranes. However, the welding method and weld ability of geosynthetics especially, geomembranes and the optimum welding method should be selected by considering the properties of raw material of geomembrane.

6 PERFORMANCE AND REGULATION GUIDE OF GEMEMBRANES

In here, something important test items for geomembranes performance are introduced. In general, evaluation methods of geomembranes performance for waste landfill application would be dependent on the used polymer properties and be done in accordance with ISO and ASTM Internationals' test methods and sometimes GRI Test Methods, prEN ISO, ISO/CEN are applied for this.

The following is a kind of test items for geomembranes performance testing and stress cracking and OIT(Oxidation Induction Time) are emphasized as the most important test item to evaluate the long-term performance of geomembranes in waste landfill application. The following is the general test items of geomembranes for waste landfill applications.

1) Physical Properties
   - ① Density : ASTM D 1505
   - ② Weight and Thickness : ASTM D 5199, ASTM D 5994
   - ③ Contents of Carbon Black and Dispersity : ASTM D 1603, ASTM D 5596
   - ④ Melt Flow Index(MFI)
   - ⑤ Water Vapor Transition(WVT)
   - ⑥ Solvent Vapor Transition(SVT) etc.

2) Mechanical Properties
   - ① Tensile Property : ASTM D 638 Type VI
   - ② Tear Strength : ASTM D 1004, Bursting Strength, Impact Strength, Puncture Resistance : ASTM D 4833
   - ③ Peel and Shear Strength
   - ④ Direct Shear and Pullout Properties etc.

3) Durability
   - ① Oxidation Induction Time(OIT)
   - ② Environmental Stress Cracking Resistance(ESCR) etc.

4) Weatherability

① Stability to temperature, thermal oxidation, hydrolysis etc.
② Chemical and biological resistance
③ UV resistance etc.

The following(above) means an example of regulation of geomembranes to Oxidation Induction Time(OIT) and Environmental Stress Cracking Resistance(ESCR) in European countries and it is seen that OIT is about 115 minutes with MQC. The following(below) shows the GRI GM 13 which is recommended by GSI(Geosynthetic Institute, Folsom, PA, USA) as a geomembranes certification related test method could involve the test items and it is seen that certification of geomembranes performance must be done to include all the durability related test items essentially.

• SCR SPECIFICATION	(>200 HR)
• SCR COVERED	234 HR
• SCR EXPOSED 9 YEARS	124 HR
• OIT QC TESTS	101-115 MIN
• OIT COVERED (SEAM) 9 YEARS	46 MIN
• OIT EXPOSED 9 YEARS	4 MIN
• SCR UNNOTCHED APEX DOWN FOLD	38 HR
• SCR UNNOTCHED APEX UP FOLD	>200 HR

- THICKNESS
- DENSITY
- UNIAXIAL TENSILE PROPERTIES
- TEAR RESISTANCE
- PUNCTURE RESISTANCE
- CARBON BLACK CONTENT
- CARBON BLACK DISPERSION
- *STRESS CRACK RESISTANCE* (SCR)
- *OXIDATIVE INDUCTION TIME* (OIT 200C)
- OVEN AGING AT 85°C (RETAINED OIT)
- UV RESISTANCE (RETAINED OIT)

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