Drawing of a security plan about geosynthetics

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ABSTRACT: The work reports the characteristics of a security plan concerning the utilization of geo-synthetics, according to the Italian Law # 494/96. Geo-synthetics are mainly utilized in works of restoration of old landfills and construction of new landfills. The following three types of material will be analyzed: 1. Geo-synthetics for drainage of leachate and biogas; 2. Geo-synthetics for drainage of water; 3. Geo-synthetics for stabilisation of slope cover soil.

1 INTRODUCTION

The Italian Law # 494/96, receipting the European Community instruction # 92/57/CEE, foresees a "plan of security" to be drawn in the executive design of complex or dangerous civil works. The plan must be drawn by an entitled technician charged by the commitment. The Decree aims at introducing a new quality standard in the field of security involving all the subjects concerned by the design and realization of public and private works. Planning the security of the working-place is a global task concerning commitment, designer and companies, pointing at the assessment of any phase of the work and out-singling of the relevant risks and safety measures, with the ultimate scope of decreasing the number of industrial accidents.

In this case, the assessment of the security plan concerning the utilization of geo-synthetics is reported. Geo-synthetics are mainly utilized in works of restoration of old landfills and construction of new landfills. The following three types of material will be analyzed:

1. Geo-synthetic for drainage of leachate and biogas. This is a draining geocomposite made up of a HDPE geonet. The last is imbedded between two polypropylene nonwoven geotextiles, either welded or draw. This material may be employed for landfill cover to form the drainage layer that is laid between the regularization soil (that covers the wastes) and the capping impervious layer. Its function is that of draining biogas and condensation water. When the cover is sloping, the geocomposite may intercept and collect possible shallow escapes of leachate. This material may also be used in place of the 0.30 m thick drainage-layer (normally made up of natural aggregates).
2. Geo-synthetic for drainage of meteoric water. This is a draining geocomposite made up of a nylon geonet (with high draining capacity), imbedded between two nonwoven geotextiles. It is utilized in the cover of landfills to make the drainage layer between the cover soil and the waterproofing layer. Usually, this material is used in place of the 0.30 m thick drainage-layer made up of natural aggregates.
3. Geo-synthetic for stabilisation of soil. This may consists of a single material, having the double function of three-dimensional anchoring and of resistance to the shear induced by the cover soil, or may consists of two distinct materials aiming at the same scopes: their employment allows stabilization of the slope cover soil even in presence of a waterproofing HDPE membrane. In the case of double material, a light, flexible geocomposite (made up of a three-dimensional anchoring polyamide-layer with random distribution) and a polyester geogrid with variable resistance, are utilized. The two components are laid separately by overlapping the geogrid to the geonet. The type of geogrid depends on the resistance to shear required by the design. The

maximum long-term strain of the geotextile must be calculated by taking into consideration the ultimate breaking resistance and the safety factors for creeping and failure.

2 CHARACTERISTICS OF THE PLAN

2.1 *Characteristics of the geocomposite and of its elements*

The relevant characteristics of the geocomposite, under the nor-mal conditions of employment, must be singled out in the security plan. Usually, these characteristics must be verified by means of lab tests before the emplacement of the material. These are listed in Table 1. The characteristics for filtering nonwoven are given in Table 2.

Table 1. Characteristics to specify for the geocomposite

Characteristic	Measurement units	Norm
Draining capacity	m^2/s	EN 12958
Unit weight	g/m^2	EN 965
Thickness	mm	EN 964-1
Resistance to traction	kN/m	EN 10319
Strain	%	EN 10319

Table 2. Characteristics to specify for filtering nonwoven

Characteristic	Measurement units	Norm
Polymer and union		
Unit mass	g/m^2	EN 965
Thickness	mm	EN 964
Resistance to longitudinal traction	kN/m	EN 10319
Strain at breaking	%	EN 10319
Pore opening O_{90}	mm	EN 12936
Permeability	$l/s/ m^2$	EN 12040

2.2 *Geometric characteristics of the material*

The specification of these characteristics allows proper planning of the location, storage, moving, and safe conservation of the material. These are: model, thickness (mm), weight (g/m^2), length (m), width (m), area (m^2), roll weight (kg).

2.3 *Other characteristics to specify for the sake of security*

For the sake of security of the working place, the material characteristics reported in Table 3 must be singled out in the plan, as well.

3 DESIGN OF THE WORKING PLACE

The plan of security must include a position plan showing a possible lay-out of the working place with the general location of the following facilities, at least:

1. Plants and networks for electricity, power, gas and water.
2. Barrack-sites and areas of storage of construction materials.
3. Possible silos for bentonite/cement/other.

4. Areas of temporaneous storage of geocomposites and geo-synthetics.
5. Areas for storage of special materials.
6. Access and service roads.
7. Temporaneous enclosure of the working place area.
8. Other characteristic elements of the specific working place.

Table 3. Other characteristics to specify

Characteristics
Toxicity at the contact
Release of toxic substances for abrasion or cut
Toxicity in case of fire
Fusion point
Resistance to chemical attack of the substances normally present in the soil
Resistance to chemical attack of specific agents in contaminated soils
Resistance to synthetic leachate
Inflammability
Minimum temperature suggested for the employment
Maximum temperature suggested for the employment
Resistance to weathering

Any of these elements must be singled out and must be thoroughly described at the scope of evaluating the relevant costs, location and possible technical or employment prescriptions. In particular, the area where the geo-synthetics will be piled up must be flat, protected from rain and wind, far from fire sources, and far from aggressive substances. Often, the rolls are longer than 5 meters: it is than necessary that the storage area be greater than 7 x 3 m, such to allow piling up of a roll over a base of two other rolls. The maneuver room for temporaneous piling up and for roll moving must be adequately dimensioned, such to prevent from damage to other materials during removal operations. In case of roofed place, the height of the storage area must be such to allow easy movement of the means.

4 EMPLACEMENT METHODOLOGY

The main working risks concerning the emplacement of the geo-synthetics are the followings: contact with leachate, fall from the slope, crushing by mechanic means, cut or abrasion injuries. Ac-cording to the emplacement conditions and the type of material, three possible operation methodologies may be envisaged for the employment of geo-synthetics:

1. GRAVITY - In the gravity system the material is anchored to the top of the slope with a definitive trench or by means of appropriate mechanic means and, then, is unrolled by gravity fall. This system is possible in case of short and low inclination slopes and when there is no risk for activities at the foot of the slope.
2. DESCENT - In this system the material is anchored to the top of the slope by means of mechanic means or a stable support. It is unrolled by sliding along the slope at a slow rate controlled by a worker team. This system is possible in case of moderate inclination slopes, when the material must be directly laid on the ground (not overlapped to a HDPE geo-membrane).
3. PULLING - In severe morphologic conditions the material must be anchored to the top on an appropriate support pro-vided with a system to aid the rotation of the roll core. After fixing one or more ropes to the free end of the material, the last may be slowly unrolled by pulling from the foot of the slope.

5 POSSIBLE CONDITIONS OF EMPLACEMENT

5.1 *Geocomposite for drainage of leachate and biogas*

This may be utilized directly into contact with the terrain to be drained. Hence, its field of application is not confined by particular constraints concerning the slope inclination.

According to the slope inclinations, the following systems may be used for the emplacement (with reference to the systems listed in the previous chapter):

1. Employment in slope with $\alpha < 30°$: systems 1, 2, 3
2. Employment in slope with $\alpha > 30°$: systems 1, 3
3. Employment in plain (drainage layer on covers): systems 1, 2, 3

5.2 *Geocomposite for drainage of runoff water*

This is utilized for draining slope and ground runoff. On-slope, the most frequent emplacement is over the waterproofing layers and under the filling vegetal soil. The HDPE membrane and the cover vegetal soil set severe constraints to the maximum inclination of the slopes. Furthermore, in case of slope > 18° it's extremely hard to maintain a stable equilibrium while moving the geocomposite over the HDPE geomembrane, even when the last is rough. So, the following systems may be used for the em-placement:

1. Employment in slope with $\alpha < 18°$, on rough HDPE: systems 1, 2, 3
2. Employment in slope with $\alpha > 18°$, on rough HDPE : systems 1, 3
3. Employment in slope, on smooth HDPE: systems 1, 3
4. Employment in plain: systems 1, 2, 3

5.3 *Geocomposite for soil stabilization*

In this case, the most frequent employment is that of a friction layer in reclamation of old landfills or landslide remediation. The material may be placed on rough/smooth HDPE or on a draining geocomposite. The following systems can be distinguished:

1. Employment in slope with $\alpha < 18°$, on rough HDPE: systems 1, 2, 3
2. Employment in slope with $\alpha > 18°$, on rough HDPE : systems 1, 3
3. Employment in slope, on smooth HDPE: systems 1, 3
4. Employment in slope with $\alpha < 18°$, on draining geocomposite: systems 1, 2, 3
5. Employment in slope with $\alpha > 18°$, on draining geocomposite: systems 1, 2, 3

6 RISK ASSESSMENT CARD

An information card regarding the emplacement of materials is to be drawn in the security plan. The first page of the card is of a general nature; it contains the followings:

- Description of the working phases.
- Possible risks.
- Safety measures and worker's protection equipment.
- Instruction for the personnel.
- Procedures to be followed in case of emergency.
- Dimension of materials.
- Indications concerning the information, the formation and the security signaling.

Other detail pages of the card contain: singling of the elementary working activities and relevant risks; safety measures and worker's protection equipment. One single risk assessment card is to be drawn for any application of geo-synthetics.

7 COSTS OF SECURITY

7.1 *Man-days estimation*

"Daily productivity cards" must be attached to the plan aiming at the estimation of the duration of each activity and number of workers required, on the base of the design data. The final value must be a provisional figure for the number of working-place man-days. These cards will report the daily productivity of a type-working-team, by singling out the working means required to support the workers.

7.2 *Security cost estimation*

The present norm foresees that the plain must quantify the security costs. These can be distinguished into the following two categories.

7.2.1 *Working place fix costs*

This category includes all cost items pertaining the enterprise organization of the working-place security, whatever the working activity and the number of workers. It includes: bureau, barracks, dressing-rooms, sanitary services, electric plants, posters, medical presidium. Such facilities are to be considered of promiscuous utilization during the working-place life, with consequent weighted repartition of relevant costs.

The general enterprise cost due to security verification and maintenance of machinery, plants and equipment, the costs due to workers formation and information about the utilization of the equipment are included in this category, as well.

The weighted repartition of costs belonging to this category is made in function of the daily number of workers at work, as well as in function of the complexity of the enterprise organization, of the typology of machines, plants and equipment utilized in the works that any company took by contract. Four different levels of cost are distinguished, according to incidence of machinery required by the working activities:

Level 1: low incidence activity. These require minor utilization of working-place machines (laying of geo-membranes, drainage geo-composite, anti-erosion).

Level 2: fair incidence activity. These require normal utilization of working-place machines, fairly distributed with the employment of labor and material (reinforced concrete simple works, green works, and so on).

Level 3: high incidence activity. These require utilization of working-place machines prevailing on the employment of labor (excavations, earth displacements, clay constipation).

Level 4: specialized activity. These require utilization of specialized machinery, characterized by strong transport, control and maintenance burdens (diaphragms, special foundations).

7.2.2 *Cost of each single activity*

This category includes all cost items deriving from the analytic risk evaluation reported in the cards. The costs concern the safety measures of each activity and, consequently, they are directly related to the number of workers employed in a given working (individual security equipment, formation and information, medical examinations, pro-capite share of the security general and organization expenses).

8 COST ASSESSMENT WITH GEO-SYNTHETICS

An example of security cost assessment, concerning the em-placement of a drainage geocomposite on a slope, is hereinafter reported.

8.1 *Working place fix costs*

The items reported in Table 4 must be quantified.

Table 4. Working place fix costs

Activity	Unit cost (Euro)	Quantity	Total cost
Enclosure	6.2	2000	12400.0
Dressing-room	258.2	1	258.2
Bureaus	309.9	1	309.9
Electric plant	1032.9	1	1032.9
Viability	1.8	750	1350.0
Signaling	25.8	50	1290.0
Water control	4.1	500	2050.0
Plants	1032.9	1	1032.9
Medical pack	15.5	1	15.5
First-aid box	56.8	1	56.8
Total			*19814.0*

The daily incidence of the working place fix cost results of 79.2 Euro/day, be the duration of the work set to 250 days.

According to the time-operation schedule (this must be provisionally drawn in the design phase) it's possible to charge a part of these general expenses on the security of each single working activity.

For instance, in the hypothesis that the slope regularization be made contemporaneously to the laying of the geomembrane, to the laying of the reinforcement system, as well as to the emplacement of the vegetal soil and hydroseeding, the daily incidence for the drainage geocomposite is the 20% of the total figure, equal to 15.8 Euro/day.

The fixed expenses for low incidence activity (Level 1) must be added to that value. Such expenses must be foreseen for any working place of duration > 1 year in the amount of 1291.1 Euro. Dividing the last for 225 working days/year, a daily incidence of 22.7 Euro is calculated.

8.2 *Laying of geo-synthetics: security costs*

A productivity card must be drawn for any employment of geo-synthetics. From this card, the average productivity of the working-place can be calculated. The type-team is formed by: one worker to the lorry (30%), one worker to the excavator (100%), and three support workers (100%).

For instance, an average working-place may show up a productivity of about 400 m^2/day. In Table 5, the minimal security equipment for 5 workers charged with the laying of the drainage geocomposite is reported.

8.3 *Total daily cost*

The total daily cost for the activity is of 49 Euro. This is given by the sum of the followings:

1. Working place fixed cost: Euro 15.8
2. Fixed cost and general expenses for Level 1 activity: Euro 22.7
3. Cost for the laying of geocomposite: Euro 10.5

As the daily productivity was set to 400 m^2/day, the incidence of the security for each square meter of draining geocomposite is of 0.122 Euro/m^2. This amount is charged on the enterprise and can't be the subjected to tender discount.

Table 5. Security equipment for the laying of drainage geocomposite

Cost item	# of Workers	Unit cost (Euro)	Annual consumption	Annual cost (Euro)	Use (%)	Cost per day (Euro)
Shoes	5	28.4	2.00	284.0	100	1.30
Gauntlets	5	2.6	6.00	77.5	100	0.30
Overall	5	17.6	1.00	87.8	100	0.40
Noise headset	5	15.0	0.50	37.4	50	0.08
Safety belts	5	38.7	0.25	48.4	20	0.04
Mask	5	1.3	10.00	67.1	30	0.07
Goggles	5	7.7	1.00	38.7	10	0.02
Helmet	5	12.9	1.00	64.6	80	0.20
Information, formation	5	258.2	1.00	1291.1	100	5.70
Medical checks	5	103.3	1.00	516.4	100	2.30
Daily cost						*10.5*

9 CONCLUSIONS

The security cost is not strongly significant in this type of material. Anyway, the cost may vary according to the operative conditions, the duration of the working-place, the infrastructures, the activities contemporaneously carried out, the efficiency of the workers, the environmental conditions, and the particular measures to be taken for guaranteeing the security of the working-place.

The design co-ordinator must thoroughly evaluate the working-place and the working activities and then he must draw a security plan based upon a precise analysis of the security problems. Then, the content of the present paper must be read as an aid for the co-ordinator during the design phase and is not in-tended applicable, as it is, to any typology of intervention.