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Assessment of Geosynthetic Properties of Rubber Reinforced Composites

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고무강화 복합재료의 지반용 특성 평가

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ABSTRACT : Rubber related geosynthetics(GS) as reinforcement and water barrier materials were manufactured by thermal bonding method and examined the their performance for applications to civil and environmental engineering fields. The spunbonded polyester nonwoven, fiber glass mat and fabric type geogrid of a high tenacity polyester filament were used as matrix and polyester film, elastomeric bitumen with SBS polymer and asphalt were used as reinforcements to manufacture the rubber related geosynthetics. A fiber glass mat and geogrid matrix GS showed more excellent mechanical properties and nonwoven and elastomeric bitumen matrix showed the more excellent permittivity. Softening points of rubber and asphalt mixture showed no difference and dimensional stability at high temperature, 120℃, represented no significant shrinkage. Resistance to ultraviolet of rubber related geosynthetics showed no visible alteration.

요 약 : 보강 및 차수재인 지반용 고무재료를 열융착법에 의해 제조하였으며 환경공학분야에 적용을 위해 성능을 평가하였다. 이들 재료를 제조하는데 스펀본드 폴리에스테르 부직포, 유리섬유매트, 고강력 폴리에스테르사를 이용한 직포형 지오그리드를 기재로, SBS 함유 탄성 bitumen과 아스팔트를 보강재로 각각 사용하였다. 유리섬유 매트와 지오그리드를 기재로 사용한 지반용 재료의 경우 역학적 성질이 우수하였으며, 부직포와 탄성 bitumen을 기재로한 경우에는 투수성이 우수하였다. 고무와 아스팔트를 혼합한 경우 연화점은 거의 변화가 없었으며, 고온에서의 치수안정성은 120℃의 경우 두드러진 수축이 발생하지 않았다. 지반용 고무재료의 자외선에 대한 저항성은 가시적인 변화가 나타나지 않았다.

Keywords :rubber related geosynthetics, bitumen, thermal bonding, permittivity, softening point.

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I. Introduction

Geosynthetics(GS) having special functions such as protection, reinforcement, filtration, drainage, water/vapor barrier have been widely used in the fields of civil and environmental applications.[1-3] Among these materials, elastomeric bitumen geomembranes combined with SBS(Styrene-Butadiene-Styrene) polymer and asphalt with puncture resistant geosynthetics are able to consistently maintain their integrity in an ever-changing, inconsistent environment. These rubber related geosynthetics have the functions of water barrier, crack resistance, shrinkage resistance at high temperature, high break and tear resistance, etc..[4-6] These geosynthetics are used in the fields to be applied excessively high hydrostatic pressure and special substrate or overlay conditions. End-uses of these geosynthetics are asphalt overlay, embankment stabilization, reinforcement in high stress areas, harsh weather region, asphalt resurfacing over portland cement concrete, airfields, railroad under ballast, flexible membrane liner for canals, dams, waste water storage, reservoirs and ponds, bridge decks, etc..[7-9] In this study, 4 types of rubber related geosynthetics as reinforcement and water barrier materials were manufactured to examine the performance for applications to civil and environmental engineering fields, and their geosynthetic related properties were examined and interpreted.

II. Experimental

1. Preparation of samples

1.1 Raw materials

Spunbonded polyester nonwoven(12 denier, 300g/m^2), fiber glass mat(3750g/m^2), fabric type geogrid(design strength 8 ton) of high tenacity polyester filament were used as matrix of rubber related geosynthetics. Polyester film(thickness 0.1 ㎜), elastomeric bitumen with SBS polymer and ready made asphalt supplied by company were used as reinforcements and binding materials to manufacture the rubber related geosynthetics.

2. Manufacturing of rubber related geosynthetics

Thermal bonding machine to be equipped the heating rollers was used to manufacture the elastomeric bitumen geomembranes and heating roller was designed to control the bonding temperatures and pressures. The range of bonding conditions were as following : (a) temperatures : 250~300℃, (b) pressures : 4~10kgf, (c) times : 5~20min. Flow charts of manufacturing process are represented to Figure 1 and Schematic diagrams of 4 types of rubber related geosynthetics-fiber glass mat based geosynthetic(FGMGS), nonwoven based geosynthetic(NWGS), geogrid based geosynthetic(GGGS), elastomeric bitumen based geosynthetic(EBGS) are represented in Figure 2.

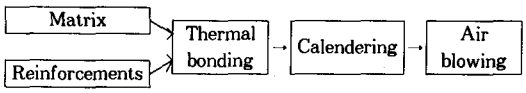
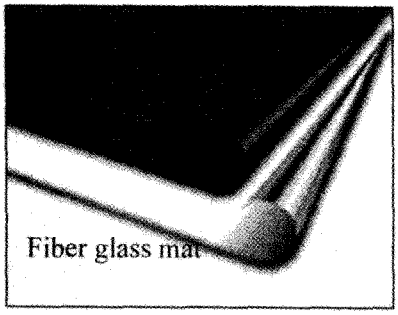


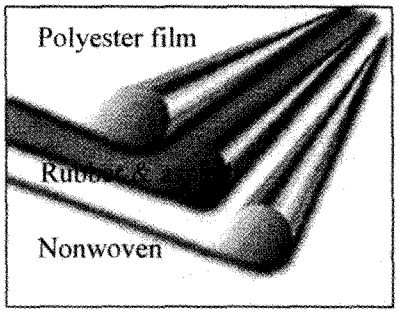
Fig. 1. Flow charts of manufacturing process of rubber related geosynthetics.

3. Measurements of geosynthetic related properties

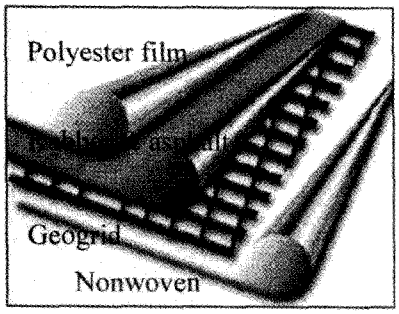
The following properties of the rubber related geosynthetics as reinforcement and water barrier



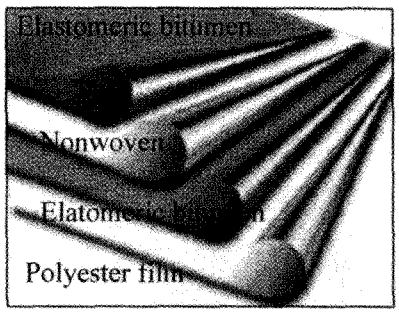
(a) Fiber glass mat based(FGMGS)



(b) Nonwoven based(NWGS)



(c) Geogrid based(GGGS)



(d) Elastomeric bitumen based(EBGS)

Fig. 2. Schematic diagrams of rubber related geosynthetics.

materials for civil and environmental end-uses were mainly estimated in accordance with ASTM related test methods.

(1) Mechanical properties
  ① Tensile properties-ASTM D 4632 : Strength and strain values at break
  ② Tear and puncture strength values-ASTM D 4533, 4833
(2) Hydraulic properties-ASTM D 4491
(3) Softening point of rubber asphalt-ASTM D 36
(4) Dimensional stability at high temperature (120℃)-UNI 8202
(5) Resistance to ultraviolet-ASTM D 4355

III. Results and Discussion

1. Mechanical properties

1.1 Tensile properties

Geosynthetics for reinforcement must have the optimum tensile strength and strain to sustain the structural stability. Especially, tension in geosynthetics is equal to the allowable stress times the unknown thickness by equation (1).

$$T=\sigma_{allow}t=\frac{T_{ult}}{RF}t \quad (1)$$

where,

T : tension mobilized in the geosynthetics
σ_{allow} : allowable stress of geosynthetics
T_{ult} : allowable tension of geosynthetics

t : thickness of the geosynthetics

RF : total reduction factors of safety for geosynthetics

Table 1 shows the tensile properties of rubber related geosynthetics. FGMGS showed the highest tensile strength and EBGS showed the highest strain at break but the strains of these were increased. From this, it was seen that FGMGS is the most excellent reinforcing material among 4 types of geosynthetics without respect to manufacturing process. Also, it was seen that tensile properties of these geosynthetics were improved by making composite materials and were increased in the case of thicker geosynthetics.

Table 1. Tensile Properties of Rubber Related Geosynthetics

Geosynthetics / Properties	FGMGS (FGM)	NWGS (NW)	GGGS (GG)	EBGS (NW)
Stress at break (kg)	1,184 (1,157)	477 (465)	846 (822)	647 (465)
Strain at break (%)	17* (3.5)	42* (46.3)	34* (17.6)	58* (46.3)

FGM : fiber glass mat, NW : nonwoven,
GG : geogrid
*: values at the first break point

2. Tear and puncture properties

Table 2 represents tear and puncture strength values of rubber related geosynthetics. Tear and puncture properties of 4 types geosynthetics are showing same tendency of tensile properties. It was shown that FGMGS and GGGS are the most suitable materials for reinforcement with respect to their tensile properties.

3. Hydraulic properties

Geosynthetics which have the water barrier function play an important role as flexible membrane liners to prevent liquid migration and to reservoir specific liquids for waste landfill system. In general, permittivity(Ψ) of geosynthetics is determined from Darcy's formula, equation (2), as follows :

$$Q=k_n i A=k_n \frac{h}{t} A \tag{2}$$

and

$$\Psi=\frac{k_n}{t}=\frac{Q}{(\Delta h)(A)} \tag{3}$$

where, Q : flow rate

k_n : hydraulic conductivity

t : thickness of the geosynthetics

i : hydraulic gradient

Δh : total head lost

A : total area of geosynthetics

From equation (3), it is known that permittivity of geosynthetics depends on each hydraulic conductivity and thickness of the composed geosynthetics. Table 3 represents the hydraulic properties of rubber related geosynthetics. In here, it was seen that 4 type geosynthetics have good hydraulic properties but EBGS has the highest permittivity.

Table 2. Tear and Puncture Strength Values of Rubber Related Geosynthetics

Geosynthetics / Properties	FGMGS (FGM)	NWGS (NW)	GGGS (GG)	EBGS (NW)
Tear strength(kg)	857 (819)	276 (248)	422 (412)	324 (248)
Puncture strength(kg)	132 (126)	22 (17)	34 (26)	25 (17)

FGM : fiber glass mat, NW : nonwoven,
GG : geogrid

Table 3. Hydraulic Properties of Rubber Related Geosynthetics

Geosynthetics	FGMGS (FGM)	NWGS (NW)	GGGS (GG)	EBGS (NW)
Permittivitty ($\times 10^{-15}\ \ell$/min/m^2)	4.7 (*)	5.8 (**)	5.5 (***)	9.6 (**)

FGM : fiber glass mat, NW : nonwoven, GG : geogrid
(*) : $2.45 \times 10^2\ \ell$/min/m^2
(**) : $5.52 \times 10^3\ \ell$/min/m^2
(***) : not applicable for manufacturer

4. Softening points of rubber and asphalt

Softening points of rubber and asphalt mixture of geosynthetics were represented in Table 4 and there is no difference of softening point among these geosynthetics. It was thought that this result is due to the same kind of SBS/asphalt mixture.

Table 4. Softening Points of Rubber Related Geosynthetics

Geosynthetics	FGMGS (FGM)	NWGS (NW)	GGGS (GG)	EBGS (NW)
Softening points (℃)	152	153	152	152

FGM : fiber glass mat, NW : nonwoven,
GG : geogrid

5. Dimensional stability at high temperature

Dimensional stability at high temperature, 120℃, was represented in Table 5 and there is no significant shrinkage for 4 type geosynthetics.

6. Resistance to ultraviolet

Resistance to ultraviolet of rubber related geosynthetics was represented in Table 6 and there is no visible alteration in these geosynthetics under the condition of 500 hours at xenon arc. From this, it was known that these geosynthetics have the excellent resistance to ultraviolet.

Table 5. Dimensional Stability of Rubber Related Geosynthetics

Geosynthetics	FGMGS		NWGS		GGGS		EBGS	
	MD	CD	MD	CD	MD	CD	MD	CD
Shrinkage (%)	0.1	0.1	-0.5	0.3	0.1	0.1	-0.2	0.2

MD : machine direction
CD : cross direction

Table 6. Ultraviolet Resistance of Rubber Related Geosynthetics

Geosynthetics	FGMGS (FGM)	NWGS (NW)	GGGS (GG)	EBGS (NW)
Ultraviolet resistance (500 hours at xenon arc)	No visible alteration - almost 100% retention of tensile strength			

FGM : fiber glass mat, NW : nonwoven, GG : geogrid

IV. Conclusion

Four types of rubber related geosynthetics (FGMGS, NWGS, GGGS, EBGS) as reinforcement and water barrier materials were manufactured by thermal bonding process and their geosynthetic related properties were examined and interpreted. From this, it was concluded as following:

(1) FGMGS and GGGS showed the more excellent mechanical properties and from this, it is thought that these materials are most suitable for reinforcing geosynthetics.

(2) NWGS and EBGS had the more excellent permittivity values and from this, it is thought that this geosynthetic is suitable for water barrier under specific load condition.

(3) Softening points of rubber and asphalt mixture showed no difference and dimensional stability at high temperature, 120℃, represented no significant shrinkage for rubber related geosynthetics.

(4) Resistance to ultraviolet of rubber related geosynthetics showed no visible alteration and from this, it is known that these geosynthetics have almost 100% retention of tensile strength.

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