ENGINEERING PROPERTIES OF VARIOUS GEO-FOAMS AS WATER BARRIER AT CONCRETE SLAB INTERFACE OF HYDRAULIC STRUCTURES

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Abstract: The feasibility to use expanded polystyrene, polypropylene, and polyethylene sheets as the water barrier for concrete slabs for hydraulic structures was evaluated. It is required that polymer water barriers provide satisfy durability, compressibility and expansibility, and bonding capability with adjacent materials. The compressibility and expansibility is more important for those water barriers used with large concrete slabs. Long term low seepage flow is also important requirement for water barriers. The results of the study indicated that expanded EPP and EPE geofoams shown a higher tensile strength than that for EPS geofoam. The elongation at break for EPE geofoam was much higher due to the closed single cell structure. All the test geofoams can be compressed to 20% of their original thickness. The test geofoams were relatively medium low permeable materials. The bonding strengths for the EPP and EPE geofoams are about 2 times and 2.5 times of that for EPS geofoam. The test EPE geofoam consisted of a relatively rough surface which can provide a better bonding surface with concrete. The seepage resistance associated with the EPE geofoam/concrete was more that 20 times of that for EPS/concrete interface. The seepage resistances at the interfaces between the test EPE geofoam and concrete block were equal and greater than 214 kPa for different placement schemes.

Keywords: Geofoam, Expanded Polyeslylene, Expanded polypropylene, Concrete Expansion Joint, Hydraulic Structures.

INTRODUCTION

Geofoam is a product created by polymeric expansion process resulting in foam structure material. The expanded material consists of many closed but gas filled cells. Expanded polystyrene (EPS) is an extremely light weight material. This product has been widely used a light weight construction fill material in numerous applications (Horvath, 1999). The use of vertical compressible EPS layers placed against rigid soil retaining wall structures to reduce lateral static earth pressures (Karpurapu and Bathurst, 1992) is one, separation is another application. The use of geofoam as an insulation of stress-waves is also studied (Wang et al., 2006). Expanded polypropylene (EPP) and expanded polyethylene (EPE) geofoams consist of a better impact resistance than that associated with EPS geofoam. EPP and EPE geofoams are widely used as protective packaging materials (Mills and Gilchrist, 2006). Polymer materials are commonly used as the primary raw materials for water barriers at the interface between concrete slabs for hydraulic structures. Compressibility, expansibility, bonding capability, and seepage resistance are all important functions for the interface materials placing at concrete slab expansion joints for hydraulic structures. Geofoams are widely used as expansion joint materials for concrete slabs. However, it is difficult to find a polymer material that would satisfy all of these functions mentioned earlier. Expanded polystyrene, polypropylene, and polyethylene sheets were evaluated as the water barrier for concrete slabs in the study. In addition to density, tensile strength, compressibility, and bonding strength at concrete interface, the permeability test of geofoam and seepage resistance test at the interface of geofoam with concrete slab were conducted. Long-term ultraviolet exposure and tensile strength degradation of the test geofoams were also evaluated.

TEST MATERIALS

A white expanded closed cell polystyrene (EPS), a white expanded closed cell polypropylene (EPP), and a black closed single cell expanded cross linking polyethylene are used in the study. The nominal thickness of test geofoam sheets are about 23 mm, 21 mm, and 20mm for EPS, EPP, and EPE geofoams, respectively. The densities of the test geofoams were measured according to ASTM D1622 and are listed in the Table 1. As shown on the table, the test materials are all very light weight materials. The test EPS geofoam is much lighter that the other two materials. The densities of the test EPE and EPP geofoams are about 14 times and 3.5 times of that for EPS geofoam.

TEST PROGRAM AND TEST METHODS

In order to evaluate the feasibility of using geofoams to provide multiple functions, including expansion, compression, and seepage resistance, at the expansion joints between concrete slabs of hydraulic structures, the tensile, compression, permeability, interface bonding strength, and interface seepage resistance were performed. The associated ASTM test standards were all listed in Table 1. Details of each test results are discussed in the following sections. To evaluate the bonding strength and seepage resistance at the interface between geofoam and concrete, two different schemes were used for the placement of geofoam at concrete slab interface as shown in Figure 1. Type A is placing a thin layer of geofoam sheet at concrete slab interface. In addition to place a thin layer of geofoam at concrete slab interface, a perpendicular thin layer of geofoam is also used to form a T shape geofoam structure as Type B scheme. 28-day compressive strength of 280 kg/cm^3 was used in the study.

Table 1. Typical engineering properties of the test geofoams

Item		ASTM Test Method	EPS	EPP	EPE
Density (N/m^3)		D1622	78.7	360.4	10987.2
Tensile test	Strength (kPa)	D1623	102.3	450.5	795.1
	Elongation at break (%)		2.13	5.52	85.31
Compression test (kPa)	@25%	D1621	43.979	228.531	289.497
	@50%		90.066	308.472	394.597
	@75%		204.216	533.798	960.956
Bonding strength (kPa)	Type A	D5239	91.9	189.6	237.5
	Type B		--	--	258.9
Permeability	k (m/sec)	D5084	5.4 E-04	6.99 E-04	3.729 E-05
	q ($m^3/m^2/sec$)		1.457E-03	1.806 E-02	2.851 E-03
Seepage resistance (kPa)	Type A	--	10.2	--	214.1
	Type B		--	--	275.2

RESULTS AND DISCUSSIONS

The tensile strength of geofoam is an important index property for engineering applications. The average tensile strengths of the test geofoams are listed in table 1. Typical tensile test results are plotted in Figure 2. As shown in the figure, the test EPS geofoam showed a relatively low tensile strength and elongation at break in comparing with the other two geofoams. EPP geofoam consisted of a reasonable strong tensile strength, but its elongation at break was relatively low. Because the EPE geofoams was processed using closed single cell structure, it provided a better tensile strength and elongation at break engineering properties than the other two types of geofoams.

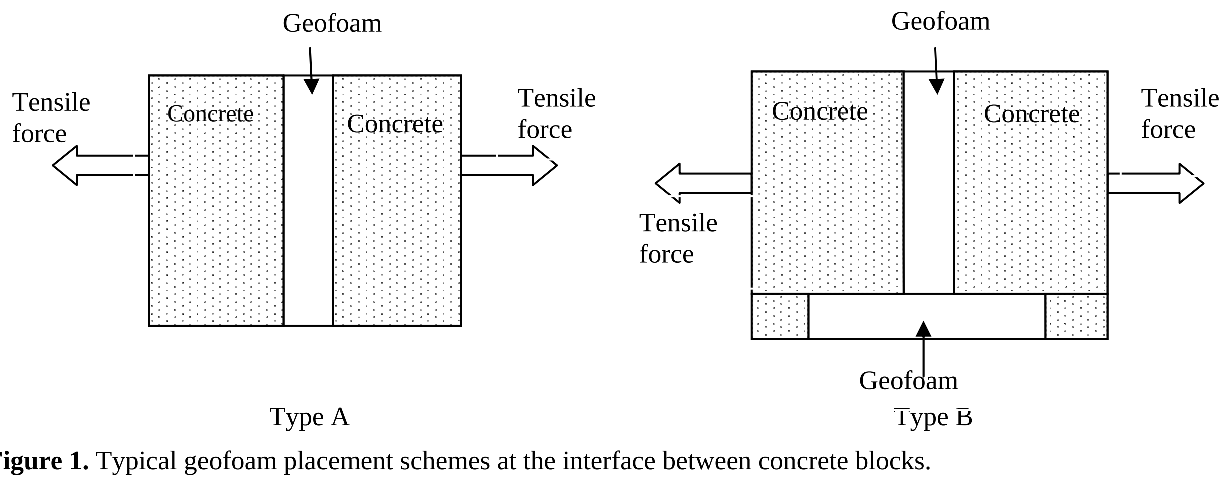

Figure 1. Typical geofoam placement schemes at the interface between concrete blocks.

Compressibility of geofoam is a necessary engineering property for the application as an interface material at expansion joint. Typical compression test results for the test geofoams are shown in Figure 3. The thickness of test specimens was varied from 20 to 23 mm. The maximum compression deformation of the tests was 80% of their original thickness. As shown in the figure, the compression curves associated with EPP and EPE geofoams shown similar behavior with three turning points along the curves. Even the density of the EPE geofoam is about three times of that for EPP geofoam, the compression resistance was only slight higher than that associated with the EPP geofoam. A concave compression curve was observed for the EPS geofoam. However, the compressibility for EPS geofoam was much lower than those associated with the EPP and EPE geofoams.

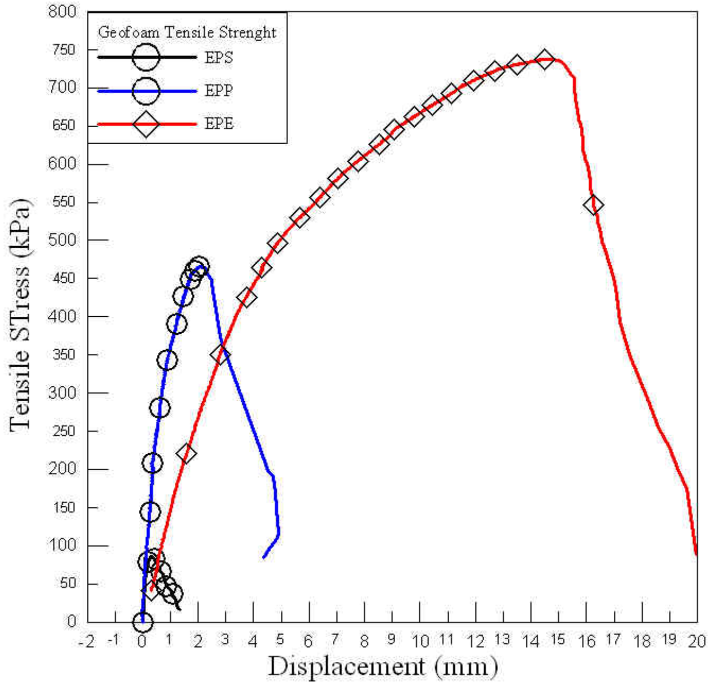

Figure 2. Typical tensile results for the tested geofoams.

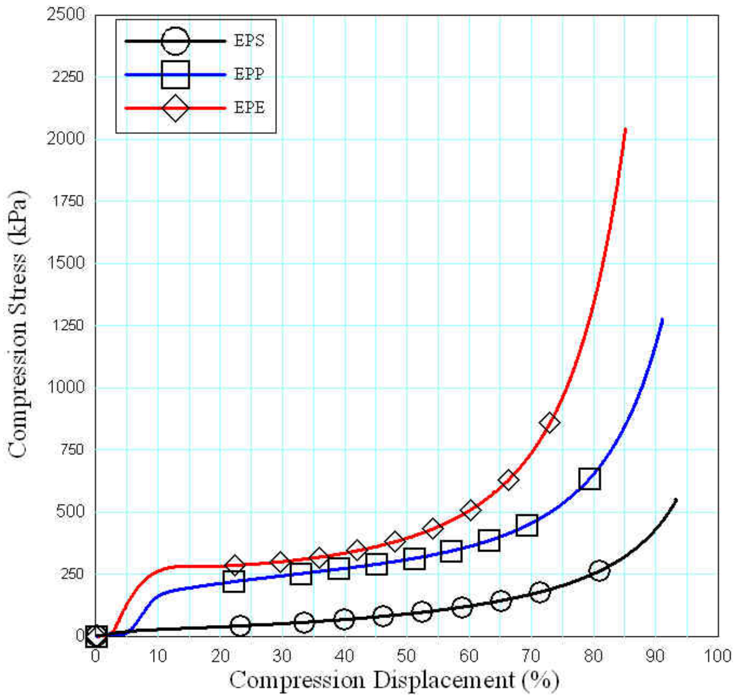

Figure 3. Typical compression results for the tested geofoams.

The 14-day bonding strengths between the EPE geofoam and concrete interface using Type A scheme are shown in Figure 4. As shown in the figure, a very low increasing rate of tensile stress was observed in the initial 2 mm extension of the specimens. This stage of stress could primarily be related to the changing the geometry of geofoam cells. Thereafter, the extension of the geofoam approximately linear increased with increasing the applying tensile stress until the de-bonding occurred. The 28-day bonding strength tests for the EPE geofoam with Type A placement scheme are shown in Figure 5. Similar de-bonding curves were observed, however, the bonding strengths were slightly increased and the variation of the curves associated with 28-day tests was less. The average 28-day bonding strengths between the test geofoams and concrete interface with Type A and Type B placement schemes are also listed in Table 1, Figures 6 and 7. The bonding strengths at the interface of geofoam and concrete for the EPP and EPE geofoams are about 2 times and 2.5 times of that for EPS geofoam. In general, rough geofoam cell surface provides a better bonding surface with concrete and creates a better bonding strength. To increase the concrete curing time would minor increase the bonding strength. Type B (T shape) geofoam placement scheme would slightly increase the bonding strength between geofoam and concrete.

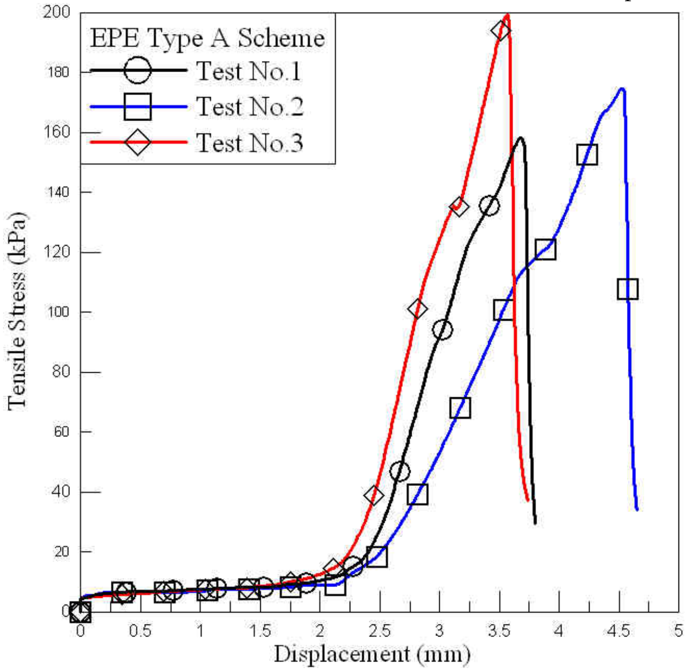

Figure 4. 14-day EPE/concrete interface bonding strength using Type A scheme.

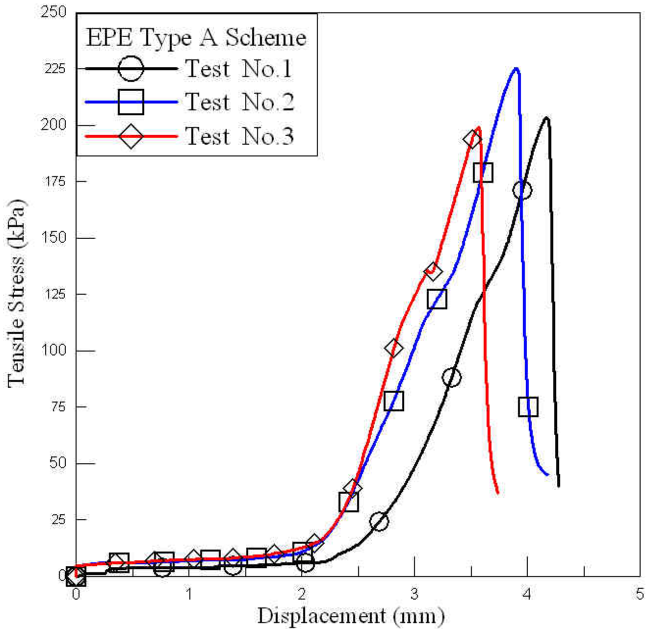

Figure 5. 28-day EPE/concrete interface bonding strength using Type A scheme.

Geomembrane generally is a near impermeable material. However, the permeability of expanded polymer material could vary significantly due to the structure of the material. The results of permeability tests are summarized in Table 1. The tests were performed according to the ASTM D5084 standard using constant head procedure. A 5.0 kPa pressure head loss was used in the test. The permeability values associated with EPS and EPP geofoams are relatively similar and greater than that observed for the EPE closed single cell geofoam. It implies that the closed single cell structure would provide fewer openings between expanded cells for possible seepage flow channels. However, the permeability of the EPE geofoam is a medium low permeable material with permeability of 3.729 x 10^{-5} m/sec.

The placement of a thin layer of geofoam at the interface between concrete slabs for seepage resistance was evaluated for the test geofoams with two type placement schemes. The results of seepage resistance tests for the EPE geofoam with two different placement schemes are shown in Figure 8. Seepage pressure was step increased at the interval of 10 kPa for lasting 10 minutes until the seepage pressure lost. The results of the test indicated that simply placing a thin layer of geofoam at the interface between concrete (Type A), a minimum of 214 kPa seepage resistance was observed. In addition, the minimum seepage resistance for Type B placement was observed with the value near 275 kPa. The additional perpendicular layer of geofoam is greatly reduced the potential flow path through the concrete joints. The seepage resistance at the interface between the EPS geofoam and concrete with Type A placement scheme was about 10.2 kPa and the result is also shown in Table 1. Due to the relatively smooth surface for the test EPS geofoam, a relatively low seepage resistance for the test EPS geofoam can be expected.

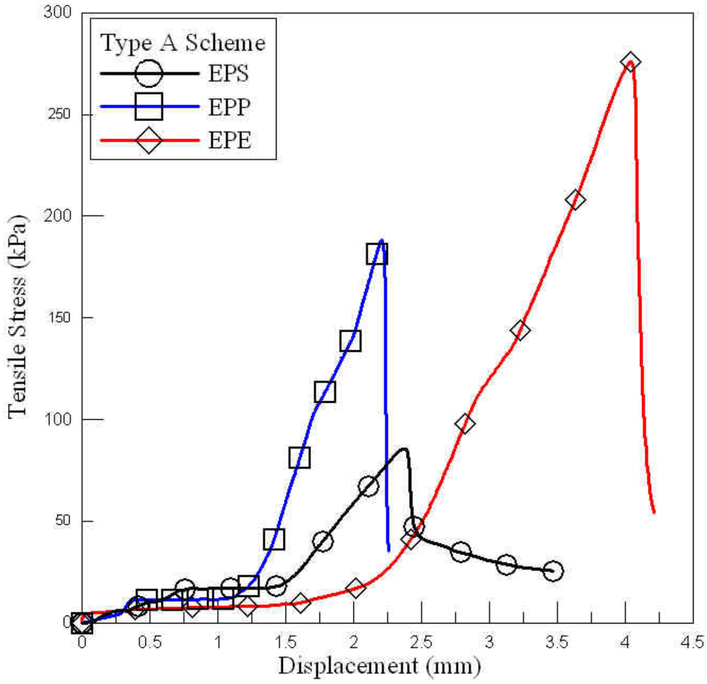

Figure 6. 28-day various geofoams/concrete interface bonding strengths (Type A scheme).

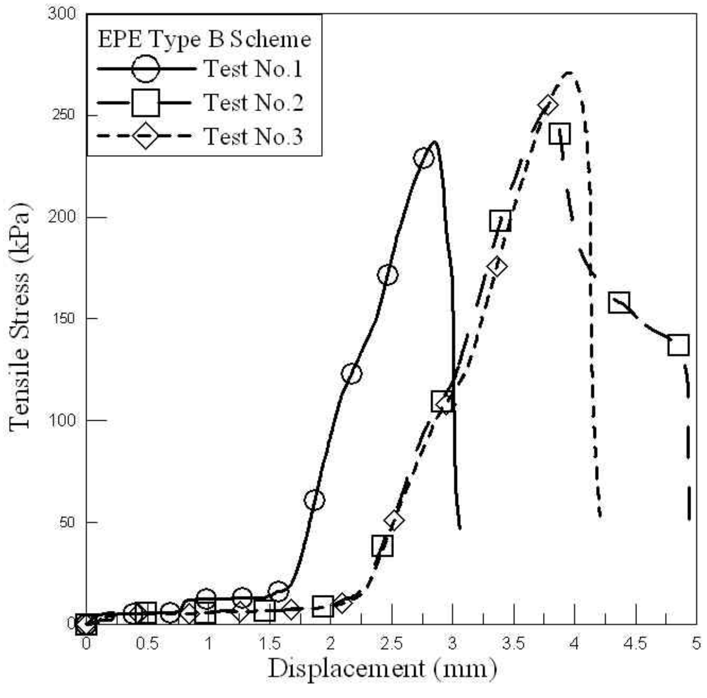

Figure 7. 28-day various geofoams/concrete interface bonding strengths (Type B scheme).

SUMMARY AND CONCLUSIONS

A feasibility study was conducted to evaluate the use of various geofoam materials as the water barrier at the expansion joint between concrete slabs. A white closed cell expanded polystyrene (EPS), a white closed cell expanded polypropylene (EPP), and a black closed single cell expanded cross linking polyethylene (EPE) geofoams were used in the study. In addition to density, tensile strength, compressibility, and bonding strength at concrete interface, the permeability test of geofoam and seepage resistance test at the interface between geofoam and concrete slab were conducted.

Based upon the test results, the following conclusions are made. Expanded geofoam is a light weight material. In general, the density of the material decreases as increasing the expanded ratio.

1. Expanded EPP and EPE geofoams showed a higher tensile strength than that for EPS geofoam. The elongation at break for EPE geofoam was much higher due to the closed single cell structure.
2. All the test geofoams can be compressed to 20% of their original thickness. Expanded EPE geofoam showed the best compressibility in comparing with the other geofoams.
3. The test EPE geofoam consisted of a relatively rough surface that can provide a better bonding surface with concrete. The results of the EPE/concrete interface bonding tests indicated that the initial 2 mm extension of the specimen could primarily be related to the changing the geometry of geofoam cells. The concrete curing time has some effects on the bonding strength between geofoam and concrete. The bonding strengths for the EPP and EPE geofoams are about 2 times and 2.5 times of that for EPS geofoam.
4. The test geofoams were relatively medium low permeable materials. The test EPE geofoam is processed using the closed single cell structure that would provide fewer openings between expanded cells for possible seepage flow channels with permeability of 3.729 x 10^{-5} m/sec. The permeability values associated with EPS and EPP geofoams are relatively similar and greater than that observed for the EPE closed single cell geofoam.
5. Because the test EPE geofoam consisted of a relatively rougher bonding surface, the seepage resistance associated with the EPE geofoam/concrete was more that 20 times of that for EPS/concrete interface. The seepage resistances at the interfaces between the test EPE geofoam and concrete block were 214 kPa and 275 kPa for Type A and Type B placement schemes, respectively.

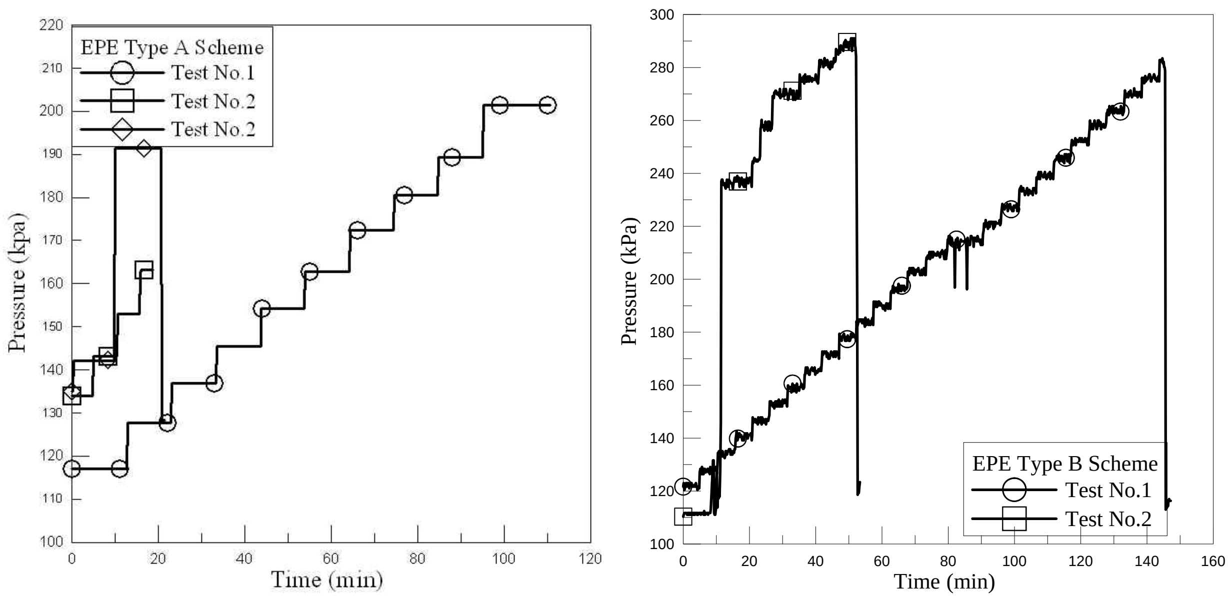

Figure 8. EPE geofoams/concrete interface seepage resistance test results (A & B Scheme).

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