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Mechanical Properties of Geotextiles after Chemical Aging in the Agriculture Wastewater

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Abstract

Aging of geotextile, which is widely used as reforming medium in structures, attracted a great deal of attention in recent years, as it is very important to the stability of the whole work. Especially, the prediction of geotextile's aging-time has become one of the focuses nowadays. In this study, four types of nonwoven geotextiles was used in tests, which are heat bounding, needle punched, chemical adhesive, and supporting by thread. The modified EPA 9090 test method was applied to compare the chemical resistance in pH 8 for agricultural wasting water in Syria. The immersion conditions are 30~90 days under 25°C and 50°C respectively. On other hand, chemical resistance of these nonwoven geotextiles was estimated by the average retentions of mechanical properties before/after exposure in the above chemical solution. However, the relied mechanical properties are grab tensile response, trapezoidal tear strength, and CBR puncture strength testes. In addition, we have compared between specimens in related to pore size volume, thickness, weight per m2, and row material. Transmissivity of geotextile for drainage were slightly decreased in pH8 solution. Finally, needle punched nonwoven geotextile has the best resistance to the tensile, tear, and puncture before and after aging.

Keywords: Geotextiles; Chemical resistance; Average retentions of tensile strength; Transmissivity

Introduction

Recently, the use of non-woven fabrics for the purposes of geological is increased. The reason for this enjoyment of characteristics suited to these purposes, exceeds the characteristics of woven and knitted fabrics, most of the studies are on plastics, and few are on fibers. Koerner [1], studied systematic investigations on the aging-time of polypropylene fibers at different temperatures have been made Moreover, a particular emphasis has been laid on how to build up the equation of geotextile's aging-time, which was based on Arrhenius equation (K=A e-E/RT). The experiments were respectively carried out at 120℃, 125℃, 130℃ and 135℃ by means of oven accelerated aging test. Then the lifetime of the fibers at normal temperature could be sscalculated according to the equation. where τ f is the final durability period; K is competitive multiplication coefficient; τ r is reference durability period; τr is reference temperature, 150℃; τi is using temperature (K); Kj is multiplication coefficient at it; Fi is time fraction of ℃i, Fi=1. Moreover, the effects of changing critical value on the equation were elucidated. Furthermore, the effect of soil's acidity (pH = 5) and basicity (pH = 9), pure water and copper ion in the water on the aging-time was discussed. The results showed that acid and alkali made the fiber's lifetime decrease about 13% and water make the fiber's lifetime decrease about 20%, while copper ion shorten the aging-time of the fiber more than 54%. Acid, alkali, metal ion would shorten the lifetime of PP fiber, and the effect of metal ion is the highest, the effect of water is the second, acid and alkali is the lowest. Under the pressure the aging rate of PP geotextile would be accelerated. This study also indicated that fiber grade anti-aging PP chip could be spun at conventional temperature; plastic and flat fiber grade would be spun at high temperature. However, high spun temperature would make the antiager consume and decompose, which will shorten the geotextile's lifetime. Therefore, the antiager and the spin ability of resin were very important. As there are different effect factors in different environment, experiment should be done based on particular natural conditions [2,3].

In another research the effectiveness of layered-geotextile protection layers comprised of combinations of nonwoven needle-punched, woven slit-film, and nonwoven heat-bonded geotextiles to minimize strains in landfill geomembranes has been examined. Results from physical experiments were reported where a sustained 700-N force was applied to a 28-mm-diameter machined steel probe on top of the protection layer, which was above a 60-mm-diameter, 1.5-mm-thick high-density polyethylene geomembrane and a 50-mm-thick compressible clay layer. The experiments are intended to simulate the physical conditions in a medium-sized landfill with an average vertical stress of 250 kPa and to capture the mean response with nominal 50-mm coarse gravel above the geomembrane. Screening tests were first conducted for up to 100 h at temperatures up to 55°C to evaluate three different combinations of layered geotextiles. Of those examined, the combination with a low-slack, heat-bonded geotextile above and below a thick, nonwoven, needle-punched geotextile as its central core was found to provide the lowest strains. A time-temperature superposition method was then developed and validated as a means to predict the long-term effectiveness of the most promising layered-geotextile composite. Last, long-term predictions of tensile strain were made and compared with proposed allowable limits. Despite the encouraging results from the short-term screening tests, even the most promising layered-geotextile composite is not recommended as a protection layer to limit long-term geomembrane strains for the particular force, particle size, and materials examined because the predicted strain after 100 years at 22–55°C of ∼10% exceeds the range of currently proposed limits of 3-8% [4].

During the revision of Technical Specification for Application of Geotextile in Marine Works (JTJ239-98) published by the Ministry

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of Communications of China, artificially accelerated ageing tests in laboratory, natural insolating tests, measurement of underwater ultraviolet radiation energy, ageing tests of buried geotextile in sandy soil and tests of specimens from practical engineering works were carried out for the monographic research on ageing resistance of geotextile. The paper is the summary of the test results, which can be of the reference for designers and contractors [5-7].

The studies in 1970 [8], were showed that nonwoven geotextiles were used for the first time in an earth dam. The geotextile acted as a filter for the toe drain and on the upstream slope below the rip-rap. In 1992, specimens were taken from both locations and performance tests were conducted in the laboratory and the main results of the hydraulic behavior of the geotextile filter in association with the soil of the damhae been presented [9]. Also microscopic analyses are presented and, as the filter is considered to be performing well, selected filter criteria are checked and the effectiveness of layered-geotextile protection layers comprised of combinations of nonwoven needle-punched, woven slit-film, and nonwoven heat-bonded geotextiles to minimize strains in landfill geomembranes is examined [10]. Results from physical experiments are reported where a sustained 700-N force was applied to a 28-mm-diameter machined steel probe on top of the protection layer, which was above a 60-mm-diameter, 1.5-mm-thick high-density polyethylene geomembrane and a 50-mm-thick compressible clay layer. The experiments are intended to simulate the physical conditions in a medium-sized landfill with an average vertical stress of 250 kPa and to capture the mean response with nominal 50-mm coarse gravel above the geomembrane. Screening tests were first conducted for up to 100 h at temperatures up to 55°C to evaluate three different combinations of layered geotextiles. Of those examined, the combination with a low-slack, heat-bonded geotextile above and below a thick, nonwoven, needle-punched geotextile as its central core was found to provide the lowest strains [11]. A time-temperature superposition method was then developed and validated as a means to predict the long-term effectiveness of the most promising layered-geotextile composite. Last, long-term predictions of tensile strain were madse and compared with proposed allowable limits. Despite the encouraging results from the short-term screening tests, even the most promising layered-geotextile composite is not recommended as a protection layer to limit long-term geomembrane strains for the particular force, particle size, and materials examined because the predicted strain after 100 years at 22–55°C of ~10% exceeds the range of currently proposed limits of 3-8%.

Finally, Answers to the problem of durability of geotextiles according to the French experience have been given particularly in papers by Sotton et al. presented at the Las Vegas conference in 1988 [12]. In addition, in contributions by Leclercq at the RILEM seminar on long-term behavior of geotextiles, held near Paris in 1986. More recently additional information has been obtained [13].

This paper will summarize the results that have been presented earlier and give new results obtained from recent measurements.

Materials and Methods of Search

Geotextile's aging-time has become one of the focuses nowadays. Therefore, that it is important to know the chemical resistance of nonwoven geotextiles.

The main mechanical properties that have been considered in this research were tensile, tear, puncture and air pockets for four types of non-woven fabrics made in different manufacturing ways (thermal bonding, needle punching, chemical paste, and sewing by supportive thread). Table 1 shows the different types of geotextile used in this work.

Geotextile types

Table 1 shows the brief idea about geotextile types.

Types of fibers of row materials used in geotextile specimens

The float solution used in chemical aging is agricultural wasting water taken from Syrian irrigation projects which consist of the elements shown in Table 2.

Chemical composition of used agricultural wastewater

Table 3 shows Agricultural wastewater has prepared of following ingredients.

Weighting of specimens

The weight of the different types of specimens was defined using electronic and accurate balance DNAUS, manufacturing by Adventurer corporate, it depends on measuring circulatory piece with exact scaling, through contingents of area we cane defining the weight per square meter. By following modified ASTM D5261 test method.

Thickness of specimens

Specimens are different in thickness, we measured the thickness of them, and the results were located in Table 4.

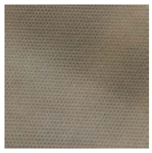
Specimen name	Specimen type	Specimen photo
A	Heat bounding nonwoven	
B	Needle punched nonwoven	
C	Chemical adhesive nonwoven	
D	Nonwoven with supporting thread	

Table 1: Geotextile types.

Mg^{++}	24.64	So_4^{--}	13.14
Ca^{++}	27.70	Cl-	50.54
Na^{+}	31.76	Hco_3^{--}	26.06
K^{+}	0.17	Co_3^{-}	0

Table 2: Types of fibers of row materials used in geotextile specimens.

Specimen	Type of raw material of specimens
A	Polypropylene 100%
B	Polyamide 50% + Polypropylene 50%
C	Cotton 67% + Polyester 33%
D	Hemp 80% + Polyamide 20%

Table 3: Chemical composition of used agricultural wastewater.

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Pore size volume defining device of specimens

The pore size volume of specimens has been defined using shaker device with sieves, manufacturing by CISA corporate, by following the modified ASTM D4751 test method. The principle of experiment depends on applying group of sieves that have sequential volume holes on the shaker device, we will put the type on the top of sieves, and we put multifarious volume sand above the type. Next, we set shaker device to work for a period in order to filter the sand grains through the type pore size, and then check up the highest volume for that grains, which is the same of pore size volume (Figure 1).

Method of chemical aging

All of specimens were immersed within path water device (Figure 2), in agricultural wastewater, depending on test method EPA 9090.

Mg^{++}	24.64	**So_4^{--}**	13.14
Ca^{++}	27.70	**Cl-**	50.54
Na^{+}	31.76	**Hco_3^{-}**	26.06
K^{+}	0.17	**Co_3^{-}**	0

Table 4: Thickness of specimens.

Figure 1: Pore size volume defining device of specimens.

Figure 2: Path water for chemical aging test.

Grab tensile response, trapezoidal tear strength, and CBR puncture strength testes

The utmost mechanical properties for geotextile are grab tensile response, Trapezoidal tear strength and CBR puncture strength. The difference between previous tests is the changing of the jaws grade and distance between them as the norm for each test.

The modified ASTM D4632 test method for grab tensile response, the modified ASTM D4533 test method for trapezoidal tear strength, the modified ASTM D6241 test method for CBR puncture strength.

Since the specimens are different in thickness, the break force [N] must divide on thickness and width to get the stress. In that way the comparison between specimen is true (Figure 3).

Results and Discussion

Mass per unit

Weight test of specimens was repeated 10 times for each type. The average values of mass per unit area are illustrated in the Table 5.

Apparent opening size test

Table 6, shows the sizes of apparent opening for all specimens, after repetitions 10 times.

We noticed that holes volume in type B is the highest because manufacturing way, it is a needle punched nonwoven, that allows to layers fabric to stay as it before. While the holes in type B are smaller than type A because this type manufactured by Heat bounding nonwoven. Type C is the lowest holes volume because this type manufactured by Chemical adhesive nonwoven way. While the holes in type D are bigger than type C because this type manufactured by Nonwoven with supporting thread.

Grab tensile resistance

Grab tensile test was done on specimens by the following parameters in Table 7, according to related test method.

Grab tensile test was done before chemical aging also after 30, 60, and 90 immersion days at 25°C. Resulted stresses [N/mm²] were shown in Table 8.

Figure 3: Grab tensile response, Trapezoidal tear strength, CBR puncture strength.

Specimen	Thickness [mm]
A	0.76
B	1.69
C	2.8
D	7.4

Table 5: Mass per unit area of specimens.

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Previous result could be in illustrative form in Figure 4, to show the behavior of each specimen under chemical aging conditions at 25°C.

Similarly, specimens were exposure to grab tensile test in the same conditions but at 50°C. Besides, force break was divided on thickness and width. Stresses [N/mm²] were shown in Table 8 and Figure 5.

Before the chemical aging, specimen B has the highest tensile resistance with 20 to 10% more than the rest, followed by D then A and C, which (A and C) have the same tensile resistance before aging.

After the chemical aging, all of specimens lose several amount of their tensile resistance, due to the conditions of aging. Nevertheless, specimen B still has the highest tensile resistance, because it lose just 19% of its resistance, so it is the best specimen against the rest. However, specimen D lose more than 44% of its tensile resistance to be in the behinds. Specimen A lose 24% while C lose 33% of its resistance, as shown in Figure 6.

Trapezoidal tear strength

Trapezoidal tear test parameters were shown in Table 9, according to related test method (Table 10).

Specimen	Weight of 1 m²
A	412.06 gr
B	314.02 gr
C	817.30 gr
D	971.27 gr

Table 6: opening size test.

Specimen	Test speed [mm/ min]	Specimen thickness [mm]	Specimen width [mm]	Distance between jaws [mm]	Test repeats
A	10	0.76	25	100	10
B	10	1.69	25	100	10
C	10	2.8	25	100	10
D	10	7.4	25	100	10

Table 7: Analogical and nominal specification of specimens for Grab Tensile tests.

Specimen	Before aging [N/mm²]	After 30 days of aging [N/mm²]	After 60 days of aging [N/mm²]	After 90 days of aging [N/mm²]
A	0.781763	0.721713	0.691716	0.634321
B	1.028188	1.012184	0.925188	0.823288
C	0.766923	0.636233	0.600223	0.587923
D	0.898662	0.728662	0.67998732	0.6134567

Table 8: Tensile test results of specimens in 25°C.

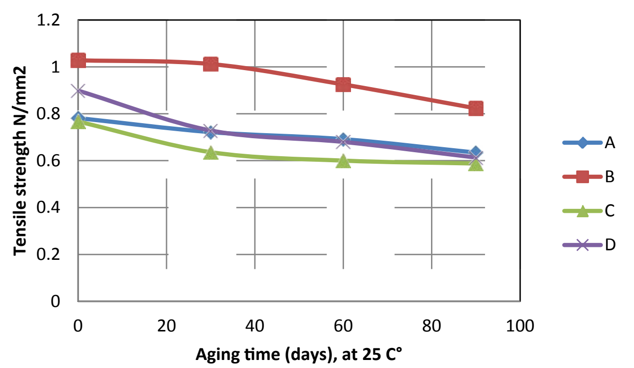

Figure 4: Tensile test results of specimens in 25⁰C.

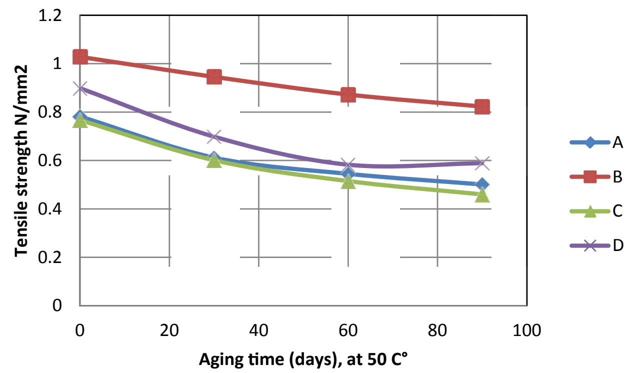

Figure 5: Tensile test results of specimens in 50⁰C.

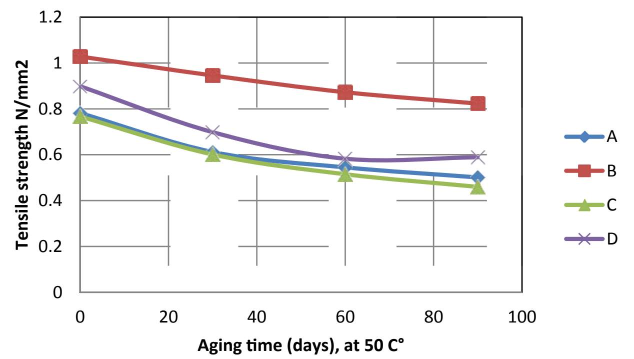

Figure 6: Differences in tensile strength for all specimens.

Specimen	Before aging [N/mm²]	After 30 days of aging [N/mm²]	After 60 days of aging [N/mm²]	After 90 days of aging [N/mm²]
A	0.781763	0.6118662	0.5448732	0.501067
B	1.028188	0.9456384	0.872488	0.823008
C	0.766923	0.601233	0.515023	0.459873
D	0.898662	0.698453	0.582648	0.588979

Table 9: Tensile test results of specimens in 50°C.

Test repeats	Specimen	Test speed [mm/min]	Specimen thickness [mm]	Specimen width [mm]	Distance between jaws [mm]	Test repeats
A	300	15	0.76	75	200	10
B	300	15	1.69	75	200	10
C	300	15	2.8	75	200	10
D	300	15	7.4	75	200	10

Table 10: Analogical and nominal specification of specimens for trapezoidal tear tests.

Specimens were exposure to trapezoidal tear strength before chemical aging in addition to after aging with 30, 60, and 90 immersion days at 25°C. Resulted stresses in [N/mm²] were shown in Table 11 and Figure 7.

Specimens were aged in the same conditions but at 50°C, after that it were tested with trapezoidal tear test. Finally, stresses [N/mm²] were shown in Table 12.

Previous result could be in illustrative form in Figure 8, to show the behavior of each specimen under chemical aging conditions (Figure 8).

Withal, specimen B is the best specimen against the rest in

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trapezoidal tear test, followed by C, D, and A respectively, Because B has the highest trapezoidal tear resistance before the aging and even after that.

Figure 8, shows that all specimens lose a convergent amount of their resistance to trapezoidal tear. However, they lose 24%, 23%, 22%, and 18% for A, B, D, and C respectively. Nevertheless, specimen B still the best specimen (Figure 9).

CBR puncture strength

CBR Puncture test has special parameters according to interdependent test method, parameters were shown in Table 13.

CBR Puncture test was applied on all specimens before chemical aging and after aging with 30, 60, and 90 immersion days at 25°C. Resulted stresses in [N/mm²] were shown in Table 14.

To see the behavior of each specimen under chemical aging conditions, previous result could be in illustrative form in Figure 10.

Similarly, specimens were exposure to puncture test in the same conditions but at 50°C. Stresses [N/mm²] were shown in Table 15.

Figure 10, clearly shows the behavior of each specimen under chemical aging conditions at 50°C (Figure 11).

Before the chemical aging, specimen A has a puncture resistance higher than specimen B with 8%. While specimen C has the lowest puncture resistance. Finally, the puncture resistance of specimen D higher than C with 30%.

Specimen	Before aging [N/mm2]	After 30 days of aging [N/mm2]	After 60 days of aging [N/mm2]	After 90 days of aging [N/mm2]
A	0.64994	0.60211	0.55345	0.50123
B	1.129412	0.976001	0.923412	0.897121
C	0.852199	0.802199	0.771909	0.723459
D	0.702717	0.678901	0.623067	0.587012

Table 11: Trapezoidal Tear test results of specimens in 25°C.

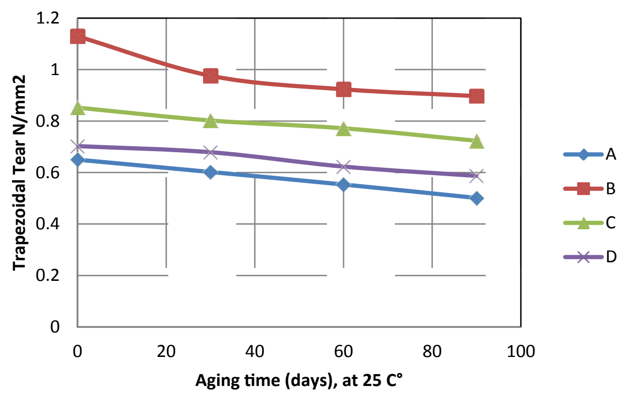

Figure 7: Trapezoidal tear test results of specimens in 25⁰C.

Specimen	Before aging [N/mm²]	After 30 days of aging [N/mm²]	After 60 days of aging [N/mm²]	After 90 days of aging [N/mm²]
A	0.64994	0.59101	0.53345	0.48923
B	1.129412	0.954001	0.900411	0.867121
C	0.852199	0.782099	0.741804	0.693459
D	0.702717	0.648901	0.591067	0.547012

Table 12: Trapezoidal Tear test results of specimens in 50°C.

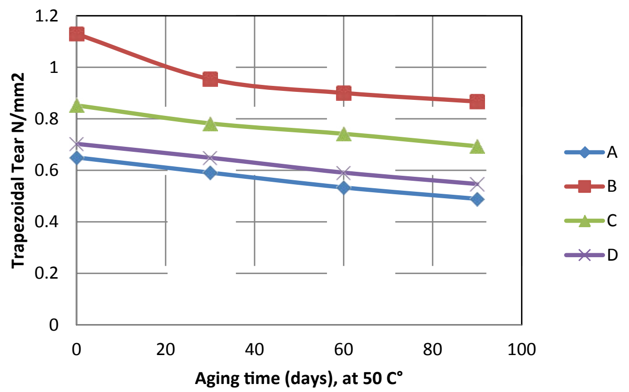

Figure 8: Trapezoidal Tear test results of specimens in 50⁰C.

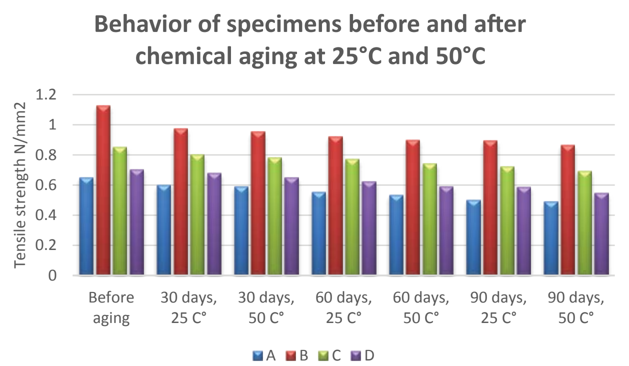

Figure 9: Differences in trapezoidal tear strength for all specimens.

Specimen	Test speed	Specimen diameter	Test cape diameter	Test repeats
A, B, C, D	100 mm/min	150 mm	50 mm	10 tests

Table 13: Analogical and nominal specification of specimens for CBR Puncture tests.

Specimen	Before aging [N/mm2]	After 30 days of aging [N/mm2]	After 60 days of aging [N/mm2]	After 90 days of aging [N/mm2]
A	1.36555	0.96525	0.80432	0.74436
B	1.248179	1.051179	0.97525	0.93325
C	0.701026	0.628106	0.574026	0.521103
D	1.008193	0.940725	0.885215	0.845105

Table 14: CBR Puncture Strength test results of specimens in 25°C.

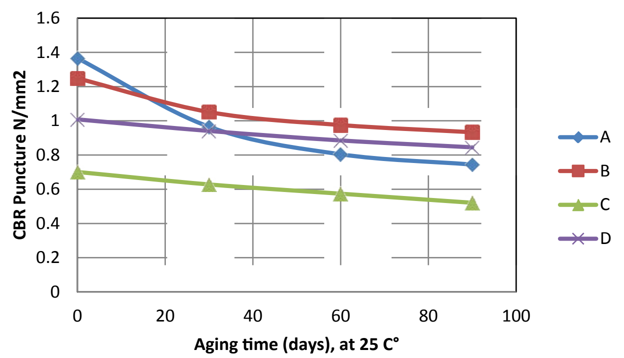

Figure 10: CBR Puncture Strength test results of specimens in 25⁰C.

After the chemical aging with 30 days only, all of specimens lose the highest amount of their puncture resistance, after that they lose a little amount of their puncture resistance.

After 90 days of chemical aging, specimens A, B, and D have a similarly puncture resistance but less than before aging with 37%, 25%, and 10% respectively. While, specimen C still in behinds by losing 16% of its puncture resistance (Figure 12).

Discussion

Specimen B

Specimen B is the best one of specimens in the three tests grab tensile, tear, and puncture, before and after aging. Regarding the situation before aging, it is made by needle-punched method; this method helps the layers of nonwoven fabric to enlacement with each other that causes to increase the resistance of this specimen against the three tests. On other hand, correlative layers prevent the tear slot to stretching, especially for trapezoidal tear test.

While for the situation after aging, this specimen has the largest pore size, which leads to the best immersion in agriculture wastewater. In addition, the raw material of this specimen (polypropylene and polyamide) did not interact with the agriculture wastewater. That explains the best results of this specimen after aging, in addition to the microscope photo to it, in Figure 13, which clarifies that is not any change on it, before and after the chemical aging.

Specimen	Before aging [N/mm2]	After 30 days of aging [N/mm2]	After 60 days of aging [N/mm2]	After 90 days of aging [N/mm2]
A	1.36555	0.90325	0.74505	0.60325
B	1.248179	1.010172	0.98425	0.92225
C	0.701026	0.579711	0.534026	0.480026
D	1.008193	0.900725	0.811215	0.735005

Table 15: CBR Puncture Strength test results of specimens in 50°C.

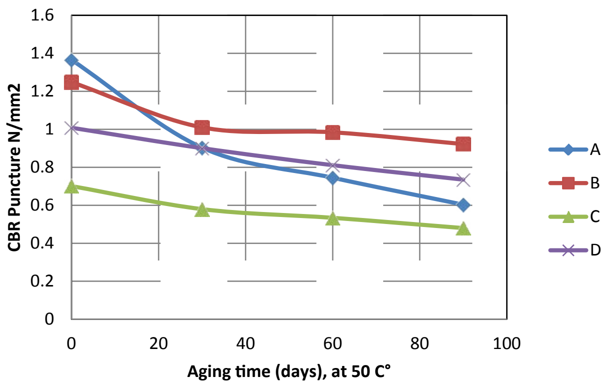

Figure 11: CBR Puncture Strength test results of specimens in 50°C.

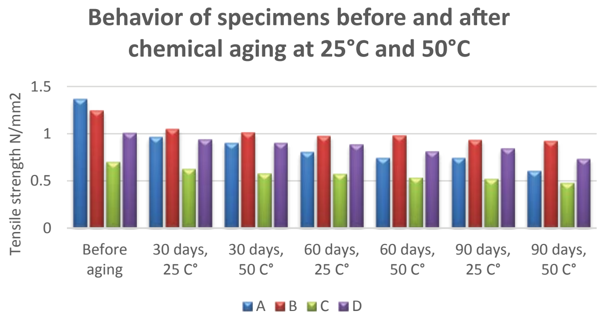

Figure 12: Differences in CBR Puncture strength for all specimens.

Specimen D

Specimen D has has a resistance to tensile and puncture less than B with 13%, 23% respectively before aging, and 25%, 9% respectively after aging at 25°C, while 41%, 20% respectively after aging at 50°C. This specimen located in the second level next than specimen B in related to tensile and puncture tests, that is because it is made of hemp, which has a heavy qualitative weight, it is clearly shown in Table 5. On the other hand, layers of this specimen also enlacement with each other in a good way by supporting thread.

But in tear test it has a low resistance less than B with 39% approximately before and after aging at 25°C, and 50°C. The low resistance against tear test is because the direction of supporting thread, it is horizontal while the test is vertical, which leads to break the specimen quickly, as it is shown in Figure 14.

Specimen A

Specimen A is the best specimen just in puncture test before aging, that is because in puncture test the resistance of specimen depends on friction between nonwoven fabric, this specimen is a heat bounding specimen, therefore this specimen has the lowest thickness that means it has high friction between layers, so it has high resistance against

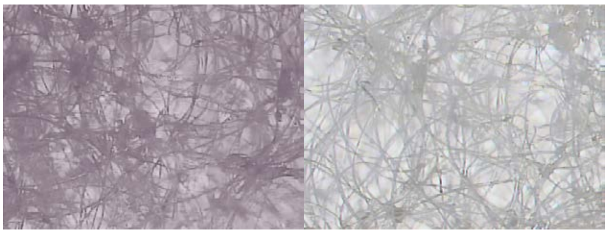

Figure 13: Microscope photo of needle punched specimen before and after aging.

Figure 14: Supporting thread specimen during tear test.

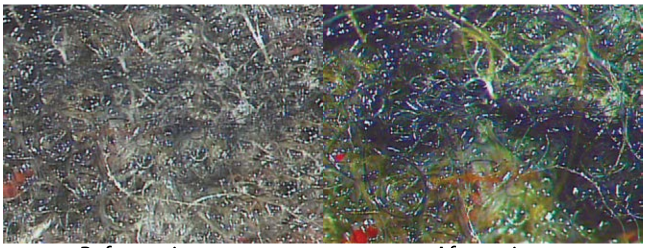

Figure 15: Microscope photo of Chemical adhesive specimen before and after aging.

puncture. While after aging, it lose a lot of its resistance especially at 50°C, to be less than B with 20%, 35% respectively at 25°C, 50°C for puncture test, also less than B with 23%, 40% respectively at 25°C, 50°C for tensile test. To explain previous result, specimen's pore size was measured by microscope, before and after aging particularly at 50°C. Figure 14, clearly displays the increment of pore size, this is due to the high temperature of aging, which leads layers to detachment of each other, so break the specimen easily under puncture and tensile tests.

For tear test, it has a resistance less than B with 44% approximately before and after aging. This low tear resistance because manufacture method (heat bounding), this method make the nonwoven fabric as one layer, it leads to be in the lowest thickness, that causes to stretching the tear slot quickly.

Specimen C

Specimen C is the worth specimen particularly after aging in related to tensile and puncture tests with 45% approximately less than B, that is because it made of natural fibers (cotton), which interacted with agriculture wastewater and lost most of its resistance. In addition to the interaction between immersion liquid and adhesive of specimen, which cause to dissolve a lot of adhesive, then layers of nonwoven fabric of specimen will disport of each other, which leads the specimen to be weak, as it clearly is shown in Figure 14. However, tear resistance of this specimen quite a bit, it is less than B with 24% before aging, and 20% after aging, this is because the random installing of specimens' filaments, which retards stretching the slot of tear test (Figure 15).

Conclusion

Geotextile nonwoven characteristics are different to each other because generally:

- Manufactured way
- Kind of raw material
- Pore size volume

Following conclusion were made after assessing the experimental results and after effecting tests (tensile, tear, and penetration) on types we notice and compare results:

- The type B, which is a needle punch specimen, was better in all situations.
- Chemical aging was affected in bad manner with higher temperature.

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