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An Experimental Study on Thickness Loss of Wilton-Type Carpets Produced with Different Pile Materials after Prolonged Heavy Static Loading. Part-I: Characteristic Parameters and Carpet Behaviour

Abstract
Three carpets from Turkey with different pile materials (wool, acrylic and PP), 1/3 V-type and woven by face to face in the Wilton system are used to evaluate the thickness loss in compression after prolonged heavy static loading. The tests were conducted in accordance with internationally accepted standard methods in a conditioned testing laboratory. The characteristic parameters, defined as the squeezing susceptibility or compression sensitivity S (%), permanent deformation D_P (%), elasticity E (%) and resilience R (%) determining the carpets' behaviours, were calculated using the thicknesses measured before loading and after various recovery periods, and the thickness differences (or deformation levels) between these periods. This study forms a part of an examination of carpets under static and dynamic loading, and includes only the static loading results.

Key words: *Wilton-type carpets, static loading, thickness loss, carpet parameters.*

Introduction

Carpets are most the textile materials widely used for floor coverings. In general, a woven carpet is a three-dimensional textile structure consisting of three different yarns, namely pile, backing and filling. In Wilton face-to-face carpet weaving, two identical carpets (a bottom and a top carpet) are woven at the same time. The piles joining these two carpets are cut in the middle on the weaving machine to obtain two separate carpets during weaving. In machine carpets, the piles are V- or U-shaped small-yarn segments. Pile yarns are supplied from a yarn package creel parallel to warp ends for backing. The piles are introduced between the ground wefts, and formed following the beating-up and cutting in weaving. The interlacing of the piles mostly follow the first, second or third weft of the ground fabric. In single-rapier weaving, weft yarns are inserted into the shed, one for the bottom and one for the top carpet. So the pile tuft is formed on every weft yarn. As it has one pile row per weft and because the pile is V-shaped, this basic structure is called a 1/1 V-type. In a double-rapier weaving, two rapiers insert two weft yarns in two sheds formed at the same time, one shed for the bottom carpet and one shed for the top carpet. So the pile tuft is formed every two wefts; this structure is called a 1/2 V-type. In the present study, the pile tuft is formed every three wefts, and is therefore called a 1/3 V-type. Figure 1 shows the typical face-to-face weaving principle of a Wilton-type carpet. More information on the latest technological developments and about carpet structures may be found elsewhere [1-3].

One of the most important quality factors in carpets is thickness loss (i.e. deformation in compression) by static and dynamic loads. By this loss, not only does the carpet appearance on the face lose its original form, but the carpet's resilience capability is also lost. The factors decreasing the resilience capability are the static pressures by massive goods such as furniture, and dynamic pressures such as walking, running or moving or furniture & other household goods that a carpet has to bear during use [4-7]. Berkalp et.al. [7] investigated the relationships between some end-use properties and the structural properties of tufting carpets (acrylic, PP and PA). They reported that the pile material had a strong effect on the loss of carpets' appearance. Onder & Berkalp [8] worked on the effects of important structural parameters on appearance retention, abrasion resistance and tuft withdrawal force by examining face-to-face woven carpets, with acrylic, wool and PP pile, varying in height and weft density. It was stated that the pile material and density are the most critical construction parameters. Liu et al. [9, 10] have developed a mathematical model to predict the wear life of wool-cut pile carpets based on Carnaby's carpet durability theory that a loop pile construction of similar pile density has a longer life than the cut pile construction. Presley [11] worked on the evaluation of carpet appearance loss by objective and subjective methods, using cut-pile nylon carpets varying in pile weight, twist, linear density and wear level. It was reported that the application of covariance through image analysis has excellent potential for the objective evaluation of carpet texture and appearance. A study was made on thickness loss by compressing Wilton-type carpets with different piles after prolonged heavy static loading and dynamic loading tests [12, 13]. Patyk & Korlinski [14] analysed the pile properties of some fur-knitted fabrics under compressing. On the basis of the compression sensitivity S which was developed, the permanent deformation Dp and elasticity E have been determined. Youseftabar [15] has developed a mechanical testing system to determine carpet durability, based on the 'step resistance factor', by simulating human walking movements which enables the calculation of the life span of a carpet under controlled laboratory conditions. In this study, three carpets with acrylic, wool and PP pile are examined in order to evaluate the thickness loss (or deformation in compression) after

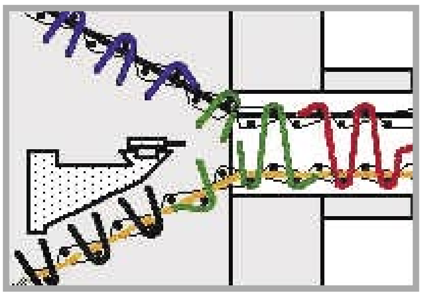

__Figure 1.__ Face-to-face weaving principle [1].

Table 1. *Main properties of the carpet samples used in the experiment.*

Parameters	Sample 1	Sample 2	Sample 3
Weft in ground and the weft density: Ne L 6 / 2 JUTE	450 x 3 = 1350 picks/m	700 x 3 = 2100 picks/m	400 x 3 = 1200 picks/m
Pile Material	ACRYLIC; Nm 16/3 Pile density: 4500 piles/dm^2 Pile height:13 mm	WOOL; Nm 13/3 Pile density: 3500 piles/dm^2 Pile height: 12 mm	POLYPROPYLENE; 2000 dtex Pile density: 2000 piles/dm^2 Pile height: 10 mm

prolonged heavy static loading. This is a part of an extended examination on the performance of carpets under static and dynamic loading, and here only the static loading results are evaluated and the discussed results are given.

Experimental study

Materials

The properties of the carpet samples used in the tests under prolonged heavy static loading are given in Table 1. All samples were characterised by the following parameters:

A - weaving type, dimension, and the end of use of the carpets: 1/3 V type, woven face-to-face in Wilton system, full dimensions: 2×3 m, end use: home floor covering in saloon or other rooms;

B - reeding: reed number and drafting: 3/50, warp ends in reed: 2 ground warp + 1 for wedding;

C - Warp in ground and the warp density: Ne 18 / 4-cotton/polyester 1000 ends in total of full weaving width;

D - Warp for wedding and the warp density: Ne 18 / 6-cotton/polyester 500 ends in total of full weaving width.

The weaving type, dimensions at end use of the carpets, and the structural parameters presented in Table 1 are identical for the samples.

The carpet samples differ in pile material, weft density in ground, and pile density. The wool carpet has the highest weft density (2100 picks/m). The weft densities of acrylic and PP carpets are 1350 picks/m and 1200 picks/m respectively.

An important difference in the structure can be noted in pile densities, (4500, 3500, and 2000 piles/dm^2), and the corresponding yarn counts (Nm 16/3, Nm 13/3 and 2000 dtex); approximately the same resulting yarn count of Nm 5, with a pile height of 13 mm, 12 mm and 10 mm are used for the carpets with acrylic, wool, and PP piles respectively.

Experimental procedures

In order to determine the loss of thickness after prolonged heavy static loading, the thicknesses of the carpets were measured. The thickness consists of the thickness of the ground fabric and its pile height. The test procedure was conducted in accordance with Turkish Standard TS 7578, which is equivalent to ISO 3416. In this method, a specimen is subjected to a prolonged heavy static load; the thickness is measured before loading and after various recovery periods. The area of a specimen is 100 mm×100 mm, and 5 specimens are used for the tests. The specimens are conditioned in a standard atmosphere for testing textiles for at least 24 h. Firstly, the initial thickness of a specimen conditioned and mounted on the thickness tester is measured at the standard pressure, (2.00 ± 0.2 kPa). Secondly, the measured specimen is placed on the static loading machine so that the pressing foot is central, and the specified pressure of 700 kPa is applied. The specimen is left undisturbed at this pressure for 24 h. The thickness is re-measured after recovery for 2 min., just after removing the load. Then, the specimen's surface of use is left uppermost, and the thickness is re-measured after total recovery times of 1 h and 24 h at the same place on the compressed area [16-19].

In this study, the carpets examined are named with respect to their pile materials as 'Acrylic', 'Wool' and 'PP'.

Method adopted

The carpet thicknesses have been measured by the procedure given above. Figure 2 illustrates the procedure schematically. In the upper part of the figure, the original thickness measured at a standard pressure of 2 kPa is shown on the far left. Next to this, the application of a static load of 700 kPa is shown. The thicknesses measured at each recovery period after removing the static load are given on the right. The recovery stages are indicated by the numbers 1 to 3; the thicknesses and the thickness differences in general have been denoted by *h* and δ respectively.

On the basis of the procedure described above, the thickness differences or deformation levels to be used in defining the characteristic parameters are shown in Figure 2, where

h_0 - is the original mean thickness of a carpet sample at the standard pressure before the application of the static load,

h - is the general mean thickness measured after a recovery period removing the static load,

h_1 - is the mean thickness measured after recovery for 2 min,

h_3 - is the mean thickness measured after recovery for 24 h,

δ - is the general difference (deformation) between the original thickness

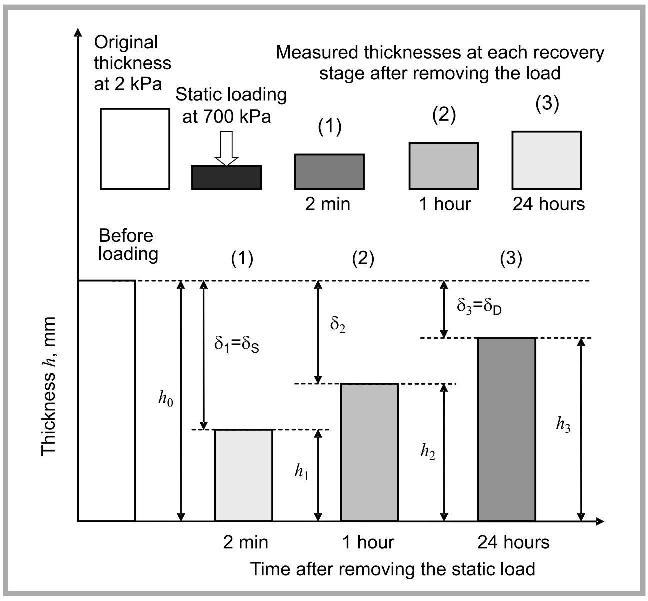

Figure 2. *Schematic diagram of static loading and measuring periods for the thickness;* $\delta=h_0-h$, $\delta_S=h_0-h_1$, $\delta_P=h_0-h_3$, $\delta_E=h_3-h_1$, $\delta_R=h-h_1$.

and the thickness measured after a given recovery period,

δ_S - is the difference (deformation) between the original thickness and the thickness measured after recovery for 2 min,

δ_P - is the difference (deformation) between the original thickness and the thickness measured after recovery for 24 h,

δ_E - is the recovered thickness difference between the thickness after recovery for 24 hours and the thickness after recovery for 2 min,

δ_R - is the recovered thickness difference between the thickness at each recovery period and the thickness after recovery for 2 min,

All dimensions are in mm.

According to the specific deformation or thickness differences between the specific thickness values defined above, the following important parameters determining a carpet's behaviour under static loading have been expressed as

$$h_L = \delta / h_0 \times 100\% \quad (1)$$

$$S = \delta_S / h_0 \times 100\% \quad (2)$$

$$D_P = \delta_P / h_0 \times 100\% \quad (3)$$

$$E = \delta_E / \delta_S \times 100\% \quad (4)$$

$$R = \delta_R / \delta_S \times 100\% \quad (5)$$

where,

h_L - is, in general, the thickness loss (or deformation in compression or deformation level) of a carpet after a recovery period removing the load, in percent,

S - is defined as the squeezing susceptibility or compression sensitivity, in percent,

D_P - is defined as the permanent deformation, in percent,

E - is defined as the elasticity after recovery period for 24 h, in percent, and

R - is defined as the resilience at each recovery period in percent.

Experimental results and discussion

Thickness variation

The full test results are given in Tables 2, 3 & 4, and indicate the individual original thickness, the thickness measured at each recovery stage of the 5 specimens, the corresponding arithmetic mean thickness, and the mean thickness losses in per cent as calculated by Equation (1).

It may be noted from Table 4 that the original thickness and the thicknesses

Table 2. *Test results of the carpet with acrylic pile (pile height:13 mm).*

Static loading and measuring after recovery periods removing the load		Thickness of the specimen h, mm					Arithmetic mean of thickness h, mm	Thickness loss h_L, %
		1	2	3	4	5		
Original thickness,	h_0	15.18	15.04	15.19	14.97	14.85	15.05	-
2 minutes later,	h_1	9.04	9.67	10.47	9.64	9.70	9.70	35.5
1 hour later,	h_2	10.62	10.47	9.79	10.42	11.22	10.50	30.2
24 hours later,	h_3	12.68	11.41	11.00	11.72	11.12	11.59	23.0

Table 3. *Test results of the carpet with wool pile (pile height:12 mm).*

Static loading and measuring after recovery periods removing the load		Thickness of the specimen h, mm					Arithmetic mean of thickness h, mm	Thickness loss h_L, %
		1	2	3	4	5		
Original thickness,	h_0	15.63	15.65	15.55	15.60	15.50	15.59	-
2 minutes later,	h_1	12.60	12.85	12.85	12.75	12.25	12.66	18.8
1 hour later,	h_2	13.80	13.70	14.20	14.45	14.40	14.11	9.5
24 hours later,	h_3	15.04	15.00	15.00	15.20	15.10	15.07	3.3

Table 4. *Test results of the carpet with polypropylene pile (pile height:10 mm).*

Static loading and measuring after recovery periods removing the load		Thickness of the specimen h, mm					Arithmetic mean of thickness h, mm	Thickness loss h_L, %
		1	2	3	4	5		
Original thickness,	h_0	8.60	8.88	8.76	8.51	8.79	8.71	-
2 minutes later,	h_1	6.38	5.89	6.00	5.86	5.96	6.02	30.9
1 hour later,	h_2	7.52	7.37	7.75	7.78	7.25	7.53	13.5
24 hours later,	h_3	7.92	7.89	8.46	7.94	8.05	8.05	7.6

Table 5. *The statistical parameters calculated from the experimental results.*

Static loading and recovery time	Parameters	Calculated values for piles:		
		Acrylic	Wool	PP
Before application	$\bar{x}$, mm	15.046	15.59	8.708
	s, mm	0.144	0.061	0.150
	V, %	0.960	0.390	1.720
2 minutes later	$\bar{x}$, mm	9.704	12.66	6.018
	s, mm	0.508	0.251	0.210
	V, %	5.240	1.980	3.490
1 hour later	$\bar{x}$, mm	10.504	14.110	7.534
	s, mm	0.511	0.344	0.232
	V, %	4.860	2.430	3.080
24 hours later	$\bar{x}$, mm	11.586	15.068	8.052
	s, mm	0.672	0.084	0.236
	V, %	5.800	0.560	2.930

Table 6. *The experimentally measured and the predicted mean thickness values.*

Recovery time and the thicknesses	Material	Thickness level h, mm	
		Mean experimental value	Predicted value
2 minutes later, thickness h_1	Acrylic	9.70	10.06
	Wool	12.66	13.34
	PP	6.02	6.73
1 hour later, thickness h_2	Acrylic	10.50	10.12
	Wool	14.11	13.41
	PP	7.53	6.79
24 hours later, thickness h_3	Acrylic	11.59	11.60
	Wool	15.07	15.10
	PP	8.05	8.10

measured at each recovery period are slightly smaller than the pile height for the carpet with PP pile. The reason for this relatively small value is thought to be that the original thickness is measured at a standard pressure of 2 kPa on the thickness tester, so the carpet surface is initially compressed by this load. Next, the carpet is loaded by the specific pressure of 700 kPa. The thickness measured consists of the thickness of ground fabric and its pile height. The pile height is mainly greater than the ground thickness level. In other words, the ground thickness level may be neglected in comparison to the pile highness. The pile tufts of a carpet are exposed to external forces, and hence they tend to bending under the pressures caused by these static or dynamic forces. In addition to flattening with pressures, the PP-piled carpet has relatively the least pile density in comparison with other carpets. Thus, this structural feature will also affect the bending of the piles. Consequently, this kind of carpet appears to exert weak resistance against initial pressure loading, which in turn has a relatively weaker position against the considerably higher pressure applied during the static loading test.

Table 5 summarises the simple statistical parameters concerning the experimental results as the mean value of thickness ($\bar{x}$), standard deviation (*s*) and the coefficient of variation (*V*) of the corresponding data.

Figure 3 shows the mean original thickness and the mean thicknesses at each recovery period. It was demonstrated that an increase in recovery time resulted in an increase in the mean thickness for all the samples. The maximum deformation occurred at the recovery period of 2 min for each sample. It may be noted that the maximum deflections, δ_S were detected as 5.35 mm, 2.93 mm and 2.69 mm for acrylic, wool and PP carpets respectively. This result is expected, as the longer the pile height, the higher the bending or flattening with pressure. Apart from this, the pile density, fibre composition and fibre linear density of pile tuft are also important parameters for these results. The maximum deflections show that the acrylic piled carpet is least resistant to the static pressure applied, whereas the wool piled carpet is moderate and the PP-piled carpet has the highest resistance. The thicknesses recorded after 24 h recovery time tend to approach the original thickness level but never reach it exactly. Nevertheless it is generally expected from any carpet under static pressure to regain its original or free thickness after a relaxation period of 24 h after removing the pressure. Hence, the mean thickness measured after 24 h recovery time are 11.59 mm, 15.07 mm and 8.05 mm for acrylic, wool and PP respectively. From the point of view of permanent deformation, δ_P can be extracted from the figure that the acrylic gave 3.46 mm permanent deformation, whereas the corresponding values for the wool and PP were 0.52 mm and 0.66 mm respectively. On this point, the wool carpet is better than those of the other carpets. The acrylic carpet is the worst in comparison with the others. The maximum recovering in the thickness, δ_E, are 1.89 mm, 2.41 mm and 2.03 mm for the carpets with acrylic, wool and PP respectively. Again, the best is the wool carpet and the worst acrylic carpet.

The results obtained show that the resilience capabilities through the relaxation period are comparably different for the samples examined. The reason for these results can be attributed to the importance of the pile material's properties and carpet construction. These parameters may be given as the fibre composition, fibre linear density, the number of fibres in each pile tuft, pile height and pile density. Here, it was not possible to investigate the effect of each parameter on the thickness loss and resilience characteristics of carpets, since this study involved industrial conditions, and commercial carpets had been chosen for examinations.

A simple linear regression approximation to the data of mean thicknesses is given by equations for the acrylic, wool and PP carpet's piles respectively shown in Figure 4 together with the correlation coefficient R. Here, x represents the recovery time in hours, and y represents the predicted mean thickness after static loading in mm.

Table 6 compares the calculated means obtained from measurements, with the results predicted using the regression equations. As can be seen, the predicted results are well suited to the corresponding actual values, especially at the 24 h recovery period. Although R for the equation describing the behaviour of PP carpets is relatively lower than those of the others, it predicts comparably good results. Therefore, these equations can be used as a model to predict the changes in carpet thickness in similar carpet constructions.

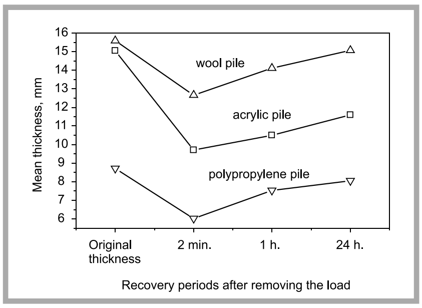

***Figure 3.** Mean thickness variation with recovery period.*

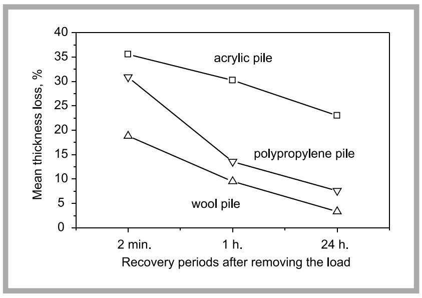

***Figure 5.** The mean thickness loss variation with recovery period.*

Thickness losses

Figure 5 shows the mean thickness losses at the recovery times. Generally the thickness loss decreases with increase in recovery time. The maximum thickness loss, called squeezing susceptibility or compression sensitivity *S*, is 35.55%, 18.8% and 30.9% for the acrylic, wool and PP carpet samples respectively. These values can be related to the energy absorbed under the static pressure applied. From this point of view, the wool-piled carpet shows the best performance. The permanent deformation D_P is 3.3% for wool-piled carpet, whereas the acrylic and PP piled carpets have 23.0%, and 7.6% respectively. From this point of view, the wool carpet is clearly better than the other carpets, although the acrylic carpet is the worst. The elasticity of the samples *E* (%) are 35.33%, 82.25% and 75.46% for acrylic, wool and PP carpets respectively. Again, the best is the wool carpet, and the worst the acrylic carpet. When evaluating these values, apart from the wool-piled carpet, it is seen that the PP carpet shows better performance. This was an unexpected result for PP carpets, since they have the least pile density.

In this study, the test purpose was to determine the thickness loss (or deformation in compression) and evaluate the carpet's characteristic parameters under static loading. For this reason, commercially-manufactured carpets have been

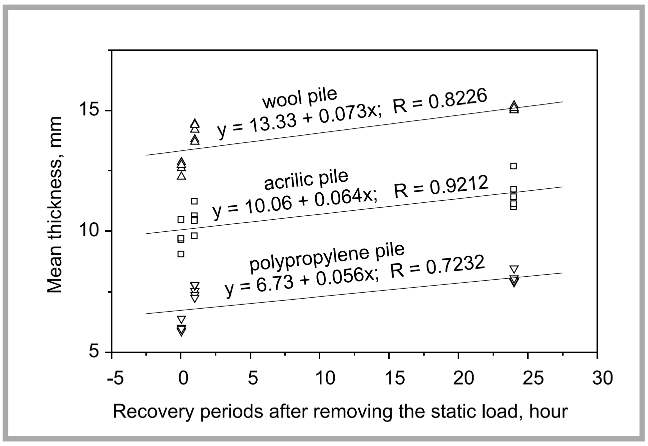

Figure 4. *Simple linear regression approximation for the thickness values.*

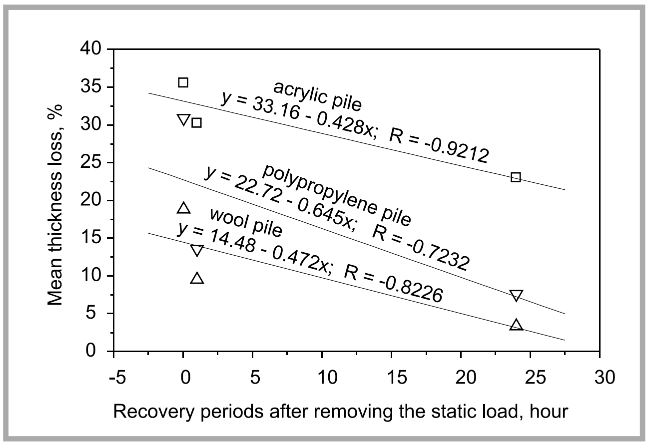

Figure 6. *Simple linear regression approximation for the mean thickness loss.*

chosen to realise this aim. It was difficult to select a certain factor affecting the defined characteristic values of *S*, D_P and *E* for the carpet samples, as the carpets have not been produced to investigate the effects of yarn, fibre material, and the carpets' constructional parameters. Hence the results cannot be attributed to only one parameter, but to the complexity of all carpet's parameters such as fibre composition and linear density, the number of fibres in each pile tuft, pile height and density. Therefore, the carpets examined were only relatively, compared on the basis of the results carried out.

The results of a simple regression analysis are demonstrated in Figure 6 and Table 7 with the help of regression equations. The equations correspond to the mean thickness loss variations for acrylic, wool and PP piles respectively. Here, x is again the recovery time and y is the mean thickness loss in per cent.

It can be seen in Figure 6 and Table 7 that these equations are well adjusted to the data measured. Since the prediction is quite accurate for all samples, these equations may also be considered when calculating the thickness loss theoretically.

Table 8 shows the characteristic parameters of the carpets together. Figure 7 compares these characteristic parameters, defined as squeezing susceptibility or compression sensitivity *S*, permanent deformation D_P and elasticity *E*, determining the behaviours of carpets. As seen in Figure 7, the *S* value is the highest for the acrylic carpet. This is an unexpected result, as the acrylic piled carpet has the highest pile density (4500 piles/dm^2) compared with the other carpets tested (Table 1). That means it is not very resistant to static loading. From this point of view, the wool carpet gives a better performance with lesser pile density (3500 piles/dm^2). The PP carpet is comparatively good, despite having the least pile density (2000 pile/dm^2). In the case of the permanent deformations , and the elasticity, the wool carpet is again the best and the acrylic carpets the worst. Hence, it may be concluded that the pile material is of greater importance rather than the pile density in determining the carpet behaviours with static loads. Besides these factors, the pile highness may also be seen to affect these results.

Table 7. *Experimentally calculated and the predicted mean thickness loss values.*

Recovery time	Material	Thickness loss hL, %	
		Mean experimental value	Predicted value
2 minutes later	Acrylic	35.55	33.15
	Wool	18.79	14.46
	PP	30.88	22.70
1 hour later	Acrylic	30.23	32.43
	Wool	9.49	14.01
	PP	13.55	22.08
24 hours later	Acrylic	22.99	22.89
	Wool	3.33	3.15
	PP	7.58	7.23

The resilience value R for the carpet samples at each recovery stage was calculated by Equation 5. Figure 8 shows the changes in resilience R by the recovery period. The maximum resilience R of a carpet sample means that the limit of the elasticity E is reached at the recovery period for 24 h after removing the static load. The resilience variations of the carpets through the recovery times demonstrate that the wool-piled carpet is best in comparison to the others, whereas the acrylic-piled is the worst, and the PP-piled carpet is comparably good.These results may be related to the internal and external structures of the pile tufts, i.e. the wool fibre is made of protein molecules; the long-chain protein molecules form the fibrils, and the fibrils form the fibrillar bundles. Thus they form the mass of spindle cells which provides superior or extraordinary elasticity. Apart from this, the wool's physical properties such as fineness, length, natural resilience, and crimp or waviness are influential parameters on the elasticity or the resilience characteristic; that is why the wool fibres are used as the pile tufts for a carpet. In general, acrylic fibres are resilient and shape-retentive. They have a wool-like handle, low density and are thermoplastic and wrinkle-resistant, although they are susceptible to deformation in steam or hot water. The glassy structure of acrylic fibres makes them very resilient. At room temperature, the fibres resist crushing, and will spring back into shape after the compressive force is released. This property makes these acrylics well-suited for use in carpets. Acrylic fibres are moderately strong, very resilient and have good abra-

Table 8. *Characteristic parameters of the carpet samples.*

Parameters	Acrylic	Wool	PP
δ_S, mm	5.35	2.93	2.69
δ_P, mm	3.46	0.52	0.66
δ_E, mm	1.89	2.41	2.03
S, %	35.55	18.79	30.88
D_P, %	22.99	3.34	7.58
E, %	35.33	82.25	75.46

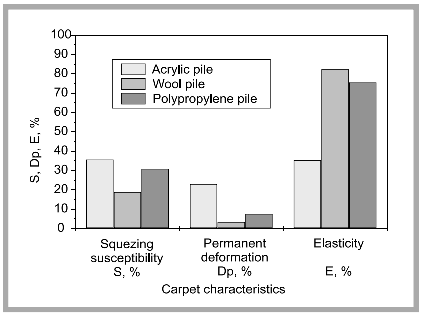

Figure 7. *Comparison of the characteristic parameters.*

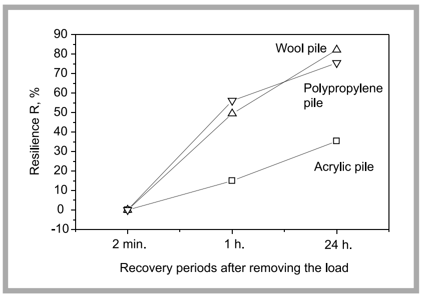

Figure 8. *The resilience characteristics of carpets.*

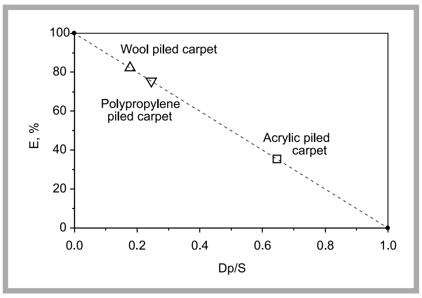

Figure 9. *The elasticity variation with D_P/S ratio.*

sion resistance. In normal apparel use, the dimensional stability of acrylic fabrics is satisfactory. The fibres have good elongation and elasticity at low levels of elongation. In knit fabrics, the stretch recovery is quite good, but in wovens, in which the construction prohibits the fabric from stretching, acrylic yarns may be extended beyond their ability to recover. PP is a solid, transparent, rodlike fibre with little internal structure. The cross-section may take any shape, but is usually round, and the fibre's resiliency is good [21- 25].

Besides these properties, the constructional parameters of the carpets such as pile height would affect the resilience properties; i.e. the acrylic has a pile height of 13 mm, whereas the corresponding pile height is 10 mm for PP. Hence, the longer the pile height, the higher the bending, and the less the recovery to the original position after the static pressure is released.

In order to obtain a general relationship between the carpets' characteristic parameters S, D_P and E, the following expression has been developed. Considering the relation between δ_E, δ_S and δ_P as $\delta_E = \delta_S - \delta_P$ and using the equivalent expressions for the carpet characteristic parameters, we obtain;

$$E = \left(1 - \frac{D_P}{S}\right) \times 100\ (\%) \qquad (6)$$

If the permanent deformation value D_P becomes zero, the elasticity value E takes the value of 1 (100%). This means that after removing the static load, a carpet will completely recover its thickness level and be equal to the thickness in the free-state position. On the other hand, assuming that the permanent deformation value D_P is equal to the value of squeezing susceptibility S, the elasticity value E will be zero (that is a carpet, which never recovers its thickness level). These are the theoretical limits for a carpet. Hence, the elasticity E value of any carpet is to be found within the range of these limit values depending on the D_P/S ratio.

Figure 9 shows the variation of elasticity E (%) with the D_P/S ratio, which as expected, is inversely proportional with D_P/S, together with the experimental results of E.

By analysing Figures 7 to 9, we see that the carpet with acrylic pile is less able to approach to its original thickness after 24h recovery, caused by smaller elasticity E, higher squeezing susceptibility S and permanent deformation D_P than those of the other carpets. From this point of view, the wool carpet has the best resilience properties, as E is quite high; the values of D_P and S are comparatively smaller. This is thought to be because of the better resilience capability of wool fibres against static loads [7, 8, 21-26].

Though the carpet with PP pile is weaker in terms of pile density, compared to the acrylic- and wool-pile carpets, it shows good resilience capability, which is somewhat higher than that of the carpet with acrylic pile, and is near the resilience capability of the carpet with wool pile.

In the planned second part of this study, further analysis will be made of the energy absorption, work done on the carpet, damping characteristics and hysteresis effects on carpet behaviour under static loading.

Statistical significance analysis

The experimental results have been statistically evaluated by using the Design Expert Analysis of Variance (ANOVA) software with F values of the significance level of α =0.05, with the intention of exploring whether there is any statistically significant difference between the variations obtained. The results of the variance analysis are elaborated in Table 9. It may be seen that there are statistically significant differences for both mean thickness variation and thickness loss of samples tested in terms of pile material and recovery time. In other words, the pile material and recovery time significantly affect the mean thickness variation and thickness loss variation with the significance level of α =0.05.

The data has also been chosen to cover the relative importance of each source of variation in the ANOVA (including the pile material and recovery time). The results thus obtained are also shown in Table 9. The main effect of pile material accounted for 90.74% of total variation in mean thickness variation, whereas the recovery time was a minor factor, contributing to only 8.98% of the total variation (the F test gives a P-value of 0.0009, compared with 0.0001 in the case of the pile material). The interaction between pile material and recovery time accounted for 0.28% of variation in the mean thickness variation.

The main effect of pile material accounted for 53.11% of total variation in the thickness loss variation as a major effect, whereas the recovery time contributed to 42.53% of total variation (the F test gives the P-value of 0.0087 comparing with the corresponding value of 0.0058 in the case of the pile material). The interaction between the pile material and

Table 9. Statistical analysis of variance results.

Parameters	Mean thickness variation, mm			Thickness Loss ,%		
	F values	P-value	% Contribution	F values	P-value	% Contribution
Pile material, PM	646.8 > 6.94*	0.0001	90.74	24.36 > 6.94*	0.0058	53.11
Statistical evaluation	Significant			Significant		
Recovery time, RT	64.01 > 6.94*	0.0009	8.98	19.50 > 6.94*	0.0087	42.53
Statistical evaluation	Significant			Significant		
PM x RT	-		0.28	-		4.36

* $F_{0.05,2,4}$ = 6.94 PM: Pile material RT: Recovery time.

recovery time accounted for a relatively low value of 4.36% of total variation in thickness loss.

Conclusions

Based on the experimental study carried out on the performance of carpets against static loading, the following conclusions can be drawn;

1. In general, the mean thickness level increases, and correspondingly the mean thickness loss values decrease by the increased recovery period for all the carpet samples examined. It was seen that the acrylic-piled carpet is the least resistant to the static pressure applied, whereas the wool-piled carpet is moderate, and the PP-piled carpet has the highest resistance to the pressure application as determined by the squeezing susceptibility (compression sensitivity) S in percent after recovery for 2 min. From the aspect of the permanent deformation Dp in percent and the elasticity E in percent, after recovery for 24 h, it was found that the wool carpet is best and the acrylic carpet is worst.
2. By using the results obtained concerning the mean thickness level and thickness loss values, it is possible to predict the mean thickness and thickness loss changes in similar carpet constructions. In other words, the variations exhibited in Figure 4 and 6 can be used as models to estimate the behaviour of any carpet in terms of its thickness and thickness loss.
3. Comparing the characteristic parameters with respect to the pile material and pile density; the value was higher for the acrylic carpet than those of the other carpets, though it has comparatively the highest pile density (4500 piles/dm^2). That means it is not very resistant to static loading. On the contrary, the wool carpet showed a better performance despite a lesser pile density (3500 piles/dm^2). The PP carpet was found to be comparatively good, despite having the least pile density (2000 pile/dm^2). In the case of the permanent deformations, and elasticity E, the wool carpet is best and the acrylic carpet is worst. For this reason, the pile material is thought to have great importance in determining the carpet behaviours to static loads.
4. A general relationship between the characteristic parameters defined as S (%), Dp (%) and E (%) has been obtained, relating the elasticity E (%) to Dp/S ratio. It was seen that the elasticity E (%) is inversely proportional with the Dp/S ratio in general. Furthermore, the increase in Dp/S ratio results in the decrease in the elasticity value E (%). From this point of view, the elasticity E (%) can be estimated in terms of the Dp/S ratio for any carpet.
5. The statistical evaluations of the experimental data showed that the pile material and recovery time have significant effect on the mean thickness variation and the thickness loss (deformation) in compression variation.
6. From the point of view of the end use, the carpet with wool and PP piles may be preferred where heavier, massive and stationary goods are used, due to the better resilience capability against static loading. On the contrary, the carpet with acrylic pile may not be so suitable, because of its poor resilience ability to static loading.

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