فصلنامه
علمی پژوهشی
انجمن علمی
فرش ایران
شماره سه
تابستان ۱۳۸۵

[3] S. Bahrami "How to Maintain Carpet," Tehran, Office for Provision and Collection of Text, & The center for publishing and picture.2nd edition, 1375, p.p 53-70.
[4] G.A Cranaby E.J Wood, "The Physic of Carpets", JTI, No1, 1989, p.p 71-90
[5] S.A Mir Jalili, "Research on The Study of Physical and Mechanical Properties of The Hand-Woven Carpet by The Application Dynamic and Static Forces", Research Center For The Persian Carpet(PCRC), 1381, 79-0910152000, p.p 99-101 and 58-68.
[6] S. J Bassam, "A Study Physical & Mechanical Properties of Symmetrical & Asymmetrical Knots", Research Center for the Persian Carpets(PCRC), 1383, p.p 22, 21, 42, 40
[7] W.E Morton, J.W.S. Hearle, "Physical Properties of Textiles Fiber" London, the Textile Institute, Second published 1975, p.p 465-466.
[8] E. Koc, N. Celik ,M. Tekin, " An Experimental Study on Thickness Loss of Wilton-Type Carpets Produced with Different pile Materials after Prolonged Heavy Static",part1, F.T.E.E, No4, 2005, p.p.56-62.

1. Textiles Section, Faculty of Engineering, Science and Research branch of Tehran, Islamic Azad University, TEHRAN, IRAN
2. B.Sc, M.Sc. AUT, Ph.D. UNSW
Assistant Professor
Dept. of Textile Engineering
Amirkabir Univ. of Technology
3. B.Sc IUST, M.Sc., Ph.D. City University of LONDON
Assistant Professor
Dept. of Mechanical Engineering
Iran university of Science and Technology
4. B.Sc, M.Sc., Ph.D.
Assistant Professor
Textiles Section, Faculty of Engineering, Science and Research branch of Tehran, Islamic Azad University, TEHRAN, IRAN
5. B.Sc, AUT, M.Sc. , Ph.D. UNSW
Assistant Professor
Institute of Technical and Vocational Higher Education, Ministry of Jahad Agriculture, TEHRAN,IRAN

Studing the equations of the table (3), it can overly be judged that the changes in the slopes and intercept (b1) is even and similar to each other. In other word, any increase in slope will bring about an increase in the intercept (b1).

Investigation of correlation coefficient of the fitted equations, in different areas with different environmental conditions suggest that the correlation coefficient for dry condition is significantly lower or lack of correlation between the time and the compression strain than those of in other environmental conditions. This result indicates that in dry condition, the compression creep behavior of Persian silk carpet does not follow the Eyring model.

Conclusion:

Experimental results indicate that the creep behavior of the Persian silk carpet under compressive load has a good correlation with that of Eyring model in mild and humidity conditions. It is found that regardless of environmental conditions, the least compression strain obtained in NP2 where creep intensity is less than other folding configurations. It is shown that in dry environmental condition the compression strain as well as is least among other cases. Investigation of correlation coefficient of the fitted equations, in different areas with different environmental conditions suggest that the correlation coefficient for dry condition is significantly lower or lack of correlation between the time and the compression strain than those of in other environmental conditions. This result indicates that in dry condition, the compression creep behavior of Persian silk carpet does not follow the Eyring model.

Therefore, it is appeared that storing the Persian silk carpet in dry conditions in a flat configuration would lead to higher resistance against compression force. To prevent any increase in compression strain, it is suggested that Persian silk carpet to be stored in a flat configuration. It is also notified that regardless of storing configuration, the humidity condition could have a sever impact on compression strain and as a result on carpet deterioration. It is concluded that the Persian silk carpet to be stored in dry condition in such a way that the amount of moisture is regulated constantly.

References:

[1] J. Yasavoli, “An Introduction to The Recognition Iranian Carpet”, Tehran, Yasavoli, 2nd Edition, 1375, p.p 61

[2] Sh. Sour Esrafil “Good carpet, Bad carpet, Standard carpet.” Tehran, 2nd Edition, First Pub, 1376, p.p 104-109

According to the experimental results, the maximum compression strain values occur within NP2, while the minimum values are obtained within NP1 area. Maximum compression strain variations taking place within TP area in which always less than the changes which occur within NP2 and greater than the changes which occur within NP1.

The analysis of variance for the average values of maximum compression strains within different areas, under the same environmental conditions and also for the average values of maximum compression strains within a specific area under different environmental conditions are performed. The statistical analysis results show that the measured compression strain values for the same environmental condition and different area are significantly similar. In addition, the statistical analysis results show that in areas of TP under different environmental conditions, the maximum compression strains within a specific TP area under mild and humidity environmental conditions are similar. It is also found within the areas of NP1 and NP2 under humidity and mild environmental conditions, the maximum compression strains are similar only at the level of % 95 confidences but this similarity obtained from TP area in the flat configuration only at the level of % 99 confidence.

In general, it may be considered that the maximum compression strain increases as the condition transients from dry towards humidity. While this increase, within all area , is suddenly occurred firstly and then gradually reached to a stable condition

<u>Comparison of compression creep behavior of Persian “Silk” carpet:</u>

In order to compare the compression creep behavior of Persian silk carpets tested under different environment and folding configurations, the slope, intercept and correlation coefficients of proposed equations are statistically analyzed and hypothesis test was performed. It is found that the slope of fitted equations within the NP1, under a defined environmental condition is always greater than those of within other areas. However, the slopes of equations within NP2 is even less than that of in TP state. Comparing the slope of creep curve for different environmental conditions, it is shown that the slope value for humidity conditions is always less than that of mild condition.

In addition, in mild condition, there is no statistical difference between the slopes of the equations within NP1 and TP areas, while this result is not true with humidity conditions.

It should be remembered that, in dry condition, because of lack of fitness equation, it would be hard to judge about the dry condition.

$$Y1+Y0 = a1\times Ln(t) + (y0 - b1) \qquad (14)$$

$$Y = a1\times Ln(t) + Y0 \qquad (15)$$

In this state

$$Y = y1 + y0 \qquad (16)$$

$$Y0 = y0 - b1 \qquad (17)$$

By comparing equations (13) and (15), it can be implicated that the parameter ‘a1’ is a variable that depends on the final strain as well as constant force; and the parameter ‘b’ is the error of measurement and fitness, which affected by the immediate strain. The value of the immediate strain is not constant and varies as long as environmental conditions and constant force change. On the other hand, in dry condition within NP1 area, the fitted equation has a form of $y1= (a1)\times t^{b1}$ which by applying the logarithmic solution the following forms may be obtained:

$$Lny1 = Ln(a1) \times t\ \hat{}\ b? \qquad (18)$$

$$Lny1 = b1\times Ln(t) - B \qquad (19)$$

And as the value of a1 is negligible

$$Y1 = b1\times \ln(t) - B \qquad (20)$$

In which Y1 is a non- Linear Function of ‘y1’.

فصلنامه
علمی پژوهشی
انجمن علمی
فرش ایران
شماره سه
تابستان ۱۳۸۵

Comparison of Maximum Strains:

Table (4) shows the maximum compression strain values, obtained for different methods of foldings along with different environmental conditions.

Table(4) Maximum compression strain values under different environmental and folding conditions

Area / condition	(NP1)	(NP2)	(TP)
Mild	(ave)4.18%	(ave)3.46%	(ave)3.46%
Humidity	(ave)4.91%	(ave)3.46%	(ave) 4.03%
Dry	(ave)2.30%	(ave)0.86%	(ave) 1.29%

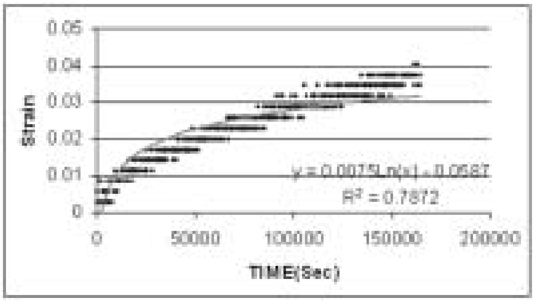


Figure 5: Compression creep behavior of Persian silk carpet in humidity environmental condition. a for NP1, b for NP2, c for TP

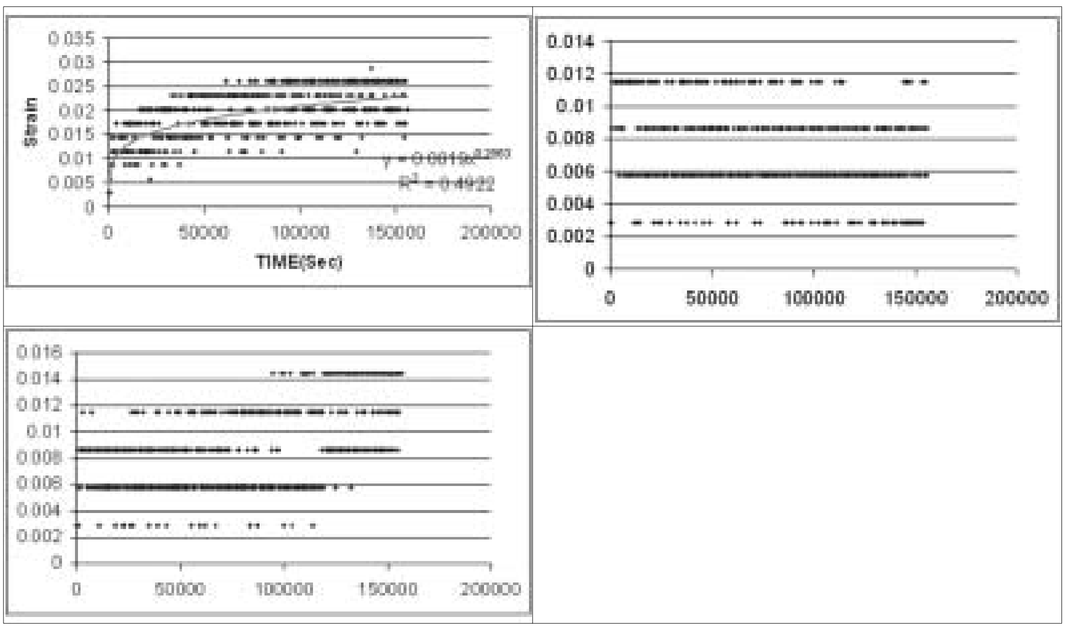


Figure 6: Compression creep behavior of Persian silk carpet in dry environmental condition. a for NP1, b for NP2, c for TP

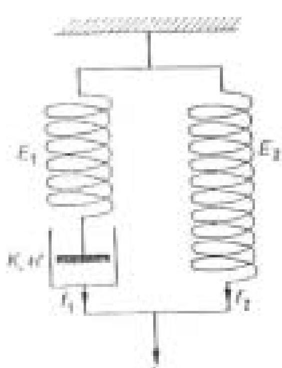


Figure 7: Eyring Model[7]

In this case, the form of compression creep is virtually the same as equation (13). It should be notified that the computed form is only true for describing the primary creep and if immediate strain ‘y0’ is added to the both sides, the resulted form could be regarded as equal to the equation(13).

Based on Eyring model (Figure 7), the following equation is represented to explain the creep behavior of textile fibres [7]:

$$Y = (y_{\infty}/\alpha) \times f_c \times \mathrm{Ln}(1 + At) + y_0 \qquad (11)$$

in which,

$$A = [\alpha \times \kappa \times fc\ (1 - Y0/ Y1)] \div [Y\infty \times \mathrm{Ln}(\coth\ \{\alpha \times fc\ (1 - Y0/ Y\infty) / 2\})] \qquad (12)$$

T: time, Y_0 : immediate strain, $Y\infty$: ultimate strain

fc: constant Force α & k: Is constant coefficient.

Now, assuming that $a = Y\infty/\alpha \times fc$, it can be concluded that

$$y = a \times \mathrm{Ln}\ (T) + y0 \qquad (13)$$

in which T is the function t and A .

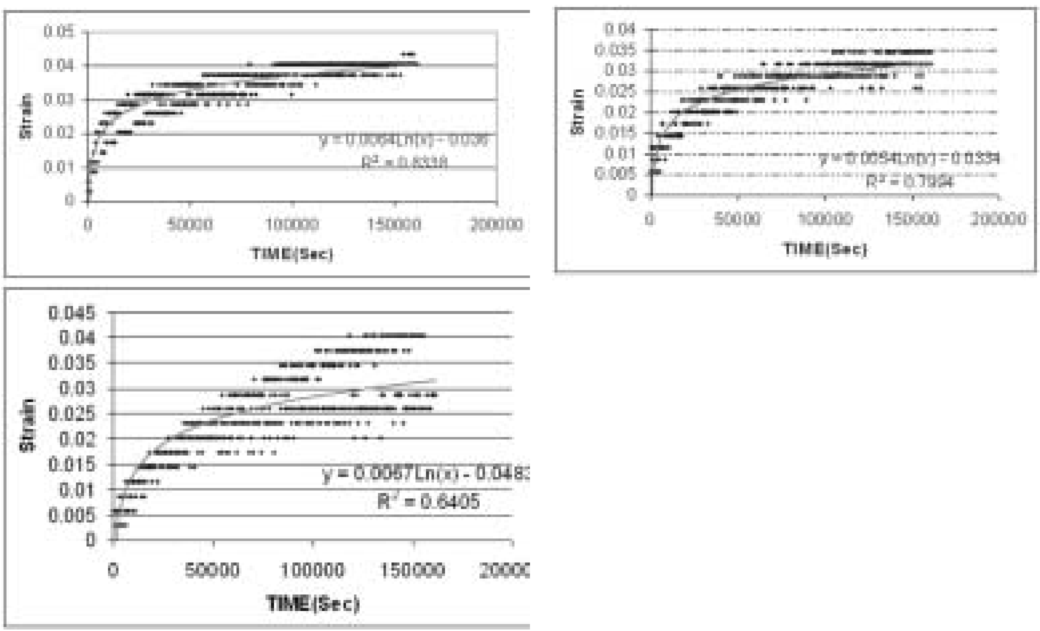
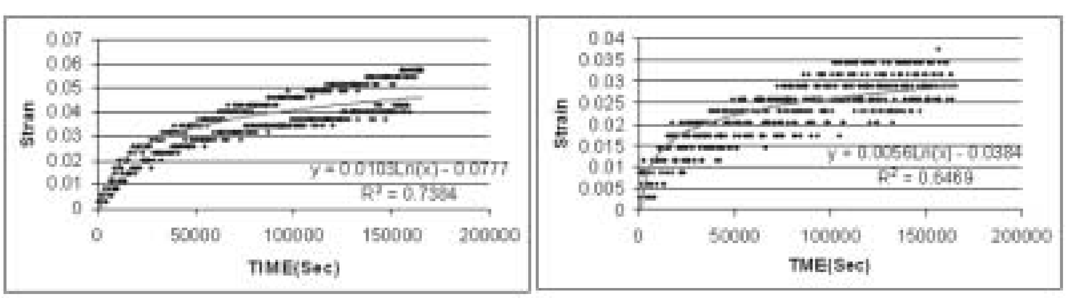


Figure 4: Compression creep behavior of Persian silk carpet in mild environmental condition. a for NP1, b for NP2, c for TP



فصلنامه
علمی پژوهشی
انجمن علمی
فرش ایران
شماره سه
تابستان ۱۳۸۵

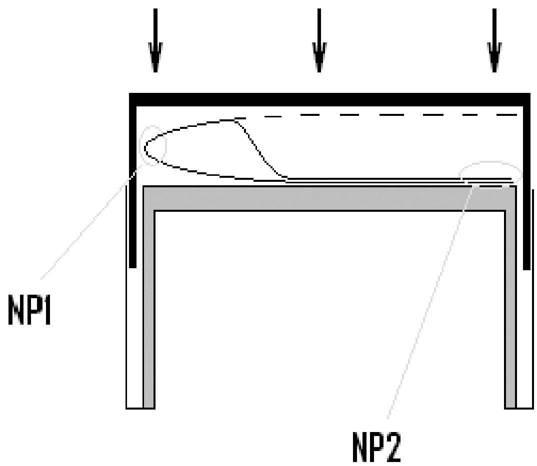


Figure (3):
A schematic diagram
of the experimental set-up
for carpet compression

فصلنامه
علمی پژوهشی
انجمن علمی
فرش ایران
شماره سه
تابستان ۱۳۸۵

Result and Discussion:
Modeling the Compressional Creep behavior of Persian Carpet:

Table (3) represents the regression equations that explain the compression creep behavior of Persian silk carpet. These equations are obtained through the process of fitting on the measured data.
Figure 4 to 6 show the compression creep trend of Persian silk carpet in different environmental and laying configurations. Regarding the obtained regression equations, it can be considered that all equations are in the non-linear, concretely linear form of Y1=a1×Ln(t)-b1, which are very similar to that of equation proposed in Eyring model to describe the creep behavior of textile fibres. It is also shown that only in dry environmental condition within the area NP1, where the lowest compression strain occurs, the fitness form changes from linear state into the non-linear form of Y=a1×(t^b1) with the lowest correlation coefficient.

Table (3): Regression Equations for compression creep behavior of Persian silk carpet in different environmental and laying configurations

Aerea / condition	(NP1)	(NP2)	(TP)
Mild	0.0064Ln(t)-.0036 R^2=0.8338	0.0054Ln(t)-0.0344 R^2=0.7994	0.0067Ln(t)-0.0483 R^2=0.6405
Humidity	0.0103Ln(t)-.0777 R^2=0.7384	0.0056Ln(t)-0.0384 R^2=0.6469	0.0075Ln(t)-0.0587 R^2=0.7872
Dry	0.0019× t ^ 0.2063 R^2=0.4922	----------------------------	----------------------------

(s^2)s is approximately zero, are chosen for computation of their *Mallow's* coefficient and picking out those which have the closest to unit value. In all computations, care must be taken to find and analyze the non-standard data by means of '*Estevansky's* equation' and remove them from the batch, which is to be considered in the process of computation. Based on the hypothesized *'Growth Equation'* on the curve fitted on the data, the equations whose correlation coefficient are much too small and nominal, the equation which has the least non-standard and non-collective data is picked out without taking into consideration the rate of its R^2.

$$CP = Rssp \div S^2 \qquad (6)$$

$$Di = eI \div \sqrt{MSD} \quad \textit{(Estevansky Equation)} \qquad (7)$$

where:

CP: is *Mallow's Coefficient*

Rssp: is standard deviation of standardized residual square

$$Yi - \dot{Y}i = eI \qquad (8)$$

$$\sum eI \div (N-2P) = S^2 \qquad (9)$$

where:

N: is the number of the given data

P: is the number of the related variables representing time and is always equal to 1.

MSD: Mean square difference

$$MSD = \sum eI \div (N-2) \qquad (10)$$

and as a result it is always equal to S^2.

Figure (2): A Typical Photo of the Simulator Apparatus to Measure Carpet Compression Creep Behavior

فصلنامه
علمی پژوهشی
انجمن علمی
فرش ایران
شماره سه
تابستان ۱۳۸۵
۹۹

of 110×110×110cm. A pressing system with a surface area of 70×80cm was installed, which has the capability of being loaded with loads of 35kg to 350kg. A Schematic picture of this pressing system is shown in Figure 3. In this set-up, the environmental conditions including temperature and relative humidity of the chamber can be changed from zero to 60°c and %10 to %95 r.h. respectively.
To measure the carpet thickness variation, a special aluminum bar with dimensions of 30×90×0.5cm was used and placed in the area of compression force. In the case of flat configuration, this bar is usually placed at a distance of 63± 5cm from the end of the carpet (called Tp area). In the case of folded configuration, this bar is placed at folded point (known as NP1), and also at a distance of 115±5cm from the end of the carpet, which is referred to as NP2 area. The variation height of this bar is registered using indicator and data acquisition system. Each indicator is connected through an Interface (RS232C) to the serial ports of a PC, through which the average changes in the thickness of the carpet is transferred regularly, every 10 minutes by the serial commands of some multi-timer designed C.K.Ts into the PC. The first data is given to the PC, 30±5 seconds after the loading the carpet. Therefore, Two different ways of flat and folded configurations and three environmental conditions; mild, humidity, and dry, were considered and carpet thickness were measured under constant two different loads of 150 and 135 kg for 48 hours. Thus, the compressional creep behavior of carpet is measured and studied in this research.
To determine the best linear equation, which may fit on the curve, the least square method is used. In this method, three concretely linear and two non-linear forms are fitted on the data in order to select the best fit by means of *'Evaluation-of-All-Available Equation'*.
* A concretely linear, linear form:

$$Y=a\times x \qquad (1)$$

* Concretely linear, non-linear forms

$$Y=a\times(x^2) + b\times x \qquad (2)$$

$$Y=a\times \ln(x)-b \qquad (3)$$

* Non-linear, concretely non-linear forms

$$Y=a\times(x^b) \qquad (4)$$

$$Y=a\times (e^x) \qquad (5)$$

In this method, the curve fitted on the data is first hypothesized in the form of *'Linear Equation of Growth'* or in the form of *'Catalectic, Logarithmic Non-Linear Equation'* and then subjected to analysis.

In the method of *'Evaluation-of-all-the Available-Equations'*, the equations with maximum coefficient correlation are first selected so as to remove the descending or emphatically descending ones; then, the equation whose computed mild, humidity, and dry, were considered and carpet thickness were measured under constant two different loads of 150 and 135 kg for 48 hours.

The specification of carpet to make the experiment is given in Table (1). Warp and pile of the silk-carpet were silk yarn and weft of silk carpet was cotton yarn. Silk Persian carpet have “Mehrabi-Goldani” pattern; its knots are asymmetrical; and in every carpet row, there are two wefts involved. The dimensions and the number of knots per unit area are measured with a precision of 0.5mm based on Iranian standards No500 and No456. The height of the pile and primary thickness were also measured based on standards ISO2949 and ISO1765 respectively.

Table (1): The Specifications of the Silk persian carpet (Average values).

Dimensions (cm x cm)	115.2 x 75.62
numbers of knots per 10 x 10 cm	102 x 97
Pile height (mm)	2.48
Thickness (mm)	3.46

To determine environmental conditions for this research, the changes in the environmental conditions in the city of Tehran were obtained from 13 synoptic sites of the Meteorological Bauru, and the average of the temperature degrees in the course of a whole year was competed. Then, by selecting the months of Oct, Feb, and July as the months when environmental would respect fully be mild, humidity and dry, a confidence interval of 99% was illustrated for the average amount of heat and rate of moisture stemming from their being more or less in a whole month.

Table 2 shows the environmental conditions considered in the current research work.

	Moisture (%)	Temperature (°c)
October	40±5%	19±2
Febuary	65±5%	6±2
July	25±5%	30±2

To measure the variation of carpet thickness with time under different in different environmental conditions, a simulator with a dimension of 185×125×135cm was designed and constructed. A typical picture of this apparatus is shown in Figure 2. This simulator has an inside chamber with dimensions experiment revealed a reduction in the thickness in the early phase, but then stopped despite the continuation of increase in the compressing force. After the removal of the force of compression, the thickness resumed increasing however; but this return, too, was so small that it could be assumed the impact was permanent [4].

Another experiment revealed a non-linear relation between the applied pressure and resulting strain for a pile carpet. To prove the existence of such a relation, despite the fact that the experiment was made under absolute isolation, the applied pressure by the 'stored energy' was computated elastically [4].

In another research done in 2002, the effect of a 24 hour static load of 7 kg/cm² on hand-woven carpets with 25 and 35 knots per 6.5×6.5 cm. was studied. The result indicates that much of the changes in thickness occurred in the early stages of compression and then slows down to a steady state condition. The experiment also showed that the rate of decrease in thickness is inversely proportional with an increase in the number of knots per unit. This, however, has no effect on the trend of change during the early hours [5].

In 2003, Bassam measured the changes in the thickness of carpets with different number of knots per unit area. This experiment was made under the conditions of a constant load of 1.5 kg for duration of 2 hours and a circular area with a diameter of 3.5cm. The result shows that the thickness change in carpet with asymmetrical knots is less than that of carpet with symmetrical knots. This research also revealed that the carpets with symmetrical and asymmetrical knots could lose half of their thickness in less than half an hours when they are under a static load [6].

In th last research E.Koc, N.Celik and M.Tekin three Wilton-Type carpets with different pile materials are used to evaluate the thickness loss in compression after prolonged heavy static loading. They measured compression sensitivity, resilience and elasticity of carpets. From point of view of them, the car pet with wool and polypropylene piles may be preferred where heavier, massive and stationary goods are used, due to the better resilience capability against static loading[8].

The objectives of this research are to investigate the compressional creep behavior of Wool hand-woven carpet ("Silk") under different environmental conditions in order to obtain the suitable storage of carpet.

Material and Method:

In this research, a hand-woven-Silk Persian carpet, "Gom", was used. Two different ways of flat and folded configurations and three environmental conditions;

Introduction:
How to Store Carpets:

Hand-woven Iranian carpets are stored and preserved in a variety of ways and methods before export. The most important ones are flat; placing the carpet of the same dimension on each other horizontally, and folded method in which the carpets are folded and placed on each other lengthwise [1].

In the former method, the carpets are sorted out in accordance with their origin, material, size and style of weaving. They are then placed on a slatted wooden pallet, which is 20cm above the ground. The height of the stack or heap in this method is about 110cm and the approximate force being exerted on the last underneath carpet would be 150kg. In the folded method, the general height remain unchanged; the force being applied to the last underneath would be 135kg; and the folds of each carpet would be similar which therefore, reduces the occupied space to one half of the space needed by the flat method [3].

Though economically advantageous from this point of view, the folded method, depending on the environmental condition and the duration of remaining folded, would change the physical and feature of the carpets [2].

The duration of storage under such conditions would last 2-7 days and the stores are mostly in the bazaar, where there is no control on the rate of moisture and temperature [3].

The Figure 1 shows two methods of storage.

Figure (1): Methods of storage; (a): Flat and (b): Folded

Compressional Creep:

In 1989, Carnaby and Wood placed a carpet under gradual compression to study the changes in the thickness of it after compression was removed. The

فصلنامه
علمی پژوهشی
انجمن علمی
فرش ایران
شماره سه
تابستان ۱۳۸۵
۱۰۳

Silk Persian Carpet under Loading in Different Environmental Conditions

S.Ali Mojabi[1], Saeed Shaikhzadeh Najar[2], Shahrokh Hosseini Hashemi[3], A.Rashidi[4], S.J.Bassam[5]

ABSTRACT:
In this research, an apparatus was designed and constructed in order to simulate the storage behavior of hand-woven carpet under different environmental conditions. Silk hand-woven carpet ("Gom") with 115×75 cm dimensions and 102×97 knot per 10 cm was selected and then inserted into the packing simulator with two different laying configurations including flat and folded. The environmental conditions was adjusted at 3 different conditions including 25 ± 5% r.h and 30 ± 2°c (July-Tehran-Dry), 65 ± 5% r.h and 6 ± 2°c (February-Tehran-humid), 40 ± 5% r.h and 19 ± 2°c (October -Tehran-mild). The carpet sample was compressed under constant loads of 135 and 150 kg. The variation of carpet thickness with time in different parts of carpet was continuously measured using data acquisition system. The result of experiment shows that the carpet thickness is suddenly decreased at a short period of time and then reached to a stable condition. The variation trend of carpet thickness with time is accordance with a logarithm equation($y=a\times Ln(t)-b$) which is highly in agreement with Eyring model proposed in creep theory . But at the dry conditions, the variation of carpet thickness at the folded point follow a non-linear power equation ($y=a\times(t)^b$) with a low correlation coefficient. However, the variation of carpet thickness at the non-folded point and flat configuration is very low.
Generally, at the humidity condition, maximum carpet thickness variation occurred at folded point with folded configuration. On the other hand, carpet thickness variations at dry condition are less those of at humidity and mild conditions. In addition, carpet thickness at dry condition more quickly reached to stable condition than those of at humidity and mild conditions.

Key Words:
Hand-made Carpet, Environmental conditions, Creep, Eyring model

فصلنامه
علمی پژوهشی
انجمن علمی
فرش ایران
شماره سه
تابستان ۱۳۸۵