THE DESTRUCTIVE IMPACT OF TEMPERATURE AND HUMIDITY SIMULTANEOUSLY ON MUSEUM CARPETS WITH NATURAL COMBINED FIBER (WOOL, COTTON AND SILK)

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Abstract. Iranian carpet consists of organic matters of wool, cotton and silk and based on their high vulnerability against environmental conditions needs exact maintenance. There are some factors with direct effect on carpet destruction as temperature and humidity. Temperature and humidity destroy carpets and they are threats against these works or provide the conditions in which other factors damage the carpets. This is a threat against conservation of these works. Bad climate, the effect of high humidity and temperature can increase the molds and can destroy organic matters including carpets. This study is empirical-analytic. At first, based on museum carpets, the samples are taken and they are under bad temperature and humidity conditions. By different tests, tensile strength tests of length (according to national standard NO. 1147-1 with reference ISO13934-1:1999), tensile strength of width (according to national standard 1147-1 with reference ISO13934-1:1999), lint strength (according to national standard 894, reference ISO4919:1978), color stability with grey criterion (according to national standard 160 with reference ISO105-A03:1993) and color stability against rubbing (according to national standard 204 with reference ISO105-X12:2001), destructions of museum carpets are defined and preventive solutions of museum carpets against temperature and humidityare presented.

Keywords: Silk, Wool, Cotton, Natural combined fiber, temperature, humidity, carpet, museum.

Introduction

Hand-woven carpet is rooted in history, civilization and culture of Iran and despite other Iranian handicrafts, it is produced by majority of people and for all classes and it is the cultural index all around the world. Iranian carpet is not only an industrial product and it is a cultural commodity with historical and artistic background. Carpet is one of the organic matters with important role in human being life. Different types of carpets are created using initial techniques and materials. Based on high sensitivity of carpets against environmental conditions, they need much protection [1]. Generally, the historical and cultural works are exposed to different risks in open space and in museum [2]. The condition of an object depends upon two major factors as diverse and different and its conservation condition depends upon it. The organic or non-organic materials are considered in carpets [3]. Organic matters accept much destruction. However, there is no matter that is sustainable in all conditions [4]. The most important destructive factors of historical and cultural works are including:

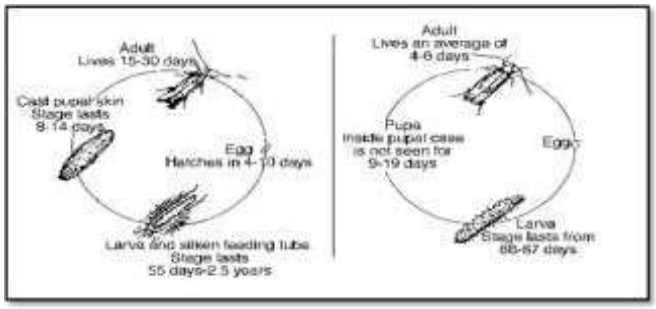
1- Ignoring of event, movement and exposure to light and heat
2- Polluted air of dust, coal, sulfide hydrogen and dioxide sulfur leading to bleaching and wearing of organic matters.
3- High humidity leading to dryness [5].

Destruction of artistic and historical objects depends upon environmental conditions [6]. There are four effective factors in environment with direct effect on destruction of materials and objects. These factors are light, temperature, humidity and pollutant gases. Each factor acts separately but the effect of each can be increased with other factors. For example, light, temperature, pollutants and humidity [7]. The evaluation of the effect of environment on artistic objects is a necessity to protect the works [8]. Temperature and humidity are the most important factors damaging the carpets directly or provide the conditions in which other factors damage the carpets [9]. This is a threat against conservation of these works. The continuous control and supervision against natural destruction of carpets is felt based on the unsuitable environmental conditions [7]. The carpets have organic source and are destroyed against environmental factors [10]. Their destruction is done at any time [11]. One of the unstable environmental conditions is high humidity and reduction or increase of temperature making carpets losing their color [12] and microorganisms, insects and molds are the greatest threats [13]. These factors can destroy these works [10].

Temporal and spatial effect of temperature and humidity on museum carpets

Relative temperature and humidity have mutual interaction [3] and these two factors can damage the tissues and they are threats for artistic works. The difference of temperature and humidity and rapid fluctuations can lead to many problems. The temperature fluctuation is less harmful than relative humidity fluctuation but their separation is very difficult as they are related to each other. The temperature increase can facilitate chemical reactions and serious structural changes in objects [7]. High temperature is indirectly associated with low humidity and increase of drought [2].

Generally, bad climate, the effect of high humidity and temperature can increase the activity of molds and destroy organic matters including textiles [14]. For conservation of organic matters, fixed relative temperature and humidity are of great importance. The sudden changes can damage these materials [11]. The increase of humidity or temperature can increase bleaching in wool and dyed cotton. This is true about high humidity. Also, the effect of humidity on light destruction of fibers is of great importance [15]. For example, very hot environment can destroy fibers and by increase of relative humidity mold is grown by 70% [11]. Temperature is another secondary factor on the growth of molds on carpet. The temperature increase with humidity can increase molds and fungus and its reduction can delay mold and fungus [16]. Insects are the most dangerous live microorganisms in hand-woven carpets. The growth of insects depends upon air humidity and its temperature. Generally, the growth of insects in hot water and air is more than other climatic conditions. Humidity beside heat is one of the factors forming harmful creatures. By its control, we can avoid other harmful factors on carpet [17] (Figure 1).



Moth of carpets Moth of textiles

Figure 1. The metamorphosis of moth in carpets and textiles

The effect of temperature on museum carpets

Heat for a long time has adverse effect on fibers and can stabilize or change color [16]. High temperature leads to dryness and increase of chemical reactions and rapid wore out of fibers. Thus, the carpets shouldn't be near the hot objects [5]. Other temperature effects are the increase of biological activities. Most of molds growth under hot conditions. Another harmful factor is the increase of chemical analysis. Temperature is effective on speed of chemical reactions and the mechanical properties are lost. The low temperature can increase relative humidity in environment and this is destruction factor in carpets. The temperature fluctuations can lead to expansion and shrinkage in carpets as if sudden changes are occurred can change the form. This is harmful for the objects made of combined matters [7]. For example, remaining of wool under hot condition can lead to dryness [18]. Low temperature is suitable for protection as it decreases the activity of insects and damage is reduced [19].

The effect of humidity on museum carpets

Humidity is one of the climatic factors destroying the carpets. The increase and decrease of humidity can lead to expansion and shrinkage of carpets [2]. In addition, fibers are swollen under humidity. Humidity is one of the main reasons of destruction of textiles to growth molds and fungus [17]. Mold is one of the risks showing high relative humidity [3]. Also, humidity changes, mechanical changes and deformation of humidity can be considered [7]. Humidity can lead to chemical corruption of biological reactions and objects. Humidity increases corruption and bleaching can occurred due to light, heat and humidity. On the other hand, high dryness can destroy some of the materials (namely the materials absorbing humidity and humidity is a part of their structure) [17]. High relative humidity can growth molds and their reduction can make the objects vulnerable and high fluctuations of relative humidity can change their form [9]. Sudden loss of humidity in organic matters as carpets can lead to shrinkage [3]. Wool, silk and cotton as the constituent materials of carpets are vulnerable against humidity [20]. Humidity has great impact on bleaching against light [18].

The protection of museum carpets against temperature and humidity

Heat and humidity can be harmful for carpet and drought can damage the elastic nature of wool and maintenance of carpet under dry condition can create humidity by silica gel crystal and these crystals are in bags and are not associated directly with fibers. Suitable humidity should be 50% for carpet and temperature 70 °F [3]. High temperature and humidity facilitate the destruction and molds can grow easily. Under ideal condition, temperature is 65-70 degree and relative humidity is 50-55%. Temperature is regulated by central heat and ventilation of control systems and high humidity is reduced using dehumidifier [21].

Laboratory studies

To evaluate the harmful effect of temperature and relative humidity in carpet museums, we need basic measurements and to do this, some test are performed in laboratory environment and acceptable results are achieved. In

laboratory section, at first, we refer to the different museums including Tehran carpet museum, Astan Ghods Razavi in Mashhad and carpet museum of Shiraz that shows in Figure 2 and that characteristic as following:

- Place: Mashhad
- Time: ¼ of century 13 (Qajar era).
- Material: warp: cotton, woof: cotton lint: wool and silk
- Size:300*410cm
- Rajshomar: 48 asymmetric nodes in 6.5cm
- Producer: Abdollah Tabrizi

Figure 2. Curtain carpet of Ghandili

Also, the carpets woven with natural fibers as wool, cotton and silk are identified. The samples of Ghajar showed that cotton was used in warp and woof and wool and silk were used in lint and they are Persian woven. As the tests on museum carpets are not possible we took samples. For s ample taking, at first we provided the raw materials of carpet, wool, cotton and silk and longitudinal and transverse section were performed by SEM and naturalness of these fibers were verified (Figure 3, Figure 4 and Figure 5).

Figure 3. The longitudinal and cross section of wool fibers

Figure 4. The longitudinal and cross section of silk fibers

Figure 5. The longitudinal and cross section of cotton fibers

Then, based on the dominant colors in these carpets as yellow, red and dark blue, the dyes were provided and Reseda was used for yellow, Rubia tinctorum for red and indigo for dark blue. To provide this dye, we took trips to different regions of Iran. Reseda was provided form Bam and Indigo from Jiroft in Kerman province and Rubia from Abarghoy of Yazd province and to be sure of the validity of the species of these plants, species study was performed in Herbarium center of Shiraz University (Figure 6 and Figure 7).

Reseda Indigo Rubia

Figure 6. Providing dyes for dyeing wool and silk

Reseda Indigo Rubia

Figure 7. The species study of dyes in herbarium center of Shiraz University

By dyes in dyeing laboratory of art and architecture School of Shiraz University, wool and silk were dyed and we applied mordant and color dyeing method simultaneously (Figure 8).

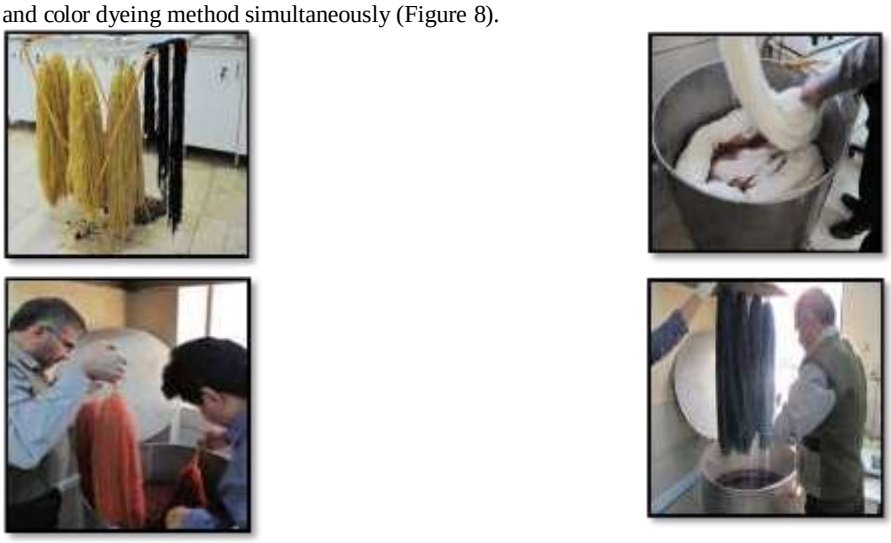


Figure 8. Dyeing of fibers

Then, fibers are woven based on a weaver and then the carpets are polished (Figure 9).

Figure 9. The weaving stages of samples

The sampled carpets are aged under standard conditions to achieve similar samples of museum carpets. Then, tensile strength tests of length (according to national standard NO. 1147-1 with reference ISO13934-1:1999), tensile strength of width (according to national standard 1147-1 with reference ISO13934-1:1999), lint strength (according to national standard 894, reference ISO4919:1978), color stability with grey criterion (according to national standard 160 with reference ISO105-A03:1993) and color stability against rubbing (according to national standard 204 with reference ISO105-X12:2001) that show in Figure 10 and Figure 11 and results are recorded in Table 1, Table 2 and Table 3.

Figure 10. Cutting samples for performing tests

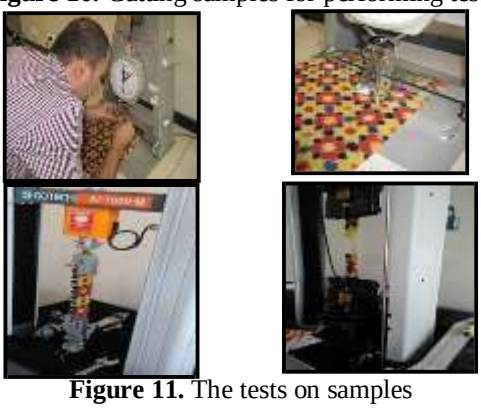


Figure 11. The tests on samples

Table 1. The results of lint strength test

Lint stability test /(kgf)		
wool	Silk	Tests NO.
25.8	26.2	Test 1
26.4	24.8	Test 2
27	25.8	Test 3
25	25	Test 4
26	27.4	Test 5
27.2	26	Test 6
26.8	27.2	Test 7
27	25	Test 8
25.2	24	Test 9
26	27	Test 10
26.24	25.84	Mean
26±1	26±1	Standard value

Table 2. The results of tensile strength test of length and width

Tensile strength of length and width (kgf)		
Tensile strength of width	Tensile strength of length	Tests No.
195.810	208.028	Test 1
193.045	209.124	Test 2
193.095	206.905	Test 3
192.910	209.702	Test 4
194.724	207.784	Test 5
194±2	208±2	Standard value

Table 3. Color stability test against rubbing

4-5	Humid	Dark blue
5	Dry	
4-5	Humid	Red
5	Dry	
4	Humid	Yellow
5	Dry	

Standard temperature of carpet maintenance of museum carpet is 20±2 and relative humidity 55±10. To put the samples under unsuitable conditions, by averaging the maximum relative humidity and maximum temperature in centers of Iran province, 39 $^{\circ}C$ temperature and relative humidity 75% can be achieved (Figure 12).

Figure 12. Putting samples under bad conditions of temperature and humidity

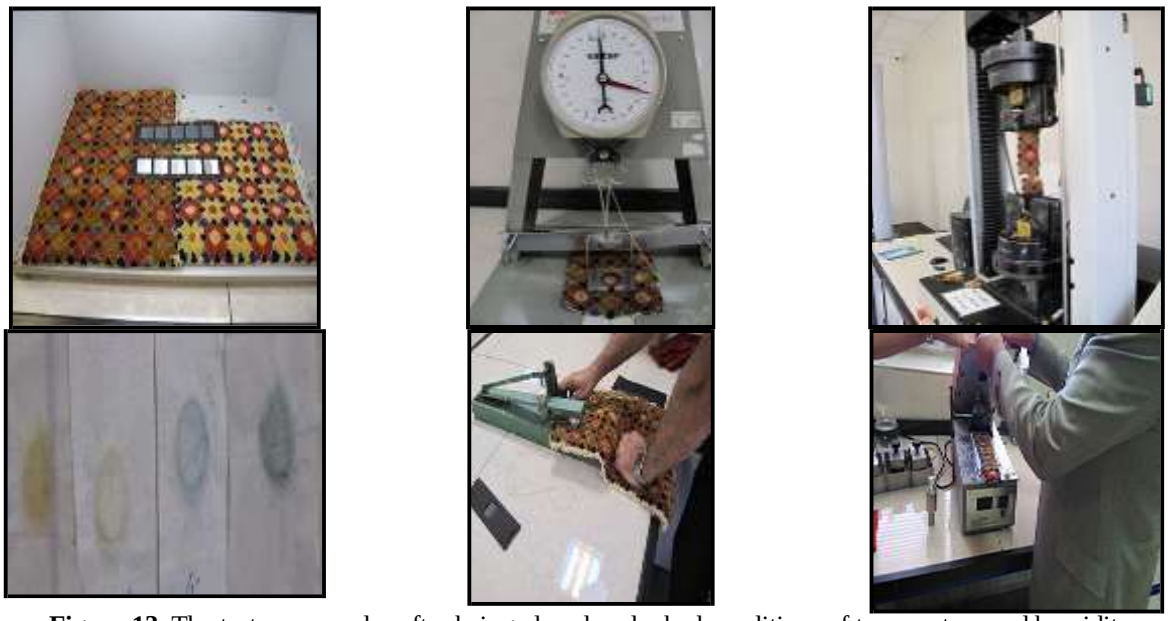


Figure 13. The tests on samples after being placed under bad conditions of temperature and humidity

The results of tests performed on samples after being placed under bad temperature and humidity (Table 4, Table 5, Table 6 and Table 7).

Table 4. The results of lint strength test

Lint stability test /Newton (kgf)		
Wool	Silk	Tests NO.
20.6	20	Test 1
21.2	21.6	Test 2
19.4	20.6	Test 3
20.8	21.4	Test 4
21	22	Test 5
19.4	21.8	Test 6
20.2	21.2	Test 7
20.8	20.2	Test 8
21	20	Test 9
19.8	21.2	Test 10
20.42	21	Mean
20±1	21±1	Standard value

Table 5. The results of tensile strength test of length and width

Tensile strength of length and width (kgf)		
Tensile strength of width	Tensile strength of length	Tests NO.
188.552	202.794	Test 1
189.941	200.622	Test 2
188.212	201.925	Test 3
186.998	200.120	Test 4
187.501	199.979	Test 5
188±2	201±2	Standard value

Table 6. Grey measure test

Grey measure test		
Explanation	Grey measure NO.	Color fiber of wool and silk
With color change yellow	2	White wool
With severe color change	2	Yellow wool
With color change	4	Red wool
	4-5	Dark blue wool
It is dark	3-4	Dark blue
	4	Red silk
	4-5	Silk
In grey measure test, all colors are dark with the roughness of fibers as felt by hand.		

Table 7. Color stability test against rubbing

4	Humid	Dark blue
4-5	Dry	
3-4	Humid	Red
4	Dry	
3-4	Humid	Yellow
4	Dry	

Conclusion. Hand-woven art-industry of carpet includes a wide range of people, ethnicities, artists, entrepreneurs and researchers who attempt to protect it as the valuable art of our country to recognize it with scientific view with Iranian carpet. The increasing threats of changes in contemporary world and modernism and serious concerns of human being regarding cultural wealth have created conservation knowledge. Indeed, traditional methods cannot fulfill the needs of modern man in protection of artistic and historical works [22]. To perform preventive protection strategies, it is required to recognize damaging factors to carpet. The important factors are temperature and humidity. Based on the studies and experiments, the most important harmful effects of temperature and unsuitable humidity for museum carpets include:

- Tensile strength of length, width and lint of carpet are reduced.
- They make the carpet dry.
- Molds are increased.
- The color is changed.
- The carpet is rough as felt
- It changes color against rubbing.
- Based on the color of fibers in carpet, the color change and tensile strength of lint are different.
- Based on the material of fibers in carpet (wool-silk), the color change and tensile strength of lint are different.

As a brief summary, we can say in museums, galleries and collections of maintenance of carpets, the environment should be clean, dark, cold and relatively dry with fixed temperature and suitable relative humidity to protect museum carpets against the harmful factors.

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