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The Influence of Environmental Aging upon the Loadbearing Properties of Polyurethane Foams

P. C. NOBLE, M. S.
B. GOODE, M. S.
T. A. KROUSKOP, P. E., Ph. D.
B. CRISP

The Institute for Rehabilitation
and Research (TIRR)[a]
In the Texas Medical Center
1333 Moursund Avenue
Houston, Texas 77030

Abstract—The effects of environmental exposure upon the loadbearing properties of nine polyurethane foams commonly used for wheelchair cushion construction were studied. Test pieces with and without a stretch cloth cover were aged in the open air at Houston over the period April 26 to October 31, 1982. The indentation resistance of each piece was measured initially and at frequent intervals during the exposure period. Resistance changes between covered and uncovered specimens were not found to be significant. All foams displayed a sharp rise in indentation resistance within the first 2 weeks of aging followed by a gradual decrease to an average 68 percent of the initial value over a 6-month period. These hardness changes were found to be strongly correlated with the density, thickness, and initial indentation resistance of the test pieces. Foams of maximum density and minimum practicable indentation resistance are recommended for wheelchair cushion construction to minimize the adverse effects of envirionmental aging upon the support properties of these devices.

INTRODUCTION

Pressure sores are a major complication of spinal cord injury due to the vulnerability of insensitive skin to the harmful effects of external forces. Most individuals using wheelchairs rely on various forms of wheelchair cushions to reduce the risk of pressure sores. These cushions are intended to redistribute body weight and restrict the levels of pressure and friction acting over the bony areas of the body. The most commonly used cushions are manufactured from plastic foams. Many such cushions are commercially available, and most give assistance in pressure-sore prevention during at least the first few months of their use. All foam cushions, however, deteriorate with age and lose their capacity to distribute body weight effectively (1, 2, 3). Clinical experience has shown that many pressure sores over the sitting area are directly attributable to the use of foam cushions that have worn out and have thus become unsafe to use (4). However, little is known at present about the causes of this deterioration, or about the actual length of the useful life of different commercial cushions, or whether measures may be taken by consumers and manufacturers to prolong cushion life. No objective accounts were found of the relative merits of different foam cushions in retaining their supportive properties with use. Traditionally, changes in the loadbearing properties of the foam cushions have been attributed primarily to the effects of repetitive compressive loading leading to fatigue softening of the polymeric matrix. This study has examined the possible contribution of environmental aging and exposure to ultraviolet light in the outdoor environment to the softening phenomenon.

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MATERIALS AND METHODS

An experiment was devised to examine the following hypotheses:

1. Polyurethane foam wheelchair cushions undergo softening during environmental exposure in conditions of heat and humidity even when not subject to the repetitive compressive loading associated with use by the occupant of a wheelchair.

2. The changes in the support properties of polyurethane foam wheelchair cushions associated with environmental aging may be partly attributed to the effects of ultraviolet exposure in direct sunlight.

3. Cloth covers used to protect wheelchair cushions significantly influence hardness changes associated with environmental exposure.

To test the hypotheses, environmental aging was adopted as a method for simulation of the condition present within wheelchair cushions due to the conditions of high temperature and humidity present in Houston during the summer months (Table 1).

Nine polyurethane foams commonly employed in the fabrication of mattresses and wheelchair cushions were selected, with densities ranging from 1.3 to 3.5 lb/ft^3 (20-55 Kg/m^3) and indentation resistances of 30 to 65 lb (130-290 N) (25% ILD). See Table 2. Test pieces measuring 6 inches × 6 inches (0.15 m × 0.15 m) were prepared, ranging from 3 to 4 inches (0.076-0.10 M) in thickness. Two identical test pieces were prepared from each polyurethane foam, one test piece being covered with a stretch fabric commonly employed in the manufacture of cushion covers. Prior testing demonstrated that the cushion covering reduced the intensity of sunlight incident upon the surface of the foam to approximately 10 percent of ambient levels in a range of outdoor conditions. In each case the duplicate test piece was left uncovered. The total array of 18 test pieces was suspended from a rack in the outdoor environment at Houston for a period of 6 months from April 26 to October 31, 1982. At the commencement of the aging period and at regular intervals thereafter, the hardness* of each test piece was measured using a 2-inch (0.051 m) diameter indentor which deformed each test piece to a depth equivalent to 50 percent of its initial thickness. For a range of polyurethane foams, the Standard Indentation Loading Deflection (ILD) test (ASTM D1564) was performed in addition to the hardness-measurement procedure using a 2-inch diameter indentor. This enabled calibration of the 2-inch indentor results in units equivalent to ILD hardness at 25 percent indentation depth.

Each test piece was preflexed twice to approximately 80 percent compression and then allowed to rest for 10 seconds prior to each hardness measurement in order to increase the reproducibility of each reading. Because the test deformation was based upon the initial thickness of each specimen, no allowance was made for the slight shrinkage associated with each of the uncovered test pieces. At the completion of the exposure period, all specimens were examined for evidence of surface changes and environmental degradation.

TABLE 1
Environmental conditions during the period of aging of the test pieces

Month	Average Temperature	Relative Humidity
April	70.1°F	74.6%
May	74.7°F	76.6%
June	79.4°F	75.6%
July	81.9°F	75.3%
August	82.7°F	75.0%
September	77.7°F	79.1%
October	68.2°F	74.9%
Total	77.3°F	76.1%

TABLE 2:
Initial Properties of the polyurethane foams selected for environmenta aging

Foam Number	Indentation resistance (25% ILD, lb)	Density (lb/ft^3)	Thickness (inches)
1	32.8	2.32	2.9
2	53.5	1.63	3.9
3	49.2	2.88	4.2
4	54.6	1.33	3.8
5	62.3	1.61	3.9
6	36.1	1.81	4.0
7	62.3	3.12	4.1
8	48.0	3.61	3.0
9	67.6	1.58	4.0

RESULTS

Superficial examination of the test pieces at the conclusion of the environmental aging revealed marked differences between test pieces that had been covered in comparison with their uncovered counterparts. The bare test pieces had been discolored to a depth of approximately a quarter of an inch (6 mm). The surface layers in some cases crumbled during examination. In comparison with its covered pair, each bare test piece displayed a loss in thickness that averaged 7 percent (range: 0-17%) without a corresponding change in density, which suggested that surface loss of polymer occurred during exposure of the uncovered test pieces.

The indentation resistences of all test pieces were found to vary markedly with duration of aging, though each test

*The expression "hardness" is used here as a convenient synonym for indentation resistance. This comment is made in consideration of the fact that some readers, particularly those with a strong engineering orientation, may tend to associate "hardness" with tests of the properties of metals and other "hard" materials and thus find it incongruous, at first, finding the term applied to a material usually considered as "soft."