Published by SET Publisher

Journal of Basic & Applied Sciences

ISSN (online): 1927-5129

Supporting Information

1. THE DIAGRAM DISPLAYS OUR EXPERIMENTAL APPROACH

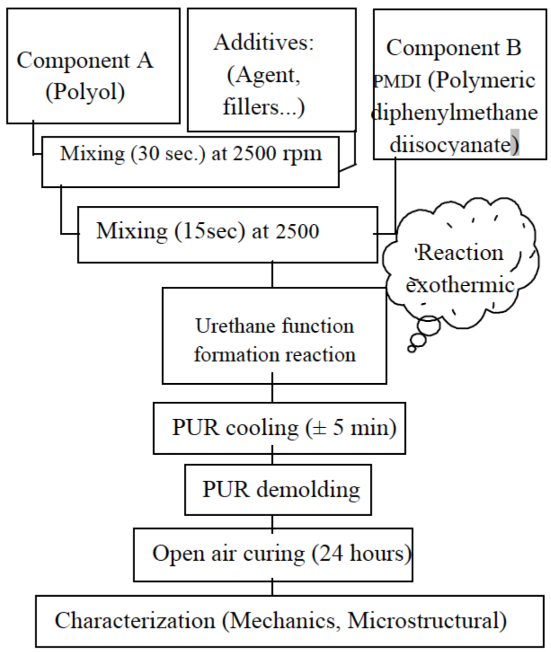

Figure 1: Work methodology flowchart.

2. CHARACTERISTICS OF THE RAW SUBSTANCES USED

2.1. Isocyanates

Isocyanates are organic compounds with the functional group N = C = O, serving as an essential source in various industries. According to their structure, isocyanates are categorized into an elephant, axial, and aromatic sequences.

2.2. Polyols

Compounds containing several hydroxyl functions per molecule are essential components for polyurethane formation. High-mass polyols are generally the most frequently used of two main types: polyesters and polyethers, which are more rarely found in other pluses for special applications: polycarbonates, polybutadienes, and poles made of fatty acids [1].

2.3. Formation

The polyurethane foams result from closely regulated chemical and physical reactions. Polyurethane is a synthetic polymer dependent on an isocyanate reaction to several other reactive groups, especially the hydroxyl group.

Polyurethane foams occur as polymerizing responses by producing gas inside the polymer. The gas creates bubbles that are picked up before the polymer has been fully formed, resulting in a cellular structure.

2.3. Properties

These values can be included in the table for estimation purposes. However, because these characteristics are typical, a new foam system for a particular application should be precisely evaluated (Table **1**).

Table 1: Typical Industrial Foam Systems Properties

Density, lb/cu ft (kg/m^3)	2
Coefficient Expansion (mm/mm/°C)	6 x l0^{-5}
Compressive strength at 10% pressure (kPa)	35
Compressive Modules (kPa)	1000
Maximum Service Temperature (°C)	200 - 250
Tensile Strength (kPa)	38
Water Absorption (kg/rn^2)	0.033
Shear Strength (kPa)	25
K Factor (W/m K)	0.12
Shear Modulus (kPa)	400

3. THE METHOD OF MACHINES USED

3.1. Hydraulic Press Working

We use a hydraulic press and cylinder to produce a compressive force. There is a plate in a hydraulic press where the sample presses. A hydraulic press is based on the theory of Pascal's Law, according to which pressure on a confined fluid varies over the entire liquid. A piston acts as a pump in the hydraulic press that provides a limited sample area with moderate mechanical power.

Measurements have been made in a test unit. Foam blocks have been mounted surrounded by two cylinders. The baseplate bottom did not shift when the two plates dropped on the sample between the pressure cylinders. We compress to 80 % of the original foam peak and return to the initial location at the matching rate. Figure **2** displays the test setup.

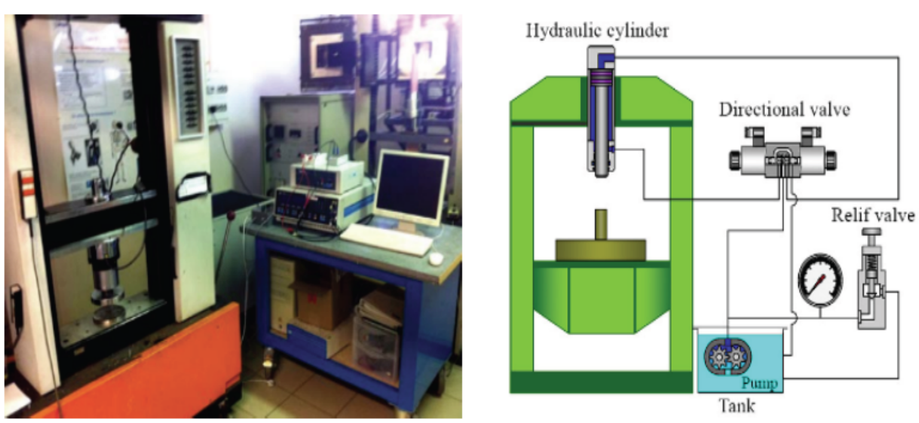

Figure 2: The compression testing machine is a 40 T dynamometer.

An electric motor powers the hydraulic pump. The pump sucks fluid from the tank and moves it through the lines of the hydraulic circuit through various hydraulic devices to the hydraulic cylinder. The direction of motion of the piston is controlled via the directional valve in the hydraulic cylinder. The hydraulic cylinder at the end of the line reflects resistance to flow. Therefore, pressure rises until the piston moves into the cylinder, overcoming this resistance. The overall pressure must be limited to protect the hydraulic circuit from undue pressure and, therefore, from overload. This medium is accomplished using a pressure release valve. The flow still provided by the pump flows directly back into the tank through the pressure relief valve. At this time, the pressure is full. The following table lists the specific compressive strength and compression modules for certain packed and unfilled polymers. Table **2** illustrates a typical polymer compressive module.

Table 2: Typical Polymer Compressive Yield Power and Compressive Module

Material (Polymer)	Compressive Modulus	Compressive Strength Yield
	GPa	MPa
ABS	2.5	65
Polystyrene	2.5	70
ABS + 35 % Glass Fiber	8	120
Polypropylene	1.5	40
Acetal Copolymer	2.2	85
Polyimide and Glass Fiber	12	220
Acetal Copolymer and 35% Glass Fiber	7.5	100
Polyimide	2.5	150
Acrylic	3	95
PET Polyethylene Terephthalate	1	80
Nylon 6	2.3	55
Polyethylene HDPE	0.7	20
Polyamide	5	130
Polycarbonate	2.0	70

1 N/mm^2 = 1 MPa = 145.0 psi (lbf/in^2) = 106 Pa.

Although there are vast differences between specific polymers, polyurethane foams have the most significant resistance to pressure and shock absorption.

4. COMPRESSIVE STRENGTH

Compression set checking is widely used in evaluating polyurethane foam inflated units' capacity to retain elastic properties under pressure. The procedure measures how long the specimen distorts as it is subjected to a compressive force. That test is ideal for systems wherein foams are continuously between low-pressure and high-pressure. A low value means this foam is resilient and can quickly revert to its usual form when compressed. A test specimen is exposed to 80 % of the total tension. Then, the foam sample is extracted, and the measurement is held at standard conditions for one day. It is then weighed again. The rate at which content is displayed C (%) is shown by the following formula (1):

$$C = \frac{t_0 - t_2}{t_0 - t_1} \times 100 \quad (1)$$

Were

t_0 is the present thickness of such a test item (m)

t_1 is mouth thickness (m)

t_2 is the thickness of the test specimen after 24 hours

A Compression force happens when an object is pushed inside by a physical force that causes it to get compact. The relative positions of the atoms and molecules of the thing will change in this process. Depending on the type of material experiencing compressive force, they can be temporary or permanent. Depending on the direction or location of the material, the compressive strength is applied, and various effects may also be obtained. Newton's Third Law of Motions states an equal opposing reaction force for each action force. The same pressure is exerted to both ends when compressing an item on a surface. The compression force is typically captured in Newtons (N), a unit of force that provides an acceleration of 1 meter per second square for a mass of one kilogram, usually referred to as "a".

$$N = m \times a \tag{2}$$

In compression tests, properties include elastic limit, proportional limit, yield point, yield power, elasticity modulus, secant modulus, and tangent module (Figure **3**). Some materials do not have a yield point; an offset yield point is arbitrarily specified in such cases. This value is typically set at a plastic strain of 0.2 %. The elastic modulus is the stress-to-related strain ratio below the material proportional limit. The Secant modulus is the pitch of a line from the origin to any point on a stress-to-strength diagram. The tangent module is the curve slope of the stress at any stress or strain defined. The tangent modulus is an indicator of elasticity below the proportional limit. The tangent modulus varies with strain above the proportional limit. Compressive strength in materials and components in compression tests determines properties such as elastic limit, proportional limit, yield point, yield power, elasticity modulus, secant modulus, and tangent module (Figure **3**). Some materials do not have a yield point; an offset yield point is arbitrarily specified in such cases. This value is typically set at a plastic strain of 0.2 %. The elastic modulus is the stress-to-related strain ratio below the material proportional limit. The Secant modulus is the pitch of a line from the origin to any point on a stress-to-strength diagram. The tangent module is the curve slope of the stress at any stress or strain defined. The tangent modulus is an indicator of elasticity below the proportional limit. The tangent modulus varies with strain above the proportional limit. Compressive strength in materials and components [2] and structures are measured [3].

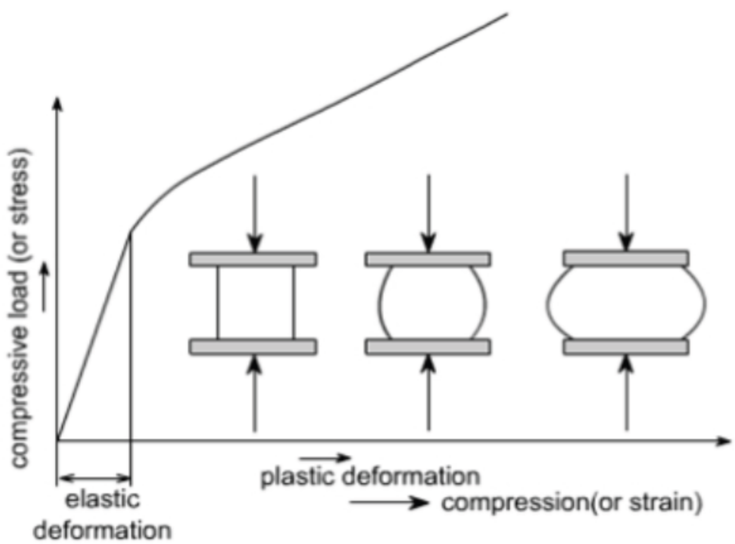

Figure 3: A diagram showing how a sample is deformed and its behavior.

In a compression test, the material complies with Hooke's law in a linear region:

$$\sigma = E \times \varepsilon \tag{3}$$

Where E refers to Young's module, in this area, the material plastically deforms and returns when the stress is shortened to its initial length. This linear area terminates at the yield point. The material behaves elastically above this stage. The load is removed and no longer grows back to its original length. Engineering stress varies from natural stress. Uni axial stress is provided by its basic definition:

$$\sigma = F/A \tag{4}$$

Were

A = area (m^2)

F = Applied load (N)

The area of the sample varies according to compression. Then, the region has a purpose for the load applied. The pressure is described as the impact divided by the field at the beginning of the experiment. It is called manufacturing stress and is determined by

$$\sigma_e = F/A_0 \tag{5}$$

A_0 is an original region of the specimen (m^2)

In engineering, the strain is most clearly described using

$$\varepsilon_e = \frac{(l - l_0)}{l_0} \tag{6}$$

Where

l_0: the initial duration of the specimen (m)

l: the current sample duration (m)

Thus, the compressive force would be the weighted mean stress point (*) defined by

$$\sigma_e{}^* = F^*/A_0 \tag{7}$$

$$\varepsilon_e{}^* = \frac{(l^* - l_0)}{l_0} \tag{8}$$

Were

l* = length of the specimen just before overwhelming.

F* = load applied immediately before overwhelming

5. STATIC COMPRESSION OF A POLYURETHANE FOAM

The characteristic force-displacement curve of polyurethane foam (Figure **4**) shows the strain regimes typical of viscoelastic materials. The first part of the curve is linear and corresponds to the elastic regime. Upon removing the stress, the strain on the sample is entirely reversible. After the yield point conforms to the end of the linear section, the strain-stress curve shows a long plateau at almost constant stress. This part corresponds to the plateau regime. It is related to the plastic deformation of the structure, and, in the case of fragile polyurethane foam, the cell walls are broken. Cell walls come into contact with each other as the voltage increases. When all the voids are filled, the strength of the foam increases rapidly in proportion to the measured stress. This latter part of the curve is known as the densification regime. According to the classical foam theory of Gibson and Ashby [4], the cell curve, whether elastomeric or not, indicates a linear phase followed by a load plateau (force) and, finally, the densification phase, in which the load increases considerably with the movement of the material. The three-step action is also well in sync with the work of Goussri [5]. The polyurethane foam force-displacement activity consists of three stages. A small dispersion is observed between the six test pieces under the same development and test conditions. They go hand in hand with the work of Bezazi and Scarpa [6], except that, for the same load rate, 80 %, the overall force obtained from them is more than double.

Cellular structures are used for shock absorbers because they can withstand significant amounts whose resilience under comparatively low compressive stresses is high. Whose resilience under comparatively low compressive stresses is high [7]. The small fraction of solids in cellular substances creates relatively little production stress and high stress during successive cell collapses, with little to no hardening. As all cells are broken up, the cellular material densities are further deformed through a much longer intensive preparation process. Estimating the intensity of individual cells in uniaxial collapse is difficult because of their shape. Homogeneous cells, such as polyurethane foam [8, 9], collapse at a constant degree of stress (df/dd = 0). Cells in these materials are equally sized, have identical wall thicknesses, and collapse under almost the same stress when taken individually. Each cell's complex collapse stress dynamics induce hardening in the collapsing regime, and an area of positive slope replaces the plateau in the F (d) curve. The constant ratio of wall thickness and cell length between different cells or the broken cell wall or other causes may result in heterogeneity [10, 11]. Cells collapse under compression in cellular material. They occur jointly with collapsed cells that cause the collapse of neighboring cells. The weakening influence on neighboring cells of a ruptured cell is induced by enhanced stresses induced by the geometry shifts of collapsing cells. A "shock" of crumbled cells spreads throughout the specimen when cellular weakening is present. Based on the quantity and distribution of output stresses on the spatial arrangement of individual cells, there may be one or more collapsing bands before densification occurs.

The flexible foam's extraordinarily dense and non-linear behavior is demonstrated through quasi-static and uniaxial compression checks. The reliance on the displacement rate is much higher during the loading phase than during the unloading phase. Figure **4** demonstrates the compressive stress-straining behavior of an elastic cellular properties system with the unit-volume energy absorbed in a plateau area. It is important to remember that any cell structure is better suited to absorb given energy, that energy that is inside the cytoskeleton where it is finally plateau stress before condensation. Increased compression rates can improve the system's physical properties, and a lower-density structure can more easily withstand high pressures and have fewer compression energies.

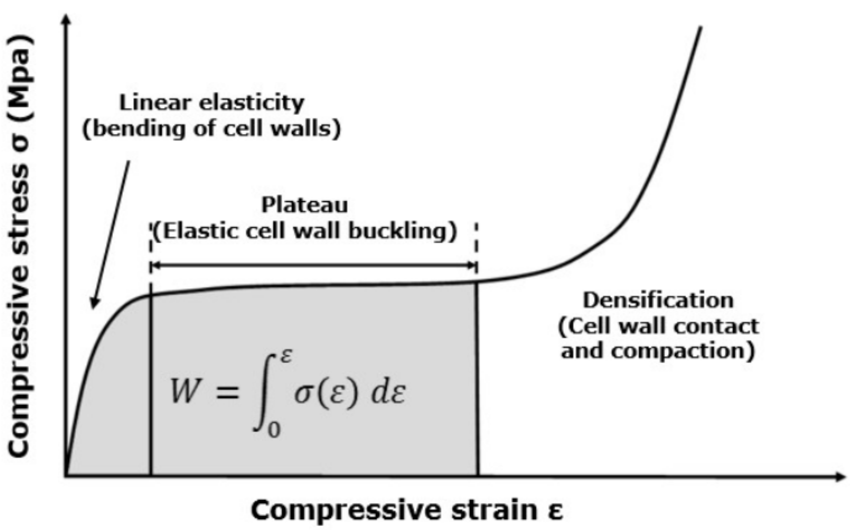

Figure 4: Schematic demonstrating the typical stress-strain compression with an elastic molecular cellular system [12].

The curve consists of three regions: linear, densification, and buckling. Each part fits based on the extent of the applied strain. The linear field corresponding to the first loading material is indicated by bending cell walls. The buckling area (plateau area) refers to foam cell elastic buckling. Here, the struts curve with little power. Foam hardness decreases with thinner material. The densification area corresponds to entirely collapsed cells; the rigid and conflicting cell walls are further compressed. With high compression, friction increases immediately, and the foam grows stronger.

REFERENCES

[1] Chiang FP, Ding Y. Size effect on stress-strain relation of neat polyurethane foam. Compos Part B Eng 2008; 39(1): 42-49. https://doi.org/10.1016/j.compositesb.2007.02.011.

[2] Urbanik TJ, Lee SK, Johnson CG. Column compression strength of tubular packaging forms made from paper. J Test Eval 2006; 34(6): 477-483. https://doi.org/10.1520/jte100030.

[3] Wriggers P. Introduction to Contact Mechanics, Springer, 2006; 101. https://doi.org/10.1007/978-3-540-32609-0

[4] Harte AM, Fleck NA, Ashby MF. The fatigue strength of sandwich beams with an aluminium alloy foam core. Int J Fatigue 2001; 23(6): 499-507. https://doi.org/10.1016/S0142-1123(01)00012-3.

[5] Goussery-Vafiadès V. Caractérisations Microstructurale Et Mécanique De Mousses De Nickel À Cellules Ouvertes Pour Batteries De Véhicules Hybrides 2004.

[6] Bezazi A, Scarpa F. Mechanical behaviour of conventional and negative Poisson's ratio thermoplastic polyurethane foams under compressive cyclic loading. Int J Fatigue 2007; 29(5): 922-930. https://doi.org/10.1016/j.ijfatigue.2006.07.015.

[7] Gibson LJ, Ashby MF. Cellular solids: structure and properties. Cambridge university press 1999.

[8] Maiti SK, Gibson LJ, Ashby MF. Deformation and energy absorption diagrams for cellular solids. Acta Metall 1984; 32(11): 1963-1975. https://doi.org/10.1016/0001-6160(84)90177-9.

[9] Fátima Vaz M, Fortes MA. Characterization of deformation bands in the compression of cellular materials. J Mater Sci Lett 1993; 12(17): 1408-1410. https://doi.org/10.1007/BF00241724.

[10] Prakash O, Bichebois P, Brechet Y, Louchet F, Embury JD. A note on the deformation behaviour of two-dimensional model cellular structures. Philos Mag A Phys Condens Matter Struct Defects Mech Prop 1996; 73(3): 739-751. https://doi.org/10.1080/01418619608242994.

[11] McCullough KYG, Fleck NA, Ashby MF. Uniaxial stress-strain behaviour of aluminium alloy foams. Acta Mater 1999; 47(8): 2323-2330. https://doi.org/10.1016/S1359-6454(99)00128-7

[12] Bates SRG, Farrow IR, Trask RS. 3D printed elastic honeycombs with graded density for tailorable energy absorption. In Active and Passive Smart Structures and Integrated Systems 2016; 9799: 979907. https://doi.org/10.1117/12.2219322