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## ***Tensile Strength Comparison of Athletic Tapes: Assessed Using ASTM D3759M-96, Standard Test Method for Tensile Strength and Elongation of Pressure-Sensitive Tapes***

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# **Tensile Strength Comparison of Athletic Tapes: Assessed Using ASTM D3759M-96, Standard Test Method for Tensile Strength and Elongation of Pressure-Sensitive Tapes**

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## **Introduction**

Athletes who train for and compete in aggressive sporting events such as basketball, football, and soccer, etc. often stress joints beyond their limitations. Injuries result when knees and ankles are bent past the natural elastic limitations of tendons and muscles. As a measure of partially immobilizing joints of the human body, adhesive tape is commonly used as a prophylaxis. In comparison, splinting of joints results in complete immobilization and is impractical for the athlete. Bracing produces different degrees of resistance depending on the style of brace used and the material of which it was constructed.

Trainers and athletes typically use prescribed methods of applying tape. In one type of application, the tape is adhered directly to the skin. When the tape gets peeled off the skin, the adhesive tends to stick and results in discomfort to the wearer. Therefore, a thin buffer tape, called "pre-wrap" is applied between the skin and the adhesive overlay tape. Pre-wrap is a non-adhesive roll product made of a foamed elastomer. It is applied in a double layer against the skin, and then the adhesive tape gets wrapped on top of the pre-wrap. Moleskin is another product that can be used as a pre-wrap for the adhesive tape. Moleskin is made from cotton flannel with a pressure-sensitive adhesive backing. Moleskin is comparatively more expensive than elastomeric pre-wrap. When moleskin is applied as a pre-wrap, the adhesive side is placed away

from the skin and the adhesive tape gets wrapped on top. In this paper, pre-wrap refers to elastomeric pre-wrap and not moleskin.

The adhesive tape industry has grown into a multi-million dollar business in the United States. Tapes are purchased by school districts, colleges and universities, and private schools to be used in interscholastic athletics. Amateur and professional sports organizations also purchase significant quantities. There is a market sector for over-the-counter sales of tapes purchased and used by the general public. In Division I university athletic programs, the common minimum amount of money spent on expendable adhesive tapes averages approximately \$50,000 or more annually. Football and basketball scholarship athletes are routinely taped for all practices and all games. Despite the large sums of money spent on sports tapes, little technical information is readily available to the practitioners for selecting tapes based on properties. Technical information is maintained proprietarily by the respective companies.

## **Tape Materials and Manufacture**

Athletic adhesive tapes usually get mass-produced in continuous types of industrial manufacturing environments. Tapes are typically sold on rolls for ease of transport and dispensability. Rolling of tape during production helps to speed production to enable uniform distribution of the adhesive backing during application, and to automate

packaging. Tapes used for sports applications are rolled with the exception of moleskin that is generally produced in flat sheets or strips.

Tape adherend materials used for making athletic sports tapes are unbleached cotton fabric, bleached cotton fabric, and cotton-polyester blends. A typical percentage breakdown is 70% cotton, and 30% percent polyester. Polyester thread is spun with the cotton yarns to produce the composite.

Pressure-sensitive adhesives used on tapes are classified as non-structural adhesives according to Lindbeck, Williams, and Wygant (1990). The adhesive bond is temporary because of the ability for adhesive to be peeled from the underlying tape substrate or adherend. Andover (1999) advertises “specially treated back cloth to help prevent excessive sweat absorption, easy and consistent unwinding all the way to the core” (p. 2). Peeling samples from the roll is facilitated by the silicone release agent, and/or by lack of sufficient tack or cohesion of the adhesive that allows the adhesive to release from the adherend. Obviously, ease of removing tape strips from the roll is critical to the success of tape use, but potentially detrimental to the adhesive bond strength and thus, the desired range of motion protection. Horath (1995) suggests that adhesives are permanently tacky and therefore do not wet the surface that they contact; thus are not suitable for high-stress applications. Horath (1995) also mentions release agents, however materials used are not specified. Manufacturers tend to keep tape materials and processing technology proprietary due to the competitive nature of the business.

Materials used to make pressure-sensitive adhesives (PSA) vary by manufacturers. Budinski and Budinski (1999) cite rubbers with tackifiers, styrene butadiene rubber (SBR), silicones, and polyacrylate esters. Thermoplastics, natural and synthetic elastomeric rubbers are reported by Lindbeck, *et al* (1990). Kalpakjian (1995) lists butyl rubber and nitrile rubber, both of which are synthetic rubbers. Adhesives are applied to the

base cloth adherends, usually over a primer that tends to anchor the adhesive to the base cloth. Deposition methods (ways to transfer adhesive to the base cloth) include roller transfer coating, spraying, and knife-coating. Uniform application of adhesives is difficult because of the nature of the woven base material. The thickness of the adhesives are generally about 0.1mm after application according to Kalpakjian (1995).

There are four typical stresses that tend to cause separation of adhesive tapes and are shown in Figure 1. The stresses are tension, shear, peel, and cleavage or tear. More stress is typically required to cause an adhesive tape joint to fail in shear and tensile situations than in peel or cleavage. During use, adhesive tape is subjected to tensile, flexure, shear, and to a lesser extent, peel forces. Ultimately, it is the synergistic properties of the tensile strength of the adherend, and the bond strength of the adhesive under shear and peel conditions that contribute to the overall effectiveness of sports tape.

### Purpose

The primary purpose of this study was to assess the tensile strength of PSA sports tapes using the ASTM D3759M-96 test methodology for comparing manufactured brands. Other purposes for the study were to help technologists better understand sports tapes and generate questions further associated with tape strength and tape evaluation methods.

### Delimitations

A calculation is included in ASTM D3759M-96 for determining ultimate elongation (expressed as a percentage) of tapes. A calculation for determining an “F” value is also included. The “F” value represents a concomitant value of load-elongation expressed in Newtons for the specimen width. Both of these calculations are based on the use and translation of graphs produced by a synchronous chart drive. A synchronous chart drive was used only for determining a factor necessary for calculating tensile strength. The “F”

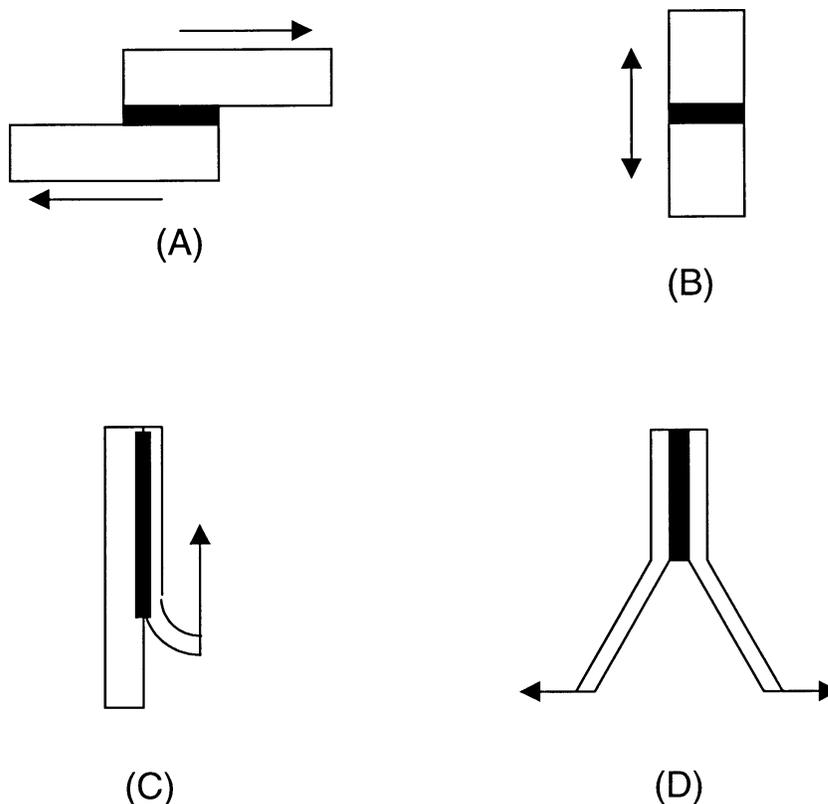


Figure 1. Typical stresses (loads) that tend to separate adhesive tape joints: (A) shear, (B) tension, (C) peel, and (D) tear or cleavage.

value and ultimate elongation were not included in this study.

Testing was performed independent of any manufacturer's knowledge or involvement. Findings were not compared with or validated by any of the tape manufacturers.

### Methodology

An Applied Test Systems Model 900 constant-rate-extension type universal testing machine with load cell and alphanumeric digital display, produced by Applied Test Systems, Inc. was set up for tensile testing. Aluminum cylinders measuring 100mm diameter by 50mm wide were positioned on the machine in place of the wedge clamps that normally occupy that position. The cylinders provided a uniform surface for holding the tape during testing. Traditional wedge-shaped jaws bite the tape, thus inducing an area of stress concentration that cause the tapes to break at a lower level of stress. None of the samples failed near the upper or lower support cylinders. A side view of the test configuration is shown in Figure 2.

Test specimens used in this study were cut from three rolls each of seven different brands of sports tape. The brands of tape tested were randomly selected off of store shelves by simply having a student who did not know of the testing that was about to occur, go out and buy roles of athletic tapes. Sampling was done in accordance with ASTM E122 (1998), Practice for Choice of Sample Size to Estimate a Measure of Quality for a Lot or Process. Practice E122 specifies testing a minimum of five specimens coming from different rolls of tape because strong conclusions cannot be based on sampling from a single unit (roll) of product.

Prior to testing, the tape rolls were conditioned in a temperature and humidity controlled environment for 72 hours; the same room in which testing was performed. Temperature was maintained at 23 +/- 2 °C and humidity ranged 50 +/- 5% as per ASTM D3759M-96 (1998). Ten specimens of each brand were cut with a razor blade from different roles during the testing with the first three to six windings

being discarded. The commercially produced specimens were measured across their width in order to calculate the tensile strength, however were not cut to widths recommended in ASTM D3759M-96 (1998). Tapes were not cut down in width because under general use the tape gets used at the width of manufacture. All tapes tested measured 38mm (1.5 inches) in width. The length of each specimen measured approximately 457mm (18 inches). Care was taken so that the adhesive did not contact its own sample surfaces, whereby removing them would have pre-stressed the tape in addition to the peel from the rolls (which cannot be avoided). Each specimen was cut from the roll and applied directly to the tensile test apparatus.

Tape specimens were applied wrinkle-free, one-at-a-time to the apparatus cylinders beginning with the top. The tape wrapped around the top half of the upper cylinder and was then adhered to the bottom half of the lower cylinder. Test specimens were stressed at a crosshead velocity of 50mm per minute as specified in ASTM D3759M-96 (1998). Each piece was stressed to its point of breaking strength. The maximum load was recorded as pounds, as were qualitative observa-

tions. After each test, the aluminum cylinders were cleaned of any adhesive residue or oil from hands with acetone, then wiped with reagent grade methanol. All tests were completed on the same day.

Test data were converted to a concomitant measure of N/100mm width of tape. The following formula was used to convert the maximum load in pounds to Newtons:

$$\text{Max. Load (lbs.)} * 4.44 = \text{Newtons.}$$

The maximum load was then divided by the common width of specimens, or 38mm (1.5 inches), then multiplied by 100 to obtain N/100mm width:

$$\text{Newtons}/38\text{mm} * 100 = \text{N}/100\text{mm width.}$$

Descriptive statistical analyses were used, as well as qualitative data for comparing test results. An ANOVA was used to compare tensile stress between subjects. An alpha level of .05 was used for the statistical tests.

### Findings

According to Van Tiem (1997), whom conducted preliminary aspects of this study as part of an undergraduate research project, each brand of tape

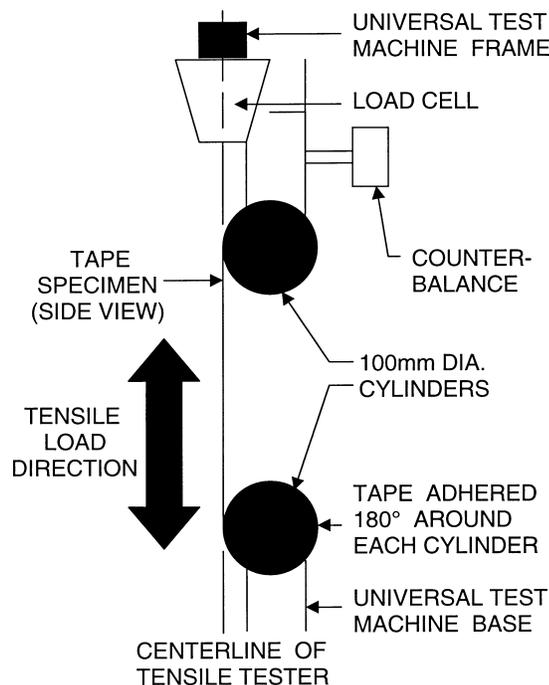


Figure 2. Test configuration for tensile testing of adhesive tapes.

broke differently when subjected to tensile stress. Five of the seven tore progressively as tension was applied. Of particular interest was one tape produced by the Mueller company. It was the most frail of the tapes. This tape tore in shreds. Mean tensile strength of Mueller tape was the lowest of the seven varieties tested; obtaining only 519.59 N/100mm width ( $M = 44.47$  lbs. tensile stress measured). Standard deviation of Mueller specimens was also greatest of the tapes tested ( $SD = 43.02$ ).

A tape produced by Cramer had the most defined break. Not only did it obtain the highest average tensile strength of 798.54 N/100mm width ( $M = 68.34$  lbs. tensile stress measured), but it failed in a brittle manner, snapping loudly and definitively, shortly into the test. It behaved in a distinctively brittle fashion, more so than other tapes that were tested. This suggests that elongation of this tape was far less than the other tapes and is therefore likely to stretch less than the other brands during use. Mean tensile stresses for each brand of tape are shown in Figure 3.

A single-factor analysis of variance was used to determine that there were significant differences between groups beyond the .05 level of confidence. ANOVA data for tensile testing of adhesive tapes are presented in Table 1.

A post-hoc multiple comparison test was performed to determine which brands of tape were significantly different from the others. Tukey's honestly significant difference test was used (Hinkle, et.al, 1994). An examination of the means in Table 2 revealed that of the twenty-one possible interactions, only four were not significant at the .05 level of confidence.

### Conclusions, Implications, and Recommendations

Following tensile testing of seven athletic tapes using protocol from ASTM D3759M-96 (1998), it was determined that there are significant differences in tensile strength between brands of tape. Different brands of tape failed in different ways; shredding (e.g. Mueller), progressive tearing (e.g. Bike, Ace, 3M, Johnson & Johnson

Coach and ZnO), and instantaneous brittle breaking (e.g. Cramer).

Implications of this study are that sports tapes used for support purposes behave differently when subjected to tensile stress. While the synergistic effects of adhesive quality and tension were not considered in this study, it is clear that tensile properties of sports

tapes do vary significantly between brands. Dynamic stresses induced during sports play will result in varying amounts of tensile force imparted on the tape fabric, resulting in unpredictable behaviors of the different tapes during use. Also, one brand of tape will carry a larger tensile load than others; not considering adhesive quality

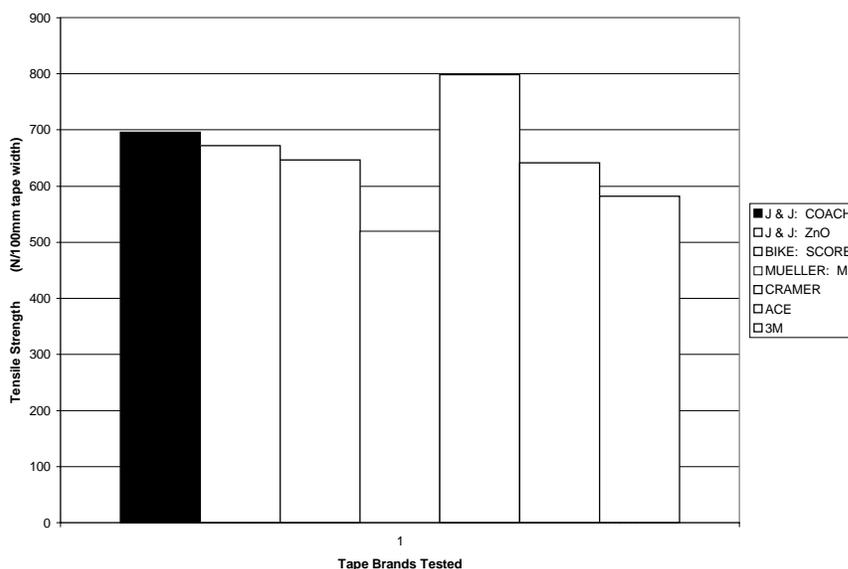
**Table 1 - Analysis of Variance for Tensile Strength of Adhesive Tapes**

ANOVA						
Source of variation	SS	Df	MS	F	P-value	F crit
Between groups	464184.172	6	77364.0287	129.145453	1.8591E-33	2.24640928
Within groups	37739.8792	63	599.045701			
Total	501924.051	69				

**Table 2 - Results of Tukey's HSD Multiple Comparison Test Regarding Interactions of Tensile Test Means for Seven Brands of Athletic Adhesive Tapes**

Tapes	Means	Mueller	3M	Ace	Bike	J & J ZnO	J & J Co.	Cramer
Mueller	519.58							
3M	581.58	8.01*						
Ace	641.34	15.73*	7.72*					
Bike	646.59	16.41*	8.40*	0.68				
J & J ZnO	672.06	19.70*	11.69*	3.97	3.29			
J & J Co.	695.76	22.76*	14.75*	7.03*	6.35*	0.83		
Cramer	798.54	36.04*	28.09*	20.31*	7.74*	16.34*	13.28*	

\* $p < .05(Q_{cv} = 4.31$  for  $df = 63)$ .



**Figure 3. Mean tensile stresses ( $n = 10$ ) for athletic tapes ( $n = 7$ ).**

and wrapping technique. Here are opportunities for industrial technologists to further study the science behind adhesive tapes, tape properties and behaviors in both static and dynamic modes, and issues regarding manufacturing processes for adhesive tapes.

Recommendations based on this study are as follows:

1. Further studies are warranted for discerning mechanical properties of sports tapes. In particular, adhesive properties should be investigated for determining if differences exist between manufactured brands.
2. The synergistic effects of tensile strength, adhesive quality, and wrapping should be tested using static and fatigue tests to determine the effects of use on the performance ability of sports tapes.
3. Prophylaxis effects of alternate immobilization techniques and materials should be studied in depth, along with cost analyses for

economic comparisons.

4. Because tapes continue to be used by athletes for injury prevention, industrial technologists should establish an optimum, consistent quality level of manufacture that provides the best material performance.

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