

SESSION IV

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PLY-TEAR WEBBING ENERGY ABSORBER

By Geoffrey W. H. Stevens*

ABSTRACT

Ply-tear webbing is essentially two plain webbings that are bound together by a portion of the warps and that can be torn apart and do work by breaking the binders. Nylon webbings have been woven to range in tear force from 1 to 10 kilonewtons. This force is substantially independent of speed, which was as high as 100 m/sec in some cases. A specific energy absorption of 90 J/g has been achieved in the dry state. However, lower rated webbings that absorb approximately 40 J/g are recommended for use in practice where it is acceptable.

INTRODUCTION

In aeronautical and aerospace engineering, the requirement frequently arises to use an energy absorber of high specific energy. The requirement has arisen particularly in airdrop equipment and aerodynamic decelerators. Some success in the technical solution has been achieved by the invention of a textile construction known as ply-tear webbing (refs. 1 and 2).

Among the materials with the highest specific strain energies are the fiber-forming polymers, having energies of approximately 300 J/g (10^5 ft-lb per lb). However, initial interest in these was concentrated on such undrawn and plasticized polymers as undrawn nylon, low-density polythene, and plasticized polyvinylchloride. Many of these materials can be worked by propagating a draw-neck through each filament, but some disadvantages are encountered. For example, stable drawing without fracture is restricted to a modest temperature range, and the speed of drawing also is limited (ref. 3). Therefore, it is desirable to ease these restrictions.

Although for a limited temperature range the specific energy to break can be higher for an undrawn than a drawn polymer, a drawn polymer maintains a usefully high value for a much wider temperature range (refs. 4 and 5). Some advantage should be gained if a method of using the material efficiently can be found; for example, breaking the fibers in many places, as in tearing a woven structure. This is the philosophy behind the invention of ply-tear webbing, in which a proportion of warp threads are repeatedly broken. The additional benefit of work by friction is obtained because the tearing of a woven structure of the type developed involves slippage of the weave.

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The purpose of this paper is to describe some of the webbings developed and to give an account of their physical properties. Some discussion of the factors in the use of webbings in an energy absorber is given, and the simple case of the mechanics, such as taking up the surplus energy in a cable release, is illustrated.

Acknowledgements are made to the Aircraft and Armament Experimental Establishment, Boscombe Down; to Hunting Engineering, Ltd.; to W. Ribbons, Ltd.; and to the Royal Aircraft Establishment, Farnborough, in particular to Mr. John E. Swallow and his staff of the Materials Department for quotations from their work and the use of illustrations of successful applications. Moreover, a special acknowledgement is made to W. Ribbons, Ltd., and the Irvin Industries, Inc., for making it possible for this paper to be presented personally by the author.

SYMBOLS

B	binder strength
c_1, c_2	velocity of propagation of strain disturbances
e_1, e_2	initial strain in cables
F, F_{\min}, F_{\max}	tear force
k	logarithmic factor for change of tension of a binder around a weft
L	length of cable
M_1, M_2	coupling masses
m_1, m_2	cable masses per unit length
N	number of binders
S	tear distance
t	time
T, T_1, T_2	initial tensions in cable
v, v_1, v_2	instantaneous velocity of end of cable

BASIC PLY-TEAR WEBBING

Ply-tear webbing can be woven on a loom with either one or, preferably, two shuttles. The warps are programmed by the "Dobby" mechanism into three sets: one for one ply or back, one for the other, and a third to provide the binders. On a twin-shuttle loom, each ply has its own weft; however, on a single-shuttle loom, the top and bottom plys are woven in sequence, four picks at a time, by a common weft between each bind. Therefore, in webbing woven on a single-shuttle loom, the weft also must break with the binders as the plys are torn apart; and, in all cases, the weft must be strong enough to withstand the pull of the binder. Although there are many possible variations of pattern, the basic construction is illustrated in figure 1. A sample of webbing for this construction is shown in figure 2. Because of the need for free ply ends to provide a means of attachment in a mechanism, all development has been concentrated on twin-shuttle looms.

Most of the webbings on which there is quantitative technical data (table I) have been based on 93 tex nylon yarn (ICI Type 242). However, a research program on the various factors in construction has been carried out (ref. 6), and this program has covered the use of polyester and nomex for binders. Moreover, most webbings have been woven and evaluated at 45-millimeter width because this width is standard in aeronautical equipment.

PROPERTIES OF PLY-TEAR WEBBING

When ply-tear webbing is torn slowly in a Dennison machine, a cyclic pattern of tear force is obtained, as shown in figure 3. A severalfold variation of force from minimum to maximum occurs. The force falls sharply on breakage and then builds up steadily as the binders slip through the weave until they are stressed to breaking point again. It appears that all the binders across the weave are being nearly equally loaded at the same time.

When the webbing is being torn at speed, such as in a drop test or in a catapult test, a much smoother tear is often experienced. A flash photograph of a sample of webbing tearing at 35 m/sec is illustrated in figure 4; the tear force in a drop test is shown in figure 5. Fluctuations of force in drop tests can be as large as those illustrated in figure 3; they are of audio frequency and responsible for the real noise of tearing. It appears that this noise phenomenon is much influenced by the mechanism or test machine in which the material is torn and by the elasticity of the free length of ply between the anchor and the point of tearing. For example, with sufficiently short leads in the Dennison test machine, irregular breakage of binders that gives an apparently more uniform tear force than that illustrated in figure 3 has been observed.

Detailed technical data on ply-tear webbings can be found in references 1, 2, and 6. The two earlier reports explored the physical envelope for the engineering use of ply-tear webbings. The work established the magnitude and the tear force and also established the important fact that the mean tear force was substantially independent of

the speed of tearing. Separation speeds up to 10 m/sec were achieved in drop tests (ref. 6) and up to 110 m/sec in catapult tests (ref. 7). If there was any trend in the magnitude of the tear force with tear speed, it was for an increase with increase of speed.

Three widths of nylon webbing (29, 44, and 50 millimeters) were available for the preliminary work, and all were similar in construction; that is, twofold warps laid in pairs and a threefold weft. For these three webbings, the mean tear forces in dynamic tests were approximately 2.7, 4.7, and 5.6 kilonewtons, respectively. The specific energy absorption is approximately 90 J/g. More work can be done when these webbings are soaked in water or light oil, (ref. 2), but then the safety margin in the backing strength becomes unacceptably low. Conversely, a resin impregnation reduces the tear force and the work done because the binders are prevented from slipping in the weave and doing work by interweave friction.

The level of work done per gram of binder yarn is very high. These yarns constitute approximately 19 percent of the weight of the types of webbing evaluated. Therefore, the specific working capacity of a ply-tear webbing, in terms of binder weight, is approximately 450 J/g, which is more than half the specific energy required to fuse nylon (ref. 1). Thus, it is unlikely that webbings of higher specific energy will be developed. In fact, more recent work suggests that if a requirement exists for operation in wet conditions or for achieving a smooth tear force, a lower efficiency webbing may have to be accepted.

The more recent work (ref. 6) by John Swallow and his assistants has been more systematic and covers 12 webbing constructions (table II), in which variations have been selected in accordance with the requirements of a properly factored experiment. A number of the constructions broke without tearing in certain circumstances. Within the levels tested, the efficiency at a given binder strength was highest at lower warp count, higher velocity, larger falling mass, and in wet conditions. However, the circumstances leading to higher efficiency were those giving the highest probability of webbing breakage without tearing. A safe limit for all the conditions examined indicated a maximum efficiency (specific energy absorption) of about 40 J/g at a maximum binder mass fraction of 0.08 and weft fraction of 0.3. For webbings of a given specific mass, the efficiency was linearly related to the tear force developed, which, in turn, was linearly related to the total binder strength. High correlation coefficients (0.98) were noted. The amplitudes of the oscillations, particularly the low frequency ones, are roughly correlated through the origin with the magnitude of the tear forces, with no evident separation between the types (nylon, polyester, and nomex) of binder material.

MECHANISM OF TEARING

The mechanism of tearing, particularly the influence of interyarn friction and the rate of tearing, is inadequately understood and has been made the subject of a research agreement with the Department of Textile Studies, the University of Manchester Institute of Science and Technology. It has been established that ply-tear webbing can be torn very fast, and experimental methods for high-speed tearing probably will involve

considerable difficulty and expense. Therefore, a good theoretical background is required before the experimental work is extended. Four major questions need to be answered.

1. What are the factors that limit the maximum rate of tearing?
2. How is the efficiency of a ply-tear webbing affected at the highest speeds of tearing?
3. At what speeds do the inertial forces become significant?
4. How can fluctuations of tear force be limited and for what penalties?

A simple illustration of how frictional forces may act in the process of tearing and determine the interval between breakages is shown in figure 6. For the binder to break, a tension has to be built up by the process of the free end of the binder being pulled through the weave. The computation of the tension between the point A of maximum stress shown in figure 6 and the free end arises from a combination of arithmetic and logarithmic increments of force at each point where the yarn is pulling through the backing. The illustration in figure 6 has been simplified by showing only logarithmic components of force. If F is the force being applied to the webbing backing, then the tension in the backing will fall between points Z and Y and, further, between Y and X. The binders within the untorn ply will be in tension, and it is impossible to represent the true equilibrium of forces without introducing the inertial forces, which cannot be neglected in the understanding of high-speed tearing.

When the binders at A have reached their maximum tension and are about to break, the maximum tear force F transmitted across the two plys is given by

$$F_{\max} = NB(1 + k + k^2 + k^3) \quad (1)$$

After breakage, the tension in the link at A falls to zero. In the next link to the right, the slippage of the binder reverses and the tension falls to k^3B , so that the tensions in this link and the fourth link to the right balance the tension in the third link as it is pulled out. Thus, the tear force falls to a minimum value

$$F_{\min} = NB(k^3 + k^2 + k^3) \quad (2)$$

The ratio of these two forces is

$$\frac{F_{\min}}{F_{\max}} = \frac{k^3 + k^2 + k^3}{1 + k + k^2 + k^3} \quad (3)$$

An example numerical value (ref. 1) of this ratio is 0.40, and a value of k that fits this ratio is 0.64, corresponding to a 0.14 value for the coefficient of friction of binder over weft. Therefore, the observation that binder breakages occur, on the average, every four links is consistent with a realistic coefficient of friction between weft and binder.

USE OF PLY-TEAR WEBBING IN MECHANISMS

Ply-tear webbing is an expendable material and, as such, must be compared with a fuel. Apart from its mechanical performance, its economic performance must be examined. Although the gross cost of the energy absorber should be used as a basis of comparison, it is possible to give some guide to the net economic efficiency of the material. Such an estimation is not easy because work has been concentrated mostly on only development weaving, which has been done on conventional looms to give a guide. With the heavy webbing used in pattern WR 1058, the economic performance is approximately 1×10^4 J per dollar. Such a figure is useful when assessing the feasibility of high-capacity systems because in many smaller systems, the net cost of the energy-absorbing material is swamped by the costs of engineering the mechanism.

The material was conceived for use in the working elements of an erectable shock absorber. Although a working model was built and underwent sufficient tests to show that the material was viable in this context, the requirement was not urgent and development in other applications has overtaken this work.

Ply-tear webbing first was successfully used to absorb the surplus energy in a partly rigid aerodynamic decelerator. This was the retarder for conventional armament. The application is illustrated in figure 7, which shows two rigging strops that have been looped up by attaching a piece of ply-tear webbing across the loop.

In the mediumweight-supplies dropping parachute platform for the airborne forces, without ply-tear webbing, damage occurred to the release mechanism because the extractor parachute was required first to break a shear wire on the emergency release mechanism before it pulled on the platform. The strain energy in the cable was transferred to kinetic energy in the coupling, causing it to strike other parts of the equipment violently and become damaged. Thus, to check the accelerations of separation, ply-tear webbing had to be placed in parallel with the slack cable connecting the components of the release mechanism. In figures 8 and 9, the link before and after tearing, respectively, is shown.

In human engineering, ply-tear webbing has excellent potential for use in crash and safety harnesses. Because tear forces are so predictable, it is possible to design for the known deceleration tolerances of the human body. Thus, in the example of the automobile seat belt, it is possible to design to take advantage of the full available stroke in a system and be acceptable at all speeds up to that which uses all the stroke. In the case of aircraft and helicopters, in which the occupant requires a harness for normal flight conditions, a case can be made for considering a ply-tear mounting of the whole seat in the airframe. However, a successful application to an industrial safety harness has been developed in England.

Ply-tear webbing is being used successfully and with quantitative precision for both main and emergency decelerators on dynamic test facilities. It is used on the Royal Aircraft Establishment rocket track and at other British research establishments.

DESIGN PROCEDURES FOR PLY-TEAR WEBBING

In many applications, it is sufficient to look at the equation of energy and work done, which, in a ply-tear webbing of a given pattern, is proportional to the weight of webbing torn. This weight can be obtained in one long length or in several shorter lengths in parallel, giving a higher total tear force. Thus, in arresting a moving body of known mass, the permissible deceleration will determine the force, and the kinetic energy will determine the weight of webbing required. The stroke is explicitly determined. When a body is falling under gravity and the tear force is equal to the weight of the body, then the latter should fall at constant velocity.

The case of the ply-tear link across a coupling in long cables requires an examination of the speed of separation when the coupling parts. The mechanics of the problem is best illustrated with reference to figure 10. The two parts of the coupling have masses M_1 and M_2 , which are attached, respectively, to elastic cables. The time interval between release and the moment when the first relaxation of strain returns to the coupling is considered. During this time, the motion of the masses is determined by the magnitude of strain e in the cables and the velocity c , with which the rate of change of strain travels. The velocities of separation of the massive parts during the initial time interval, before any reflection of strain relaxation occurs, are shown in figure 10. If the coupling masses are small, the separation velocities will quickly approach the asymptotic values e_1/c_1 and e_2/c_2 , respectively. At the ultimate strains for steel and nylon cables, these velocities are approximately 50 and 275 m/sec, respectively, typical of the accidental breakage situation. When working at a safety factor of three, the velocities are approximately 15 and 90 m/sec, respectively.

In many practical cases, the mass on one side of the coupling is much larger than on the other side, so that the simple case of the movement of one member with respect to a fixed mass is appropriate. This simpler case will be chosen to illustrate the effect of inserting a ply-tear link. The tension T_1 in the cable is proportional to strain and can be written $m_1 e_1 c_1^2$ or $m_1 c_1 v_1$. If only a partial relaxation occurs, as when the acceleration of the mass is restrained by a tear force F , the instantaneous velocity v is determined by the following equation of motion

$$T - mcv = M\dot{v} + F \quad (4)$$

for which the solution, for the condition $v = 0$ when $t = 0$, is

$$v = \frac{(T_1 - F) \left(1 - \exp \frac{-m_1 c_1 t}{M_1}\right)}{m_1 c_1} \quad (5)$$

This equation holds for a time $2L/c_1$. The corresponding tear distance S is

$$S = \left[\frac{2 - \left(1 - \exp \frac{-2m_1 L}{M_1}\right) M_1}{m_1 L} \right] \left(\frac{(T_1 - F)L}{m_1 c_1^2} \right) \quad (6)$$

It is seen that v can only be substantially reduced by making F nearly equal to T_1 and that the length of tear webbing required is correspondingly made shorter. The work done by this tear link is

$$FS = \left[\frac{2 - \left(1 - \exp \frac{-2m_1 L}{M_1}\right) M_1}{m_1 L} \right] \left(\frac{(T_1 - F)FL}{m_1 c_1^2} \right) \quad (7)$$

which is a maximum for a single link when $F = T_1/2$. The total strain energy in the cable before release is $LT_1^2/2m_1c_1^2$, so that the fraction of it absorbed by a single link is

$$\frac{1}{2} \left[\frac{2 - \left(1 - \exp \frac{-2m_1 L}{M_1}\right) M_1}{m_1 L} \right] \quad (8)$$

Thus, when M_1 is finite, a single link of $F = T_1/2$ cannot absorb all the energy, and the remainder must be released as kinetic energy in the cable and coupling.

The significance of the ratio of the coupling mass to the total cable mass can be illustrated with reference to a numerical example. The case of a nylon cable of 30-kilonewton breaking force tensioned to 10 kilonewtons is considered. A cable of

this type of breaking force would have a mass per unit length of about 0.1 kg/m. The coupling mass is assumed to be 1 kilogram. The velocity of propagation of strain disturbances in woven nylon cables is approximately 1000 m/sec. For convenience, the unstrained length of the cable is chosen at 10 meters, for which it is implicit that the extension is 1 meter for the loading conditions stated. For these data, the total length of cable will weigh the same as the coupling mass; thus, by the time a strain disturbance has traveled the length of the cable and back to the coupling, the value of the exponential term is 0.135. On substituting numerical values in equations (5) and (8), the separation velocity is still 43 m/sec, and 56 percent of the energy has been absorbed. Of the residual energy, 19 percent is in the coupling mass and 25 percent in the cable. The length of tear will be approximately 0.56 meter, and this value can be exceeded slightly by virtue of the inertia of the coupling.

An improvement in energy absorption can be obtained with two parallel tear links, one of 4.2 kilonewtons tearing for 0.34 meter and another of 2.8 kilonewtons tearing for 0.80 meter. Therefore, a total tear force of 7 kilonewtons acts over the first 0.34 meter, and a reduced force acts over the remainder of the stroke. This system would absorb 70 percent of the energy.

The practical problem of setting the tear force at a high proportion of the initial tension concerns the peaks in the tear force. An initial peak in the tear force is unlikely if a little slack occurs in the link, although a final peak, as seen in figure 5, can occur. This fact requires caution in the design of a system with a low residual retention of energy.

PRACTICAL FACTORS AFFECTING PREMATURE BREAKAGE

It has been observed that the backing ply of a wet nylon webbing may break prematurely, whereas it is quite safe in the dry state (ref. 6). The reaction of the wet backing is caused by two factors: first, the wet backing is 15 percent weaker than in the dry state, and, second, the tear force is greater because the binders are kept cooler and are stronger.

Another factor leading to premature breakage is an impact on the ply backing while tearing is taking place. Even the impact of the section of untornd ply against the backing has caused a breakage at the point of tearing. Thus, it is important to control the motion of the untornd webbing by a scheme as illustrated in figure 11, where it is stowed in a satchel. The untornd webbing is laid in flakes parallel to the backing so that the transverse motion is minimized. The actual article is shown in figure 12.

If the tear link is in a mechanism that can rotate during tearing, care must be taken in the layout so that no part of the mechanism can strike the link during the subsequent motion because the shock loads arising from such impacts are difficult to predict. If an impact on the webbing cannot be avoided, then the tear strength/backing strength ratio must be reduced and be satisfied with a tear webbing of lower specific energy.

CONCLUDING REMARKS

Ply-tear webbings have now been available for approximately 5 years, and during this time, a number of successful applications have been found. An important property of a tear webbing is that the tear force is independent of the tear speed, so that design calculations for an energy absorbing mechanism can be kept simple. The material is primarily appropriate to long-stroke shock absorbers. Satisfactory tearing of nylon webbings has been achieved at separation speeds slightly in excess of 100 m/sec, but the maximum separation practicable and at what efficiency level is yet to be established.

REFERENCES

1. Stevens, G. W. H.: Ply-Tear Webbing as an Energy Absorber. TR 68164, Royal Aircraft Establishment (Farnborough, Hampshire, England), 1968.
2. Longrigg, J. C. H.: Tests of Ply-Tear Webbing. TR 69012, Royal Aircraft Establishment (Farnborough, Hampshire, England), 1969.
3. Stevens, G. W. H.; and Bluett, F. C.: A Technique for Studying High Velocity Drawing of Polymers. Current Paper 1061, Aeronautical Research Council, Her Majesty's Stationery Office (London).
4. Baker, A.: The Mechanical Properties and Porosity of Parachute Fabrics. Report Chem 507, Royal Aircraft Establishment (Farnborough, Hampshire, England), 1956.
5. Vincent, P. I.: The Strength of Plastics. Plastics, vol. 28, parts 11-13. IPC Industrial Press, 1963.
6. Swallow, J. E.; Webb, M.; and Watts, Shirley A.: The Energy-Absorbing Efficiency of Ply-Tear Webbings of Various Constructions. TR 72051, Royal Aircraft Establishment (Farnborough, Hampshire, England), 1972.
7. Bluett, F. C.; and Longrigg, J. C. H.: The RAE Nylon Rope Catapult. TR 69108, Royal Aircraft Establishment (Farnborough, Hampshire, England), 1969.

TABLE I. - SUMMARY OF PLY-TEAR WEBBINGS

Type number	Warps				Weft		Width, mm	Weight, g/m	Tear force		Backing strength		Specific tear energy, J/g	Application
	Single ply		Binders		Count tex	Picks, 10 mm			Slow, kN	Dynamic, kN	Nominal, kN	Test, kN		
	Count tex	Number	Count tex	Number										
WR 1017	93×2	104	93×2	22	93×2	10	45	75.7	2.70	1.52	12.5	9.6	57	Industrial safety harness Motor industries research Rocket track decelerator
WR 1018	93×2	104	93×2	22	93×2	Single shuttle 20	45	77	3.12	2.25	12.5	--	63	Royal Aircraft Establishment research and development
WR 1058/1	93×2	50×2	93×2	44	93×3	7.5	29	73	5.0	2.7	--	--	--	Weapon retarder tail Erectable shock absorber
WR 1054	93×2	80×2	93×2	72	93×3	7.5	45	121	8.2	4.7	20.2	14.4	83	Airdrop platform Automotive seatbelt
WR 1058/2	93×2	92×2	93×2	84	93×3	7.5	52	133	9.6	5.6	22.1	19.9	87	Royal Aircraft Establishment research and development
WR 1127	93×2	80×2	^a 93×3 93×2	36 36	93×3	7.5	45	124	7.9	--	20.2	17.0	--	Irvin Industries, Inc. Log transporter.
WR 1146	93×2	92×2	^a 93×3 93×2	36 36	93×3	7.5	50	145	--	--	22.1	--	--	Irvin research and development
WR 1147	93×3	100	93	88	93×3	7.5	48	105	3.35	--	18.8	--	--	Automotive seatbelts
WR 1147/6	93×2	100	^a 93 47	44 44	93×3	7.5	48	99	3.9	2.9	18.8	14.2	63	Automotive research and development
WR 1147T/6	110×3	100	^a 93 47	44 44	110×3	7.5	48	117	2.65	--	--	--	--	Polyester research and development
WR 6157	93×6	92	93×3	84	93×4	--	52	185	--	--	33.1	--	--	

^aThe heavy and light binders alternate across the width of the webbing.

TABLE II. - CONSTRUCTION OF EXPERIMENTAL WEBBINGS

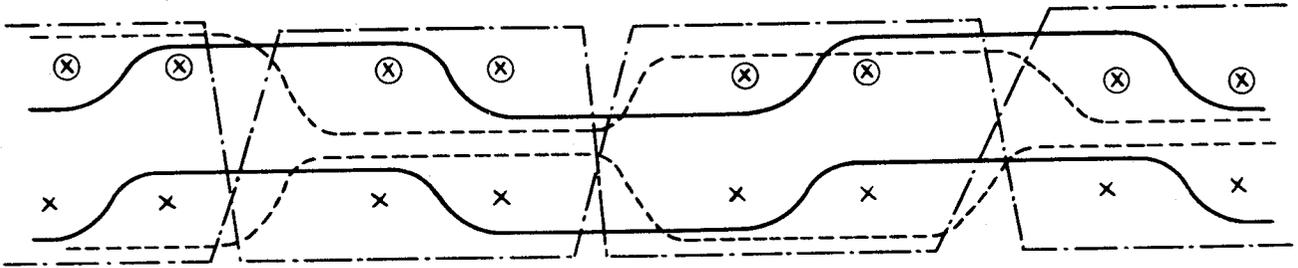
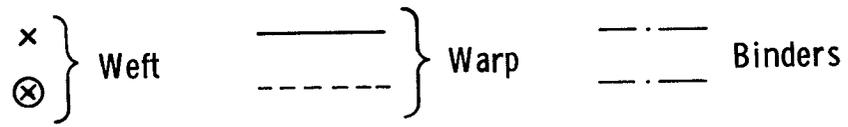
Factor	Webbing number											
	1	2	3	4	5	6	7	8	9	10	11	12
Nominal warp count ^a tex	93	93	93	93	93	93	93×2	93×2	93×2	93×2	93×2	93×2
Nominal weft count ^a tex	93×2	93×2	93×2	93×3	93×3	93×3	93×2	93×2	93×2	93×3	93×3	93×3
Nominal binder count ^a tex	93×2	22×4×2	110×2	93	22×4	110	93	22×4	110	93×2	22×4×2	110×2
Binder material	A ^b	B ^c	C ^d	A	B	C	A	B	C	A	B	C
Number of binder pairs	22	16	11	22	16	11	16	11	22	16	11	22

^aIn accordance with BC 946:1970, single to fold designation.

^bA = nylon.

^cB = Nomex.

^dC = polyester.



Note: Section along warp normal to weft

Figure 1. - Construction of ply-tear webbing weaving sequence.

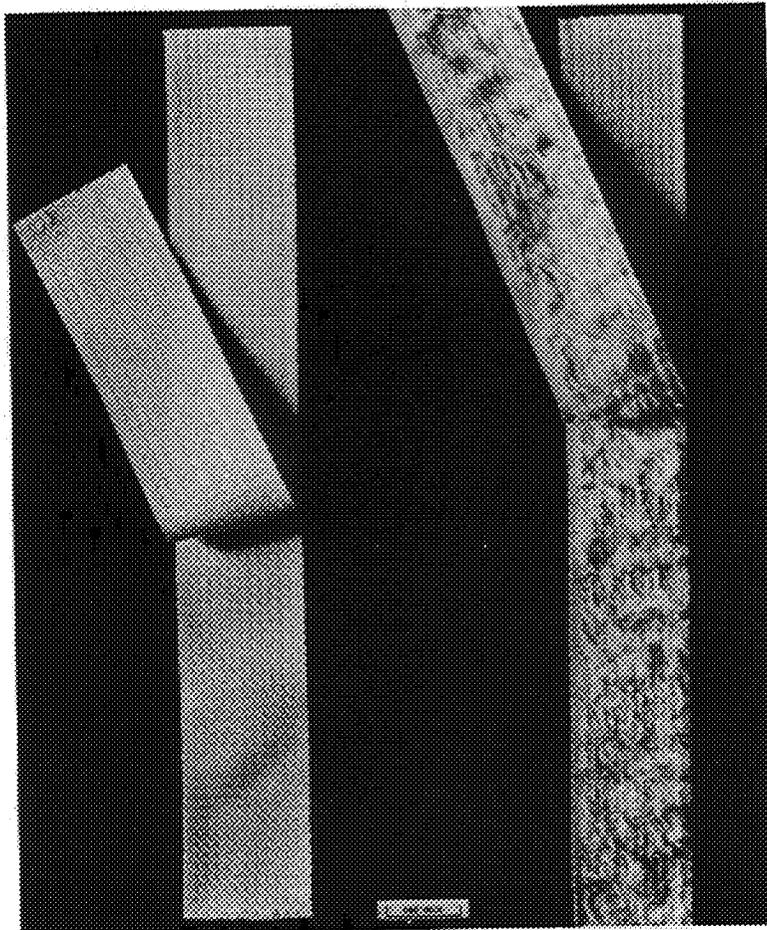


Figure 2. - Ply-tear webbing type WR 1017.

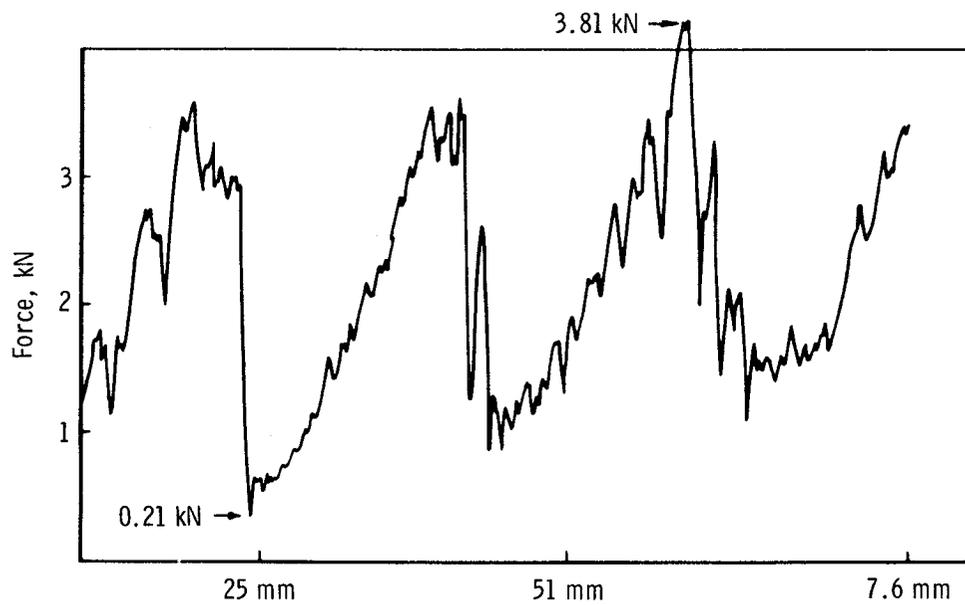


Figure 3. - Nylon webbing WR 1017 slow-speed tearing on a Dennison machine.

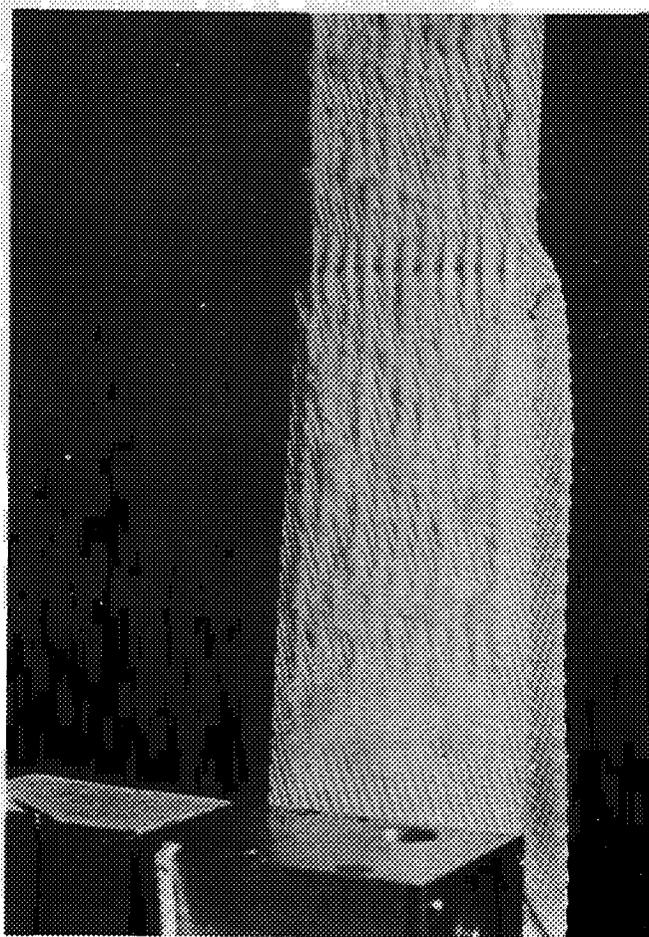
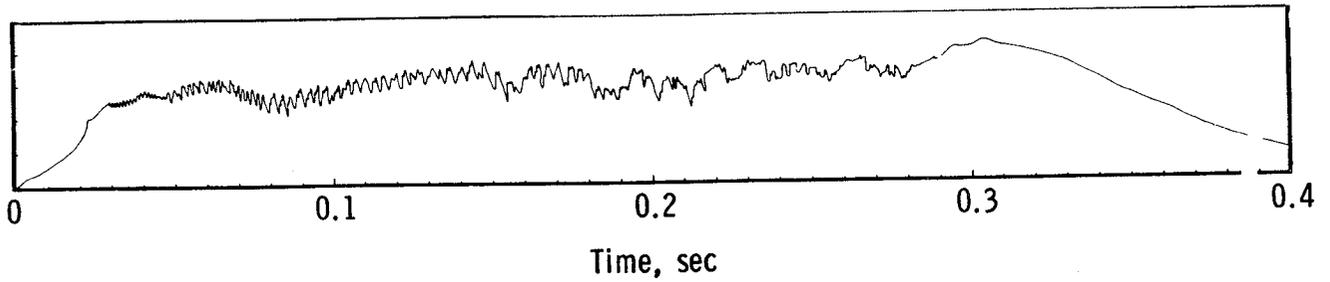


Figure 4. - Type WR 1017 webbing tearing at a rate of 35 m/sec.



Descent velocity at start of tear, m/sec . . . 10
 Free-fall distance, m 4.9
 Weight of dummy, kg 83.5
 Mean retardation, g 4
 Full scale of force, kN 6.7

Figure 5. - Force/time record of retardation of a dummy by ply-tear safety harness.

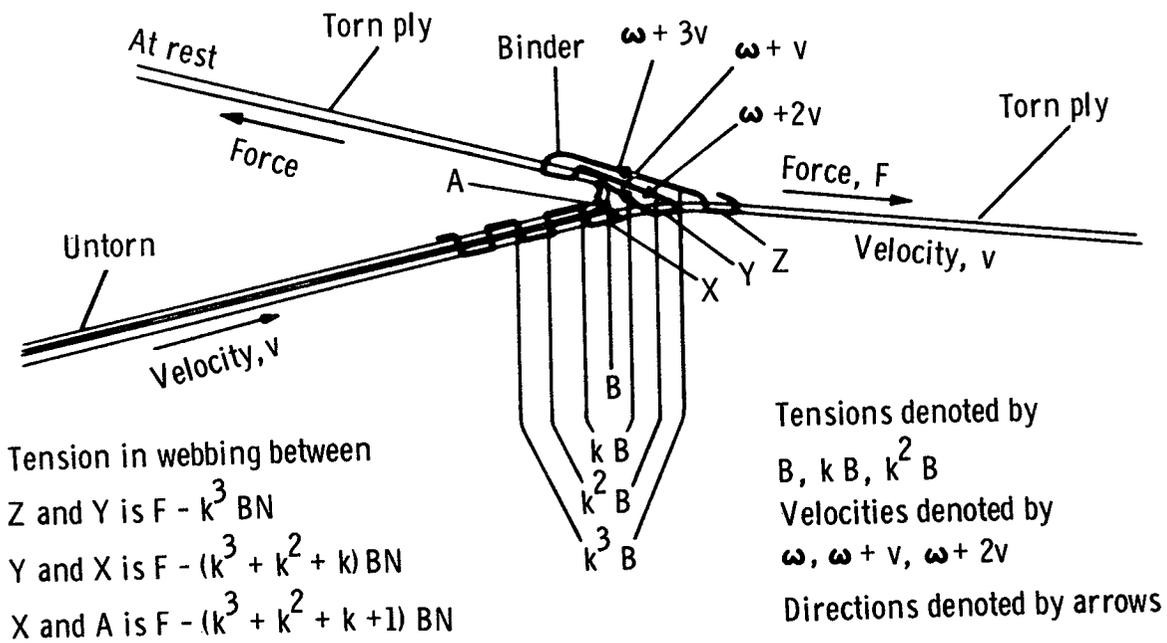


Figure 6. - Analysis of tearing forces.

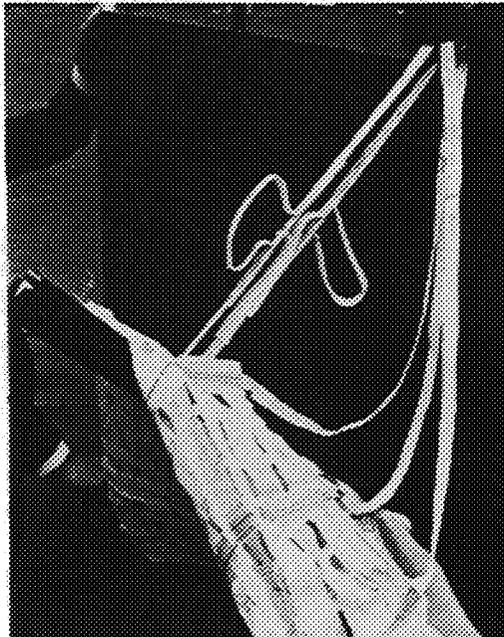


Figure 7. - Ply-tear webbing links retarder unit for bomb.

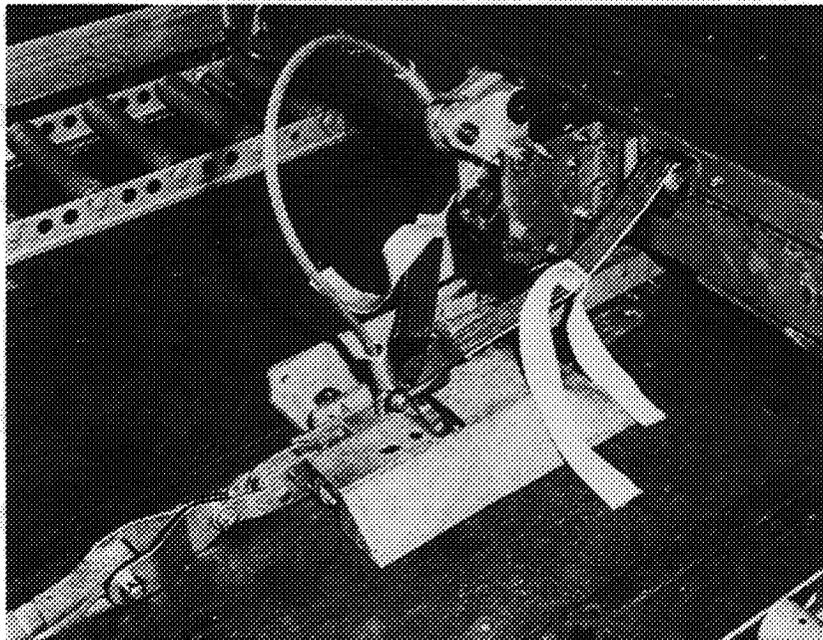


Figure 8. - Mediumweight-supplies dropping system (ply-tear link across extractor parachute emergency release).

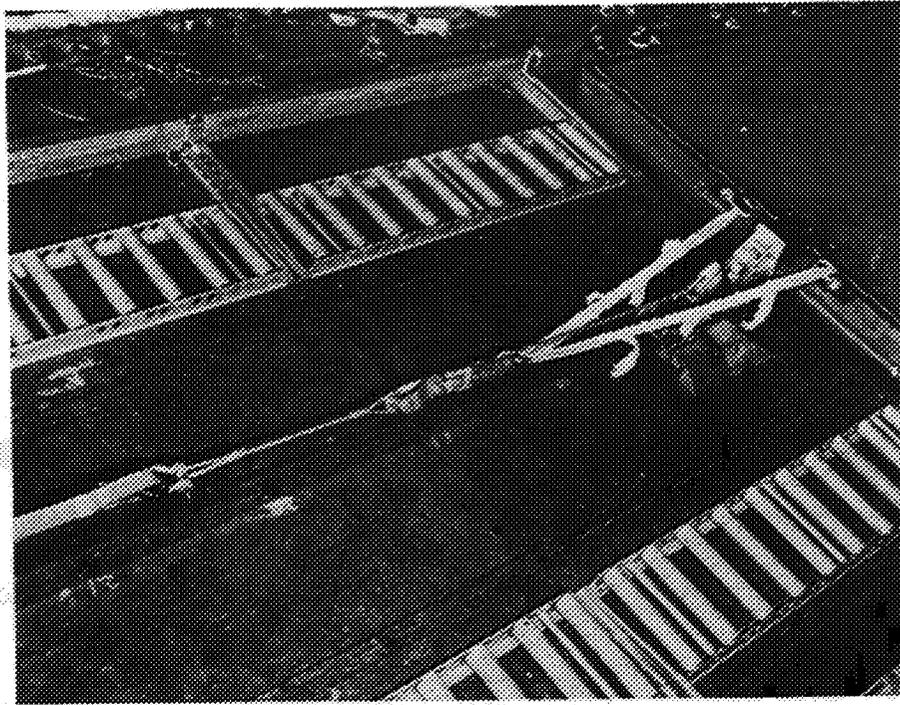


Figure 9. - Mediumweight-supplies dropping system (link torn and supplies platform under extraction load).

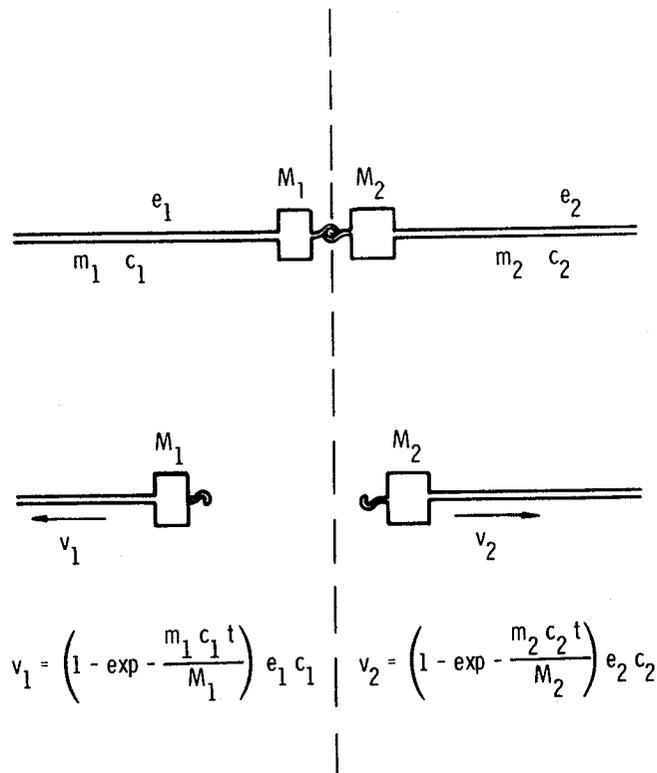


Figure 10. - Motion of masses and elastic cables after instant of release.

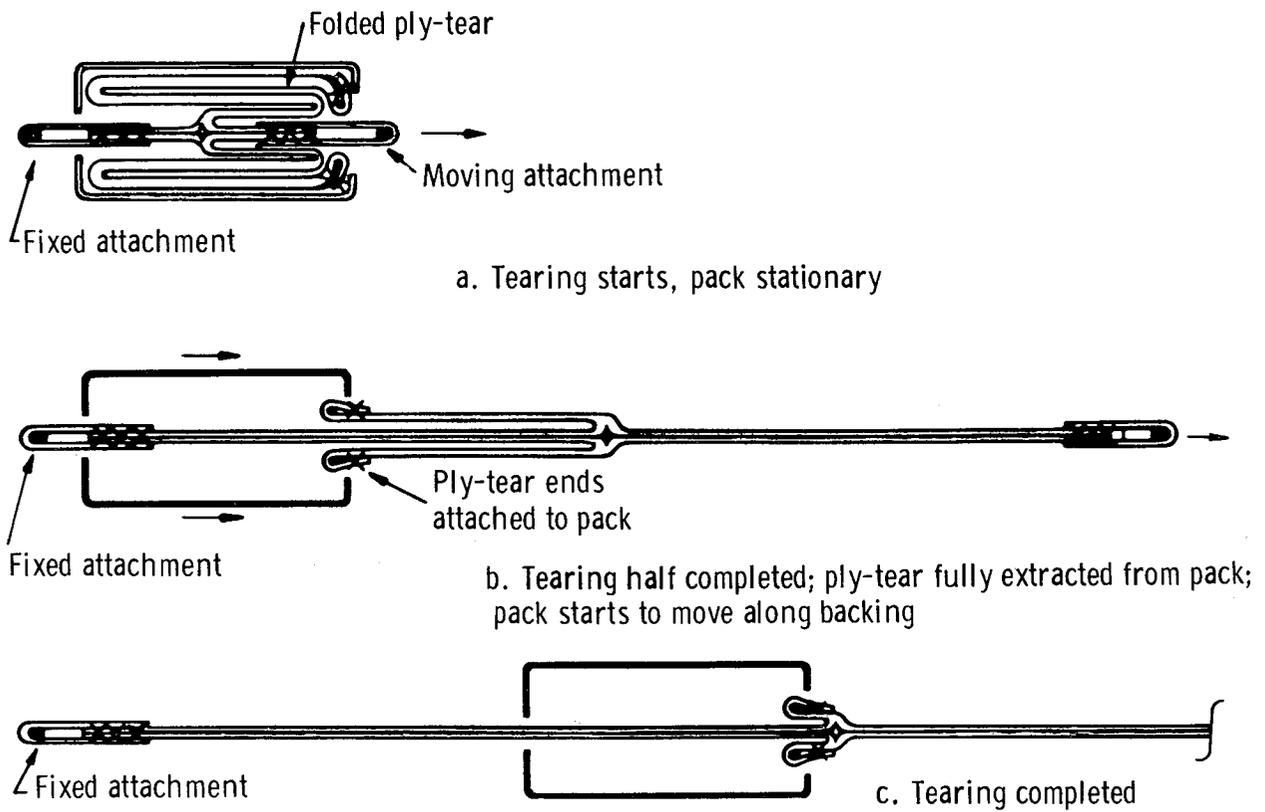


Figure 11. - Ply-tear webbing pack design to restrain untorn webbing ends.

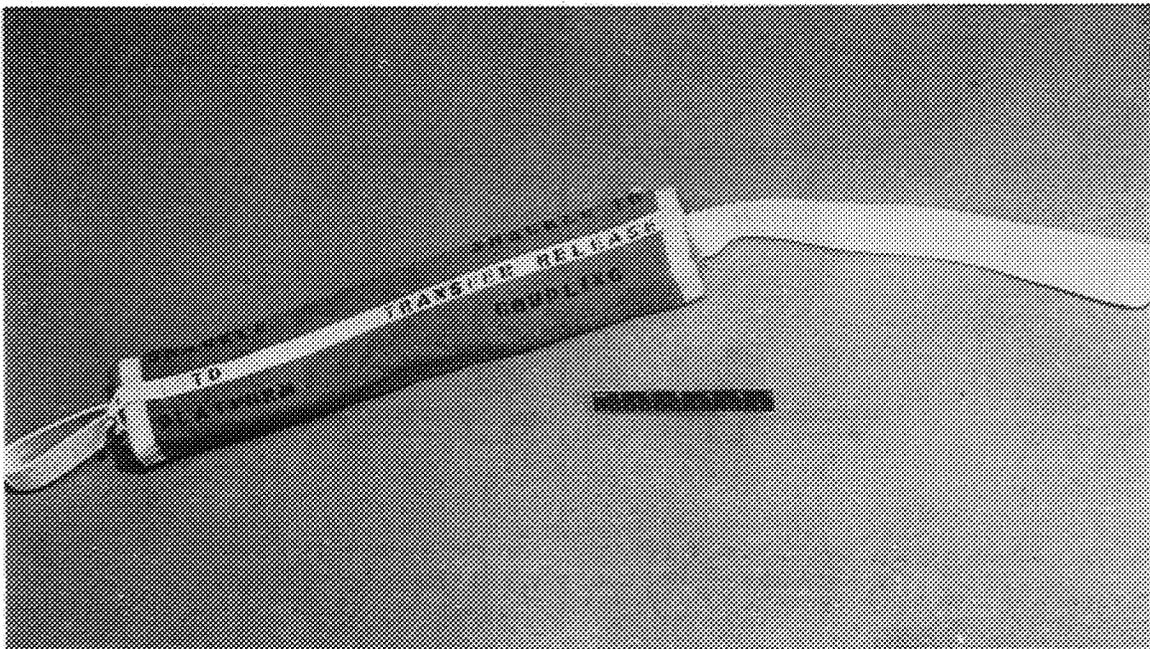


Figure 12. - Ply-tear webbing pack design for heavyweight-supply-dropping application (mean tear force, 9 kilonewtons; extension, 8.4 meters from 1.1 meters).