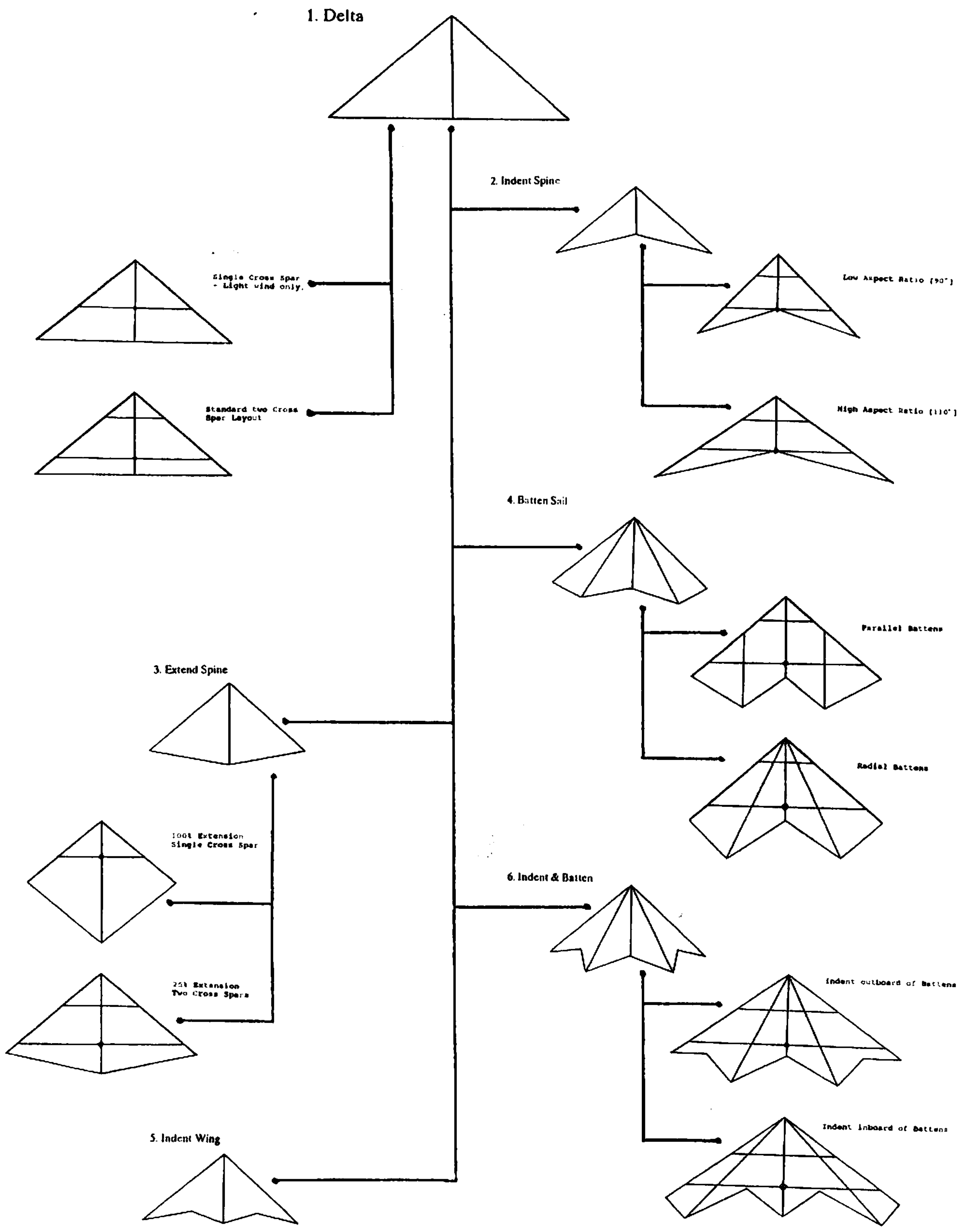


Swept Wing Stunt Kites

Mark Cottrell 1990

Recycled From Kite-Eating Trees

Swept Wing stunt kite design is something about which you won't find anything remotely usable written anywhere. And yet, there are at least 60 companies throughout the world making a living from swept wing stunt kites, many thousands of swept wing stunt kite fliers and a fiercely competitive stunt kite competition circuit.

So how do swept wing stunt kites get designed/built? Trial & error?, experience?, or the massive overkill of computer aided design techniques?

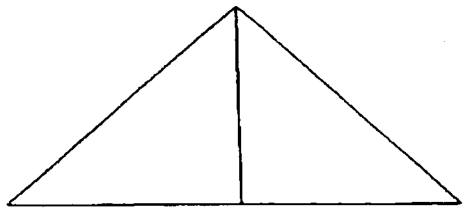
When I made my first swept wing stunt kite it was designed on graph paper, in pencil, and worked over till it looked right- total "design" time 3 hours- flew properly first time. The last one was a proper computer simulation (really) and each re-iteration of the design after an alteration took a long time (about 6 hours)- total design time now coming up on 85 hours and it still isn't "right".

Contents

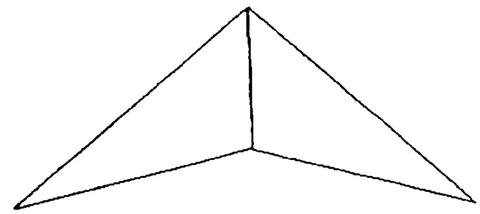
1. Form, function & other basics

The generic term "swept wing" is currently applied to the class of stunt kites based on the delta form which is essentially, a triangle with supported leading edges,a central spine and a free, unsupported trailing edge. Within this incredibly vague description many variations and possibilities exist for change in shape and form. A few of the common variants;-

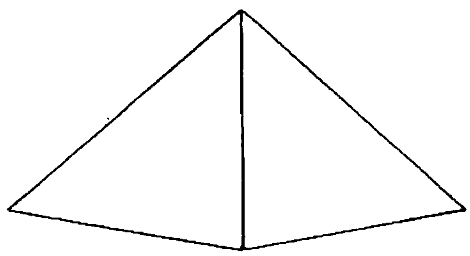
1. Delta



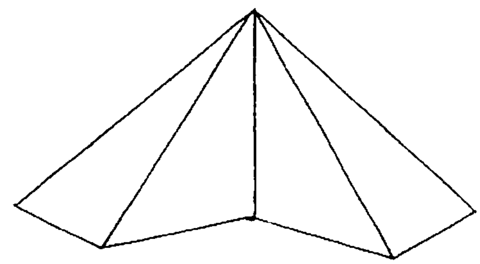
2. Indent Spine



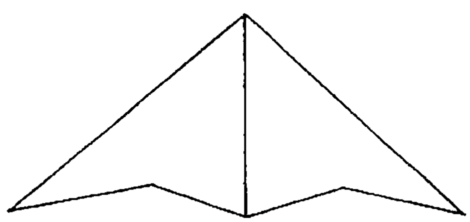
3. Extend Spine



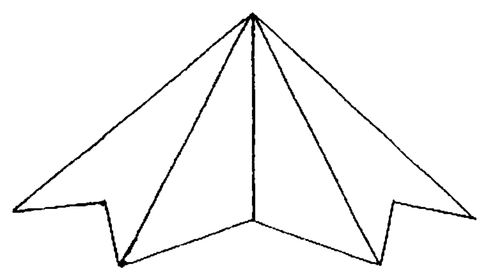
4. Batten Sail



5. Indent Wing



6. Indent & Batten



With swept wing stunt kites the word speed is important- the wind speed range the kite will fly in, the flying speed range of the kite and the speed at which the kite turns are the three crucial design criteria for a swept wing. To a large extent these three factors interact and finding an optimum balance can be most time consuming.

The wind speed range of a swept wing is often quoted in typical "our kite's better than anyone else's" advertising and is nearly always a pile of rubbish. I have a thing about measuring wind speed correctly- I will say again what I tell everyone who asks; no cheap (less than $500) wind speed meter is accurate below 10mph. I have a fancy wind flow meter which was independently calibrated by a certification laboratory and comparing the cheapo's with this is enlightening to say the least.

At the low end of the wind speed range the amount of energy available in the moving air and the efficiency with which this can be extracted are the limiting factors. Taut sails, light weight and high aerodynamic efficiency are pre-requisites for light air flight and with modern materials not too difficult to attain.

So what have I measured as typical minimum wind speeds for flight- the least I have had a ripstop sail/graphite spar stunt kite fly in (without me moving) was 4mph (doing the sums for energy actually available from the moving air indicates that flight in about 3.2mph should be possible for a perfect kite made from these materials).

Just for fun I measured a couple of well known Ultra-light stunt kites- both had claimed 4mph minimum flying speeds- one flew at 6mph, the other at 7mph- hmmm. Curiously, I have seen claims for flight at 1mph for one kite and 2mph for quite a few others- either; 1. These kites are full of hot air or 2. The manufacturers are.

High end wind speed performance is a function of how strong your frame is and how strong you are rather than the aerodynamics of the sail form. Roughly, available wind energy is related to the square of the wind speed and the flying load imparted to the frame (and then to you) varies in a similar manner. By using the minimum wind speed required for flight and a factor for the strength of the material used for the frame it is possible to predict with reasonable accuracy the upper wind speed limit for any given frame. Typically, I use frame factors of 6-8 for glass fibre tubing and 10-15 for carbon fibre tube. In real life this means a glass framed kite which flys in a minimum of 6mph will stand approximately 15-16mph before it shows signs of disintegration (frame goes "floppy"), in carbon fibre the kite would stand around 19-21mph (the calculation goes as follows- square the low wind speed, multiply by the frame factor and then square root this number to give upper end speed- more of this later in the section on frames).

Speed range (the difference between slowest and fastest forward speed of the kite) is almost never quoted yet it is possibly the most important design point. A kite which can be slowed or accelerated with just a touch on the lines is a delight to fly. Unfortunately, not a few commercial designs belong in the all or nothing school of speed design. They either scream about the sky like the proverbial bat out of hell or fall out of the sky like a brick.

Designing speed range in is, well, fun. Most basic sail layouts (like those shown earlier) are actually quite good about having smooth wind speed/forward speed transfer characteristics as long as sail form is maintained, so simply stepping backwards or forwards will give you reasonable speed control in these layouts. However, maintenance of accurate sail form at low flying speeds can be difficult. Since the aerodynamic loads on the sail are very low they can no longer be used to form the sail into an efficient shape and other devices such as sail battens (stiffeners sewn into the sail- they can be straight or pre-formed to a shape), sail stretchers or support lines have to be used. At the other end of the wind spectrum, as wind speed (and thus flying speed) increases the sail load will progressively deform the frame & thereby spoil the sail form until eventually a limit is reached above which forward speed decreases due to this loss of form. Frame stiffness is thus the limiting factor and needs careful matching to sail form & loads for best performance.

A neat way of stretching speed range is to design a sail form with two different "modes" of flight. This is the basic idea in the Mabel & Rosebud designs where at low speeds the sail behaves as gently reflexed wing (flattened S shape camber line- that is the curvature of the sail) & as wind speed increases this gradually deforms to a single cambered wing with a terrific increase in speed. My favorite flight trick involves snapping back & forth between the two modes- the trick is simply to pull a vertical dive in the wind centre, turn one loop and stop, dead, dead wind centre.

Turn speed is related to kite mass (for now think of mass as weight) & lift differential. Kite mass influences turn speed due to inertia- objects like to continue to travel in whatever direction they were previously travelling in, heavy objects especially. So a heavy kite will want to keep on going wherever it was going and take much longer to start to turn than a light kite of the same size. Lift differential, the difference between the amount of lift/drive on each half of the kite, is what turns the kite and kites which turn quickly do so because either one side of the sail drives the kite around the turn or one side stalls and drags the kite back through the turn.

As an example of this, a Spin Off drives on through turns whilst a Fire Dart drags back through turns. The sharpest turns come from kites that drag through turns while kites that drive through fly more smoothly and lose less speed in a turn. Again it is possible to make kites that switch- eg LiteFlite S- the pointy wing tips allow switching as wind speed increases due to the sharp tip stall characteristics of pointed tips.

A number of other specific factors interact in a fairly complicated manner to affect turn speed- these include depth of sail, centre of lift position of each semi span and rotation shadowing (typically your average human can push/pull the handles through 15", on an average 8ft stunt kite this equates to about +/- 15 degrees of rotation around the spine axis. If the sail is of deep section then the rotation may allow the windward half of the sail to shadow the leeward part to such an extent that the kite won't turn).

So now we have a kite that flies in a good range of wind, at a reasonable speed and turns nicely, but what shape is it? Swept wing shapes derived from the two primary sources. The first, much quoted, is the triangular soft fabric wing invented by Francis Rogallo and used by many early hang gliders (the best source of any technical information on wing shapes, lift/drag ratios etc is hang glider research/ literature). The second, and somewhat forgotten, is J.W.Dunne and his inherently stable aeroplanes which were of swept wing planform.

Figure 1. is a generalised swept wing layout and shows the names and where you'll probably find parts on later drawings;-

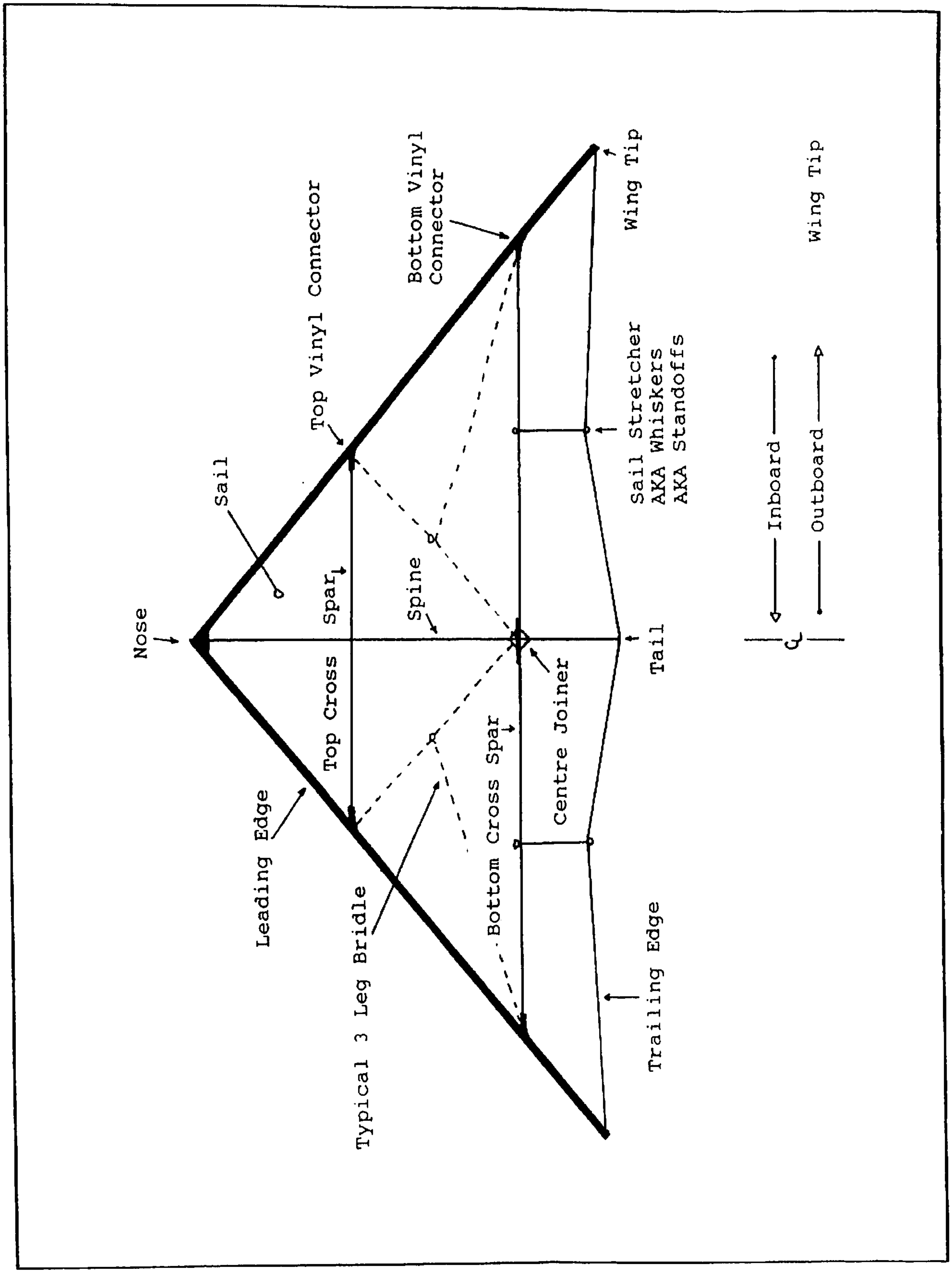
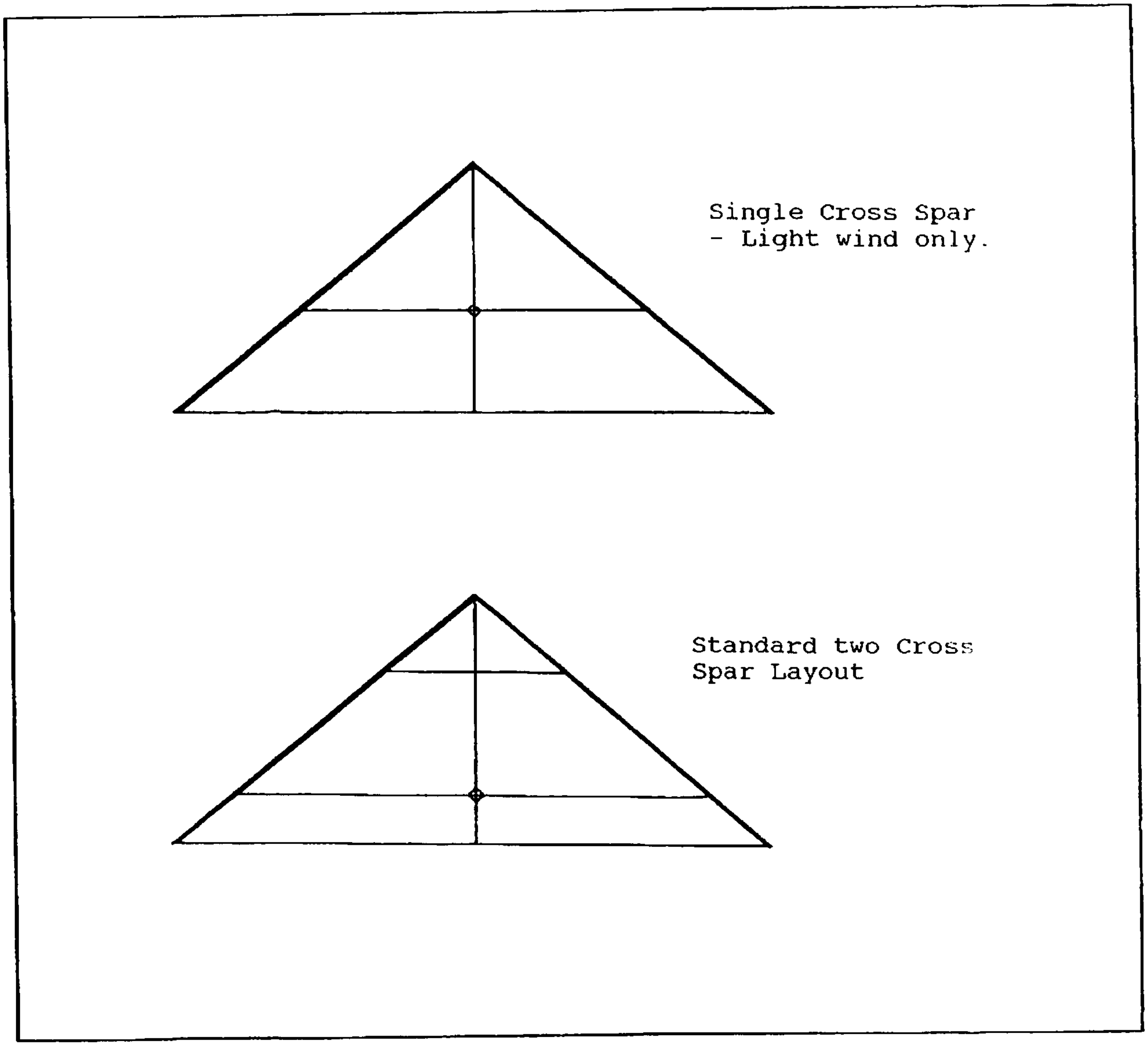


Figure 1. Swept Wing layout/part names

There are a number of different planforms (the basic flat shape of the sail) in common use (as depicted earlier)- I make it about 6 main classes and many variations thereon. Each has its own particular foibles and as a quick guide consider;-

1. The Delta shape;- The triangular delta shape as a flying form existed long before Rogallo's soft wing patents. Indeed, current delta shaped stunters owe more to solid delta wings than to soft practice.

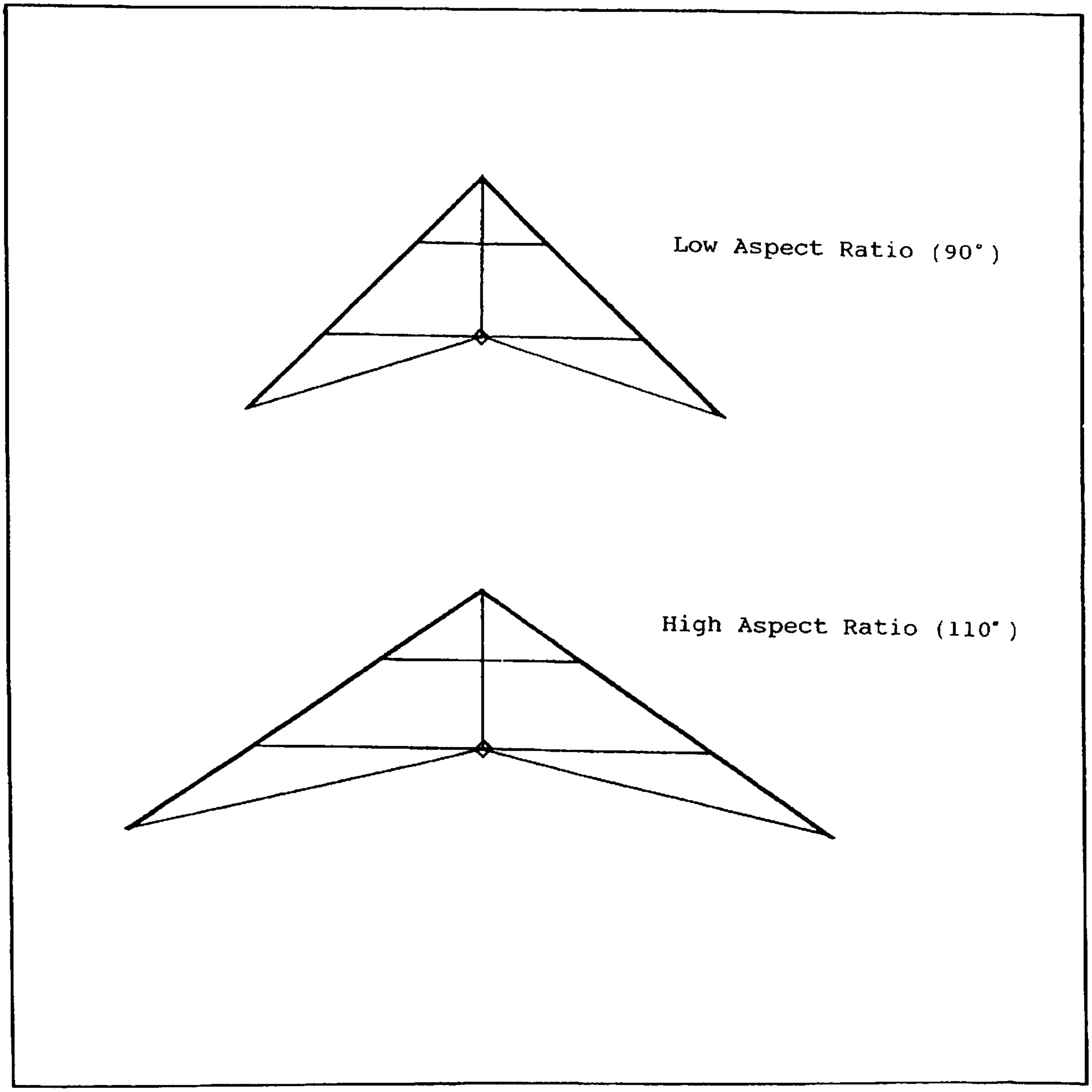
With a delta you can have "rigid" sails (held stretched by battens/whatever) or "soft" sails (blown out by the wind). Both fly in a similar manner although some rigid sails are very noisy. Flight speed is slow/medium, turns are medium and required wind about 6 mph. The most unpleasant characteristics are the poor wind edge performance (sail stalls easily and drops nose unrecoverably) which can prove frustrating and the necessity to maintain reasonable airspeed to allow control.



Typical nose angle range 90-110 degrees.
Typical close up angles 8-12 degrees.
Minimum wind 6mph.

2. **Indented Spine;**- By shortening the spine (compared to the standard delta shape) a considerable part of the "draggy" part of the sail is removed. This increases the lift to drag ratio of the wing and produces a kite that flys faster. The pointy wing tips also increase the turn rate due to tip stall in tight turns (very pointy tip shapes lose lift very suddenly as air speed drops and produce large amounts of drag when this occurs- effectively the tip gets stuck to the sky and the kite turns around the tip).

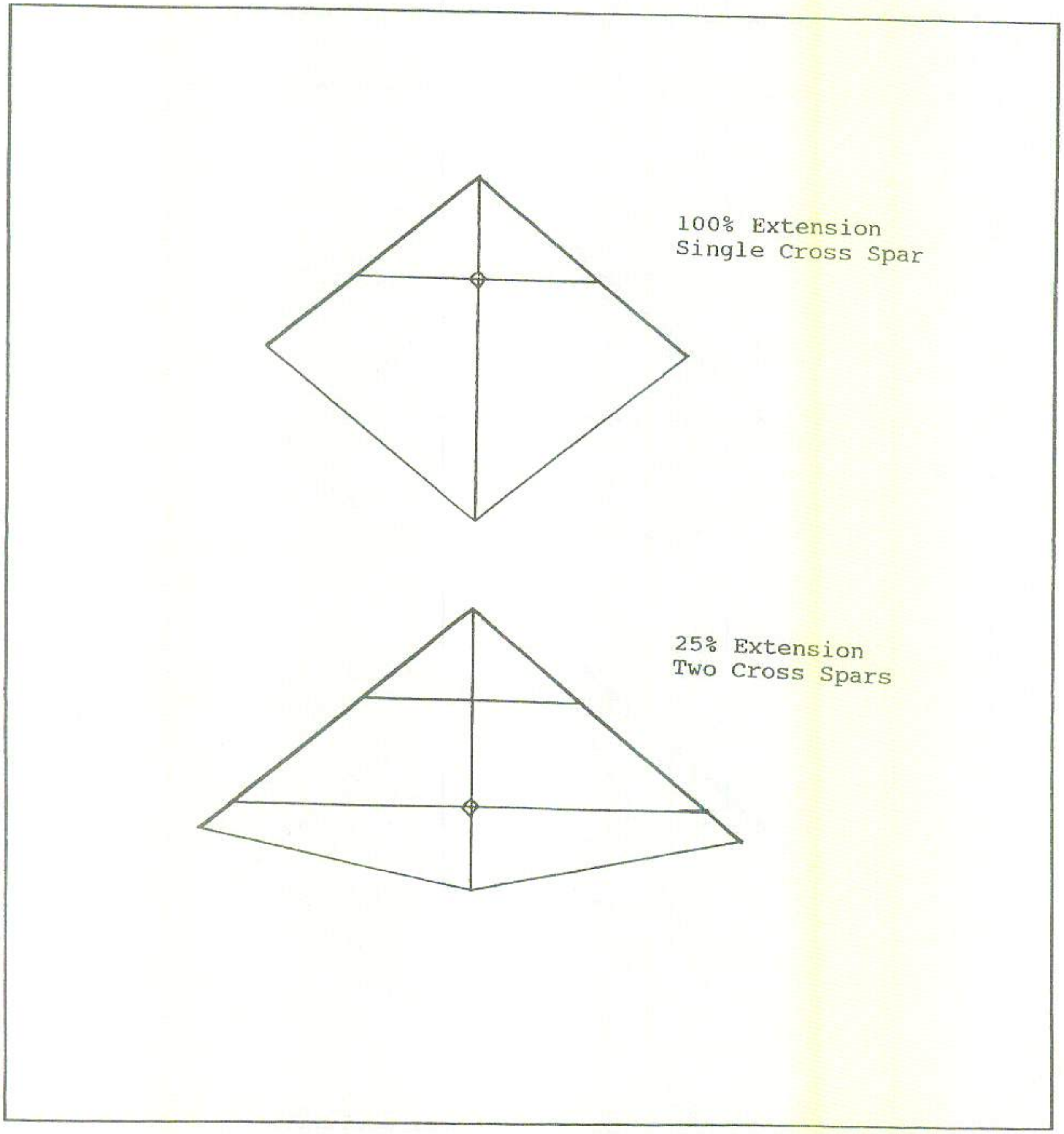
The tip stall is also the prime disadvantage of this design- flying too slowly will stall both tips dropping the kite into a nice backward tumble. Another problem arises from the reduced sail area (when compared with a delta) for the same spar weight- the kite is denser and needs more wind to perform.



Typical nose angle range 90-120 degrees.
Typical close up angles 5-15 degrees.
Minimum wind 6mph.

3. Extended Spine;- By extending the spine the sail area of the kite is increased quite considerably without a great increase in spar weight. However, the longer trailing edge and greater sail loads imposed on the frame distort the frame badly in anything but a light wind with current frame materials.

Having said that this shape will fly in the lightest wind of any of the designs and has extremely good pitch stability (very difficult to stall even in turbulent air). The high pitch stability makes bridle adjustments easy and non-critical. Forward speed is slow/medium & turns are of medium speed.

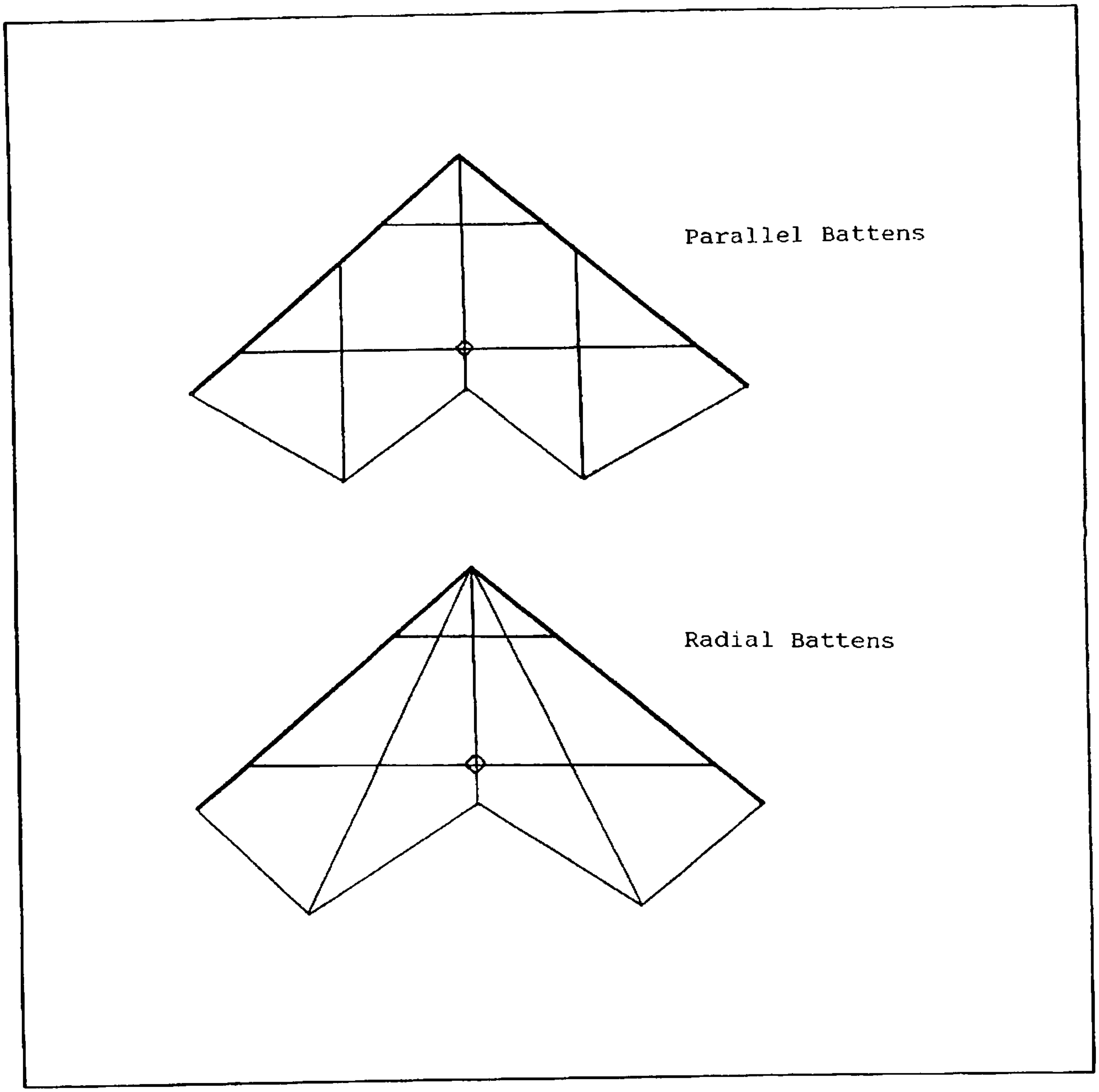


Typical nose angle range 75-115 degrees.
Typical close up angles 10-20 degrees.
Minimum wind 4mph.

4. Battened Sail;- Introducing another set of spars into the sail itself allows the form of the sail to be preserved in stronger winds than if it was unsupported. Since these spars can be longer than either the spine or leading edge the sail area may be increased compared to the standard delta.

The disadvantages of battens are twofold- they have weight and they have to be rigidly controlled otherwise they can induce all sorts of mischief in the flight characteristics (such as single sided stalls &/or total sail collapse).

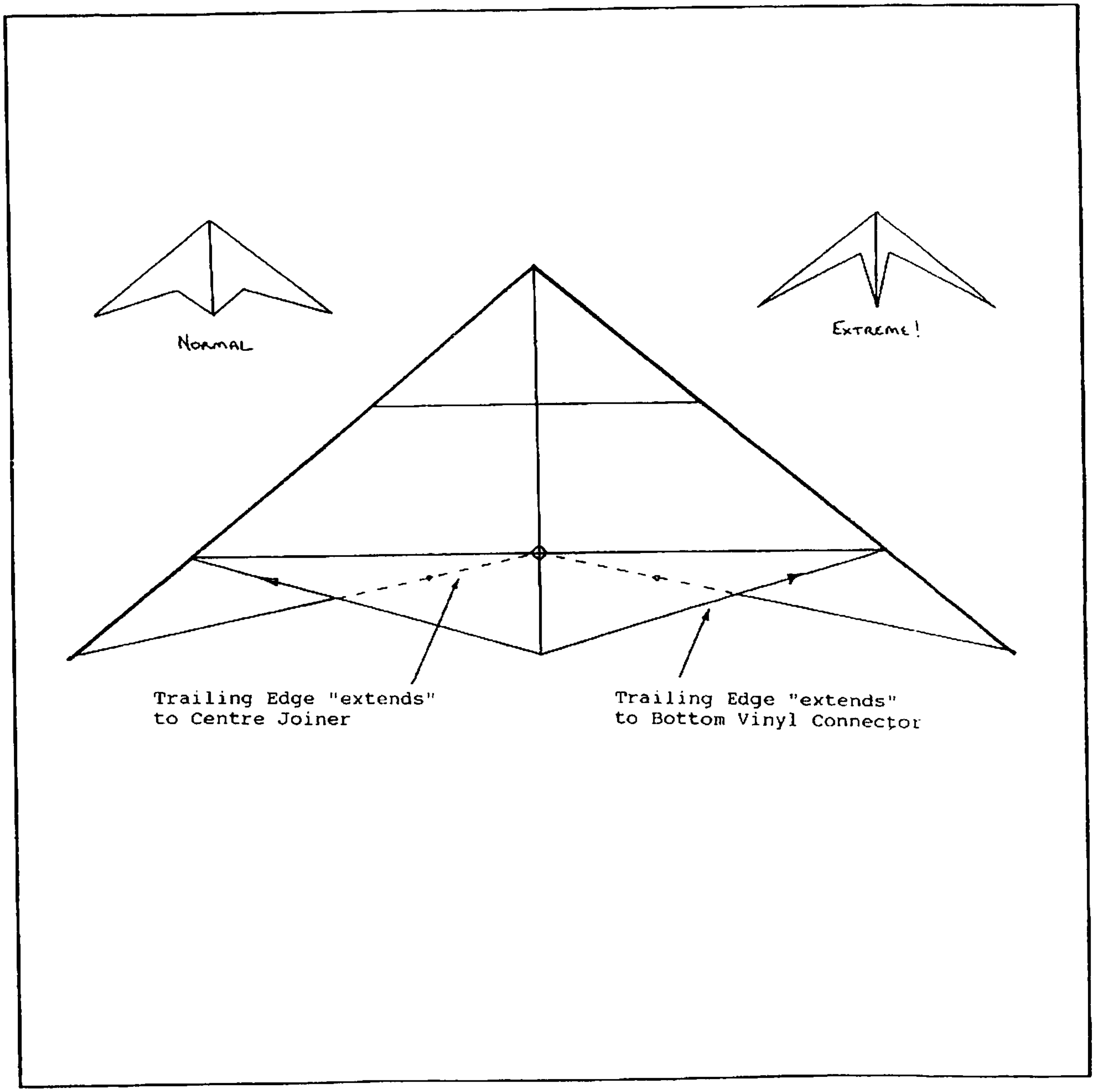
Flight speed is medium/fast and turns are slow/medium (due to the increased inertia of the extra spar set).



Typical nose angle range 95-120 degrees.
Typical close up angles 5-15 degrees.
Minimum wind 6mph.

5. **Indented Wing;**- All swept wings show stress lines in the sail due to the wind loading. The major stress line runs from the wing connectors of the bottom spreader to the bottom tip of the spine. If the trailing edge is cut to correspond to this line then the stress line pulls the trailing edge taut. By using a similar method for the outboard trailing edge using tip and bottom spar crossover point as the stress line a very taut indented trailing edge is produced.

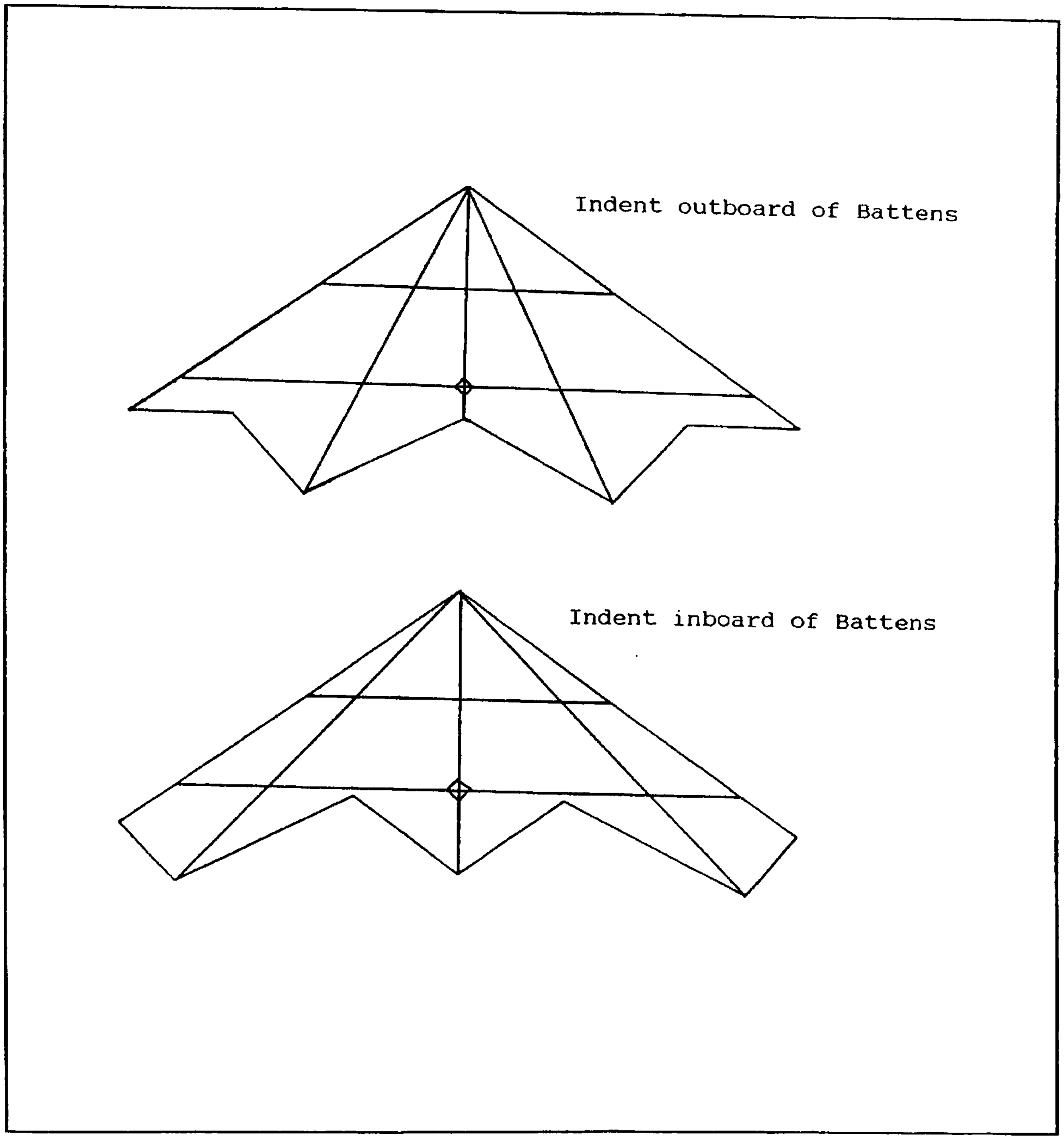
Kites with this sort of trailing edge are fast, noisy (the taut TE rattles & hums) and comparatively light on the lines, although the high airspeed produces a lot of pull in stronger winds. However, the indentereduces pitch stability drastically making this a difficult form in anything but smooth air. Most of the current crop of "high performance" open class stunt kites are of this type with slight variations (curved TE, radialised sails etc).



Typical nose angle range 100-130 degrees.
Typical close up angles 5-20 degrees.
Minimum wind 6mph.

6. Indent sail & batten;- By combining the indented wing with a battened sail it is possible to produce a kite that isn't quite as lively as the plain indent, but will fly in considerably less wind. The only problem with the layout is in defining where the return TE from the tip should run- get this wrong and the kite is sluggish and noisy- get it right and the layout is delightful.

Flight speed is medium and turns are fast- turn rate can be increased further by using virtual battens viz.an auxillary strain member is used to pull the sail out in the same way as if the batten was present (see LiteFlite- the short sail stretcher effectively replaces the full length batten that would otherwise be necessary).



Typical nose angle range 90-125 degrees.
Typical close up angles 5-25 degrees.
Minimum wind 4-5mph.

On all of these designs, at the bottom of the page, you will have noticed the words "close up angle". Close up angle is the difference between the nose angle of the flat, stretched out planform and the nose angle of the finished planform you will be flying. If there was no close up angle the kite would simply be a flat plate of slightly unusual shape and have the flying characteristics of such an object. As you close up the nose angle of the sail "bagginess" is introduced which is blown out by the wind to form your working aerodynamic surface. Sails with low close up angles (say 5 degrees) are considered to be flat and are of low lift. However, they also have low drag, so tend to fly fast and be difficult to control- very small control movements are required otherwise the kite slides off the wind and tumbles out of the sky uncontrollably. Sails with high close up angles (say 20 degrees or more) are deep, have high lift & high drag. They fly slowly and can be ponderous in their flight, but they do tend to be efficient in their use of available wind. Close up angles of 10-15 degrees give the best all round performance and when you actually measure most commercial designs you find that practically all fall in this range.

Whilst nose angle is self explanatory the range of nose angles used in practice is limited for a number of reasons. The two main reasons are wing load and frame loading...the three main reasons are wing load, frame loading and esthetics....the four main reasons are wing load, frame loading, esthetics and aerodynamic considerations. Right, four main reasons then.

Starting with wing load (that is the amount of weight carried per unit sail area). If you fix the length of the leading edge and spine then a 90 degree nose angle will give you the greatest supported sail area and the lowest wing load for any given set of materials- ten degrees either side of this makes little difference, twenty degrees and the differences start to mount rapidly (the kite acquires a much higher sail loading).

Similarly, with frame loading, although low nose angles minimise the length of cross spars etc (it is the loading on these spars that is particularly affected by nose angle), at 90 degrees nose angle, spars that are strong enough for the leading edge are strong enough for the cross spars. Above 100 degrees nose angle the required strength in the cross spars increases rapidly which can cause problems due to weight/ sectional thickness etc.

Esthetically, nose angles of 105-120 look really nice, 105-90 not bad and below this downright pointy, but this is an intensely subjective matter and you may feel totally different/indifferent on this point.

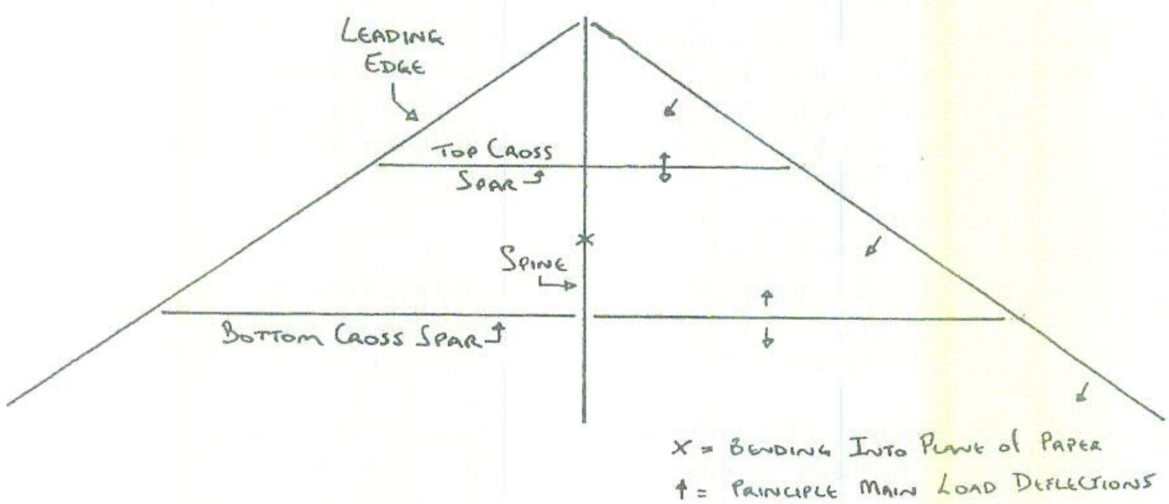
And finally, aerodynamics, well, as a general rule, wide kites (say more than 110 degrees) are much more efficient than narrow (less than 90 degrees) kites in converting wind energy into lift/forward drive ie they fly in less wind..

However, wide kites have their own problems, the most important of which is tip stall. Since all wings have a definite minimum flying speed (stall speed+ a tiny fraction) with a wide kite it is possible to have a situation in which the centre line of the kite is proceeding forward at the minimum flying speed, and then you start to turn the kite- at this point the inner wingtip loses speed (and stalls), the outer wingtip speeds up (and produces more lift), and the kite slides in towards the stalled tip, progressively stalling the rest of the sail and then fluttering down out of the sky. Although it is possible to produce this sort of stall in any sort of swept wing the situation is aggravated in wide kites because of the large distance between each tip which increases the tip speed differential in turns (remember that minimum turn radius for many stunt kites is in the order of 15ft and if the kite has a wing span of 10ft then the speed differential ratio across the wing can be of the order of 5:1).

Without being too obvious, the function of the frame is to support and hold the sail in the defined position. The function of the sail is to convert the incoming wind energy into usable "stunt" energy. It is important to realise just how closely linked these two processes are and how feedback from one can affect the other.

As a general rule, a stunt kite frame should be as strong and as stiff as possible with the least weight necessary to carry any reasonable flight load. If you were to prioritise these criteria then the order runs strength, weight, stiffness- strength & stiffness are not the same, strength is the ability to carry the load, stiffness is the ability not to deform under the load (well, it is easier to think of it that way).

With all of the previously discussed planforms the actual frame shape is, to all intents, identical and can be skeletised thus;-



Each spar carries its own unique set of loads and needs to be optimised for these loads. These loads are also somewhat dependent on the planform chosen (as well as nose angle- high nose angles mean long cross spars which necessitates the use of high strength/stiffness materials). To give some guidance on the loads encountered during flight in these various planforms consider the following table;-

Design	Leading Edge	Bottom X-spar	Spine
Delta	Low	Medium	Low
Indent Spine	Low	Medium	Medium
Extend Spine	Low	High	Medium
Batten Sail	Medium	Medium	Medium
Indent Wing	Medium	High	High
Ind. & Bat	Medium	Medium	High

These are just intended to give some guidance as to where the strength needs to go in any particular frame design for the indicated planform rather than absolute strength (ie don't try and design a frame scoring low as base strength, medium as twice as strong etc)- for example, make an extended spine kite with all the spars the same strength and you would find that the spar most likely to break will be the cross spar.

Stiffness in the frame derives from the stiffness of the actual frame material and all the triangles inherent in the standard planform- if you look at a typical frame it is composed of triangles within triangles and the only possible improvement you could make to this layout would be to add a spar from the bottom cross spar joiner to the top cross spar leading edge junction although it would be of limited benefit except in very strong winds. However, this stiffness acts only in one plane, stiffness in the other plane (ie in the plane of the depth of the kite) comes from the action of the wind on the sail and the restraining pressure of the bridle.

It must be remembered that this restraining pressure can be very large and is transferred into the frame at the bridle attachment points. It is traditional for these points to be at the top cross spar/leading edge point, the bottom cross spar/leading edge point and the bottom cross spar/spine junction point. The first two points are excellent transfer points, but the last one is a compromise. The problem derives from the two.... three functions (!) of the bridle and will be covered in the section on bridles.

So the frame is strong, stiff and light and thus should be ideal to hang your sail on, but there is one other nasty lurking to catch the unwary- resonance. Many a normally well behaved commercial kite will demonstrate the effects of resonance as the wind speed increases. Resonance effects include wing waggling (one wing bends up, the other down & then the cycle repeats), cross spar jumping and pitch shrugging (feels like sharp juddering). The problem stems from the fact that all structures have a natural resonant frequency- that is, the frequency at which the structure vibrates in response to incoming energy- and since conical rogallo sails are very good vibrational energy generators (viz they are very noisy) it is not surprising that so many designs show resonant effects.

Minimising resonant effects is not difficult. The ground rules-

1. The stiffer the frame the higher the resonant frequency viz. the stiffest frame is best. Although a very flexible frame would absorb and damp resonance the flying characteristics

would be horrible- if the resonant frequency is high enough 1-vibrations are short lived & 2-the inertia of the kite masks the effects of the resonance.

2. Do not allow any frame sub-dimension to be the same as or an exact multiple/sub-multiple of any other frame sub-dimension except where absolutely necessary (the sub-dimensions are the measurements internal to the layout eg. between the two leading edge connections or the top leading edge connection to nose dimension). This needs careful design and even a 1cm variation in a spar can change a waggly winged kite into a quiet well-behaved kite and vice versa.

Suitable frame materials include wood, glass re-inforced plastic rod, spiral wrap glass re-inforced plastic tube, carbon re-inforced rod, carbon re-inforced tube and spiral wrap carbon re-inforced tube (in terms of ascending strength/ stiffness/ price).

It would be unusual to find any frame member with anything but a circular or tubular cross-section since these shapes remove the possibility of uneven flex- for example, box or I sections have definite preferred directions of maximum strength/ minimum flex. For any material tubes have the greatest strength/weight ratios and equal flex in all directions which makes them the first choice for frames- however due to the nature of glass fibre/ carbon filled plastics it is difficult to make satisfactory tubes below about 5mm in diameter and for small diameters you will have to content yourself with solid rod.

Actually specifying any one material/size for a particular spar can be difficult- the interaction between the frame components and the sail loading can lead to unexpected stresses in strange places.

Consequently, it is normal practice to start with all spars the same (that is in terms of diameter & material) and refine your design as you either break spars or don't. For a swept wing of 8ft wingspan typical spar sizes would be .275"-.350" O.D in glass fibre tubing or 5-6mm O.D in carbon tubing (most glass fibre tubing comes from America and is supplied in odd imperial sizes, nearly all carbon originates in England or France and is supplied in metric sizes)- wood would only be used in small, light wind swept wings.

As mentioned earlier one way of estimating the top end of wind speed range for conical rogallos (conical vs cylindrical sail design later) is to use the minimum flying speed and a frame factor. Although this is only a guide it can save an expensive prototype frame from being needlessly trashed. To state the sums formally;-

$$V\,(max) = V\,(min) * V\,(min) * F$$

where V (max) = maximum wind speed
V (min) = minimum wind speed
F = Frame factor, for which, use;-

.275" GF tube	6
.350" GF tube	8
5mm CF tube	10
5.5mm CF tube	14
6mm Alloy/CF	18

But, I hear you moan, I've seen kites made from these materials fly in more wind than this. Well, yes you have, but this flight will invariably have been obtained by moving the bridle setting from the original minimum wind point (and thus increasing the minimum fly speed) and if you should bother to now measure the min. fly speed and do the sums again you will find that V (max) has increased correspondingly- moving a bridle point to increase max. wind is acceptable if you have strong, consistent wind otherwise it is better to design in as wide a wind range as possible.

The function of the sail is to convert the incoming wind energy into forward (reverse ?..!) movement by a process of deflection. By deflecting the wind drive for the kite is actually derived from two separate means- by straightforward Newtonian action/reaction principles and also from Bernoulli's principle (difference in pressure exerted by fast & slow air flows). The problem with stunt kites is that the wing operates over such an unusually wide range of incident air flows and forward speed conditions it is extremely difficult to separate out which process is driving the kite forward.

Looking at a kite in flight from behind gives you a fair idea which process is prevalent at any particular point in the flying arc- for instance, at the extreme edges of the operating arc the incident air flow is at a very low angle of attack to the wing and I would suspect that at these points the majority of lift is being derived the faster air flow over the back of the kite (compared to the flow on the front).

At wind centre the effective angle of attack is dependent not only on the attitude set by the bridle, but also on the forward speed of the kite- the faster a kite flies the flatter the effective angle of attack due to the vectoring of the wind direction relative to the moving kite. In sailing terms this is referred to as apparent wind direction and there is a relatively simple formula for calculating the speed & direction. However, as usual with kites, life isn't as easy since rather than flying in a straight line (as in the sailing case) stunt kites fly in fixed length upwind/downwind arcs (aaaaargh, this is not a nice function to program onto a modern digital computer, however, it isn't too bad on an analog computer). After investigation you find that at the wind centre the kite is being driven by reaction- the effective angle of attack is so high that the sail is stalled for the purposes of deriving lift from Bernoulli.

But why does this matter? well, there are two forms of Rogallo wing possible- the conical (where the sail shape is mapped onto the surface of a cone) and the cylindrical (where the sail shape is mapped onto the surface of a cylinder)- and each has its own unique set of flight characteristics. Stated bluntly conical sails are better behaved than cylindrical sails over a wider range of angle of attack and forward speed and so practically all swept wing stunt kites to date have used conical sails. They also have the advantage of being simple to make requiring only straight leading edges rather than the helical leading edges inherent in cylindricals.

Anyway, the actual form of each of these types is illustrated in appendix 4 and suffice to say that when you have looked at what is involved in the production of a cylindrical wing I think it will be apparent why they are almost non existent in SWSKs.

There is one thing that cylindricals do better than conicals and that is they fly fast with little noise. In the conical layout the trailing edge becomes loose and flappy as the outer wing tips bend under flight loads. This, as well as the fact that all swept wing kites have to be bridled to fly at very nearly the never exceed speed for soft sails, gives rise to the roar/buzz/noise that is now indelibly associated with large swept wings. In the cylindrical layout the precurved leading edge is inherently stiffer than the straight leading edges in the conical and combined with the lower sail drag produces an almost silent sail right up to the never exceed speed- The never exceed speed is the flying speed at which the aerodynamic loads imposed on the sail cause it to start to ripple and lose inflation. The actual never exceed speed can be calculated if you know angle of attack and lift/drag ratio characteristics of the sail and lies in the range 50-60mph for the conical layouts used in 8ft kite practice. This means that typical flying speed range for a kite (in 15mph of wind) would be from 45-65mph. For a cylindrical sail the never exceed speed is much higher, around 90mph, although drag on the exposed spars never lets the kite fly this fast. The real disadvantage of cylindricals is that they will not slow down without stalling and dropping out of the sky.

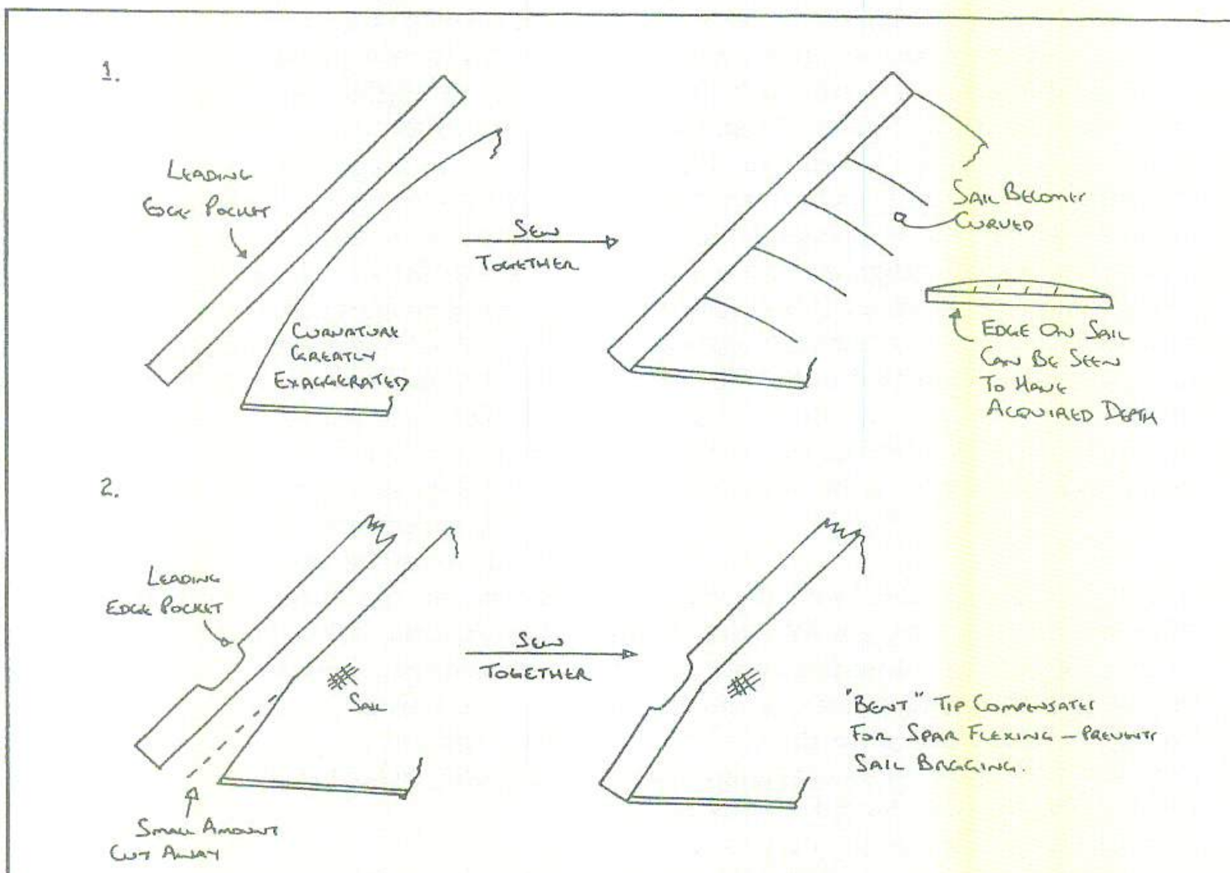
In single string kites you strive to achieve the highest lift/drag ratio possible (combined with stable flight) because this gives the greatest height realisation for a given length of line. In two string practice a high lift/drag ratio equates to a wide operating arc and for a weightless kite typical operating arcs would be;-

Lift/drag of 1.0	= 90	degrees operating arc
" " " 2	= 126	" " "
" " " 3	= 143	" " "
" " " 5	= 157	" " "
" " " 8	= 166	" " "

Note that these are figures for a weightless kite- a real kite would manage, at best, 10 degrees less operating arc. Again, measuring a few operating arcs of well known, "fly 90 degrees to each side", stunt kites reveals average L/D ratios of 2.5 at best, down to 1 (the Revolution 1 four line kite only manages an L/D of 0.8 but this is a very special case and normal for kites capable of symmetrical flight due to the considerable compromises that have to be made in the designs). To be honest, L/D ratio is a bit of a red herring in stunt kite design and given the extremely low values not really worth worrying about to any great extent.

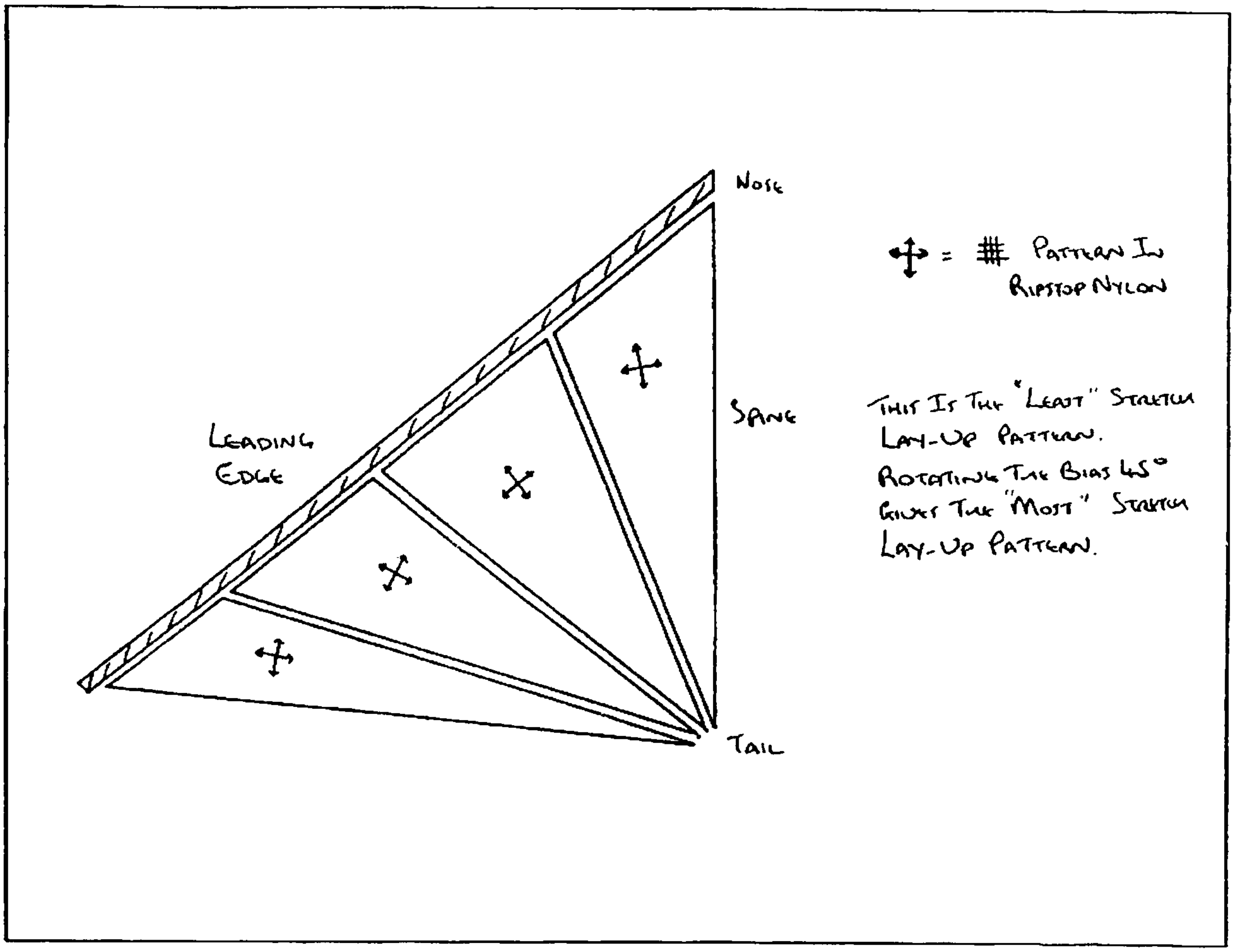
Having said that I suppose it was worth mentioning that conical standard Rogallo sails have L/D ratios in the range 1-3, high aspect ratio conical Rogallos (the indented spine design) up to 4.5 and cylindrical Rogallos up to 17 (although the kite would be very nearly unflyable at this sort of figure).

So far the sails described have just been closed up cones or cylinders without any sort of form being cut into them. By form I mean tailoring of the sail shape to introduce curvature for one reason or another. The two popular form cutting methods are to use a curved leading edge on the sail sewn into a straight leading edge pocket to give camber to the sail or the trimming of the leading from the lower spar connector to the tip to reduce trailing edge flap.



The disadvantage of cutting camber into a sail is that it destroys the natural stability of the conical layout and although it can yield a fast, quiet kite it does make bridle adjustments difficult and flight control tricky. If you must have camber in your sail then it is better to introduce it by using the natural stretch/elasticity of the fabric as it is deformed/loaded by the wind to give you the camber- as the wind drops you regain the natural sail stability as the fabric returns to its natural position (an excellent exxample of this can be seen in the sail cut/lay up of Tim Benson's Phantom stunt kite- observing this kite from behind as it moves through the flight arc it is fascinatinating to watch the sail progressively deform/reform as the loads vary upon it).

A popular and simple method for doing this is to radialise the sail into triangular segments and change the bias layup angle in each segment;-



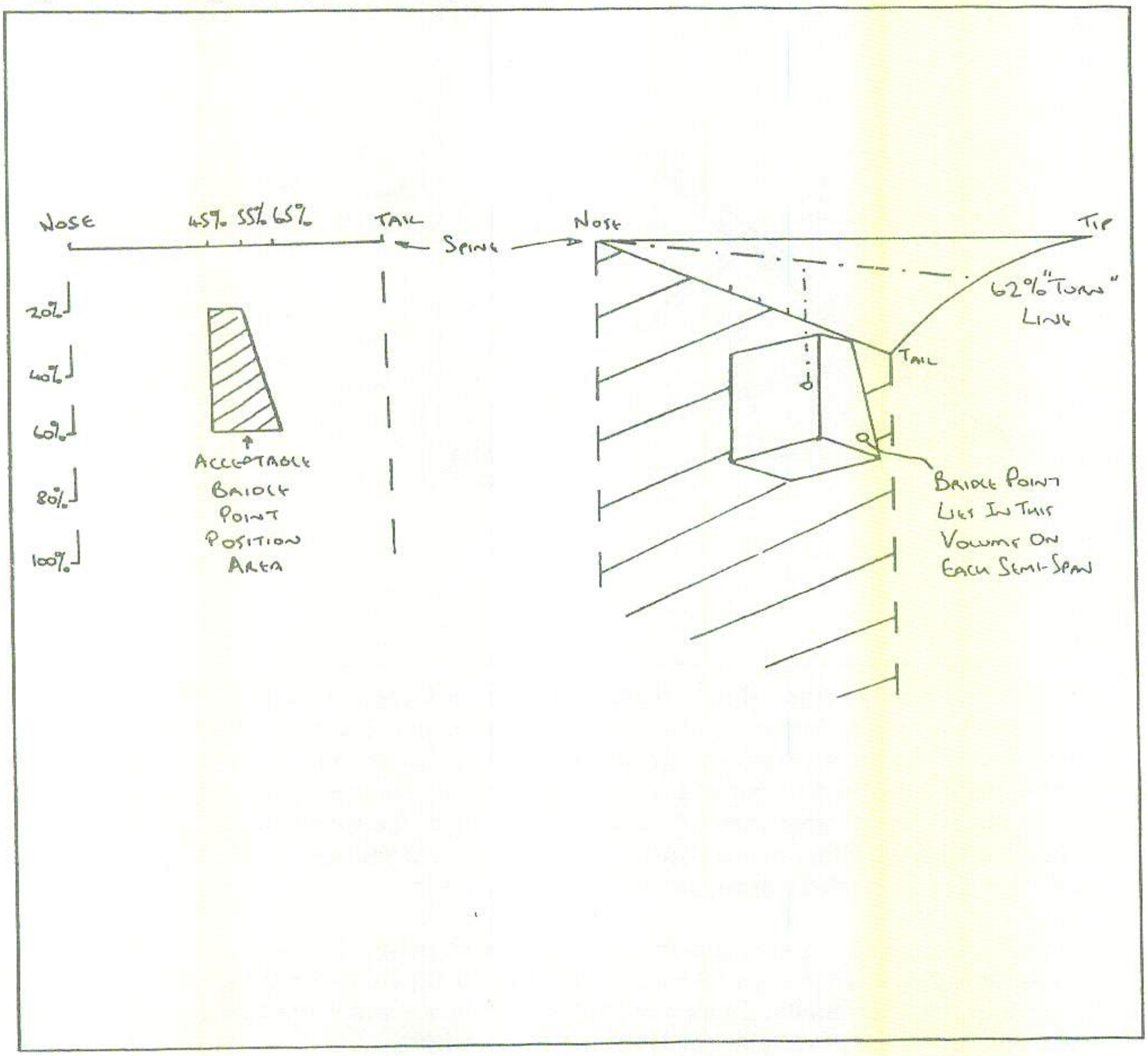
Since this relies on the fabric stretching evenly then the choice of fabric is going to be important. Given the requirements of light weight, weather resistance, strength and controlled stretch/elasticity then currently only two materials are really suitable- nylon or terylene (Dacron) sail cloth with a polyurethane or silicone coating (silicone gives a better sail but polyurethane is considerably easier to handle and sew) in the weight range of 1-3 ounces per square yard. Most kites are made from 1.8oz cloth (1.3oz if you are American- your yard is only 28" wide for some weird reason) and this gives good life etc.

Another advantage of this material is its great strength. This means that the only re-inforcement required is at points where holes are actually cut in the sail (eg centre connectors or batten stretcher points). In all other cases the fabric is strong enough to stand flight loads without further re-inforcement (and increase in sail weight).

3. Bridles

Bridles on Stunt Kites have three functions;- they set the angle of attack of the wing, they provide the load offset necessary to steer the kite and they spread & integrate the sail load into the two flying lines. Unfortunately, some of these functions conflict and actually producing a satisfactory bridle requires you to trade off a bit of one for a little of the other. Taking the functions in turn;-

1. Setting the angle of attack. When you adjust the bridle on your average stunt kite what you are actually doing is altering the relative angle the surface of the wing takes with respect to the wind flow. For any conical Rogallo the range of adjustment is well documented and proscribed- your fore/aft point has to go in this range or the wing won't fly (without doing something odd to the wing like adding cambered battens or cutting holes in the sail!). As you adjust the bridle you also alter the lift/drag ratio (and the physical values thereof which are important to your flying speed- see section on Vne at end of book) of your wing which affects line pull and forward speed. As well as the fore/aft distance being well defined the actual depth away from the plane of the sail of the adjustment range is pre-defined. Combining these you end up with a diagram indicating where your fore/aft bridle point should be;-

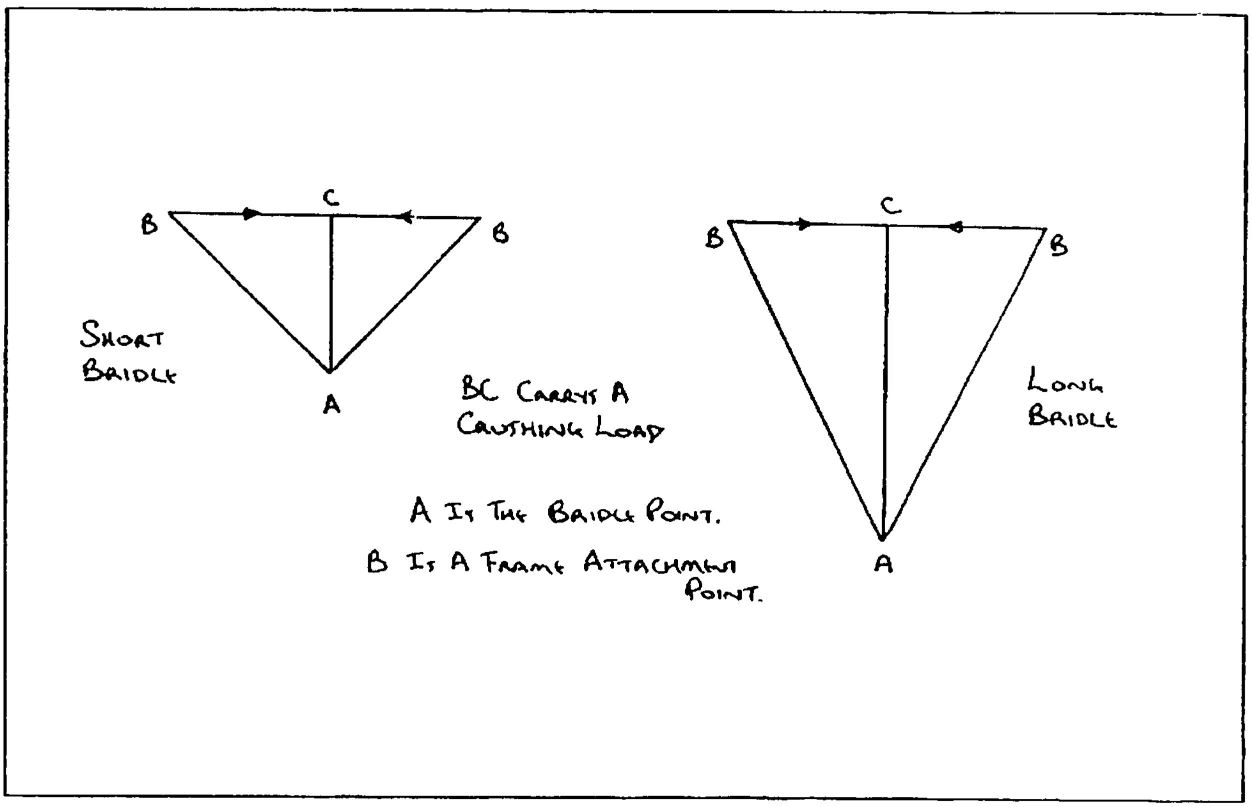


2. Offset necessary to steer the kite. Similarly there is a best point for the offset. Roughly, it corresponds to a line running at 62% of the semi-span of the kite (the position is related to aerodynamic load distribution on the sail)- further outboard than this and there is a tendency for the kite to stall into the turn, closer in and the kite is reluctant to start turning. Again, while this is true for simple conical sails, adding battens, sail stretchers or any other sail deforming device can alter this point- start at 62% and refine accordingly.

3. Load spreading. Since kites are made of materials of finite strength it is necessary to try and take the load from a wide, flattish, variably loaded surface and concentrate it into two thin flying lines in such a way that at no point in the frame is the resultant stress such that the frame ruptures.

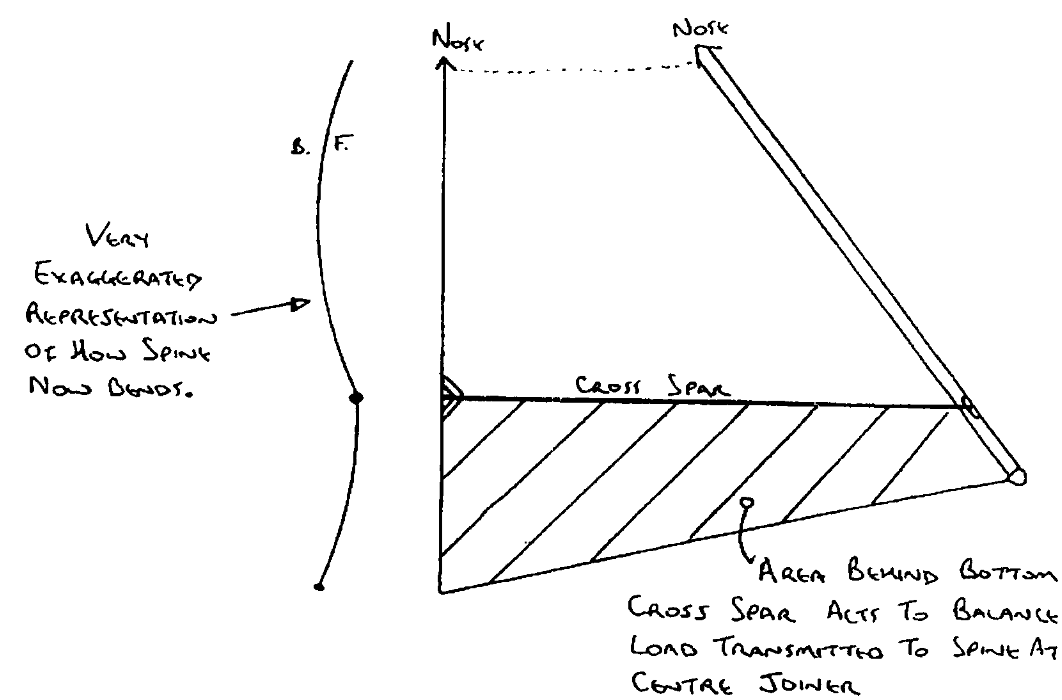
The simplest possible bridle attachment method- tying the lines directly to the frame- violates the fore/aft attachment point envelope requirement (diagram above) as well as placing the largest strain on your frame. This method does work but frequently develops pitch wobbles (kite bucks on lines).

Thus, it is normal for the bridle to be composed of two, or more, lengths of line on each semi-span running from the frame to the main line attachment point and, to minimise unwanted crushing side loads being imposed on the frame, for these lines to be as long as possible while still satisfying the previous conditions for fore/aft & offset positioning, consider;-



In the drawing on the left the lines in a 2 point bridle are at the shortest length possible. In the drawing on the right they are at the longest length allowed. The undesirable portion of the load being transmitted is represented by the line BC in both cases and the physical value is dependent on the ratio between AC:BC (viz on the left about 1, and on the right about .6). By making the bridle longer you have reduced the crushing side load being imposed on the frame by 40% and as result it is always worth fitting the longest bridle you can get away with to save your frame.

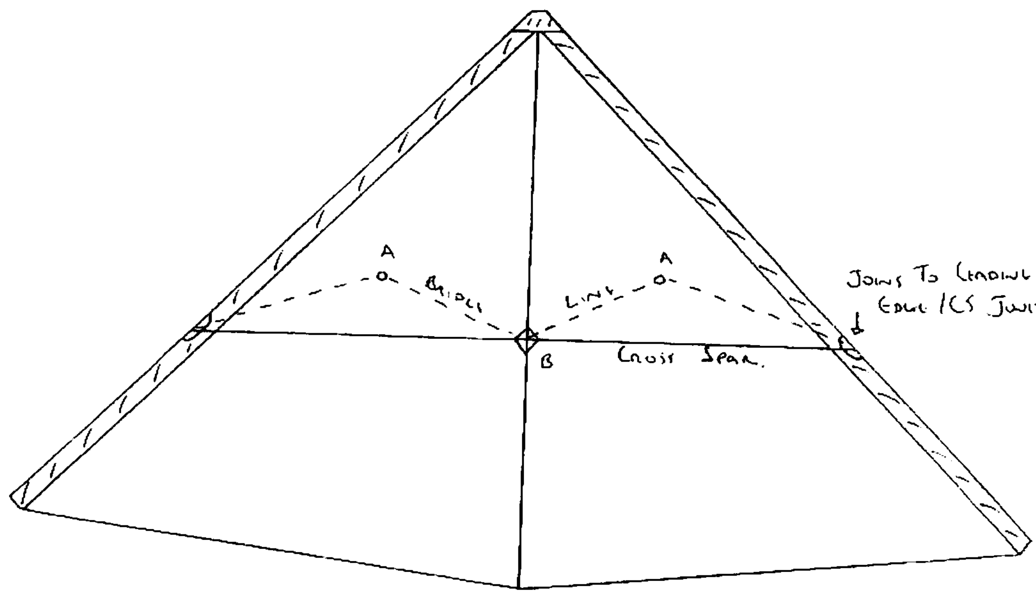
As mentioned earlier the attachment points for the bridle are usually at the outboard end of the bottom spreader, the outboard end of the top spreader & at the centre joiner on each semi-span. A problem arises with this last attachment point- the two wing points carry reasonably balanced loads on either side of the attachment point, but the centre point tends to be towards the extreme end of the spine and imposes a severe bending moment on the spine which is a frequent cause of spine failure in certain designs (the Spin Off is very prone to this particular frame failure). There is a simple cure for this (at the design stage)- move the crossover point up the spine thereby placing part of the sail behind the cross spar. The result of this is for the load behind the cross spar to partially balance off the load in front of the cross spar and straighten up the spine;-



Most, if not quite all, new designs now do this and the resultant drop in sales of replacement spines has been irritating for Kite Store Keepers (joke, OK). Typical cross over point now lies between 15-25% of total spine length up from bottom of spine (I find 20% to be a good compromise).

The number of lines used to make up your bridle depends on exactly what you are trying to achieve. Taking each in turn;-

1. 2 Points on each semi-span.



A: Tow Rings/Swivels

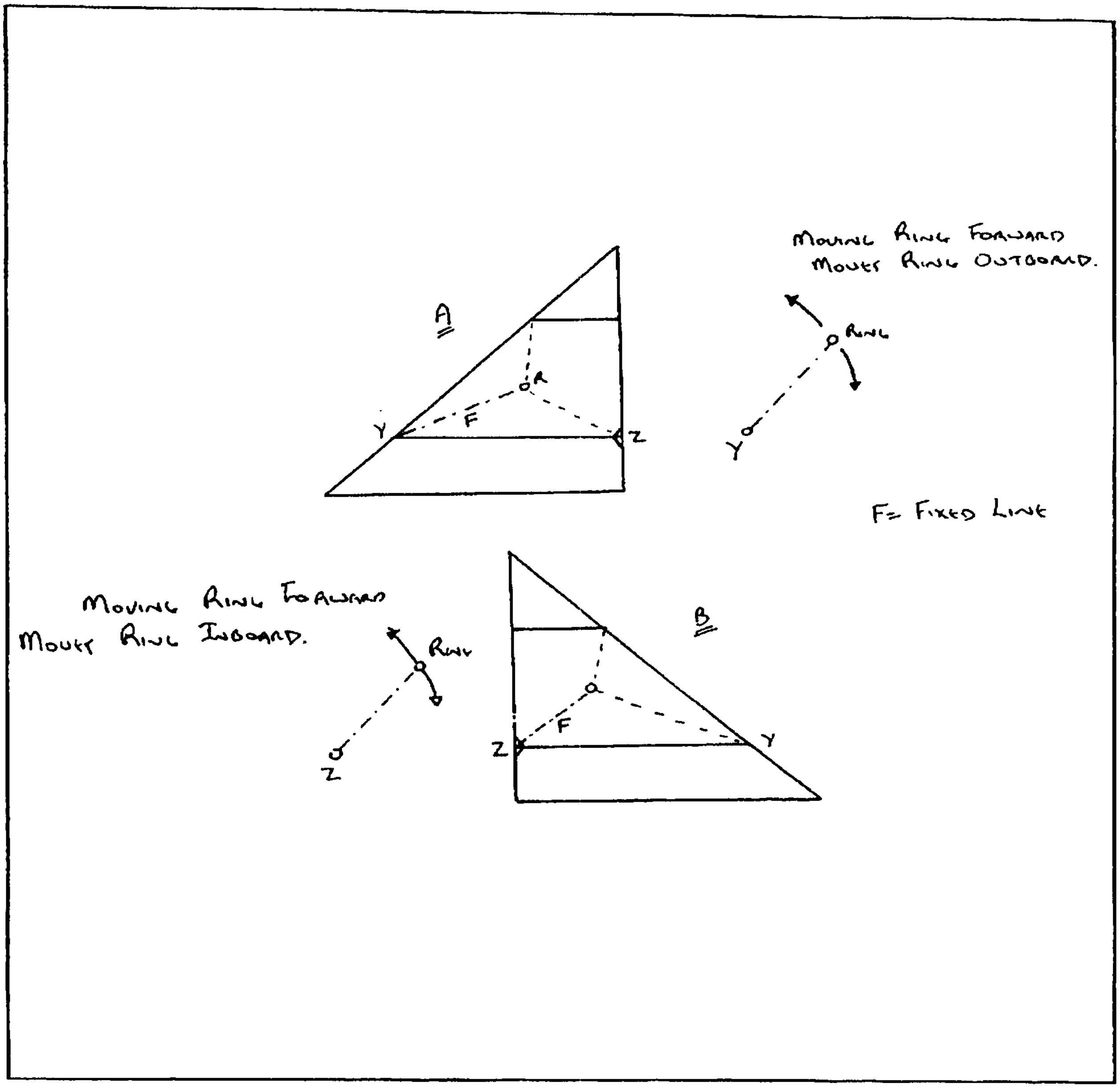
B = Centre Joiner: Bridle May Be Fixed Or Free To Run At This Point.

Remember: Single Cross Carries Entire Flying Load And Needs To Be 50% Stronger Than Comparable Cross Spar In 3 Leg Bridle

Pitch Stability Entirely Dependent On Sail Form And Cannot Be Altered By Bridle Position.

In this layout pitch stability is dependent on the aerodynamic characteristics of the sail and requires an extremely well behaved stable sail layout. The position of the cross spar sets the flying angle and finding exactly the right position for the cross spar is not easy. Adjustment is limited to moving the rings inboard/outboard thereby altering the turn rate. The lack of pitch adjustment makes this a very unusual layout and is only seen on small, light wind stunt kites (eg some of the small Gayla plastic delta stunters and the steerable delta detailed later).

2. 3 Points on each semi-span.



The most popular layout around, the 3 point layout exists in two common variations differing in the way the bridle ring moves in relation to the body of the kite on the attached bridle lines;-

a). the fixed line is attached to the outboard end of bottom cross spar and adjustments are made to/from the end of the top spreader/centre joiner or -

b).the fixed line is attached to the centre joiner and the adjustments are made to/from the two spreader end points on the wing.

Both of these layouts compromise turn rate as they move the line attachment points back/forth across the optimum turn position- method b). is better in this respect providing the bridle is the right size (ie longish rather than short). Method a). gives a better pitch adjustment range compared to b). Indeed, while a). may have 3" of adjustment range b). frequently only has 1" of usable adjustment range in 8ft swept wings.

As a final diversion cconcerning three point bridle systems consider this (for small bridle position adjustments);

In layout a. moving the bridle ring;-

Forward - Increases turn rate, decreases sail load
Backward- Decreases turn rate, increases sail load

In layout b. moving the bridle ring;-

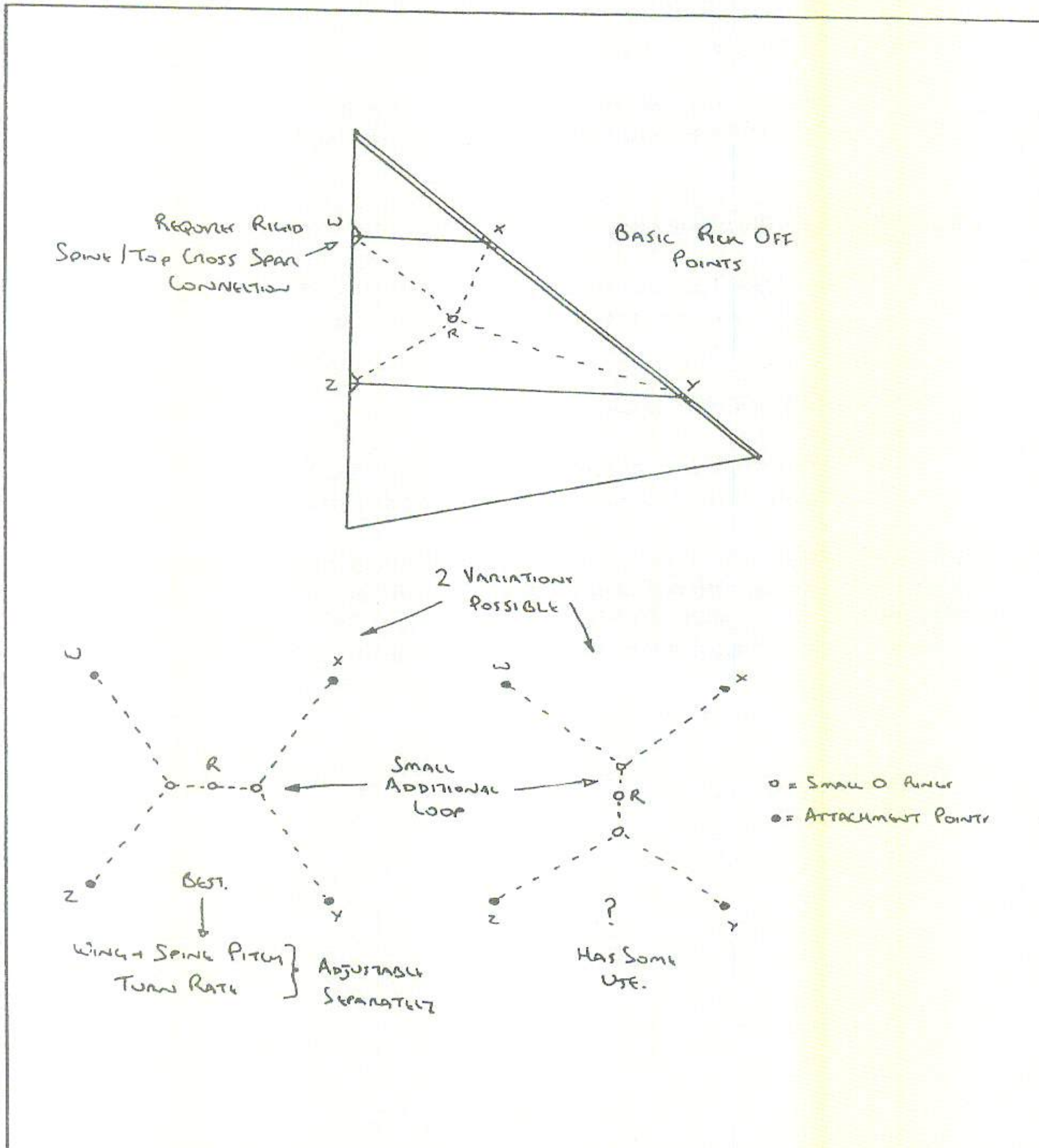
Forward - Decreases turn rate, decreases sail load
Backward- Increases turn rate, increases sail load

Question- What bridle layout would produce;-

Forward - Decreases turn rate, increases sail load
Backward- Increases turn rate, decreases sail load

I don't think that this last layout is possible to implement with only three points on a conical Rogallo. However, on reflexed conical sails this combination does occur and can give trucly curious flying characteristics (not to mention problems in bridle adjustment as every adjustment feels back to front and against the "natural" way of doing things).

3. 4 Points on each semi-span.



The most unusual and complicated bridle you are likely to find on a swept wing. the 4 point system allows you to adjust pitch & turn minutely, but is an absolute sw***e to set up first time out. It is also an immensely "strong" bridle spreading/concentrating the sail load into the flying lines as near to perfectly as is possible.

There is one other point to note about this layout. In order to attach the top centre point you have to rigidise the crossover by attaching the cross spar to the spine. This places an unreasonably large load on the top cross spar and requires the use of a cross spar at least twice as strong as normal.

4. Weight, C of G and Sail Loading

While a weightless kite would be nice we do live in a real world and all practical kite building materials carry the penalty of weight.

For any stunt kite you build down- viz reduce the weight to the minimum while retaining adequate flight strength. You do this for two reasons- 1. Light kites fly in less wind than heavy kites (although the difference is not as marked as many people would have you believe) and 2. Light kites turn faster than heavy kites (the real reason for building light).

There are two areas on a stunt kite where you can save weight- in the sail and in the frame. Where you actually save weight is up to you but consider-

In a stunt kite of 8ft span you have about 12 square feet of sail area. If you use typical nylon sailcloth of 1.8 ounces per square yard (9 square feet) the sail material will weigh 2.4 ounces. Changing down to the lightest grade available- .9 oz/sq.ft. would reduce the sail weight to 1.2 ounces.

In the same kite assuming you had framed it in typical glass fibre tubing the frame would weigh about 8 ounces. Changing to similar strength/stiffness carbon tubing would reduce the weight to 4 ounces.

All the other bits in your kite will total about 3 ounces and are difficult to reduce in weight whatever you do.

Now putting these figures together we get;-

A. Base (heavy) kite	= 2.4+8+3 = 13.4 oz
B. Light sail	= 1.2+8+3 = 12.2 oz (8% lighter)
C. Normal sail + carbon	= 2.4+4+3 = 9.4 oz (30% lighter)
D. Light sail + carbon	= 1.2+4+3 = 8.2 oz (39% lighter)

So it would appear that D. is the best choice. Wrong-it may be the lightest but C. is the best combination for normal use- the light sail has only 1/4 the strength of the standard sail and if you insisted on using it you would suffer all sorts of fabric failure in anything but the very, very lightest of winds. Indeed the 9% weight saving only equates to a 5% difference in minimum flying speed (or about .2mph at 4mph)- 30% weight saving represents about 15% difference or a whole .7mph!). Well, I did warn you weight wasn't as significant as many people think.

C of G (centre of gravity- the "balance point") represents another red herring in stunt kite design. In Rogallo wings used as free gliders C of G is very important, in steerable Rogallo kites it really has little relevance to performance unless it has been adjusted to a really extreme position. Why it is unimportant is related to the high sail load to kite weight ratios stunt kites normally function at- effectively the centre of sail load becomes all important with regard to the bridle setting and influence of the poor old C of G is totally swamped- it is not unusual for sail loads to exceed kite weight by a factor of 30 (in free flight the lift/sail load is very nearly the same as weight).

The only time C of G manages to get a look in is at very low wind/forward flying speeds when the sail loads have declined to levels comparable with the weight of the kite. If the C of G is somewhere odd this is when you find out. Roughly a stunt kite should weight balance at 50% of total height- measured from nose to most rearward extension of wings. If the position is forward of this the kite will drop its nose in slow speed turns (cf flight of Fire Dart)- if too far rearwards the kite tends to sit nose up as the wind drops (cf flight of Basic Hawaiian Team Kite).

Producing a kite with the C of G at this point isn't too hard- all the basic layouts outlined earlier have "natural" C of G's close to this point (if you use equal diameter /weight framing throughout) and moving the bottom cross spar back/forth by about 5% will frequently be sufficient to shift the C of G into the desired position. The only time this probably wouldn't work is in the case of a multiply battened wing where the C of G is always going to be well back- possibly nose ballast may be required to make the kite fly acceptably in a case like this.

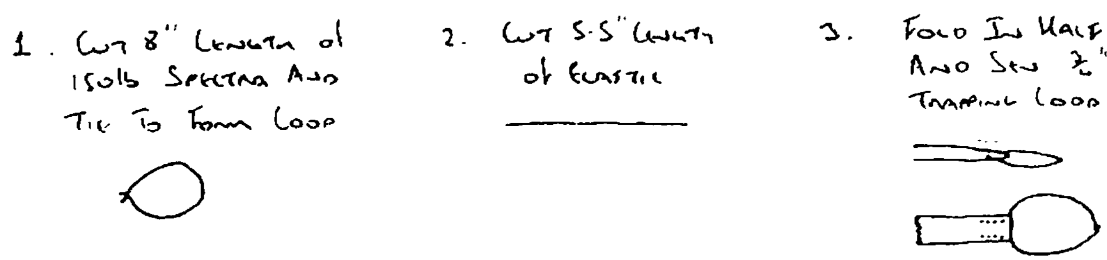
5. Introduction to the Designs

In all of my current kites I use standardised construction methods and bridles. Some of these techniques look a little odd, but have proved reliable and efficient. So to start;-

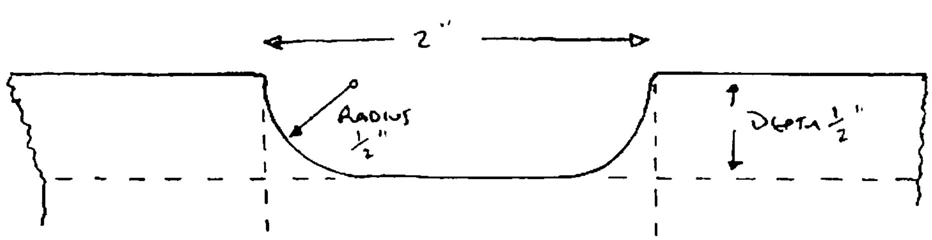
1. Elastic pockets; Instead of using the customary bungee cord and arrow nock detailing on spar ends I elected to use pockets made from 19mm wide elastic of the type found in clothing. In these designs there are two pocket types, the spine pocket and the wing tip pockets;-

a. Spine pocket;

b. Tip pocket



2. Dacron leading edges; I use leading edges formed from 2" wide dacron tape f(3.5oz/ sq yd) folded in half and then sewn onto the sail. The cut outs are of standard form so;-

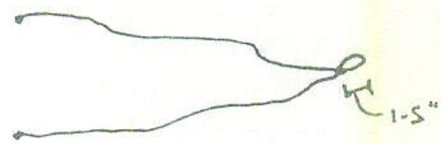


3. Bridles; All my large (and some small ones) wings use a standardised bridle composed of a centre loop and two tip bridles. I use Spectra for these and details are as follows;-

a. Main loop;

1. Cut 84" Length of 200lb Spectra

2. Fold In Half And Tie 1-5" Loop In Centre



b. Tip bridles;

1. Cut 26" Length of 150lb Spectra

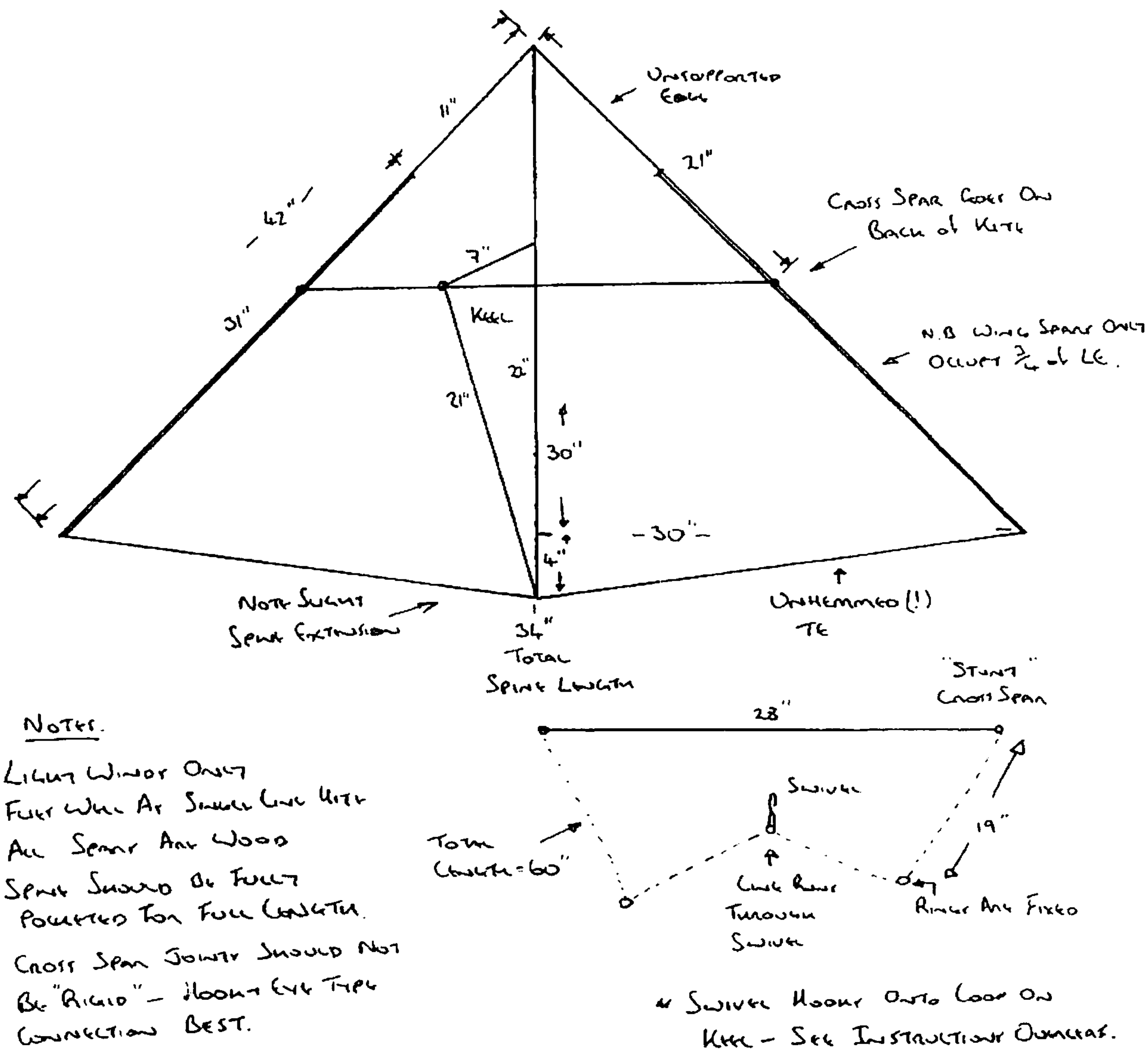
2. Tie 4" Loop On One End

4. Spars; All the designs (except the stunt delta) use 5.5mm carbon fibre tube of the "flexible" type rather than the rigid arrow shaft type. The LiteFlite and Mabel will work well in arrow material but the Heavy needs flexibility to function properly.

Finally, a look at any commercial kite will tell you much more about SWSK construction technique than any book could- so go look (closely) and learn.

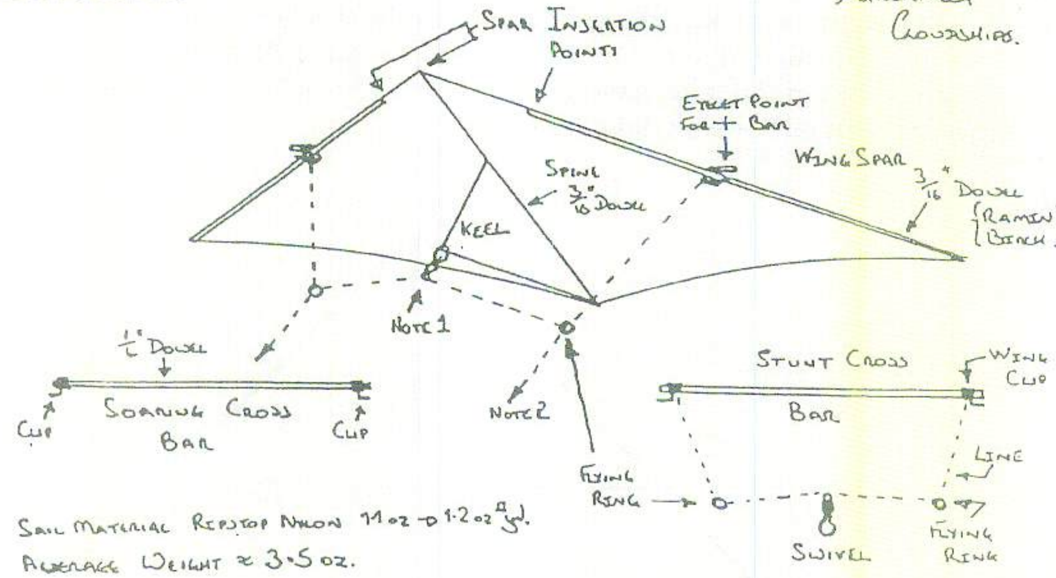
1. Stunt Delta;

Dating from 1977 this was my first stunt kite I produced and sold (all 270 of them). Really designed as a simple reliable delta the addition of the stunt cross bar transformed the kite into an excellent light air stunter. The spars are all wood 3/16 dowel (!) and there is no re-inforcement worth mentioning anywhere. Overleaf you will find a copy of the original instructions the kite went out with all those years ago.



STUNT DELTA

HAND MADE BY
AEIRESEARCH
CROUDSHIPS.



SAIL MATERIAL RIPSTOP NYLON 1.1oz - 1.2oz/yd².
AVERAGE WEIGHT ≈ 3.5 oz.

SOARING VERSION (NOTE 1)

INSERT SOARING CROSS BAR WING CLIPS INTO EYELETS ON WING SPAR ENSURING THAT SPAR IS ON BACK OF KITE. THIS IS THE OTHER SIDE FROM THE KEEL. TIE FLYING LINE (RECOMMENDED STRENGTH 30lb. BS, 15kg. BS) TO EYELET AT THE POINT OF THE KEEL.

STAND WITH YOUR BACK TO THE WIND AND RAISE KITE, NOSE UP, INTO THE AIR FLOW. LET THE WIND TAKE THE KITE FROM YOUR HAND STEADILY, BUT TRY TO KEEP LINE TENSION FAIRLY CONSTANT. IF KITE DROPS SUDDENLY STOP FEEDING LINE. IF KITE STILL DROPS PULL/WIND IN SOME LINE.

STUNT VERSION (NOTE 2)

INSERT STUNT CROSS BAR WING INTO EYELETS. FEED THE LINE WITH RINGS AND SWIVEL ON AROUND THE FRONT OF THE KITE. CLIP THE SWIVEL ONTO THE KEEL POINT AND ATTACH TWO FLYING LINES, ONE TO EACH FLYING RING (RECOMMENDED STRENGTH 30lb. BS, 15kg BS EACH LINE).

TO STEER: PULL GENTLY ON THE LEFT LINE TO TURN THE KITE TO THE LEFT AND VICE VERSA. NOTE THAT PULLING ON A LINE GOVERNS THE RATE AT WHICH THE KITE TURNS AND NOT THE FINAL DIRECTION I.E HOLDING RIGHT TURNS THE KITE IN A CIRCLE AND DOES NOT MAKE IT PROCEED TO THE FAR RIGHT. ABOVE ALL PULL GENTLY AND DO NOT PANIC/FREEZE WHEN STEERING.

IMPORTANT

DO NOT FLY NEAR POWER LINES, ELECTRIFIED RAILWAYS, TRAM LINES.
THOU SHALT NOT FLY IN STORMY WEATHER, NEAR AIRPORTS, AIRFIELDS OR AIR CORRIDORS.
THOU SHALT NOT FLY IN STORMY WEATHER/ELECTRICAL STORMS AND THOU SHALT OBSERVE THE 60m/200FT HEIGHT RESTRICTIONS UNLESS THOU HAS A FERVENT DESIRE TO OBSERVE THE WORKINGS OF THE LOCAL MAGISTRATES COURT.

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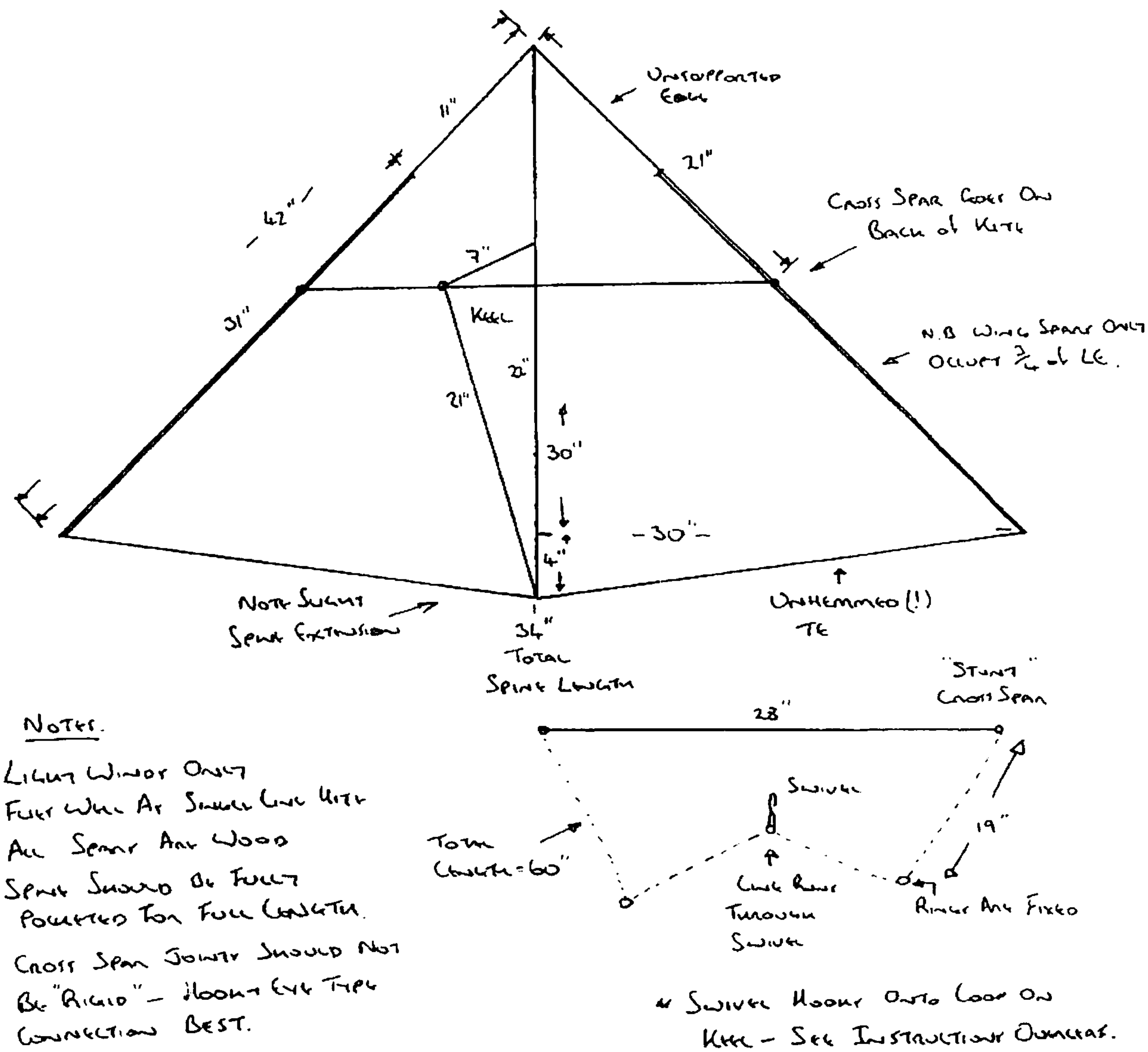
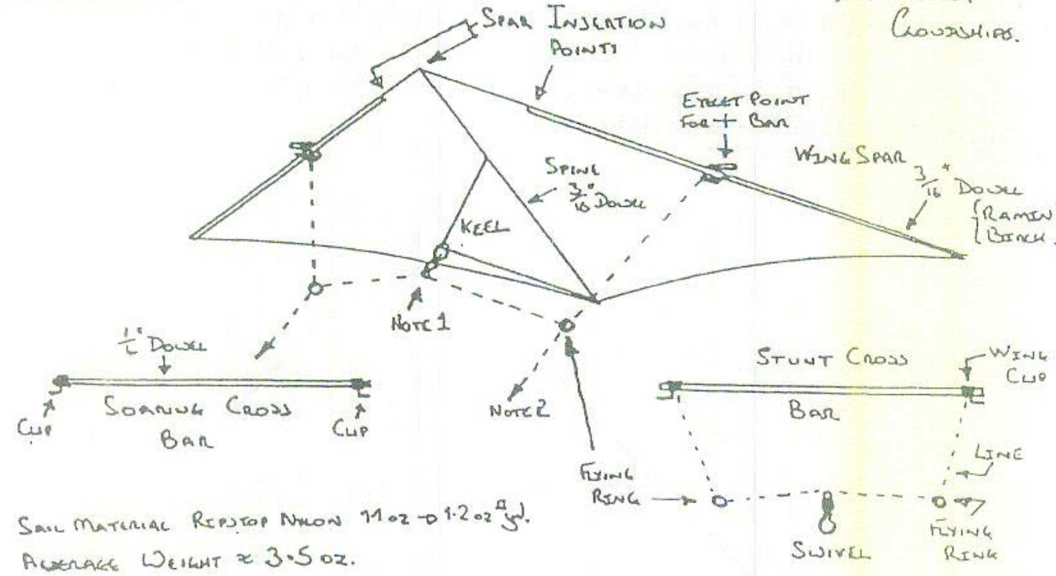


STUNT DELTA

HAND MADE BY AEIREXARLH CROUSHIPS.



SAIL MATERIAL RIPSTOP NYLON 1.1 oz - 1.2 oz ^{2}/yd.

AVERAGE WEIGHT ≈ 3.5 oz.

SOARING VERSION (NOTE 1)

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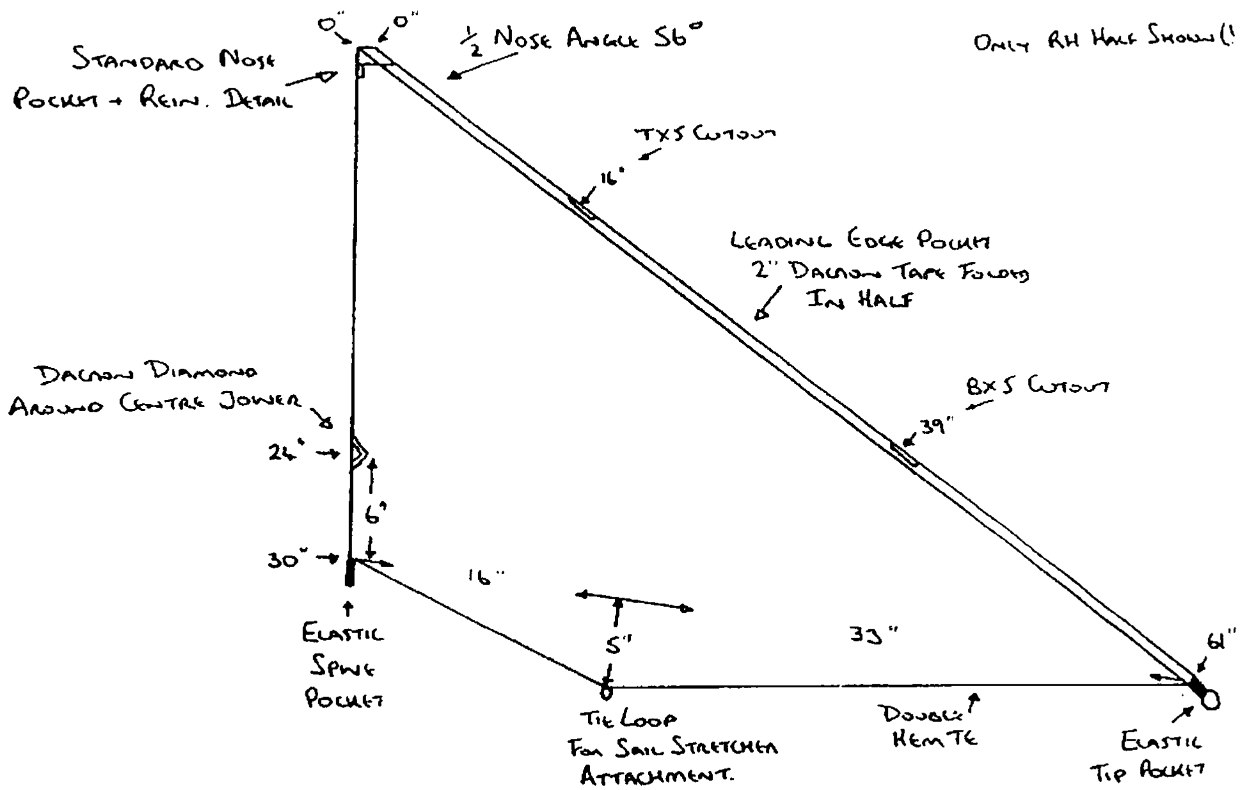
2. LiteFlite

This is my light wind stunt kite- large size, reflexed sail and low weight all combine to give a kite capable of flying in less wind than you can feel. Won't fly well above 12mph unless you fit very rigid spars.



Standard Bridle.

Frame 5.5mm Carbon Fibre

Top Cross Spar = 24¾"

Bottom Cross Spar = 30"

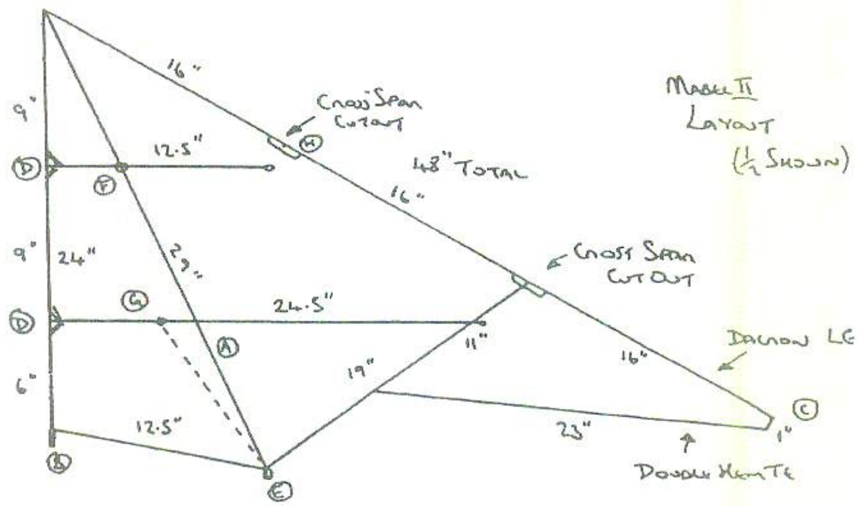
Sail Stretcher = 19"
(4mm GRP Rod)

Sail Stretcher Runs From Fitting On Bottom Cross Spar To Tie Loop On Sail And Must Be Tight Enough To Stretch Sail.

NB. TXS = Top } Cross Spar
BXS = Bottom }

3. Mabel

This is one of my latest SWSKs incorporating a second set of sail stretchers operating from the front cross spar onto sail battens to give a very rigid, reflex cambered wing. The beauty of this layout is that it is nearly perfect as regards section shape and flies with little noise or pull (although the wide nose angle makes for largish turns).



Ⓐ Full Length 2mm Carbon Rod Sail Batten, In Full Length Pocket.

Ⓑ Elastic Spine Pocket

Ⓒ Elastic Tip Pocket

Ⓓ Rigid Spine/Cross Spar Attachments.

Ⓔ Sail Stretcher Attach. Point

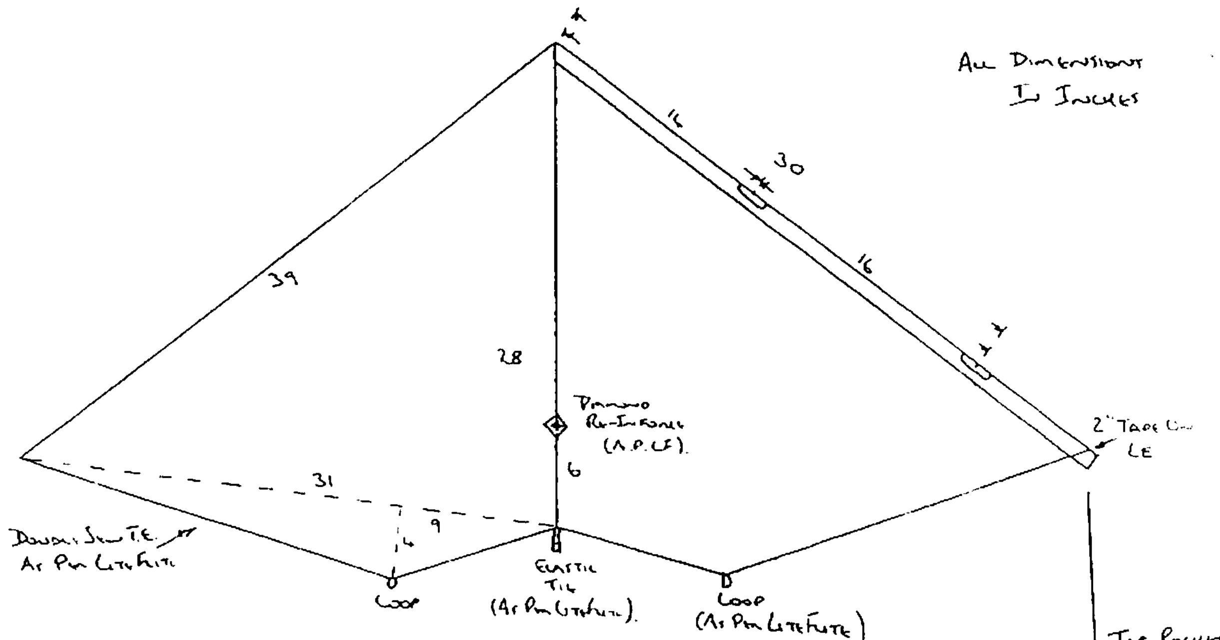
Ⓕ Forward Sail Stretcher Attachment Point. 4" Stretcher Runs From Top Cross Spar To Sail Batten And Is Tight Enough To Bow Batten.

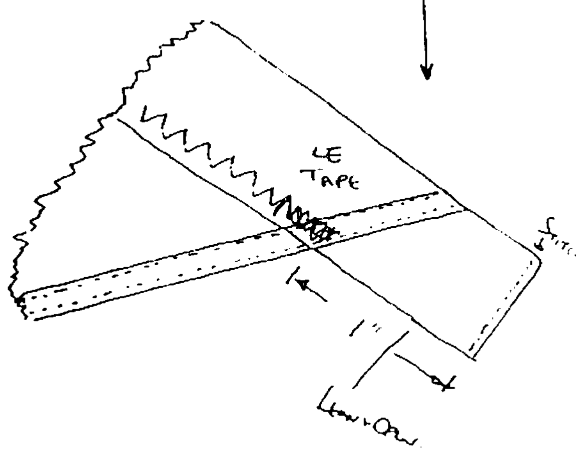
Ⓖ Rear Sail Stretcher Attachment Point. 14.5", 3mm Carbon Rod Stretcher Runs From Ⓖ On Bottom Cross Spar To Ⓔ On Sail.

Bridle Is Of Standard Form With Loose Loop Fastened To Bottom Cross Spar Cut Out Point And Main Loop From Ⓑ To Ⓗ.

4. LiteFlite Heavy

A curiousity- a conical Rogallo that deforms in flight to become a cylindrical Rogallo with the consequent increase in flight speed and turn rate. Easy to make, a horror to fly- the take off is difficult since the wing has to deform before it will fly properly.





Top Cross Spar = 19¾"

Bottom Cross Spar = 21¼"

Sail Stretchers = 14¼" (Use 6mm GRP Rod)

Standard Bridle.

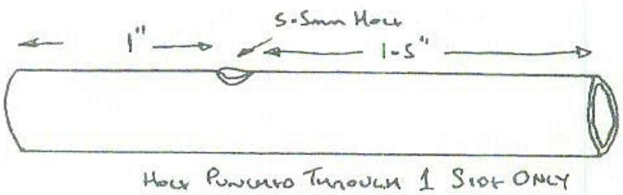
Frame Must Be "Flexible" 5.5mm Carbon Fibre Tube.

Wind Range 12-55 mph.

Final points concerning the designs.

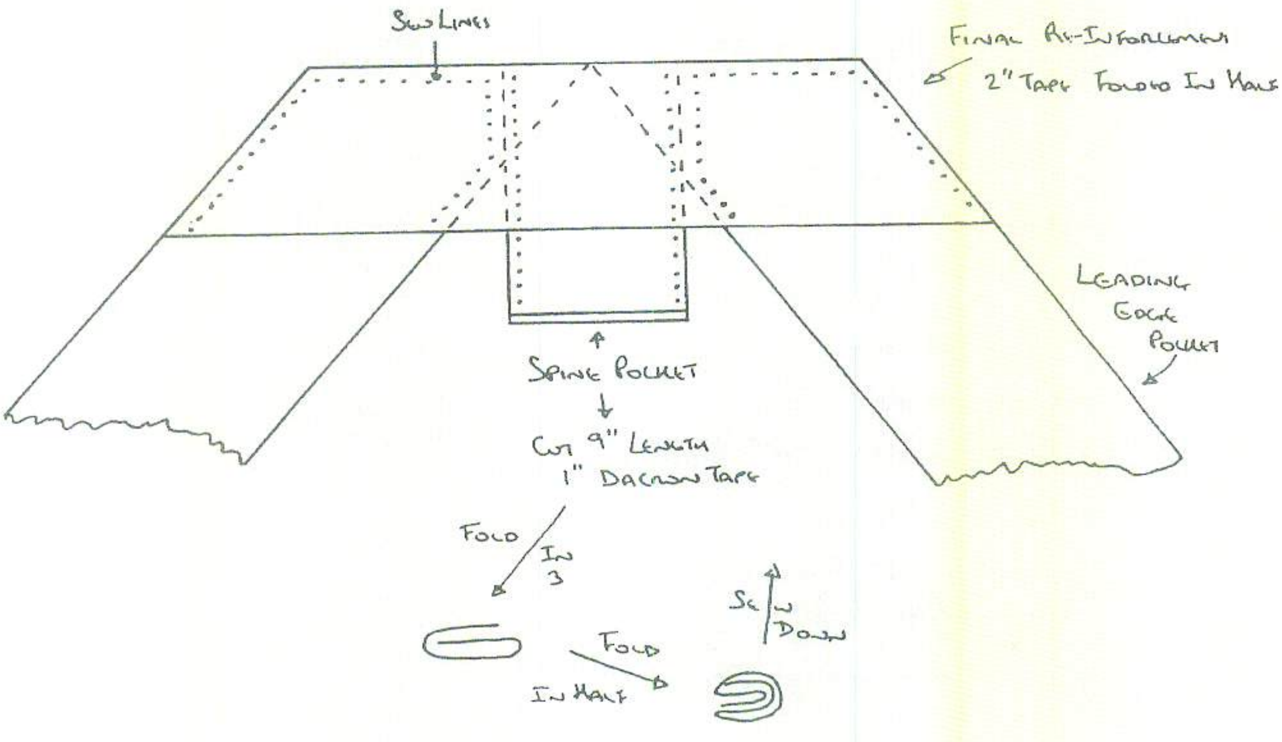
All the sails are drawn flat- when you put the spars in they will billow out accordingly- always use the given dimensions for the spars and do not try to measure off the diagram (similarly, the wing cutouts do not appear to line up with the centre joiner when drawn flat but will line up when the cross spars go in).

All the vinyl connectors are 3/8" OD tube with 1/16" wall thickness punched/cut as follows;-



The top end of the main bridle loops are tied to the top vinyl connectors using a slip knot that self tightens.

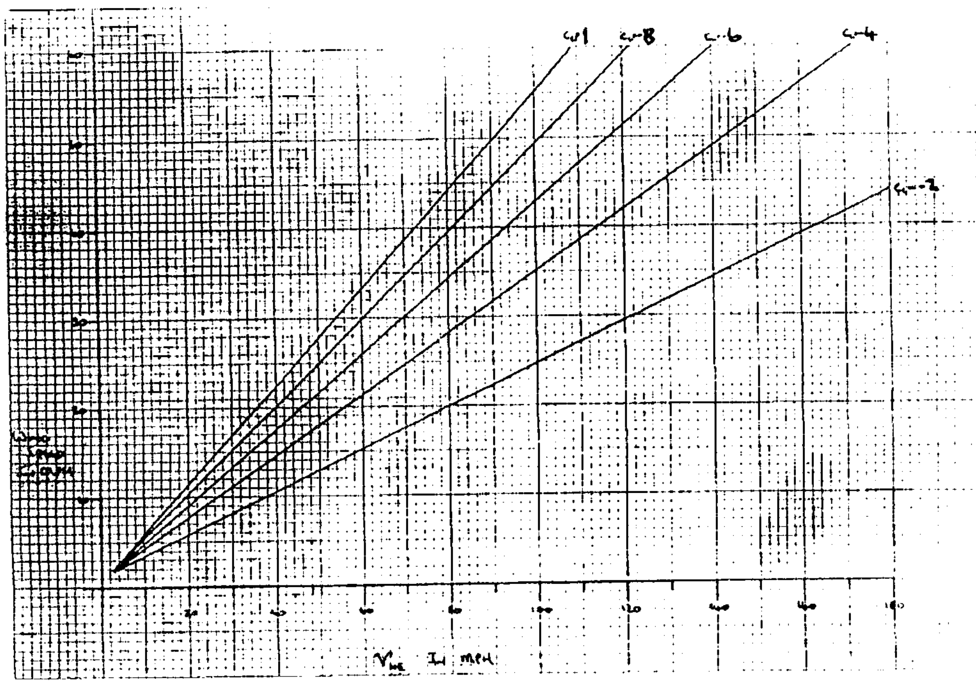
Nose pocket formed as follows;-



Appendix 1. The Matter of Vne & L/D

Earlier, the importance of the never exceed speed for conical Rogallos was briefly touched upon in respect of its importance in SWSK design.

In soft fabric wings the entire rigidity of the wing is dependent on the action of the air upon the wing (compared to those great hulking solid metal things you find attached to the sides of 747s & other aircraft) and there is a finite relationship between the coefficient of lift of a soft rogallo form wing (which itself is a function of the angle of attack of the wing & the billow/close up angle of the sail) and the never exceed speed- the speed at which the airflow becomes truely unruly over the back of the sail and ripples the sail out of shape. If you plot the graph (below) of incident wind speed against never exceed speed then a number of things become apparent;-



Although the graph covers the rather fanciful range 0-180mph on the never exceed axis and 0-60mph on the wind speed side a number of interesting bits of information can be extracted from the graph.

To start, consider the wind speed range 0-10mph- at 2mph wind speed (WS from now on) and never exceed (Vne) are convergent- in other words no soft wing will fly below this speed whatever you do to it. At 6mph any wing with a coeffient of lift (Cl) above .4 is only flying at 10mph and so would have a very restricted arc of operation- the low value Cl wings show much greater range of speed operation and would fly better at low wind speeds (!)

Now, consider a normal range of operating WS for a typical kite, say 5-20mph. In this range the higher values of Cl only give a very restricted forward speed range and would be boring kites to fly, however they would fly very steadily and be easy to keep airborne. Low values of Cl (say .2 and below) yield kites with a very wide forward speed range although with extremely low values of Cl it is easy to drop the kite out of the sky simply by stepping forward.

Remember that the axis "wind speed" should really be read as apparent wind experienced by the kite so as the kite starts to move the "wind speed" experienced by the kite increases. Thus with high Cl kites you get a kite that rapidly accelerates to flying speed and stays there, with low Cl the acceleration is even more rapid but equally rapid deceleration is possible as the wind drops (or the flier takes a step forward).

For a good competition grade SWSK you want the benefits of a low Cl wing (low wind operation, good speed range), but, since your operating arc is dependent on the overall lift to drag (L/D) ratio of the kite, if you build a wing with a low Cl then for the kite to have a reasonably high L/D ratio (and correspondingly wide operating arc) the coefficient of drag (Cd) of the kite must be very low. In practice this means narrow spars, fine line for bridles, no tails, taut sail and general attention to drag producing details (viz. fat nose re-inforcement, over-large wing connector cutouts, untidy stand offs etc etc.).

The other point about Vne is that it represents the ultimate speed attainable by a soft wing flown âüasü a kite (variable sail loading which is a function of forward speed) and should not be confused with Vne in Hang Glider practice where the sail loading is fixed (as is Vne). What prevents a kite from reaching Vne is the increase in drag on all the exposed surfaces of the kite as the speed increases (the drag increases roughly in proportion to the square of the airspeed of the kite).

Which brings us to the thorny problem of how fast can a SWSK fly? 160 Knots airspeed should be possible (about 185mph airspeed)- this is airspeed, the speed at which the kite moves through the air not groundspeed, the speed at which the kite moves over the ground. For the Guinness book of records the speeds quoted are groundspeeds and the current record of 122mph (?) for a Flexifoil equates to an airspeed of (only) 108mph for the quoted conditions. To put this in perspective on Christmas morning 1990 I went flying in London in 48 knots (!) of wind with an experimental cylindrical rogallo. I measured an airspeed of 145mph which equated to a ground speed of 95mph (you video the kite from a fixed point with a linear wide angle lens as it flies between fixed markers on fixed length lines and then spend many an hour, a frame at a time, measuring/calculating how fast later).

Of course, you are now totally confused as to how one kite can have a groundspeed higher than its airspeed and the other lower than its airspeed. I measure average speed to 20 degrees either side of the mid wind point, but I suspect the Flexifoil speed quoted above is the peak groundspeed measured at 10 degrees off mid wind point on the down wind leg of the flying arc (actually Flexifoils are limited to a maximum airspeed of around 108mph due to the mechanics of ram air inflation- at this point external aerodynamic pressures start to exceed the inflation pressure available from the ram air intake which causes the kite to deflate/slow down and thus self regulate at this point).

Appendix 2. Time for Standard Class SWSKs?

Competitive stunt kite flying has advanced greatly in the last five years and the improvements in the performance of the kites has been similarly great.

However, like one or two other sports, competitive flying is reaching a point at which the designs used are becoming positively dangerous in the sense that with increasing demands from judges for manouevers of considerable complexity and finesse SWSK designers are producing kites that are, too be blunt, difficult to fly for the inexperienced and often made from expensive, fragile and possibly hazardous materials.

In other sports where this sort of development has taken place (eg Gliding, Hang Gliding, Motor Racing) the governing bodies have introduced Standard Classes for competition where certain essential parameters for the equipment used are specified.

The beauty of doing this is that competitions within Standard Classes are reduced to the skill level of the competitor being the most important element rather the basic performance of the equipment being used.

For SWSK I would suggest the following as being a guide to producing a "Standard Class" stunt kite;-

Any SWSK sail planform allowed

Sail area to be 9-15 square feet

Leading edge to be 54-66 inches

Spine to be 24-40 inches

Nose angle to be 90-120 degrees

Weight to be 10-20 ounces

No Ballasting allowed

Any sail battening arrangement allowed

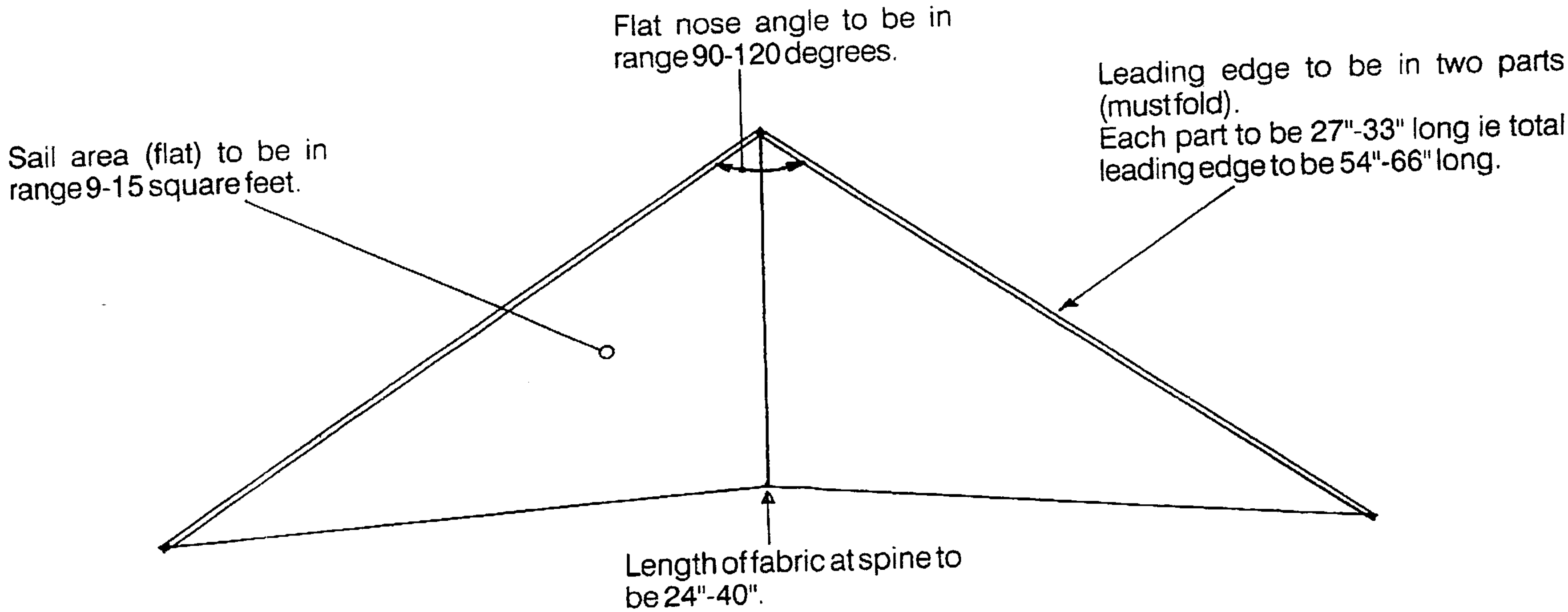
Any stand up system allowed

Any bridle method may be used

Any cross strut arrangement allowed

What this guideline specifically excludes are ultralight kites (invariably made from expensive, fragile materials) and small, fidgety, hard to fly kites.

A Standard Class 2 Line Stunt Kite



Weight to be;-

10oz Minimum.

20oz Maximum.

Sail Loading range = .66-2.2 oz sq ft.

Other;-

Any sail battening arrangement allowed.
Any stand up system allowed.
Any bridle method may be used.
Any cross strut arrangement allowed.

Appendix 3. Sail wear (& tear!)

Since the sail of your kite can represent many, many hours work it can be enlightening to discover just how long you can expect it to last!

The greatest source of sail wear is the trailing edge flap & flutter- not only does this steadily destroy the proofing on the fabric it also destroys the very fabric itself.

At the typical 60mph flying speed of SWSK the trailing edge vibrates at 80-100Hz (cycles per second). Taking the lower figure, in a minute the TE vibrates 4800 times, in an hour 288000 times. For a nylon fibre of the type used in kite ripstop, 8-20 million cycles represents an average lifetime before the fibre fails. Translating this into time you find that at about the 30 hour flying time mark the first fibres will be starting to fail in the fabric- at 60 hours you will have lost about 1/2 the original strength of the fabric.

This accumulated fibre failure is not the only strength reducing damage that your sail has to endure. Since it is out there in the sun (you do fly by day, don't you) you have also to consider the effects of ultraviolet radiation on the fibres. Nylon (and terylene/dacron), in spite of all its good qualities, has a chemical structure which is sensitive to degradation in the presence of ultraviolet. Although manufacturers try to reduce this sensitivity by using absorbative dyes and protective coatings the sensitivity lingers. For normal colours (say those in a natural rainbow) the sensitivity is slight and the fabric will tend to suffer fatigue damage (see above) before the ultraviolet damage becomes noticeable.

However, in the case of those wonderful trendy fluorescent colours that are so popular at present a different set of rules applies. Since fluorescent colours derive their fluorescence from the presence of ultraviolet putting a standard thickness UV blocking coating on the fabric is a no-no and since the dye is absorbed onto the surface of the fabric this surface layer receives a fairly hefty UV dose. This dose degrades both the surface and the dye causing 1. the surface layer to become weaker and 2. the dye to fade (thus increasing the UV dose to the underlying fabric). In practice this means that fabric with a fluorescent dye can lose 1/2 its original strength in less than 10 hours exposure to strong sunlight and begin to show visible dye fade after 30 hours exposure- by strong sunlight I mean the sort of sun you would encounter in Death Valley (viz very intense sunlight with little moisture to mitigate the intensity)- under more normal conditions (say here in England) fade starts to make itself apparent at around 100 hours (I have a kite with over 400 hours exposure that is still a reasonably fluorescent pink- pink is by far the worst offender in the fade stakes and turns a nasty off white before losing all its strength).

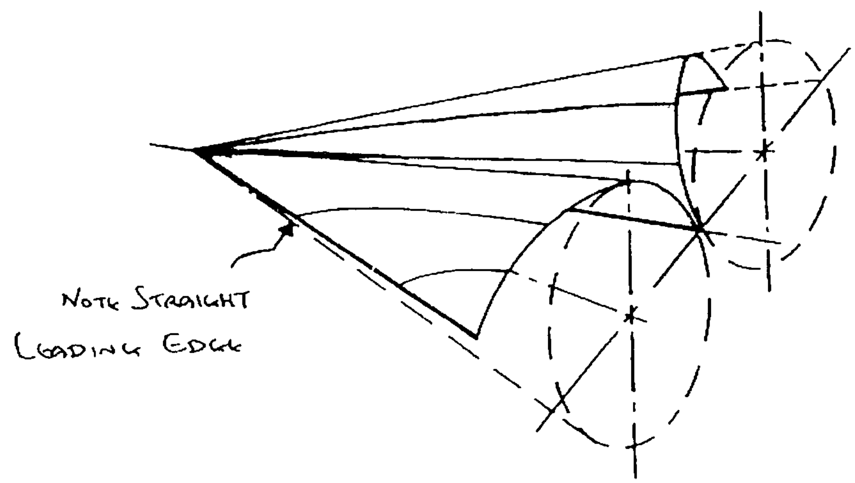
A third type of failure you see in old kite sails is delamination /separation of the protective proofing layer applied to ripstop. This layer serves the dual purpose of protecting the fabric from UV and stabilising the stretch in the fabric. However the failure of this layer (normally made apparent by the appearance of white streaks on the surface of the fabric) is totally inconsequential in terms of the change in fabric strength and is best thought of as being a cosmetic blemish.

Admitably, there is a slight risk of increased UV damage from this delamination, but given the manner in which the coating has peeled off all the samples I have seen the increased damage is going to be tiny.

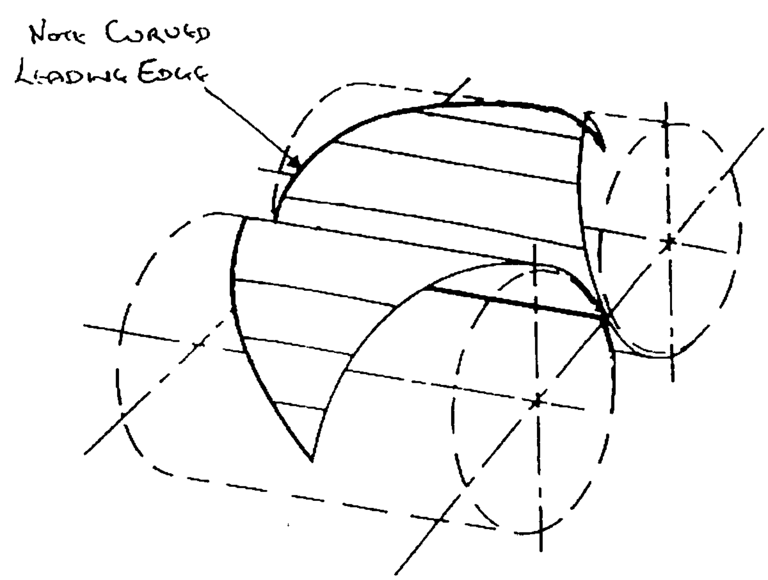
So taking all these factors together how long will your sail last? For a vibrating SWSK sail flown in medium strength winds (say 12-20mph) then at the 100 hour mark the sail is going to start showing appreciable "wear" and be liable to acquire small splits/tears from general handling (sails almost never tear when in flight, but the slightest poke from a spar end to an old sail when on the ground can rip the sail). For a light wind/non-vibrating sail the same level of sail "wear" is reached at the 250 hour mark. To put this in perspective 100 hours represents flying time (not "sitting on the ground while you talk about flying it" time) of 3 hours on each & every Saturday & Sunday for 17 weeks (say 3 months), 250 hours- 42 weeks. In other words the average sail lasts about a year for an average flier before needing replacement given the actual flying times most people put in.

Appendix 4. The form of conical & cylindrical Rogallos

Conical layout; the flying surfaces are inscribed onto the surfaces of two identical cones placed side by side. Note that all the spars in this layout are straight;



Cylindrical layout; the flying surfaces are inscribed onto the surface of two identical cylinders placed side by side. Note that the leading edge is curved in this layout;



Appendix 5. Stiffness, Flexibility & Strength

The terms stiffness, flexibility and strength are, when used in reference to spars in stunt kites, used in the loosest possible way. The problem lies in what people perceive and what material scientists perceive as being the properties ascribed to the aforementioned three terms. Now as I remember the proper definitions of this terms (well, its been a long time since school);-

Stiffness; a measure of the ability to resist deflection by a load.

Flexibility; a measure of the amount of deflection by a load.

Strength; An arbitary term to describe the ability of a material to withstand a stated load applied in a defined way.

Now that's as clear as mud isn't it. Put it this way, when people/catalogues etc say stiffness (this shaft is stiffer than that shaft) what they actually mean is "we put a weight on the end of a length of shaft and measured how far it bent" & so what they really mean is they measured its flexibility for that load. If you actually know the stiffness of a material you can predict exactly how far it will bend for any load within the material's elastic limit. If you just have a flexibility value you only know how far the material will bend for the measurement load and can infur no other information about the material (to all intents and purposes a single flexibility value is meaningless).

However, it is possible to measure a material's stiffness from a series of flexibility measurements at different loads. The classical method is to measure the deflection of the material at a number of differing loads all the way up to the breaking point of the material. Plotting the graph of deflection vs load yields (normally) a graph with a nice straight line to start off with that tails off to a reducing curved top (as the material approaches the breaking point) finishing with the break point. The stiffness of the material is taken as being the slope of the straight line portion of this graph (which is then subject to a number of correction factors to allow for the cross section of the material- was it tube, rod or whatever- and for the actual area of the material cross section).

Anyway, having got that out of the way, if you consider the stiffness, flexibility and "strength" characteristics of the four most common kite framing materials then the following sequences can be written (where glass is epoxy/polyester glass fibre re-inforced tube, wood is ramin dowel, carbon is typical arrow shaft material and aluminium is high grade aircraft style alloy tube);-

1. Stiffness;

Carbon > Aluminium > Glass > Wood.

2. Flexibility;

Glass > Wood > Carbon > Aluminium.

3. Strength;

Carbon > Glass > Aluminium > Wood

Scoring out each of these sequences to give the "best" material yields (using 1st=40, 2nd=25, 3rd=15 & 4th=10);

Carbon scores out as 1.3.1 = 95 pts
Glass scores out as 3.1.2 = 80 pts
Aluminium scores as 2.4.3 = 50 pts
Wood scores out as 4.2.4 = 45 pts

So (as expected?) carbon & glass appear to be the best materials. The only other factor which isn't considered here is weight- there certainly exist situations in which the lighter weights possible with aluminium and wood would be of benefit (eg for wing battens etc where actually flying loads imposed are low).