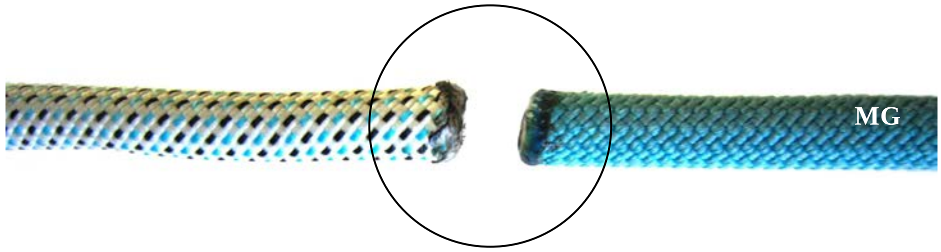
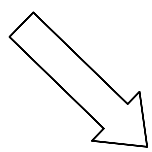
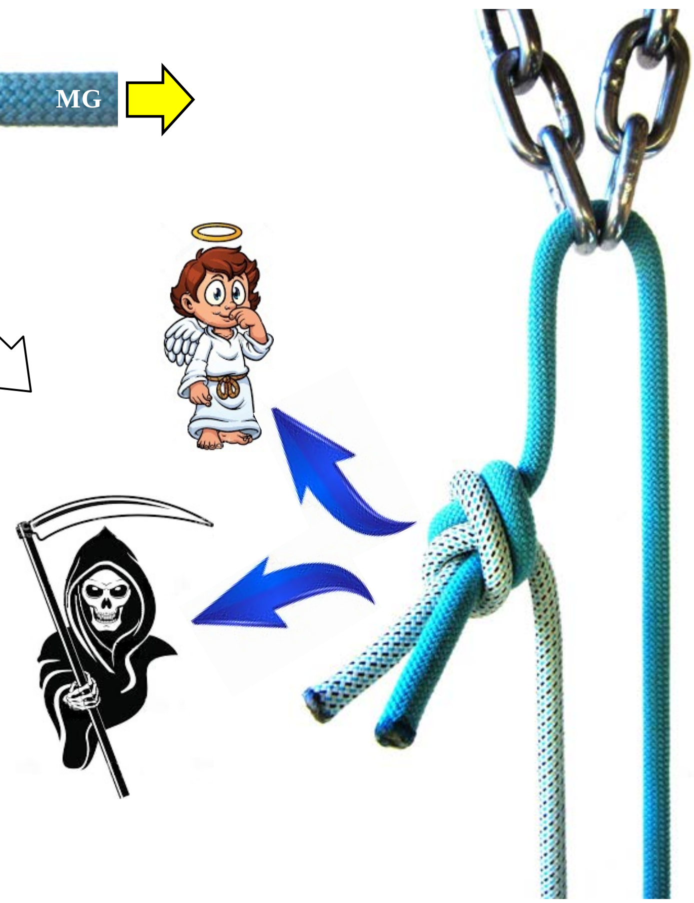
Analysis of offset end-to-end joining knots

Knots used to join two ropes together for longer abseil descents…



#1410 Offset Water knot
(Offset overhand bend)





WARNING / ACHTUNG !
All of the knots depicted in this paper are generally loosely tied and have very short tails. This was necessary for close-in macro photography – so that all of the knot structure would fit within the narrow field of view of the camera lens.

CONTENTS

WARNING!
The knots depicted in this paper are typically tied loose so that it is easy for the reader to discern structural detail. In order for the image to fit within the macro field of view of the camera lens, the tails had to be tied short. In real life applications, knots must be properly set and dressed with appropriate tail lengths.

Preamble

The offset Water knot (offset Overhand bend) is found at illustration #1410 in the Ashley Book of Knots published in 1944.

This particular knot has attracted significant controversy – particularly in the climbing community.

This paper attempts to present facts and dispel some of the myths.

The idea for this paper had its beginnings soon after completing my work on Bowlines.

There is no universal law or regulation compelling climbers to use a particular end-to-end joining knot to unite their ropes. It is entirely up to the individual – usually the most experienced person in the group – to decide which knot (or 'bend') to use. The same can be said of tie-in knots for a climbing harness. Some climbers prefer secure Bowlines while others prefer the Figure 8 eye knot (ABoK #1047).

There have been several accidents resulting in serious injury and in some cases death as a consequence of human error in joining ropes together. If the parties involved had access to better (prior) information, perhaps the outcomes may have been different.

Part of the reason for embarking on this project is to dispel the myths and set the record straight about offset rope joining knots. Other reasons include making available a concise body of knowledge with accurate information that interested individuals can source.

It is also hoped that this work might reduce risk and contribute to safety.

Mark Gommers
09 June 2017

Acknowledgments:
Many people have contributed to this work. The content published in this work does not necessarily imply an endorsement from any contributor.

WHAT'S IN A NAME ?

Knotting experts refer to the Ashley Book of Knots (ABoK) as an authoritative source on knots. This masterpiece was published during WW2 by Clifford Ashley. Every knot presented has a unique serial number. For example if you look up illustration number *1410*, you will find none other than the offset Water knot (aka Offset overhand bend). Knotting experts would write this as 'ABoK #1410' (or simply #1410).

The offset overhand bend (ABoK #1410) has been known by a number of alternate names including; one sided overhand bend, flat overhand knot, flat overhand bend, and Euro Death Knot (EDK). All of these names are technically inaccurate with the latter name generating undeserved controversy.

<u>Why are there so many confusing names?</u>
Part of the problem is that most climbers are not *knotting experts* – rather, they are *users of knots* (and only a limited selection of knots). An anology is computers. Many people are proficient users of computers, but this does not mean that they know how all the components work inside the case, or how to build a computer from individual parts. The same can be said of cars. Most people are proficient users of cars but have limited or no knowledge of how things work under the bonnet.
Many climbers learn from a friend who in turn also learned from a friend and so on – so their knowledge is linked to what they gleaned from a close circle of climbing acquaintances – a process of informal learning. Detailed technical knowledge about knots and knot theory is generally lacking because it is not an essential requirement to participate in climbing (or other roped sports) and because it is perceived to be the realm of academia.

Additional sources of knowledge include books and magazines and of course, online forums – and it is here that a good deal of misinformation is spread. To the best of my knowledge, the only knot book author who actually used the correct term to describe ABoK #1410 is Clyde Soles ('The Outdoor Knots Book' ISBN-13 978-0898869620) – where he used the term 'offset overhand bend'.

The origins of the unfortunate and ridiculous name 'EDK' in the USA is hard to pinpoint.

According to Jeff Lea – a former AAC representative to the UIAA safety commission, the Offset overhand bend (#1410) was:-

"… used by French guides in Chamonix in training at ENSA for their IFMGA certifications in the early 1980s, and British climbing friends of mine, who commonly tied their rappel ropes together end-to-end with either a Double Fisherman's bend (#1415) or a Figure eight bend (#1411), referred to it by the term EDK. As the American delegate on the UIAA Safety Committee at the time, I had several discussions at meetings at ENSA with French guide instructors and learned of testing they had done to support the efficacy and safety of using the Offset Overhand bend to join ropes for rappels, whether of equal diameters or not. I've used it consistently ever since for this purpose."

And in response to a question when the term 'EDK' entered into the common vernacular in the USA:

"…that certainly it was commonly referred to in that manner among many climbers in New England of my acquaintance who had also climbed in Europe and/or Great Britain prior to 1985. That is not to say I believe that it "had entered into the common vernacular". It was usually used in a jocular fashion, and often directed at those of us who had adopted the Offset Overhand Knot as our knot of choice for joining rappel ropes. I CAN say for certain that the first time I heard it was in Chamonix in the summer of 1982, after descending from the Aiguille de la Blaitière with a British partner, alongside a rope team of French Aspirant Guides, with whom we were sharing rappel anchors. This sharing may seem unusual to some who have climbed in the alps; my fluency in French as a career teacher of the language certainly helped our interaction, as did the fact that I had spent the previous week at ENSA representing the AAC at the meetings of the UIAA Safety Commission."

Link: http://www.neclimbs.com/SMF_2/index.php/topic,9754.msg81125.html#msg81125
Date/time stamp: 27 November 2017
Jeff Lea

An event that may have acted as a catalyst in bringing the term ‘EDK’ into the mainsteam consciousness occurred in the Grand Teton National Park:-

On 13 September 1998, Karen Turk fell while descending from a route (ie rappelling / abseiling) on ‘Guides wall’, Grand Teton USA. In the report, the joining knot was referred to as a ‘Euro Guide Knot’ (EGK). It is possible to surmise that this name was then morphed to ‘Euro Death Knot’ – on account of its appearance and because of the terrifying near miss experienced by Ms Turk (she was lucky – the outcome could have been much worse). Its not hard to imagine how the word ‘Guide’ in the original name EGK was changed to ‘Death’ (giving rise to EDK).

Here is an extract from the accident report:
Link: http://publications.americanalpineclub.org/articles/13199808000/Fall-on-Rock-Rappel-Ropes-Knot-Unraveled-Wyoming-Grand-Teton-Guides-Wall

At this point, Goewert started to untie the knot by loosening it (for a single rope rappel) then decided to keep the ropes tied together as the final rappel would be another long, double rope rappel. Goewert re-secured the knot by pulling on all ends to tighten, which he demonstrated. The ropes were threaded through three rappel rings which were secured by multiple pieces of webbing tied around a tree. Goewert then rappelled approximately 80 to 90 feet to the next ledge. When Goewert finished this rappel, Dagher said that she and Turk moved the knot about twelve inches forward, but did not adjust it. Turk then proceeded to rappel. When Turk was approximately 30 feet above the ledge, Dagher states that she watched the knot “unravel” causing Turk to fall. Turk fell about 15 to 20 feet, struck her back against a rock prow, then fell another 10 to 15 feet onto the ledge, landing on her back.

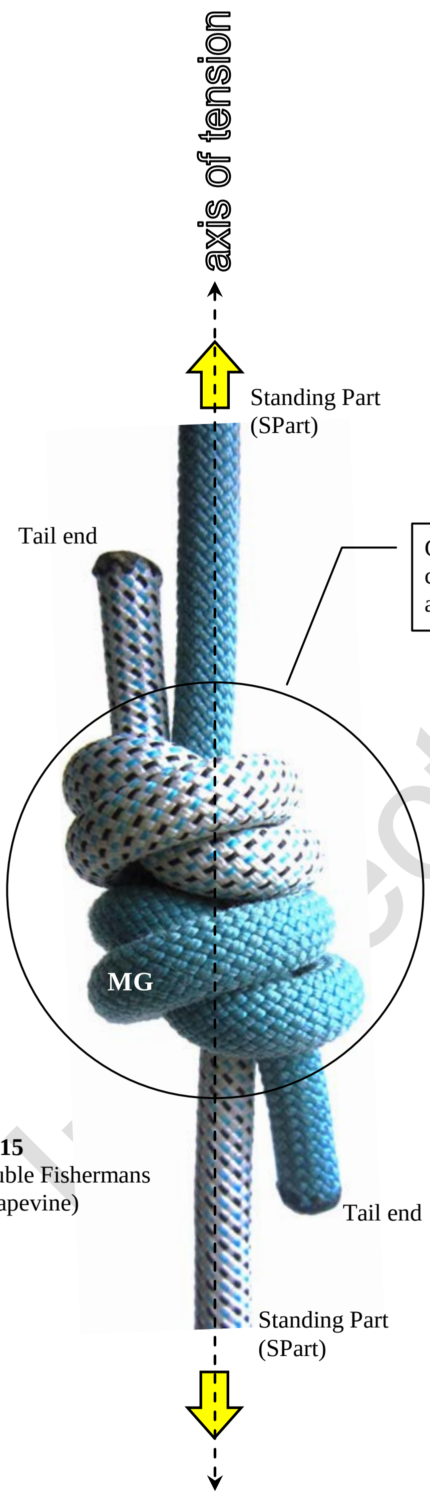
Dagher had made a comment about the knot, to the effect that “it looked pretty weird” and she wasn’t clear how it could hold. This comment was made at the last rappel station. Turk said she was aware that Goewert had adjusted the knot at this station but did not see him do so.

…

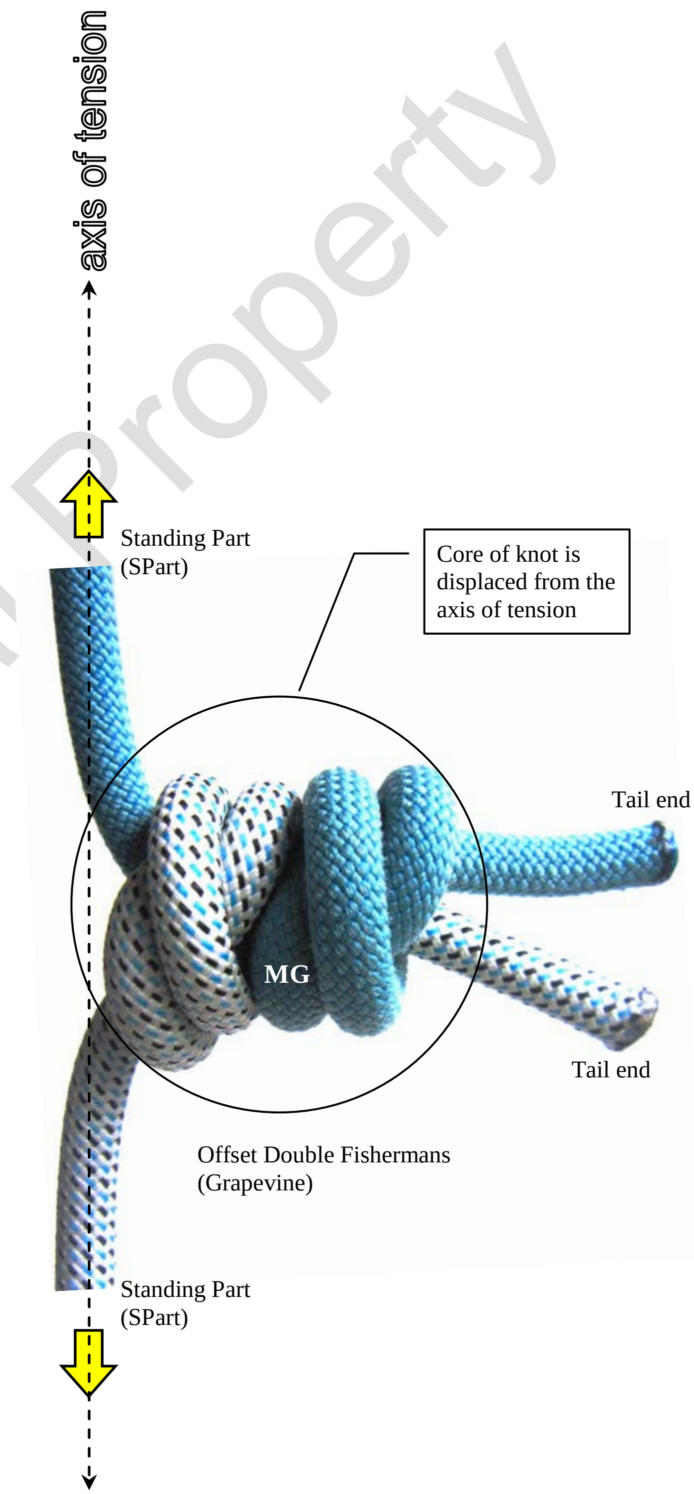
There is also this link: http://canyoncollective.com/threads/euro-death-knot-a-story.15096/
Date/time stamp: 27 Dec 2009
Tom Jones

OFFSET JOINING KNOTS: A definition

The term ‘offset’ refers to the core of the knot being displaced from the *axis of tension*. A consequence of this displacement is the Standing Parts (SParts) converge and then follow a parallel pathway that is perpendicular to the axis of tension. The persistent use of the term ‘flat’ or ‘one-sided’ is incorrect and it is hoped that this paper will assist in correcting the nomenclature.



#1415
Double Fishermans
(Grapevine)



Offset Double Fishermans
(Grapevine)

RELATIONSHIP TO WATER KNOT (RING BEND) #1412

The offset Water knot is derived from #1412 Water knot (also known as a Ring bend or Tape knot). The choice of tail and Standing Part (SPart) determines the loading profile which in turn results in a different knot.

#1412 Water knot (Ring bend)
Uniform compact dressing

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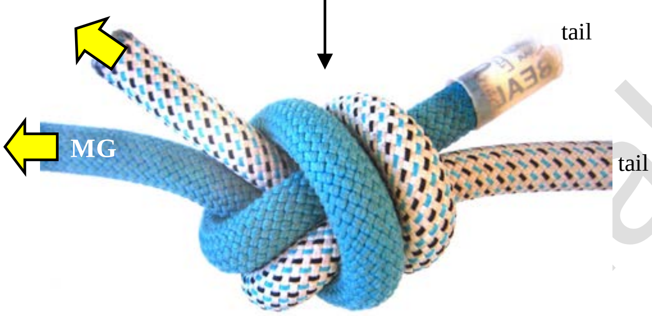


#1412 Water knot (Ring bend)
Note the choice of SParts...

=

#1410 Offset Water knot
Uniform compact dressing

Derivations of #1412 Water knot based on choice of SPart and tail.

=

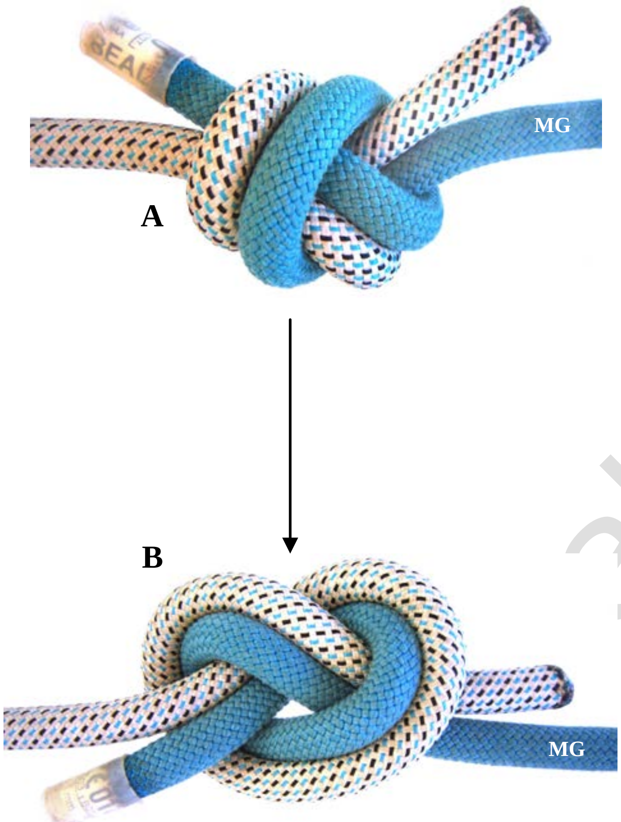
INTERESTING FACT

All 'bends' have 4 corresponding eye knots.

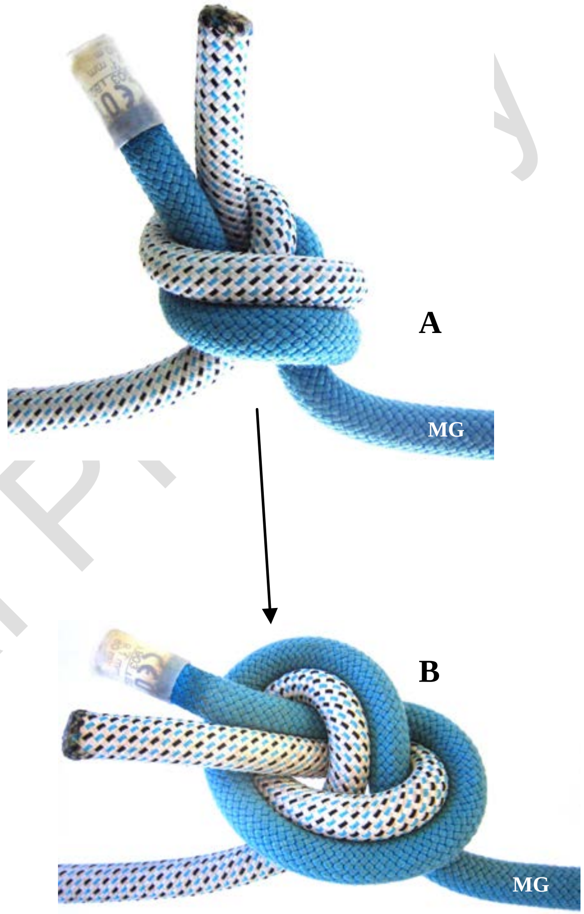
=

DRESSING STATES

The dressing of a knot influences its performance and response under load. Uniform compact dressings tend to maintain their original geometry and aid in recognition when checking. It is theorised that uniform compact dressing states increase the surface contact area between adjacent rope segments – which in turn boosts core friction and security. It is strongly recommended that all end-to-end joining knots used in life critical applications are tied with identical length tails – which serves as a visual cue for any undue change or slippage.



#1412 Water knot (Ring bend)
Flattened parallel dressing state



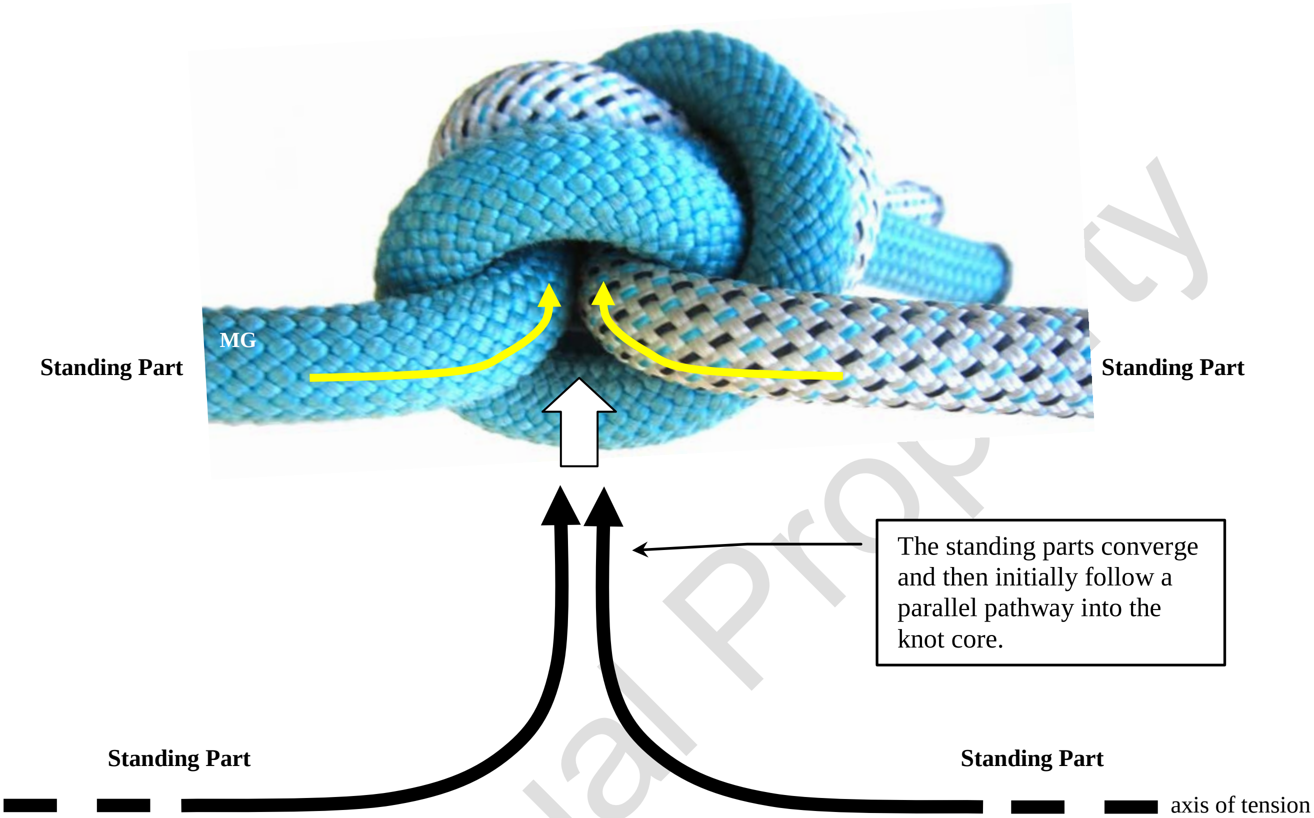
#1410 Offset overhand bend
Flattened parallel dressing state

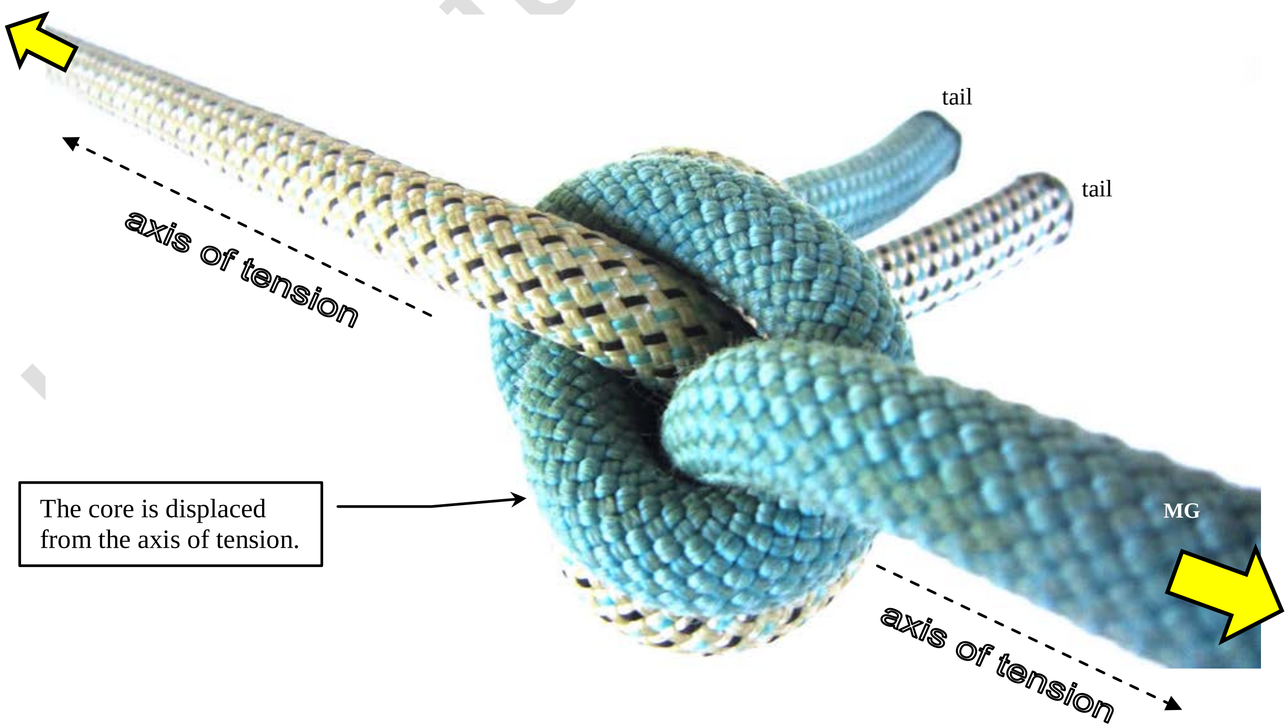
The 'A' and 'B' versions of each knot are *topologically* equivalent. However, the geometry in the 'B' version has been flattened into a parallel dressing *state*. It is properly described as a dressing 'state' because any application of load will quickly deform and transform these structures. These dressing states are inherently unstable.

In a literal sense, the 'B' versions are 'flat', and this amplifies why the persistent use of the term 'flat' to describe offset knots is problematic.

GEOMETRY

A consequence of the offset geometry is that both standing parts converge and then initially follow a parallel pathway into the core of the knot.

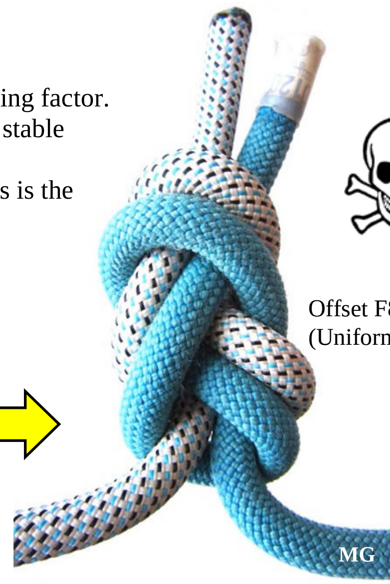




OFFSET FIGURE 8 BEND

The offset F8 is sometimes confused with #1410.
The persistent use of the term ‘flat’ to describe #1410 is likely a contributing factor.
Various tests have demonstrated that the F8 bend in its offset form is less stable than #1410 – and will capsize at a lower load threshold.
If the climbing community insists on the use of the term ‘EDK’ – then this is the structure that it should apply to.

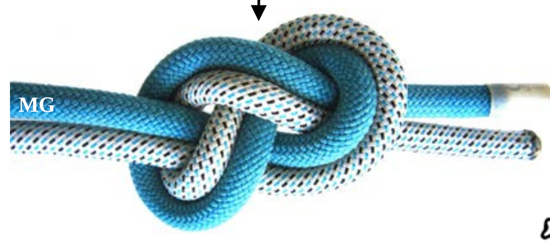
Tail ends



Offset F8 bend
(Uniform compact dressing)

#1411 Figure 8 bend
(Flemish bend)

#1411 Figure 8 bend
Unstable flattened parallel dressing state



Tail ends

Offset F8 bend
Unstable flattened parallel dressing state

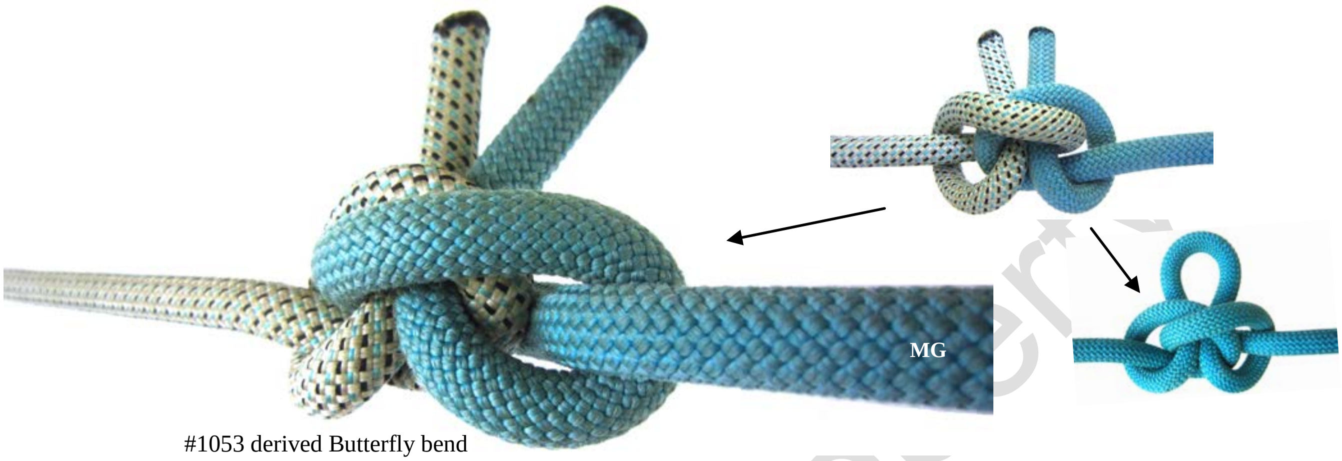
INTERESTING POINT
Little testing has been done to investigate various dressings of offset F8. It is theorised that a stable dressing state can be achieved.

Tail ends

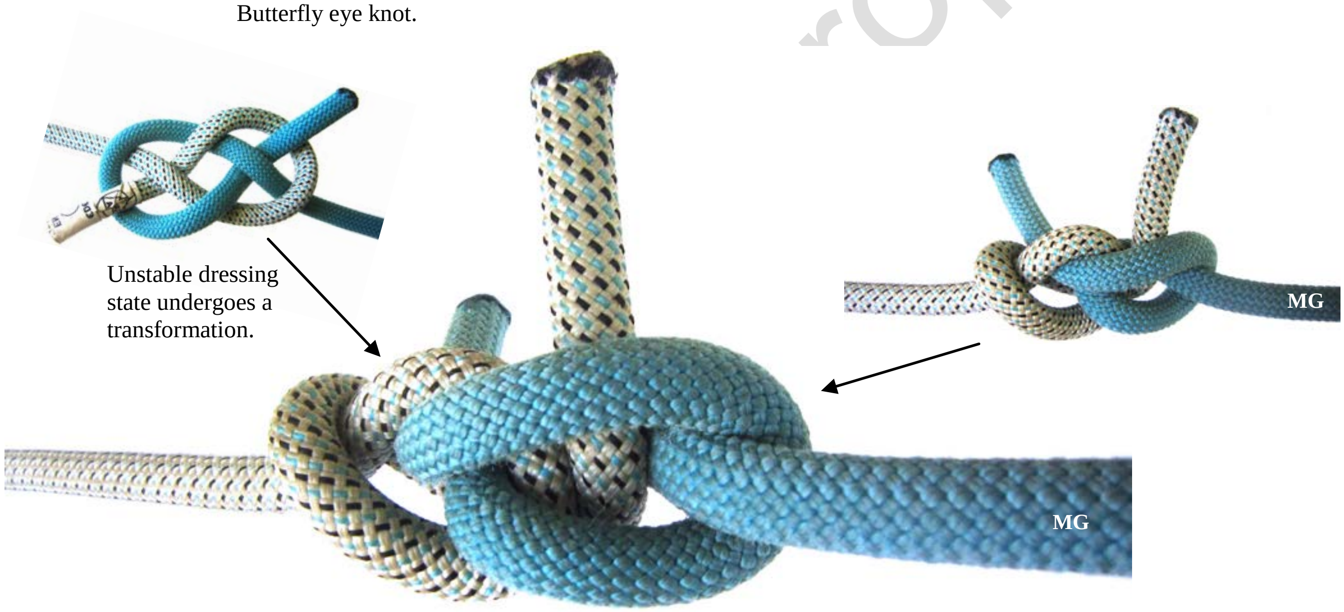
Offset F8 bend
(it is possible to induce a choking effect but this is dependent on careful dressing and orientation).

A COMPARISON OF OTHER END-TO-END JOINING KNOTS

None of these end-to-end joining knots are offset, although each has merit in certain applications. The Carrick bend (#1439) name dates back to at least 1783 although the origin of its discovery is unknown. The Butterfly bend isn't offset, however it is asymmetrical. None of these knots will easily translate around a 90 degree edge.

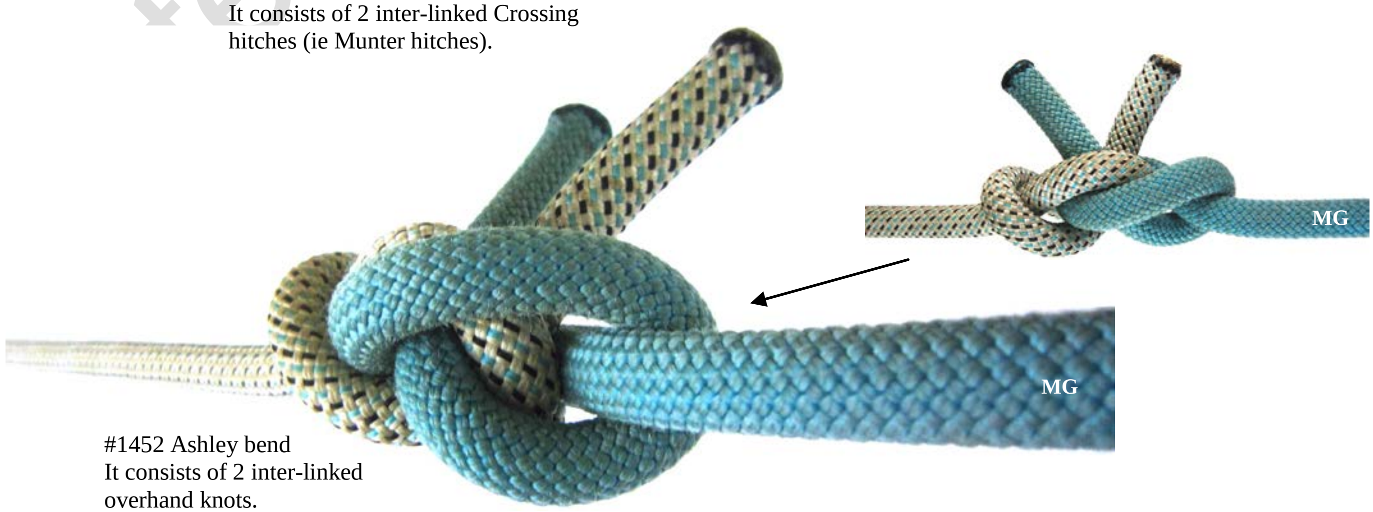


#1053 derived Butterfly bend
It is a well-known derivation of the Butterfly eye knot.



Unstable dressing state undergoes a transformation.

#1439 Carrick bend
It consists of 2 inter-linked Crossing hitches (ie Munter hitches).



#1452 Ashley bend
It consists of 2 inter-linked overhand knots.

PROBLEMS WITH RETRIEVING JOINED ROPES

<u>What is the underlying reason for using *offset* rope joining knots?</u> Climbers discovered that classic end-to-end joining knots such as #1415 'Double Fishermans' (aka Grapevine) were more likely to get stuck on an edge during attempts to retrieve their ropes (which would have serious consequences). A further complicating factor is that some knots have a propensity for jamming. If a knot is difficult to untie, this will have consequences. A solution had to be found – and so climbers started to experiment with different knot joining structures.

The classic #1415 Double Fishermans (Grapevine) bend is more likely to get **stuck** on an edge – particularly a 90 degree edge from low anchors.

It also has a propensity to **jam**. This is exacerbated if climbers are heavy and consecutive descents are made by people in a group.

View from underneath
This is the reason why this particular knot translates well over edges. The main bulk (core) of the knot is **offset** from the *axis of tension* – which eliminates protrusions that could snag on edges.

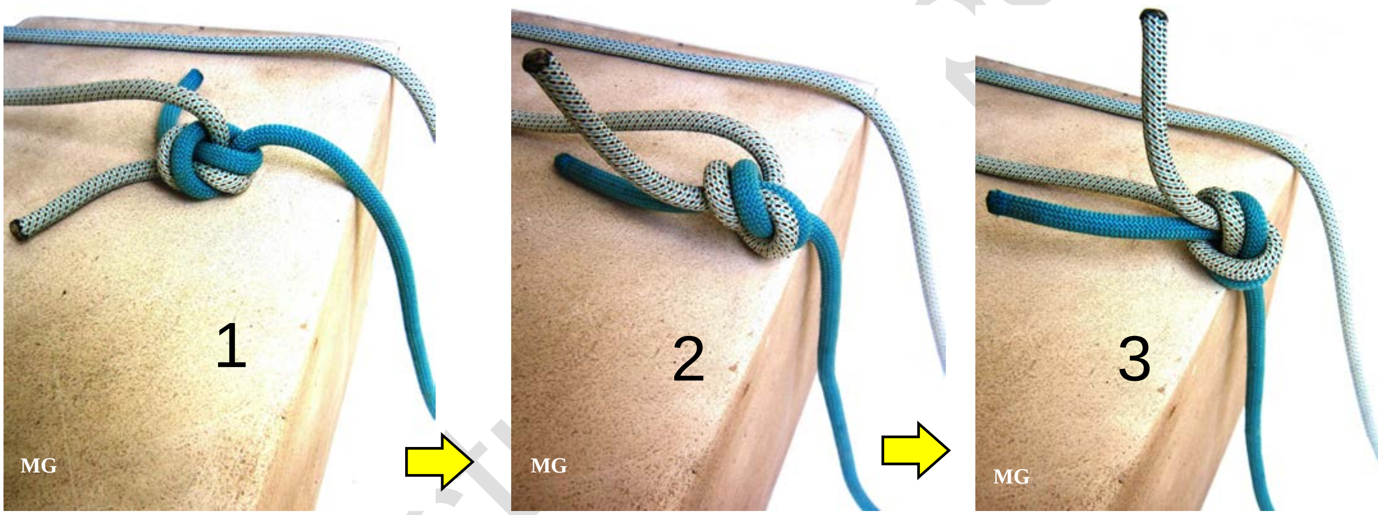
Offset knot structures have a strong tendency to self-align and more easily translate around a 90 degree edge.

TRANSLATION AROUND A 90° DEGREE EDGE

A characteristic of offset rope joining knots is that they have an inherent tendency to roll so that the core *projects away* from the rock surface. Ordinary end-to-end joining knots which are not offset (eg #1415 Double fishermans) do not behave in this way.

As tension is applied during the rope retrieval process, force is directed along the ‘axis of tension’. The rope always tries to align itself in a straight line – along the axis of tension. As the rope aligns itself, there is a downward acting force which induces a roll moment around the axis-of-tension. This causes the knot core to project away from the rock surface.

It is this inherent tendency to roll into a favourable orientation that facilitates translation of the knot around an edge and successful rope retrieval.



In this simple test, the offset knot (#1410) was deliberately oriented upside down.

Almost immediately after initiating rope retrieval, the knot has started to roll.

Roll complete, as the knot draws to the edge.

PULL DOWN TESTS

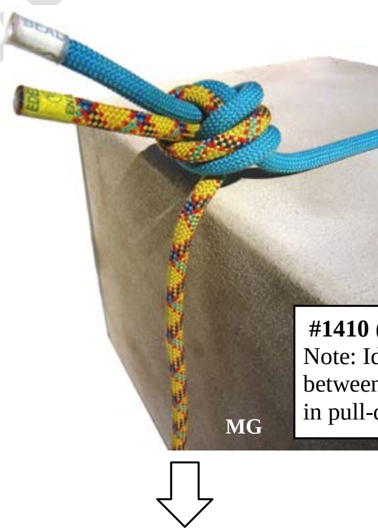
The force required to get a knot to translate around a 90 degree edge was investigated by David Drohan in Sep 2001.

The David Drohan report is hard to find on the internet these days but, it is available courtesy of the PACI website. Direct link to page: http://www.paci.com.au/knots.php (at #9 in the table).

The actual test results are not contained in that pdf file – they are in separate appendix sections which are no longer available for download.

Independent testing conducted by Mark Gommers in 2009 produced the following results:

ROPE JOINING KNOT	Pull down force to initiate translation around a 90 degree edge	Remarks
#1410 Offset Overhand bend	0.46 – 0.72 kN	Never got stuck at edge – even if the knot was deliberately laid upside down it self-corrects and rolls to upright orientation.
#1415 Double Fishermans	> 1.5 kN	Unsuccessful – greater than 1.5 kN force – further pull down efforts would have damaged the rope
Zeppelin Bend	1.02 – 1.34 kN	Difficult – but with significant effort the knot eventually translated.
#1411 Figure 8 bend	Not yet tested	Further testing is planned – but it is thought that the results will be similar to the Zeppelin bend.



#1410 (derived) 0.46 – 0.72 kN
Note: Identical structure along *axis of tension* between this and #1410, so there is no difference in pull-down test results.

These tests demonstrate that only ‘offset’ rope joining knots easily translate around 90 degree edges.

OBSESSION WITH STRENGTH

Across the entire outdoor recreation world, there seems to be a persistent focus on the importance of raw MBS yield (ie strength), and that a stronger knot is by default a better knot. The reality is somewhat different.

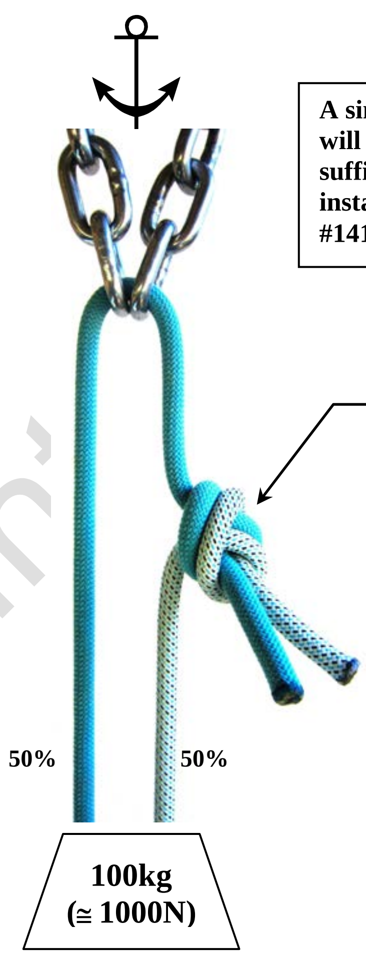
A significant number of online authors who write about #1410 like to refer to Tom Moyers tests dated 09 Sep 1999 – conducted some 17 years ago.
Link: https://user.xmission.com/~tmoyer/testing/EDK.html

The principal focus of these tests was to investigate strength. Testing did not investigate data points such as; jamming threshold, instability threshold, changes in tail length as load increases and the effects of different dressings. In a nutshell, the concept of strength is being confused with security and stability.

<u>The following information is relevant for rope diameters in the range 9-11mm</u>
In more recent times, tests have demonstrated that #1410 remains stable and secure at loads up to approximately 5kN (about 1100 pounds). Any climber can prove at least a basic level of stability for themselves – join 2 pieces of climbing rope using #1410 and vigorously bounce your body weight on the knot (which could approach 2kN force). Nothing happens, because at these loads the knot remains stable. The jamming threshold of #1410 is around 3kN (about 660 pounds). This means that you will not be able to untie #1410 *by hand* if the load reaches a threshold of around 300kg (660 pounds) – you will need to use tools, which will likely cause some damage to the ropes.

In a standard retrievable abseil system, load will be distributed across two ropes in a 50/50 split. For example, a person with 100kg mass will generate a force of approximately 1000 Newtons (force is the result of Earth's gravity which is 9.81 m/s²).This means the force exerted on the joining knot is around 500 Newtons. Even when applying a safety factor of 5 (5 x 500 = 2500 Newtons or about 550 pounds), this is still nowhere near the threshold of instability.

A single person abseiling will not be able to generate sufficient force to reach the instability threshold of #1410.



Only 50% of load on knot (50kg / ≅ 500N)

Weight is actually a force due to the Earth's gravity
At the Earth's surface, acceleration due to gravity is 9.81 m/s² (32.17 ft/ s²).
In the metric system (SI units) force is measured in Newtons (N).
Example: A 100kg mass weighs 981 N.

Note: 100kg ≅ 220 pounds (1 lbf ≅ 4.45N)

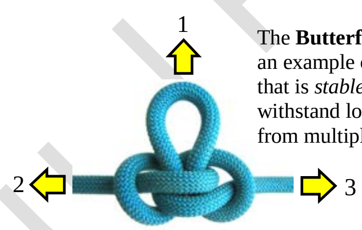
ABSEIL ROPE JOINING KNOT DESIGN GOALS

A surprising number of knot book authors and other commentators place significant emphasis on the MBS yield point of a knot (ie strength). A likely explanation for this is that much of the information about climbing knots in general has been copied or parroted from one person to the next (or from one author to the next) without questioning its authenticity, accuracy or validity. It is simply assumed that existing published works are factual and/or valid. In the case of #1410 Offset overhand bend, strength is actually irrelevant! The following table outlines important design goals:

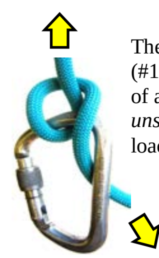
1	Jam resistant	The knot structure resists jamming at nominal loads (easy to untie after loading). Some knots have exceptional resistance to jamming even at loads exceeding 50% of the MBS yield point (eg Zeppelin bend).
2	Stable	The knot structure resists change or alteration when load is applied, and does not have vulnerabilities to particular loading profiles. Examples of unstable structures include the Munter hitch and the Carrick bend (refer to diagrams).
3	Secure	The knot structure resists loosening/slippage when a nominal load is applied along the axis of tension, including resistance to cyclic loading events. An example of an insecure structure is the Simple (#1010) Bowline which is vulnerable to cyclic loading and slack shaking (the knot structure will loosen and fail). The properties of stability and security are interrelated.
4	Small foot print	The knot structure has a low overall volume/size.
5	Verifiable	The knot structure has distinctive features which are recognisable – a pattern which can be relatively easily memorised (not a random tangle/form).
	Offset	The core of the knot is 'offset' from the axis of tension.

*Nominal means: "Within expected, acceptable limits"

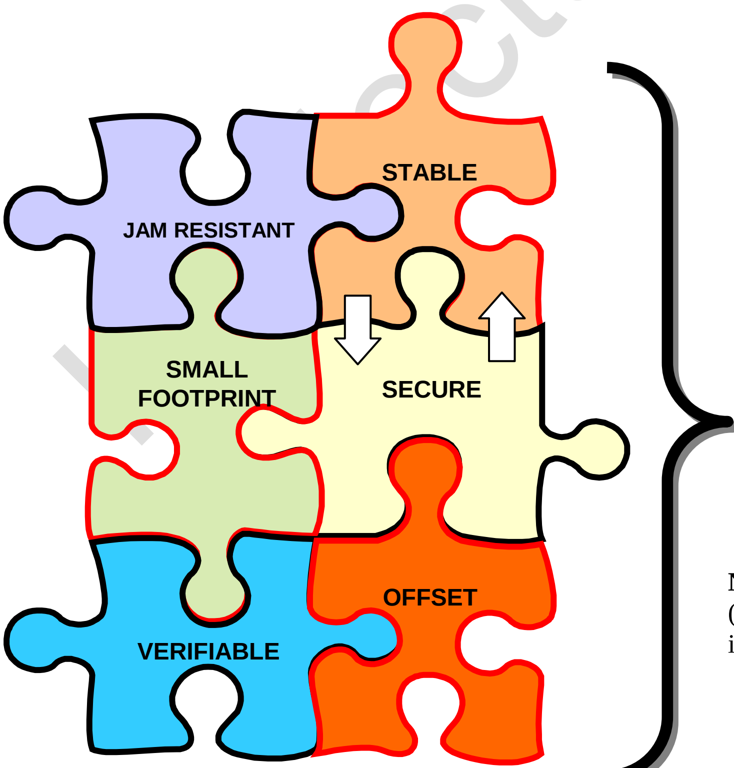
Axis of tension
All knots have an axis of tension along which load is intended to be directed.



The **Butterfly** eye knot is an example of a structure that is *stable*. It can withstand loading profiles from multiple directions.



The **Munter** hitch (#1195) is an example of a structure that is *unstable*. A reversal of load triggers capsizing.



IDEAL ROPE JOINING KNOT

NOTE: MBS yield (strength) is *not* an important design goal!

The Simple (#1010) **Bowline** is an example of a structure that is *insecure*. In modern abseiling and climbing ropes, cyclic loading and slack shaking will trigger loosening and failure.

The **Carrick** bend (#1439) is an example of a structure that is *unstable*. Application of load triggers structural change.

CORRECT DRESSING IS CRITICAL

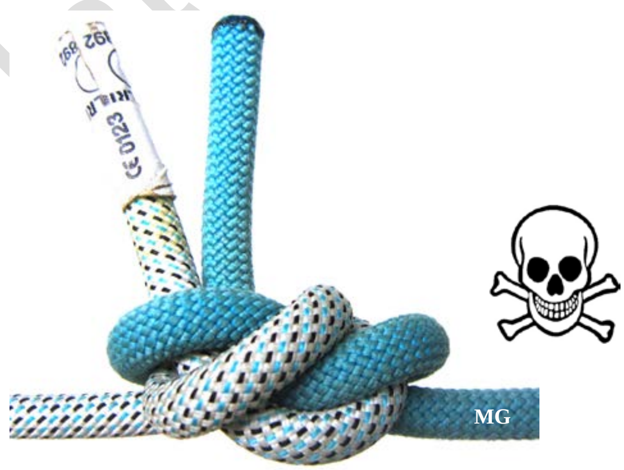
Careful and diligent attention to dressing will enhance stability and security. In short, the knot will behave predictably under load. Most climbers learn (or hear from others) that dressing of knots used in life critical fall-arrest applications is an important safety consideration. For example, the knot used to tie-in to their climbing harness is typically given a lot of attention and is checked (and ought to be cross-checked by their climbing partner/belayer). End-to-end rope joining knots are no different…the same degree of diligence is required.

SAFETY RULE: Always set the tails to identical lengths.

This provides a visual 'tell-tale'…so after tying the knot and using it to descend (ie abseil); any changes in relative tail lengths will alert the user to potential danger. Corrective action can then be taken.

SAFETY RULE: Pay close attention to 'dressing'. You must diligently and accurately dress the knot. Close enough is *not* good enough! Its either 100% correct or its 100% wrong – there is no in-between,

SAFETY RULE: Always set and tightly dress all offset knots by incrementally pulling against each of the four rope segments. You must compress the structure into the smallest footprint possible. You must be diligent and you must check the result of your efforts.



DIFFERENT ROPE DIAMETERS

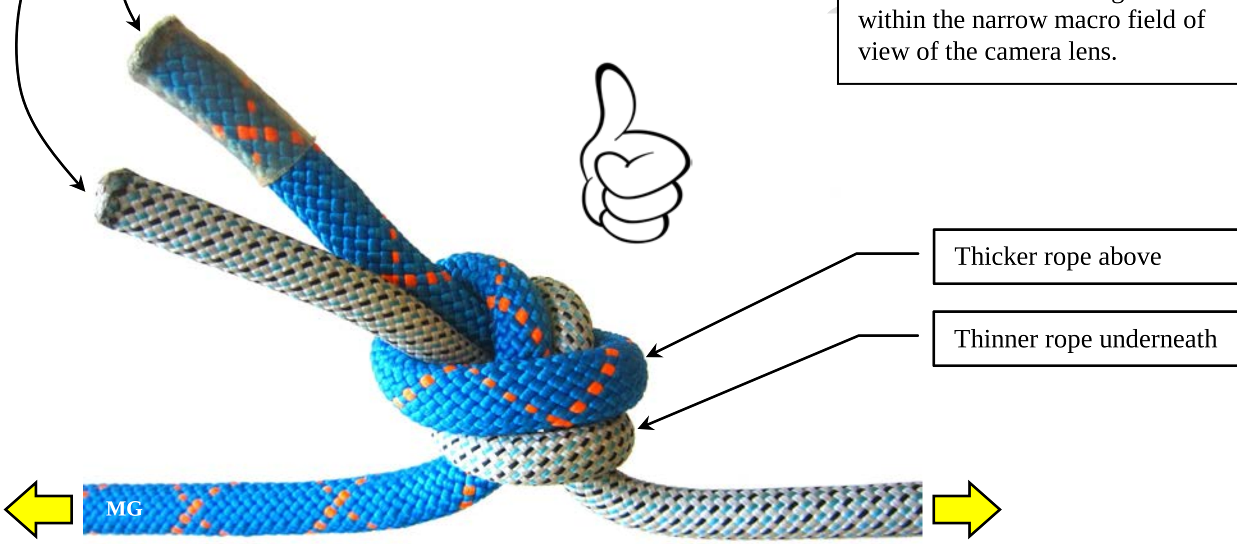
ABoK #1410 can be tied with different rope diameters – without impacting security or stability. However, it is critically important to position the thinner rope *underneath* the thicker rope (refer to the photos). Dan Lehman reported this often overlooked fact some time ago and it is surprising that no testers have investigated this further.

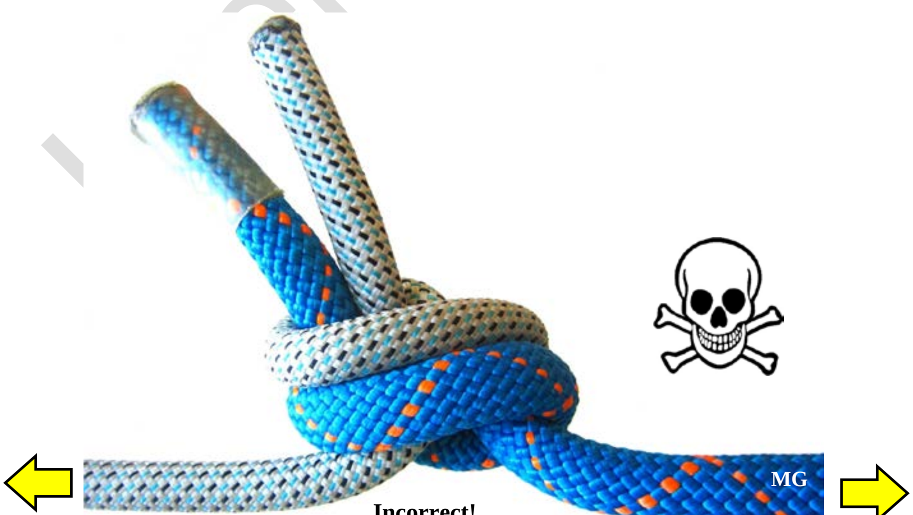
There is a link to a forum here: https://www.mountainproject.com/forum/topic/108214858/joining-unequal-diameter-ropes-for-rappel where 'rgold' posted a correct image showing the position of the unequal diameter ropes (posted June 2013). It is presumed that he obtained this information from 'knudeNoggin' (link still working as at 17 June 2017).

'knudeNoggin' had previously posted information in a rock climbing forum (Dec 10, 2005, 11:14 PM) about the proper positioning of unequal rope diameters here: http://www.rockclimbing.com/forum/Climbing_Information_C2/Beginners_F16/Joining_Different_Diameter_Cord_P1235361-3 (link still working as at 17 June 2017).

SAFETY RULE!
Always ensure the tails are of identical length.

WARNING!
The tail lengths in each photo are deliberately tied short. This was to ensure the full knot image would fit within the narrow macro field of view of the camera lens.



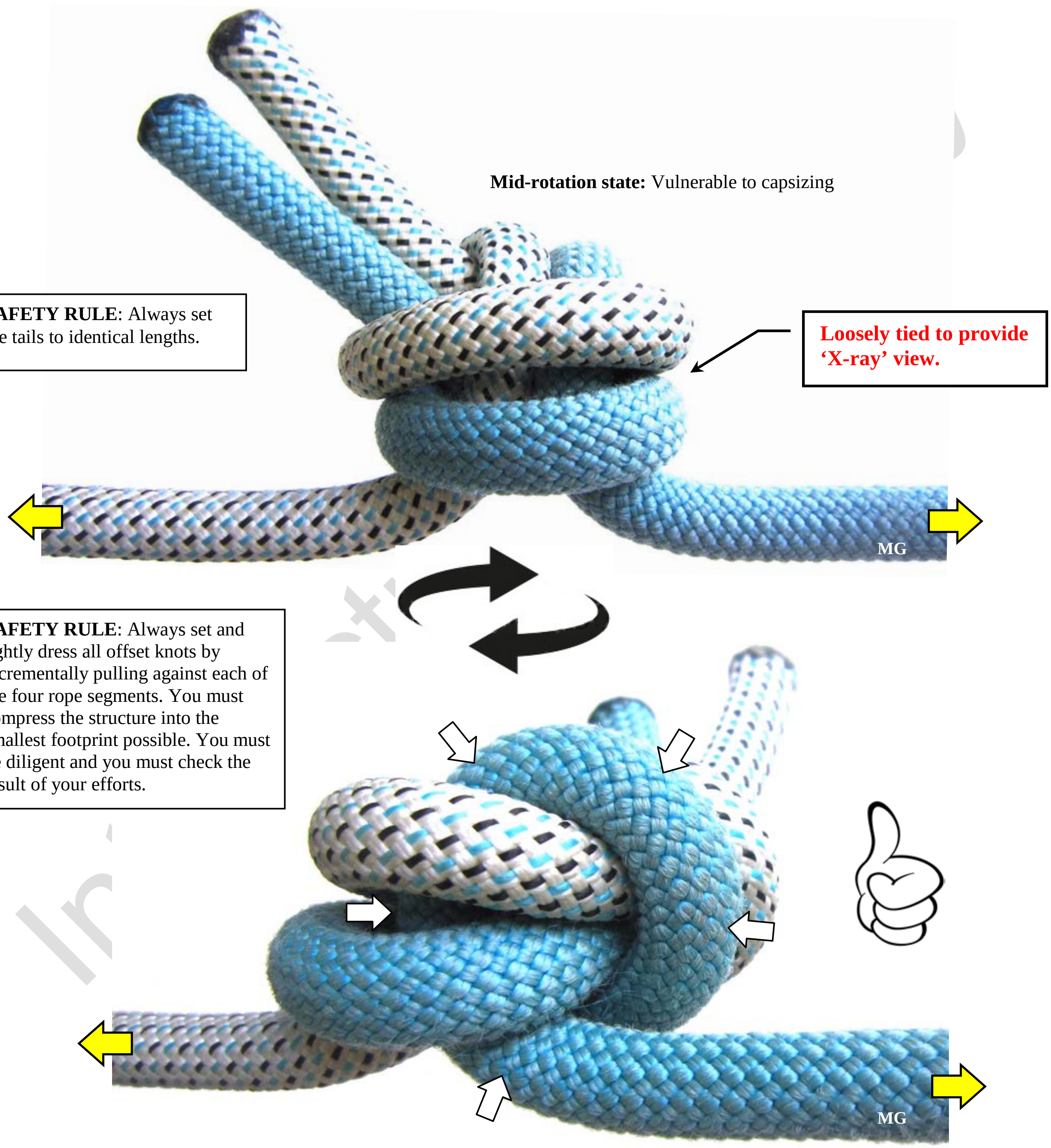


Incorrect!
This form is potentially unstable.

EFFECT OF ORIENTATION ON STABILITY AND SECURITY (Part 1 of 2)

A simple rotation of #1410 can induce a 'choking' effect to trap and crush the tails.

Dan Lehman reported the potential benefits of such a simple rotation some time ago – and it is surprising that not a single test has been performed to investigate this further. To the best of my knowledge, no tests have ever been conducted to investigate the effect of rotation – and of course, this begs the question…Why?



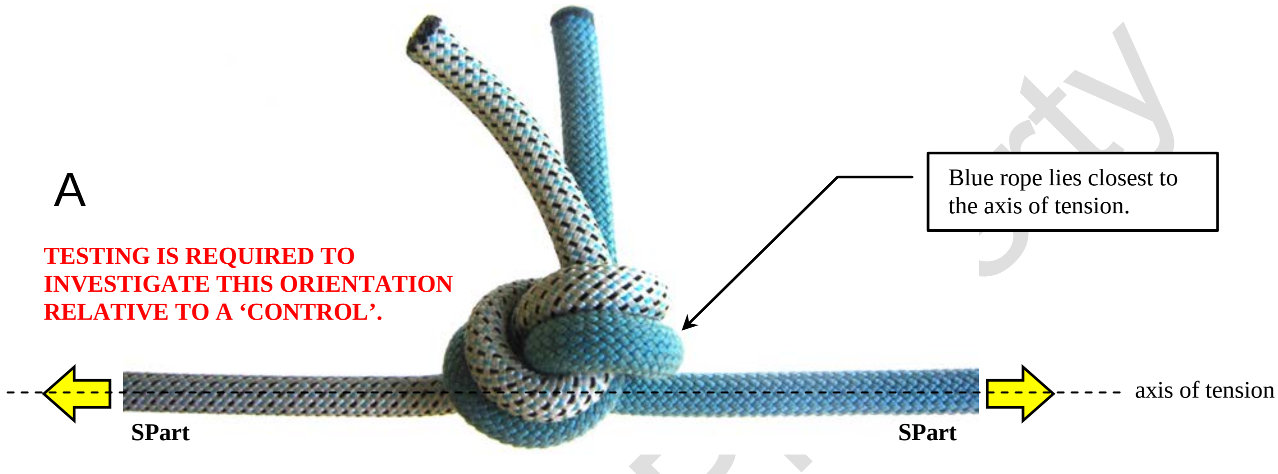
SAFETY RULE: Always set the tails to identical lengths.

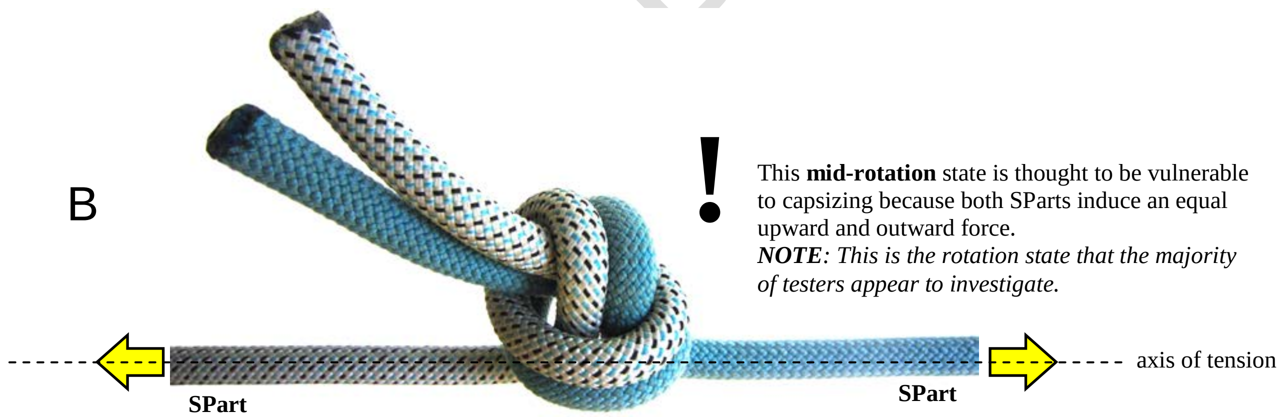
SAFETY RULE: Always set and tightly dress all offset knots by incrementally pulling against each of the four rope segments. You must compress the structure into the smallest footprint possible. You must be diligent and you must check the result of your efforts.

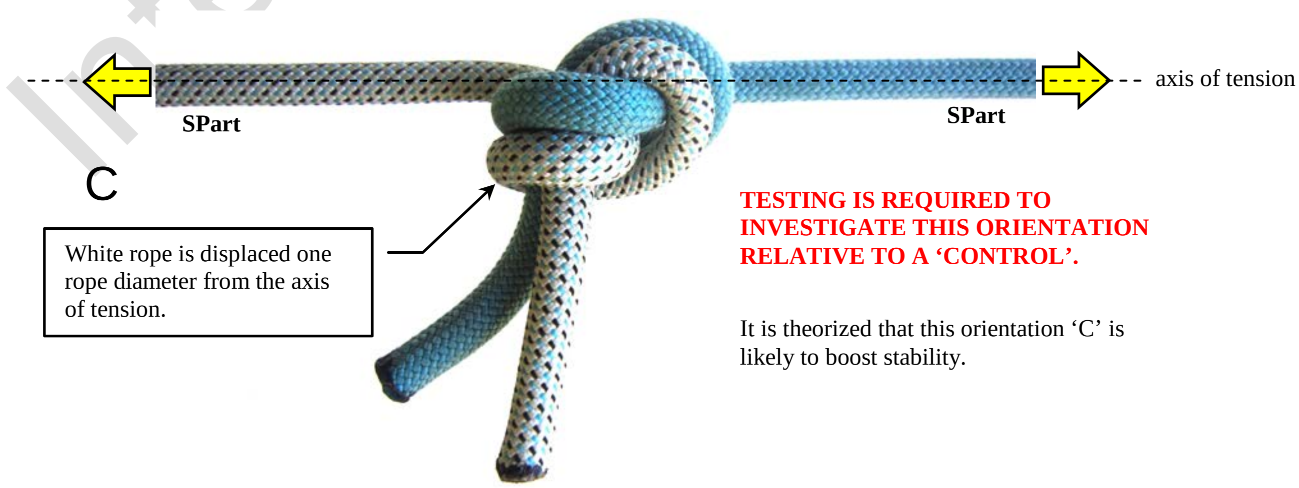
In this configuration, the knot has been rotated so that the blue rope induces a choking effect to trap and crush the tails. **NOTE**: The knot can also be rotated in the opposite direction, in which the white rope would induce the choking effect. Testing is required to confirm how different orientations affect stability.

EFFECT OF ORIENTATION ON STABILITY AND SECURITY (Part 2 of 2)

The following diagrams illustrate various degrees of rotation – from top view perspective. Image ‘A’ shows what is *theorised* to be an effective orientation - the blue rope lies closest to the *axis of tension* and induces the choking effect. Image ‘B’ shows the knot in its mid-rotation state – which is *theorised* to be most vulnerable to capsizing. Image ‘C’ shows the white rope inducing a choking effect – and is displaced farthest from the axis of tension. Dan Lehman posits that each of these rotation states need to be followed up in a round of testing to investigate response to loading (relative to each other). This author posits that image ‘B’ would serve as the ‘control’ for the test.







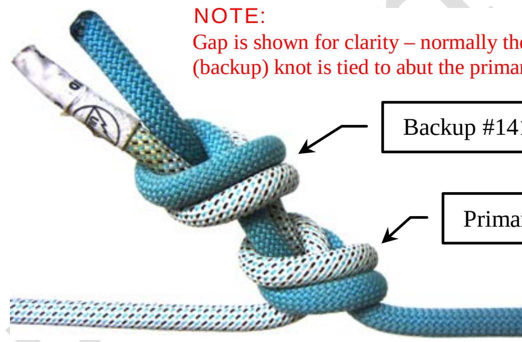
#1410 BACKED UP WITH ANOTHER #1410 (DUPLICATION)

Some commentators suggest duplicating #1410 with a second #1410 in a stacked configuration. The underlying theory for this configuration is that it essentially serves as a ‘backup’ to safeguard against two things:

1. human error; and
2. insecurity caused tail slippage.

In terms of the first proposition (human error), the typical argument that is advanced is in the context of mountaineering (or big wall climbing); where climbers may be fatigued, hypothermic, dehydrated, oxygen starved, unable to think coherently, and generally under extreme pressure to descend quickly. This argument is frequently tendered and often quoted – and appears to be a favourite paradigm of advocates supporting #1410 knot duplication.

The theory is that under these extreme conditions, human error is a real likelihood – and so a duplication of #1410 safeguards against mishap. The proposition is of a qualitative character – and so testing to prove or disprove the matter would be difficult. There are many things that could go wrong in mountaineering – any one of which could have serious consequences. Skills need to be practiced to the extent that they are automatic and repeatable even under times of stress.



In terms of the second proposition, the underlying assumption is that #1410 is inherently unstable and/or insecure. Given a nominal load of just one person – and where the knot is <u>properly dressed and all 4 rope segments cinched tight</u> – the likelihood of any instability or insecurity manifesting is *remote*. Interestingly, some commentators and testers have reported that it is at <u>very low cyclic loads</u>, that insecurity is more likely to manifest (ie via tail slippage failure mode). This needs to be investigated in a round of peer reviewed (and repeatable) tests. It is likely that any such manifestation of insecurity is associated with very slick and/or very stiff ropes or perhaps, in ropes that are frozen/iced.

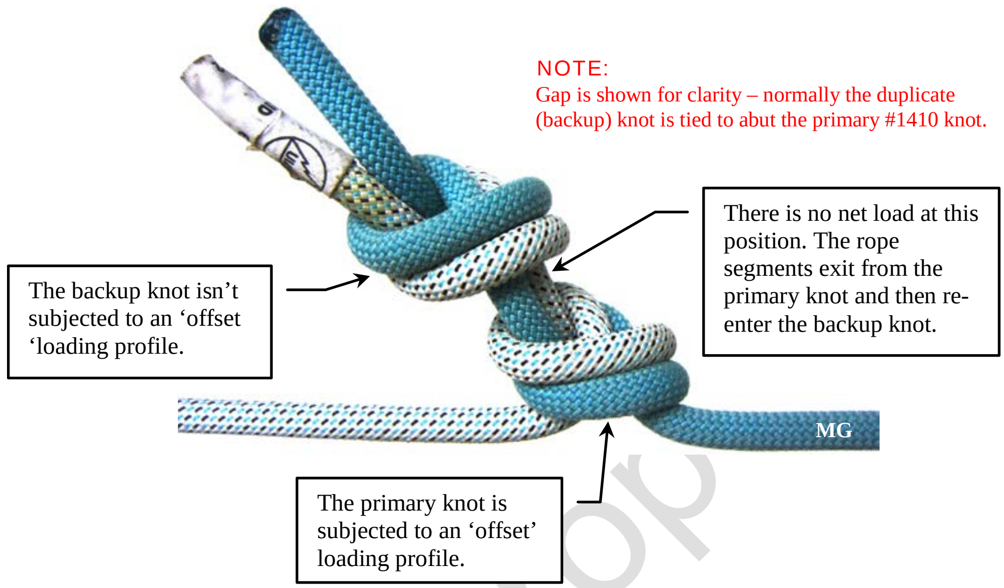
<u>Dan Lehman is an advocate of duplicating #1410 and has posted the following remarks on the IGKT forum:</u>

“Circa 2006, Steve Reid of Needle Sports reacted to a report of another presumed failing of the ‘offset figure 8’ *knot by introducing what he then called the* "double overhand knot" *and which is better named, per its construction, the* "offset water knot with stopper (knot)" *--and in the common parlance among rock climbers,* "EDK-backed-EDK" *will be an even clearer communication of the knot. In short, the primary offset water knot (#1410) which will absorb the main force has its tails --both--tied in a 2nd (duplicate) overhand knot. This 2nd, "back-up" knot will not be loaded in an ‘offset loading profile’ but loaded as a "stopper" knot as its drawn-in to abut the primary knot --and retards any potential slippage of tails out of that primary knot.*
The current reference for the Needle Sports article is date stamped 29/01/2015 and presents this doubled overhand knot at this link: www.needlesports.com/content/abseil-knots.aspx (Lyons test data is also published on this site).

While adding a 2nd, duplicate knot to ‘stopper’ the primary increases the knotted bulk, it does so in a way that ought not to be any problem in general, as this added knot will fit through slots and bounce over/around impediments along with the primary knot. Moreover, it is a better thing to do with the recommended ‘long tails’ --i.e., to knot them—than merely have long tails. At this point, it should be noted that the two knot halves of this compound knot can be tied in either order: once can tie a knot ‘with long tails’ which then are used to make the 2nd knot as a stopper, or if the tails come out not so long, tie the 2nd knot in front of the first -- two ways to the arrive at the same result.

Considering the more material-efficient knots recommended by this paper, one realizes that their aptness often comes with making a particular tying decision. If one gets this wrong, results are not necessarily good. But in reference to Steve Reid’s article in ‘needle sports’; indeed, it seems that one can violate many of the preferred tying recommendations of dressing and orientation with this duplicated knot and the structure will still hold. That is no small commendation for it, at least under certain circumstances!
It is a knot that should be known, and sometimes used.”

#1410 BACKED UP WITH ANOTHER #1410 (DUPLICATION) ... continued



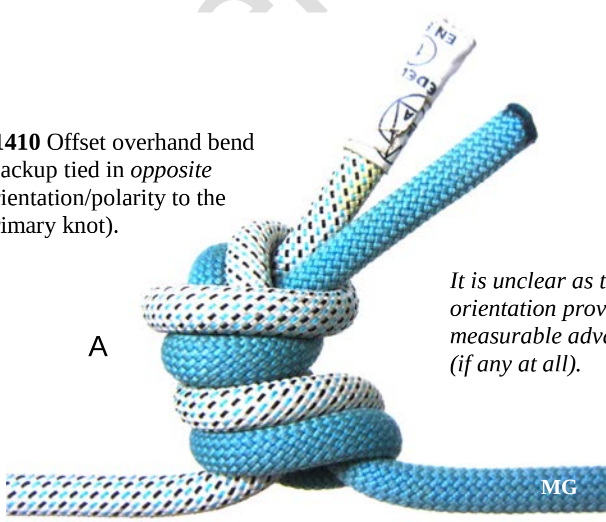
The act of tying a second #1410 to function as a 'backup' doubles the overall footprint (ie area/volume) of the structure. This in turn defeats one of the (ideal) design goals of a rope joining knot – to achieve the smallest possible footprint. The opposite view is that area/volume (ie knot footprint) is irrelevant – and will not contribute to risk of jamming or fouling. A logical view is that as the footprint of a knot increases, so too does its propensity to foul or get stuck somewhere.

Further testing is needed to probe the causal factors that trigger insecurity of #1410. Testing should investigate tail slippage under a variety of test conditions – using a 'control'. Test specimens should include:
[ ] new ropes with slick/slippery sheaths
[ ] stiffer ropes
[ ] ropes with frictive sheaths
[ ] wet and/or icy ropes

Testing should investigate low, cycling loads which is thought by some commentators to be a candidate for triggering insecurity. Until then, it is unclear if duplicating #1410 is simply providing a psychological boost for a problem which is non-existent.

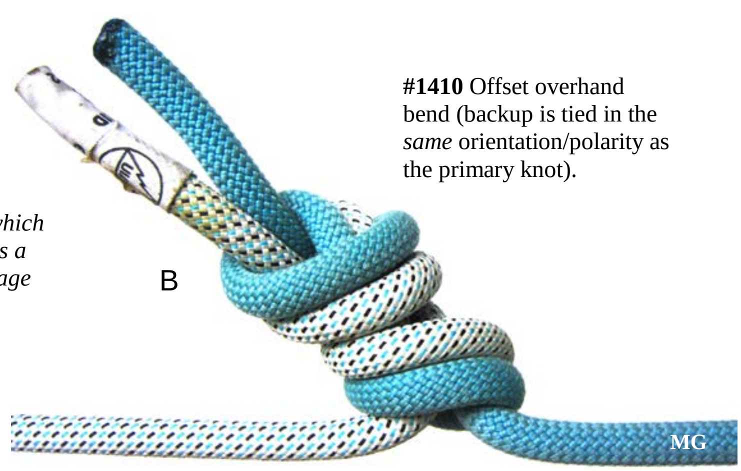
#1410 Offset overhand bend (backup tied in *opposite* orientation/polarity to the primary knot).

A



It is unclear as to which orientation provides a measurable advantage (if any at all).

B



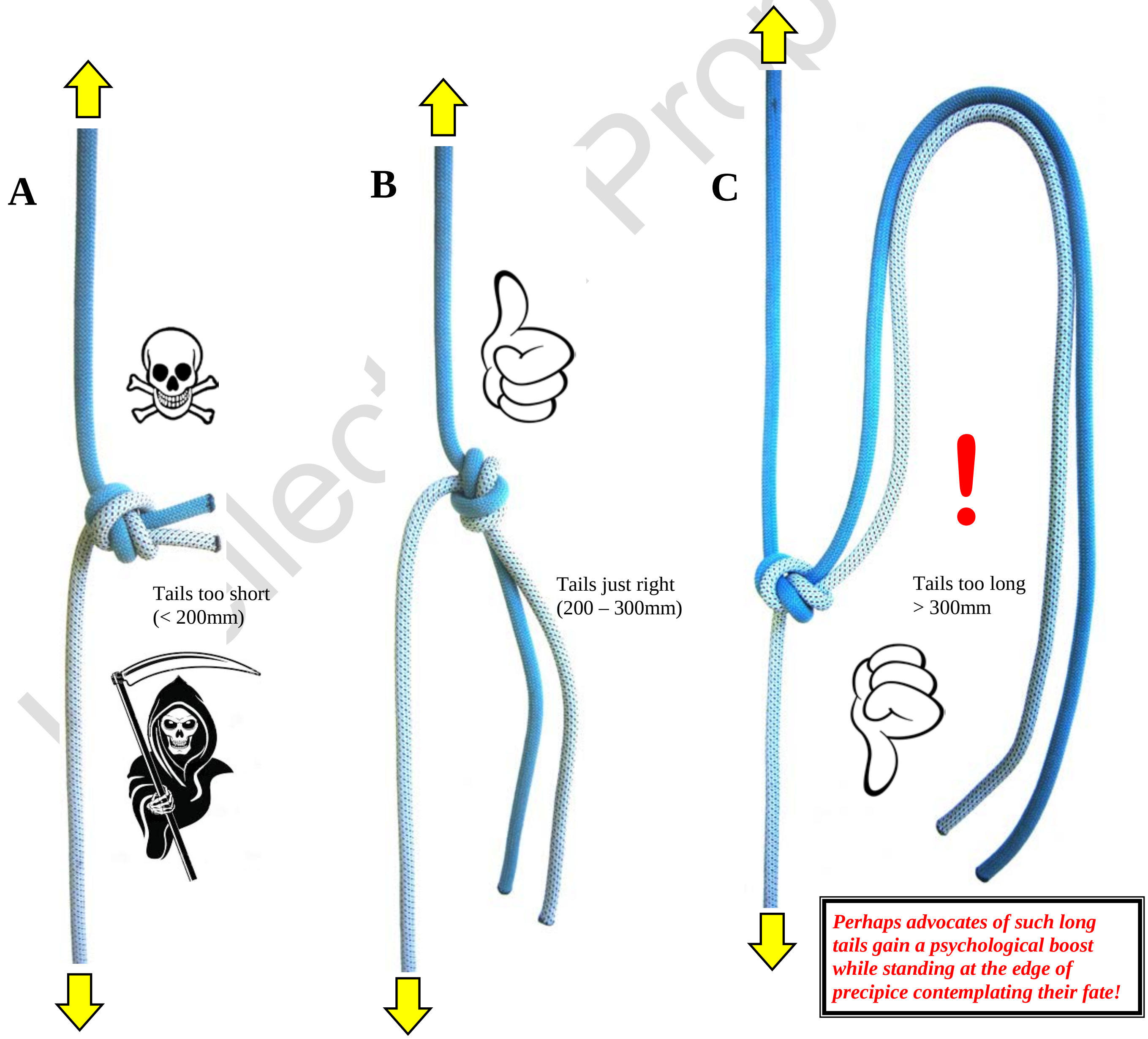
#1410 Offset overhand bend (backup is tied in the *same* orientation/polarity as the primary knot).

LONG TAILS... Does size matter?

Some commentators advocate the use of long tails – with some even suggesting tails as long as 1.0m!

Commentators who advocate long tails are basing their recommendation on the assumption that #1410 is inherently insecure and/unstable. Tying longer tails compensates for this alleged insecurity/instability. In load testing where the force is steadily increased, the knots core (nub) is compressed. As the core compresses, material is drawn in and there is a corresponding and incremental reduction in tail length. This is not 'slippage' – rather, it is a consequence of compression. Vulnerability to *capsizing* appears to be more likely at its *mid-rotation* state but, this can be mitigated by orientating the core so that a choking effect is induced by the rope lying closest to the axis of tension.

This author is of the view that creating long tails (per image 'C') is simply providing a psychological boost for a problem which is largely non-existent. The instability threshold of #1410 appears to be above 3kN – and based on a nominal load of one person, reaching such loads is unlikely to occur. However, little testing has been carried out with icy ropes – and this is an area that future testers should investigate further. It has to be pointed out that mountaineers are the likely 'class of persons' to encounter this icing phenomenon and presumably would have awareness of a range of risks associated with climbing in such conditions (risks are not just confined to joining 2 ropes together).

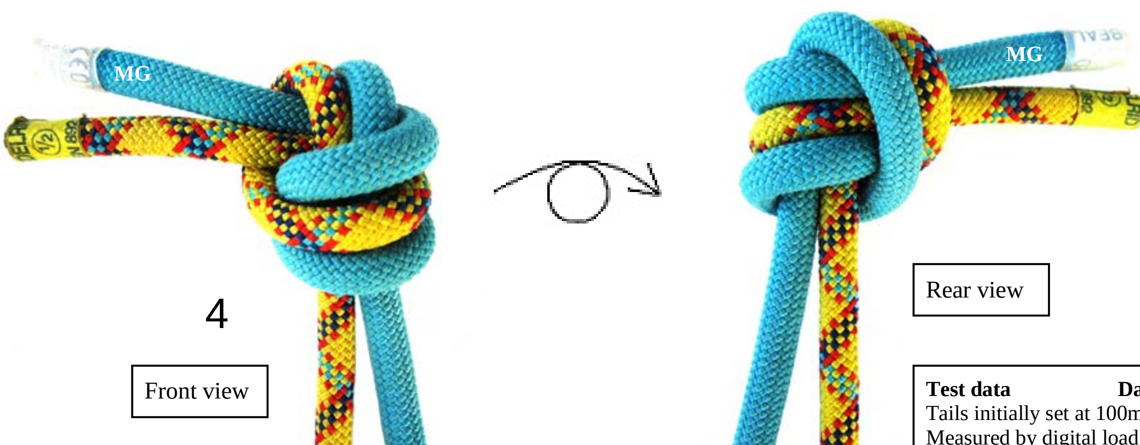


A SIMPLE LOCKING MECHANISM TO ENHANCE THE SECURITY OF #1410

The addition of an extra turn provides a simple locking mechanism to enhance security. The footprint (ie overall area/volume) is not significantly increased. This structure is derived from ABoK #292.

SAFETY RULE…always tie identical length tails with offset knots (minimum of 200mm).

NOTE: Set and dress tightly so that tails are at *minimum* of 200mm when using this knot for human life support

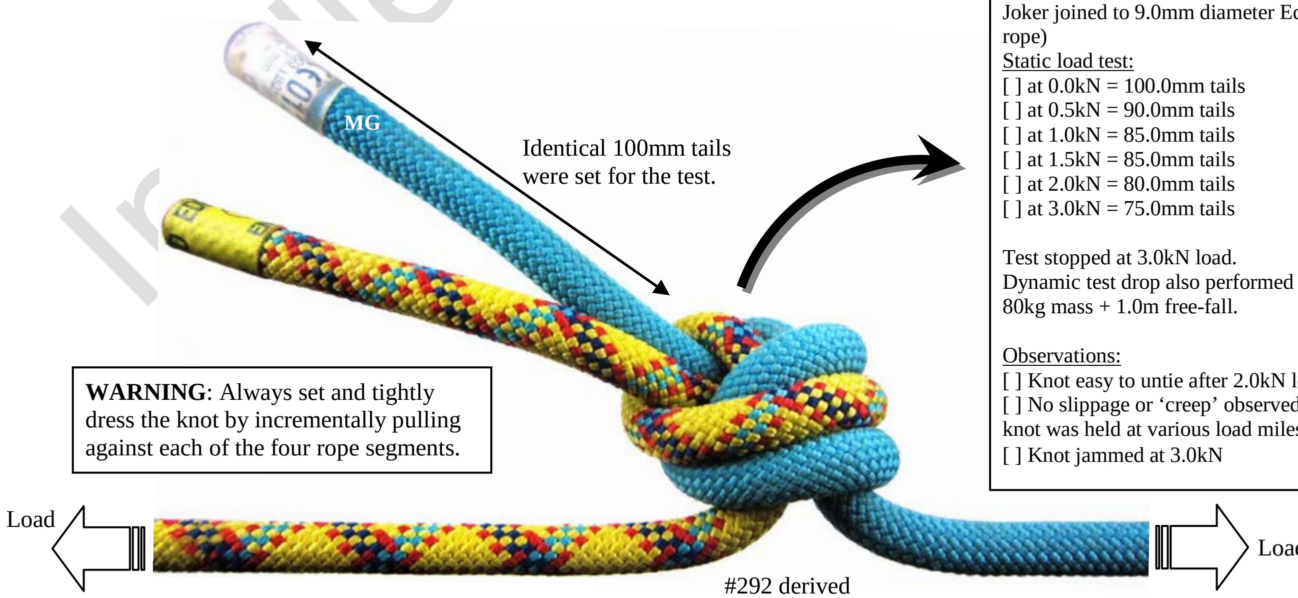


Test data **Date: July 2011**
Tails initially set at 100mm lengths.
Measured by digital load cell.
[ ] EN 892 dynamic ropes (9.1mm Beal Joker joined to 9.0mm diameter Edelrid rope)

Static load test:
[ ] at 0.0kN = 100.0mm tails
[ ] at 0.5kN = 90.0mm tails
[ ] at 1.0kN = 85.0mm tails
[ ] at 1.5kN = 85.0mm tails
[ ] at 2.0kN = 80.0mm tails
[ ] at 3.0kN = 75.0mm tails

Test stopped at 3.0kN load.
Dynamic test drop also performed with 80kg mass + 1.0m free-fall.

Observations:
[ ] Knot easy to untie after 2.0kN loading
[ ] No slippage or 'creep' observed while knot was held at various load milestones.
[ ] Knot jammed at 3.0kN



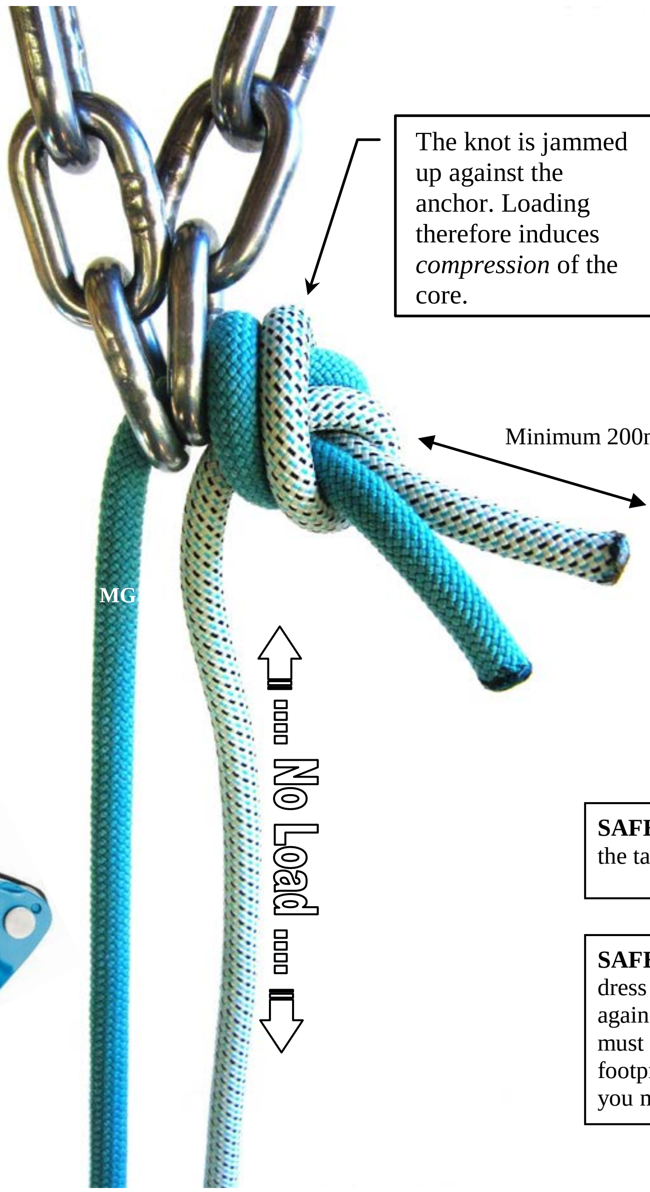
WARNING: Always set and tightly dress the knot by incrementally pulling against each of the four rope segments.

#292 derived

RIGGING FOR A SINGLE ROPE DESCENDING DEVICE

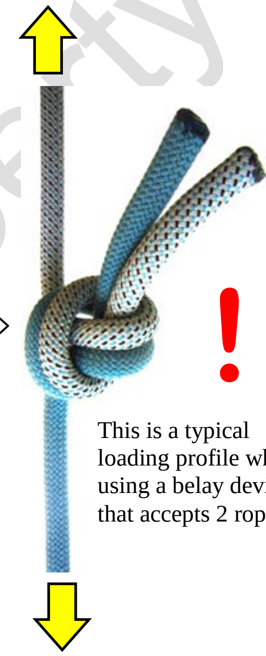
This technique can be used when a person descends with a device that can only accept a single rope (eg a self-locking device such as a GriGri). The loading profile induced on the knot core is different because only one SPart is under tension (the opposite SPart experiences no load). This causes the knot core to be compressed up against the anchor that the ropes are fed through (eg chain links, or rings, etc). Test data of this particular loading profile is very hard to find… (this author could not find any data as at the time of this writing).

WARNING!
Always check and confirm that the knot cannot pull through the anchor. You must be diligent and you *must check and then re-check*. Your life depends on this!



The knot is jammed up against the anchor. Loading therefore induces *compression* of the core.

Minimum 200mm tails



This is a typical loading profile when using a belay device that accepts 2 ropes.

Note: Some belay devices only accept a single rope.

SAFETY RULE: Always set the tails to identical lengths.

SAFETY RULE: Always set and tightly dress all offset knots by incrementally pulling against each of the four rope segments. You must compress the structure into the smallest footprint possible. You must be diligent and you must check the result of your efforts.

Load

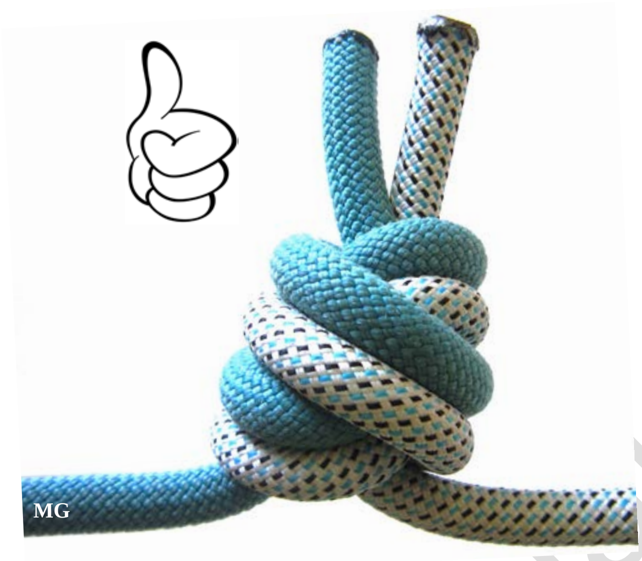
Pull this end to retrieve the ropes.

ALTERNATIVE OFFSET BENDS TO CONSIDER

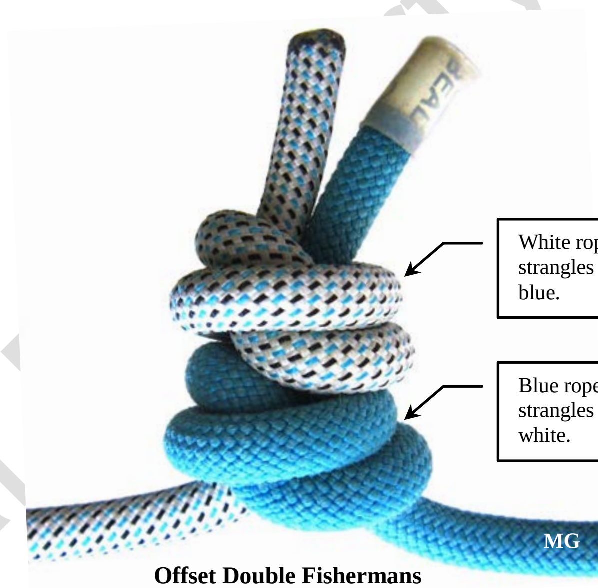
#1410 is the simplest offset end-to-end joining knot. However, there are alternatives although they will all have a larger footprint.

SAFETY RULE: Always set and tightly dress all offset knots by incrementally pulling against each of the four rope segments. You must compress the structure into the smallest footprint possible. You must be diligent and you must check the result of your efforts.

SAFETY RULE: Always set the tails to identical lengths.



Offset Double Overhand Bend



White rope strangles blue.

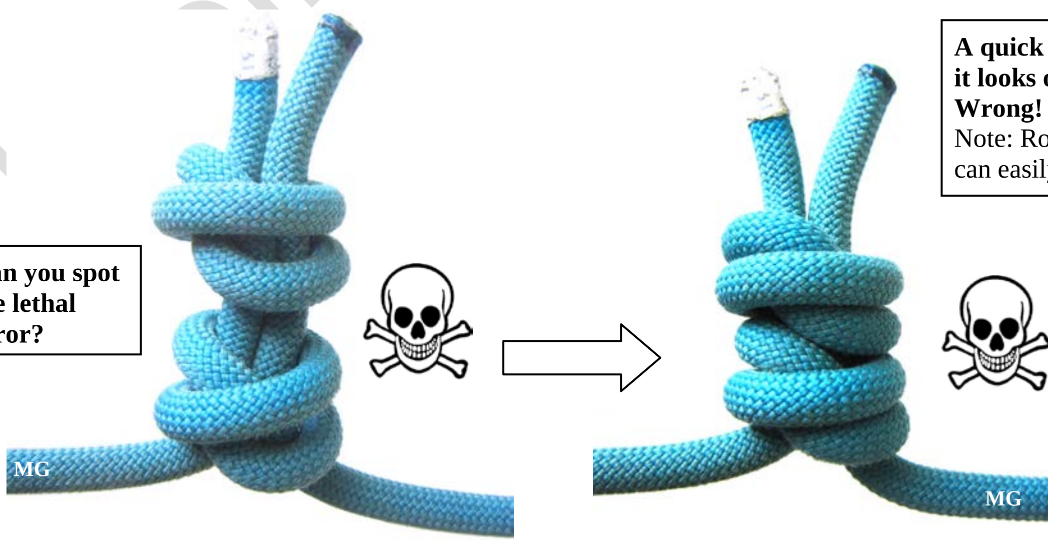
Blue rope strangles white.

Offset Double Fishermans

Warning!
Avoid using 2 ropes of the same color. It is critically important that each rope strangles its *opposite* color.

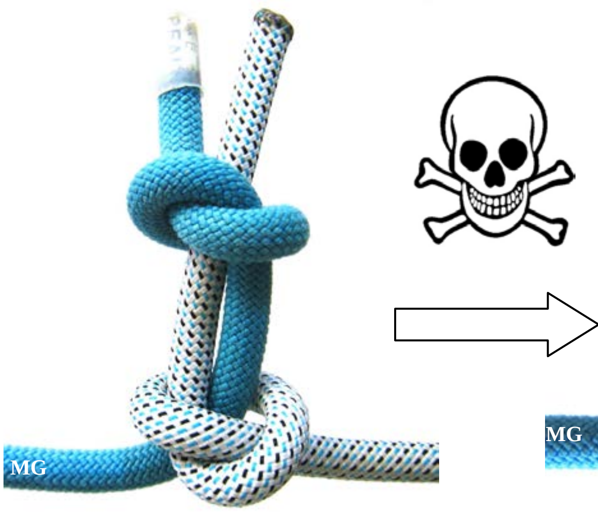
A quick glance of this knot… it looks okay - right? Wrong!
Note: Ropes of the same colour can easily mislead users.

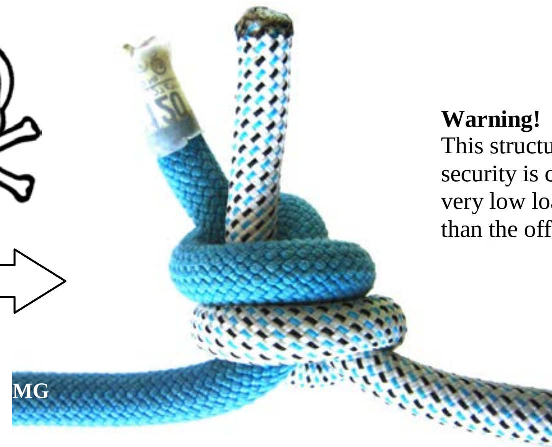
Can you spot the lethal error?



UNSAFE OFFSET KNOTS (AVOID)

Each of the following offset bends involves significant risk of injury or death.





Warning!
This structure is unstable – security is compromised at very low loads – even lower than the offset F8.

Offset Single Fishermans Bend

Offset Figure 8 Bend
(flat dressing state)

Offset Figure 8 Bend

The offset figure 8 has been implicated in some accidents.
One of the problems with follow up investigations involving joining knots that come apart is that there is no evidence left to examine (because the ropes became separated). This results in some speculation as to what may have occurred.

SYMMETRIC vs. ASYMMETRIC BENDS

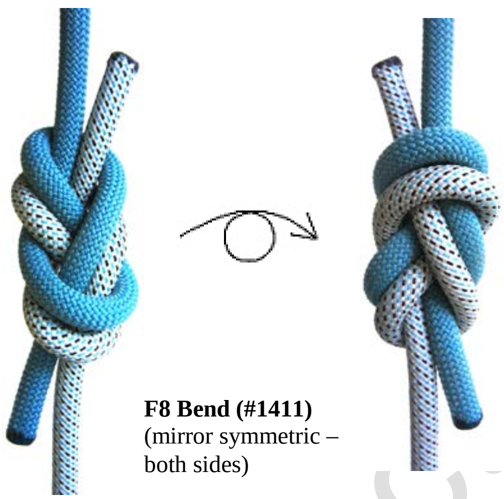
End-to-end joining knots may be symmetric or asymmetric.

Symmetry has a complex meaning in geometry since there can be different forms such as:
[ ] mirror symmetry (aka reflectional symmetry)
[ ] rotational symmetry
[ ] point symmetry

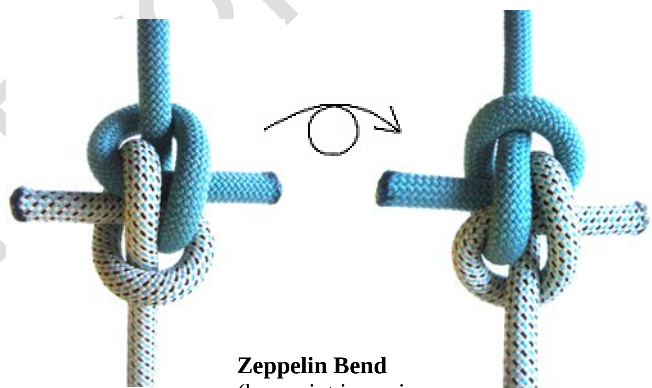
In geometry, two figures or objects are **congruent** if they have the same shape and size, or if one has the same shape and size as the mirror image of the other. For two dimensional shapes, "reflectional symmetry" refers to a "mirror image" on both sides of a 'line of symmetry' (also known as 'axis of symmetry').

For an in-depth treatment of symmetric bends, refer Roger E Miles "Symmetric bends: How to join two lengths of cord" ISBN 981-02-2194-0 published in 1995 by World Scientific Publishing Co.

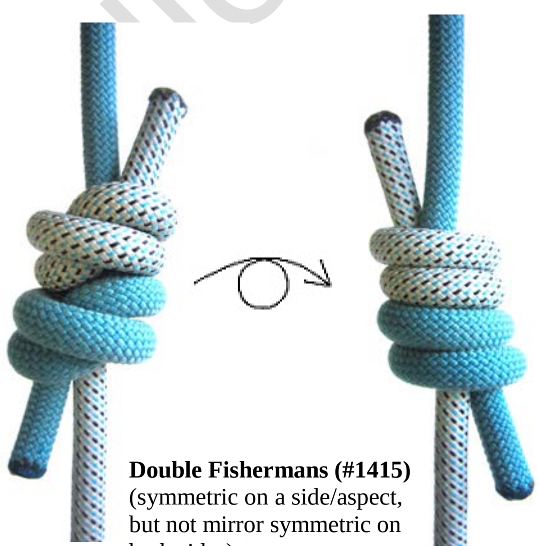
<u>Examples of symmetric bends</u>



F8 Bend (#1411)
(mirror symmetric – both sides)



Zeppelin Bend
(has *point inversion symmetry*



Double Fishermans (#1415)
(symmetric on a side/aspect, but not mirror symmetric on both sides)

WARNING!
The tail lengths in each photo are deliberately tied short. This was to ensure the full knot image would fit within the narrow macro field of view of the camera lens.

SYMMETRIC vs. ASYMMETRIC BENDS continued...

These end-to-end joining knots are asymmetric.

#1053 derived
(Butterfly bend)
Warning… this knot can easily be miss-tied resulting in a less stable form.

Warning!
Do not use #1431 (Sheet bend) for life critical applications. This knot is shown to illustrate a concept only.

#1431 Sheet bend

#1410 Offset overhand bend

WARNING!
The tail lengths in each photo are deliberately tied short. This was to ensure the full knot image would fit within the narrow macro field of view of the camera lens.

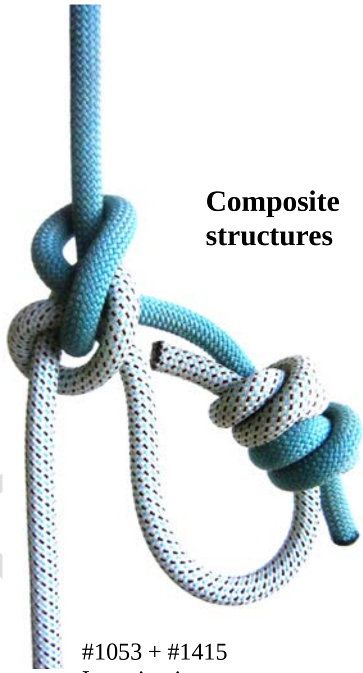
ALTERNATIVE RETRIEVABLE ABSEIL CONFIGURATIONS

The following photos indicate a range of different joining knots. Note that none of these knots are ‘offset’ – which means you need to be 100% certain that there is no possibility of edges upon which the knot could snag or get caught up on during the retrieval process. The Zeppelin bend is particularly remarkable because it is jam resistant, works with unequal diameter ropes and is inherently secure.

Very secure

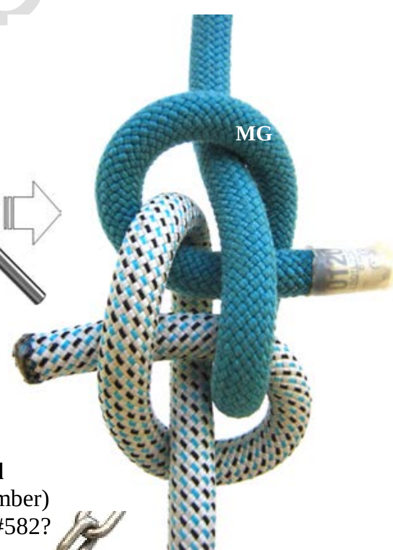
#1415
(Double Fishermans)

Composite structures

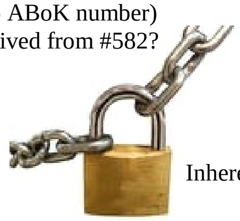


#1053 + #1415
Intention is to create a fixed eye which can aid knot bypass procedure

#1402 + #409
Sometimes referred to as a ‘Square fishermans’



Zeppelin bend
(No ABoK number)
Derived from #582?



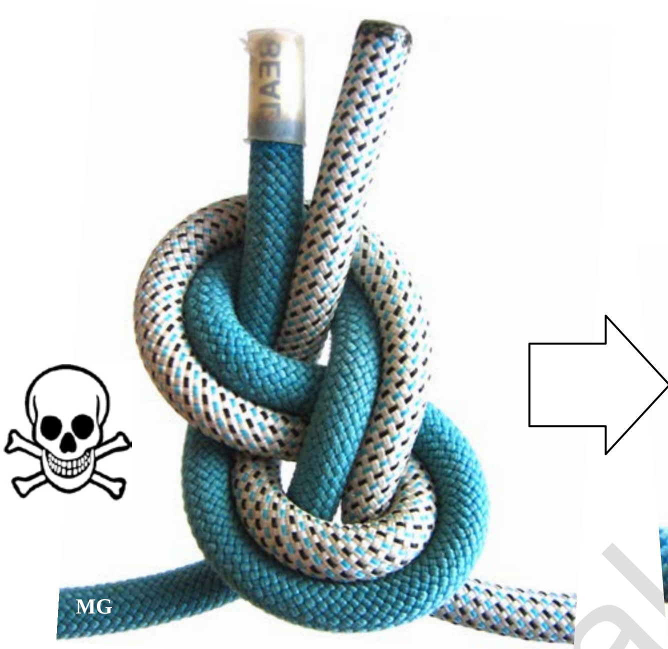
Inherently secure

#1053 derived
(Butterfly bend)

FUTURE INVESTIGATION AND TESTING

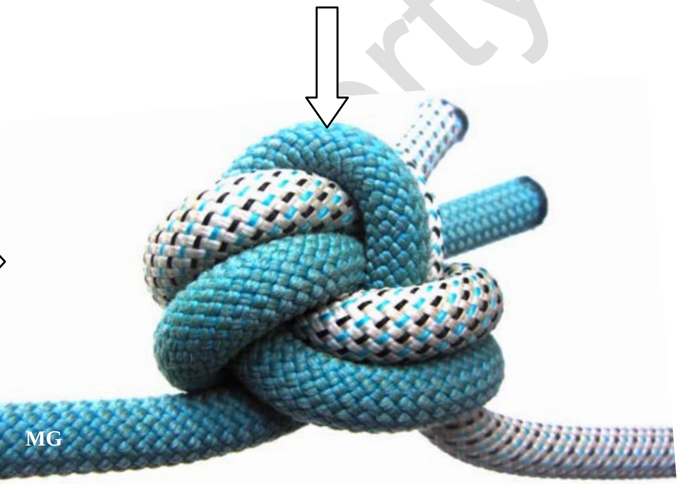
The offset Figure 8 (F8) can in fact be cinched and oriented so that a choking effect is induced to trap and crush the tails. This requires *diligence* and *patience* to achieve. This author was unable to find any test data about different orientations of the F8. Most knot testers simply dismiss the offset F8 bend as unsafe – without investigating different dressing states.

<u>Offset figure 8</u>



This flat dressing state is inherently unstable

The blue rope is oriented to induce a choking effect to trap and hold the tails.



This dressing has not been thoroughly investigated or tested.

Another variation of the offset F8 where the tails exit the core in *opposite* directions. This dressing has not been thoroughly investigated or tested.
Dan Lehman refers to this structure as "Offset 8-OH" (due to the integration of an '8' and an 'overhand' knot).

It is hoped that future knot testers will adopt a different mindset from the norm of raw MBL break tests.

<u>More test data is required in the following areas:</u>
[ ] threshold load that triggers instability (which may be a 'probabilistic' load or a range)
[ ] threshold load that triggers jamming
[ ] comparative testing of the relative rotation states (the mid-rotation state would be the 'control')
[ ] comparative testing of different rope diameters and their position relative to each other
[ ] tail draw-in as load increases…what minimum tail lengths are sufficient to counter any tail shrinkage due to core compression?
[ ] pull down tests to investigate force required to initiate knot translation around a 90 degree edge
[ ] dynamic drop tests to investigate knot response to shock loading (rather than slow pull testing)

CONCLUSION

A quick browse on internet social forums reveals continued confusion, disinformation and heated debate about what is the 'best' end-to-end rope joining knot.

Here are some links that illustrate the attitudes and opinions of contributors on some online climbing forums:
Link: https://www.mountainproject.com/forum/topic/112376280/euro-death-knot-flat-overhand-barrel-knot-evolution
Link: https://www.ukclimbing.com/forums/t.php?t=426658
Link: https://14ers.com/forum/viewtopic.php?t=50757
Link: http://www.climbing.co.za/forum/viewtopic.php?t=16566
Link: https://northeastalpinestart.com/2016/09/27/one-of-these-knots-can-kill-you/

Reading through these forums is like pulling teeth – it is painful and you just want to reach the end. But it does serve as a useful barometer of the general level of knowledge in the community. Why so much confusion and disinformation? The answer to this question is that climbers (in general) aren't knotting experts – they are *users* of knots. Knowledge and skills are typically learned ad-hoc from friends and acquaintances – and some concepts are simply *assumed* to be correct. There is no singular authoritative source of information and the climbing community (from a world perspective) is fragmented and self-regulating. Internet discussion forums are a prime source of both inaccurate and (rarely) accurate information.

Joining 2 ropes together is an essential skill for climbers, canyoners and cavers, because it enables longer abseil descents and also because it enables ropes to be retrieved. This is considered particularly important in activities that involve *multi-pitch* descents.

Often cited reasons for using a particular rope joining knot include:

1. ability of others in the party to check and verify that the knot geometry is correct; and
2. strength (ie MBS yield).

The argument that you should only use knots that others can check and verify is nonsense and effectively inhibits innovation and progress. There are classes of users who climb solo (ie rope solo) and there are also professional Guides who offer private (ie one-on-one) services. The rope solo climber has no one to check or verify anything. The professional Guide who is with a novice 'client' can't ask that client to check and verify a particular knot – that would be a *meaningless* gesture. In the typical example of social groups who undertake adventures at height, there is usually an imbalance of knowledge, skill and expertise within the group. More often than not, one individual has the most experience and is largely responsible for the technical decisions at crucial points in the activity. Again, the lesser experienced members of the group aren't in a position to provide *meaningful* checks on safety elements.

What matters most is the *confidence* and level of competence of the individual. There are 4 stages of competence as follows:

1. Unconscious incompetence; and
2. Conscious incompetence; and
3. Conscious competence; and
4. Unconscious competence.

If you are going to be in a situation where knots will be employed in life critical applications (to avoid injury and/or death), you need to be at stage 3 or 4 in the development cycle. In other words, if you are going to join your ropes together using a particular knot, you need to be 100% confident in your own ability and be 100% certain that the selected knot will perform as intended.

Climbing instructors should broaden their skill base beyond that which was initially learned – and even go so far as to question old ideas. There are many accepted norms in climbing/abseiling/caving sports, some of which are simply passed by word-of-mouth from one generation to the next. Knots aren't the only source material that is continuously subject to debate – other 'controversial' topics include aging of ropes (expiry dates), weighing more than 80kg and falling on a dynamic rope, dropping carabiners, exposure of textile PPE to non-acidic chemicals, which tie-in knot for climbing is best, and which type of bolt and bolting system is best for a given rock type and local environment conditions (this list is not exhaustive). The early pioneering days where 'the climber must not fall' were simple.

With regard to knot 'strength'...

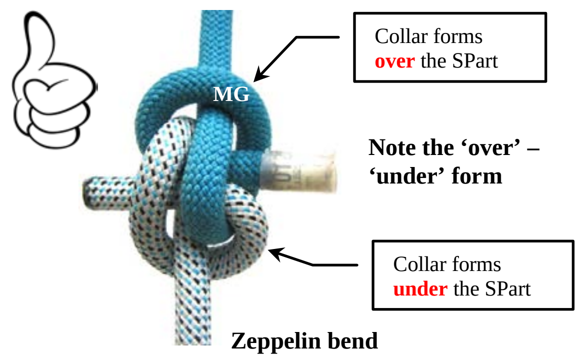
Raw 'pull-to-failure' tests to investigate the relative MBS yield of knots produce misleading results and are often *irrelevant*. The ability to select and tie an appropriate rope end-to-end joining knot (ie 'bend') that is both secure and stable is more important than strength. Furthermore, the nominal load is only the weight of one person. In a typical retrievable abseil setup, the joining knot will only experience 50% of the load.

And yet, the climbing community and the majority of knot testers have a default mindset that knot 'strength' is the singular most important factor. Knot testers typically base all of their conclusions on one criterion – strength. And so the knot testers themselves are part of the problem – in that they publish their results into the public domain – and the lay public simply assumes that their information and results are meaningful. Commentators often confuse strength with security and stability – and fail to understand that there is no load that a climber/abseiler/caver can generate that will reach the MBS yield point of a knot. This begs the question; why is knot strength given such a high level of importance? It is likely that the concept of knot strength has been passed from generation to generation while rope performance in particular has improved by orders of magnitude. The days where 'a climber must *not* fall' have long expired – with the norm being substituted with 'falls are now a routine occurrence'. It has to be stated that knot book authors are also guilty for influencing thought patterns on knots – where they typically publish 'knot efficiency' data showing relative % strengths / breaking loads. It is hoped that this paradigm will change.

If there is almost zero chance of a knot becoming stuck at an edge or being caught up somewhere on the cliff, there are less restrictions on choice. A Zeppelin bend is one of the most secure and stable joining knots known – and it is totally jam resistant. But, as with any knot – due diligence and attention to detail is required when tying – and it can be confused with #1425A Riggers bend (per Phil D Smith) aka 'Hunters bend' which has a propensity to jam.

There is absolutely nothing wrong with learning new knots, and this author recommends the use of the Zeppelin bend where it is *unlikely* to get caught up on edges. If the rope joining knot has to translate around a 90 degree edge, only an 'offset' knot will be suitable.

ALWAYS SET
IDENTICAL
TAIL LENGTHS



#1410 Offset overhand bend (with extra binding turn).
Concept derived from #292 Gut knot.

Zeppelin bend
(no ABoK number)

PRACTICE IS KEY – YOU MUST BE WILLING TO INVEST TIME AND EFFORT IN DEVELOPING ROBUST KNOTTING SKILLS.

It is important to emphasise that no matter which end-to-end rope joining knot is selected, due diligence is required… that is, you must carefully and accurately tie the knot and pull incrementally on each of the 4 rope segments to properly set and dress the structure. Sufficient *identical* tail lengths must be protrude from the knot core – at *least* 200mm (but not excessively long tails). Check and then re-check the knot to make sure it is 100% correct.

Dressing and orientation of offset knots will impact upon stability and security. A simple rotation of #1410 can significantly boost its stability. Future testing should investigate this further.

It is hoped that the information presented in this paper will contribute to safety and help correct some of the myths surrounding #1410.

Mark Gommers
17 June 2017