Anchors and anchoring gear

Kim Klaka Dec 14

Contents

1. INTRO

The Sleep Test: If you won't sleep well at anchor with the system you have, then it is the wrong system.

The Mooring Test: If you prefer to pick up a mooring rather than anchor overnight then you have got the wrong anchor gear.

A good anchoring system will keep you in place but who knows how dodgy that mooring is? Even if you dive on it you can't see a corroded link buried in the sand. So how do you end up with a good anchoring system when there is so much conflicting advice out there?

2. REVIEW ON ANCHORING TECHNIQUE

If you have a good anchoring technique then you can probably use an old washing machine for an anchor and it will do the job in most conditions. If you have bad technique then the best anchor in the world won't keep you in place when things get dodgy.

2.1. Scope

The most frequent reason why anchors drag is the mantra repeated in books, training courses and club bars that "you need three times the depth of water" as your anchor scope. Totally inadequate! Use a minimum scope of either 20 metres or 5 times the water depth, whichever is greater (7 times depth if you have a rope/chain mix). If you have less than this and it gets a bit choppy, there won't be enough give in the length of cable to absorb the snatch loads. This will either cause the anchor to drag, or the cable to break, or pull the cleat out of the deck. Let more than this amount out if you can. Anchor cable sitting in your chain locker is not helping to keep your boat safely anchored.

2.2. Deployment

Don't just plonk it all out on the seabed. Bring the boat to a stop before letting the cable out. Let about 1.5 times the water depth out, then gradually let the rest out as the boat falls back with the wind (or as you motor gently back). Pay out the cable so that it lies in a smooth, roughly straight line from the anchor back to the boat. If you let it all go out in a rush it will just sit in a tangled pile on the seabed, a useless mess.

Having let it out, cleat it off somewhere strong and motor back at high revs for at least 30 seconds. Line up two marks on a transit athwartships to check if you are dragging. If the marks go out of line then you are dragging. Pick the anchor up and try again. Don't mess around letting out more scope, it won't work.

3. ANCHOR TYPES

Flat
Danforth, Spade, Fortress

Claw
Bruce

Plough
CQR, Delta

Grapnel
Fisherman, grapnel

New generation
Rocna, Manson, Sarca, Kobra

4. HOW ANCHORS WORK

It's all about pressure – high pressure to make it dig in and low suction to stop it pulling out.

Digging in
You need a certain minimum weight to start penetrating the seabed. The amount depends on the seabed and the surface area presented by the anchor i.e. it is really pressure that counts rather than weight e.g. a heavy fisherman with low surface area will penetrate most seabeds, but….

Staying put
Once the weight has pushed the anchor into the seabed, its holding power is strongly affected by the surface area of the anchor. The greater the surface area for a given load from the boat, the less the suction pulling the anchor out. How much suction will pull an anchor out? It depends on the sea bed – soft mud requires very little suction for the anchor to break out, whereas hard sand or clay requires a very high load to move the anchor. A fisherman anchor is especially poor because it has such a small surface area.

5. WHAT IS THE BEST ANCHOR?

That is a rather pointless question because:

- As you will soon see, there is no anchor that fits all circumstances best, and
- you will need several anchors, so it makes sense to have more than one type.

5.1. Number of anchors

How many for offshore/ocean cruising ?

1. One main anchor
2. Second anchor for double-anchoring

3. Third anchor for different seabed
4. Fourth anchor in case you lose one (or lend it to friends!)
5. Dinghy anchor

Total = 5 anchors!

5.2. In-line holding power

H = high M = medium L = low

	Neeves	Hodges & Springer	Allisy	Sezerat	Gree
Britany			M	M	H
Claw/Bruce	(L)	L		L	M/L
CQR	(L)	L	L	H	M
Delta	(L)	M/H	M	M	
Fortress		H	H	L	H
Kobra	(H)		H	H	
Manson		H	H		
Oceane		H			
Rocna		H			
Sarca	(H)	M			
Spade	(H)	H	H	H	
Wasi Bugel		M			
West Marine Performance 20		L			
Fisherman	(L)				L

Table 1 In-line holding power

Notes:

I have put Neeves (2011) categories in brackets because he does not provide test results for holding power; he simply lists each anchor as either low or high power. Therefore I have disregarded this column when drawing conclusions, though his categories align with test results except for the Delta.

The Gree tests were for an alloy Britany, not a Fortress. They looked similar and the results were similar so I have counted them as Fortress to indicate how alloy anchors perform in general.

5.3. Re-setting

G = good A = average P = poor

	Neeves	Hodges & Springer	Allisy	Sezerat	Gree
Britany			A		
Claw/Bruce	P	P		P	
CQR	P	P	P	P	
Delta	A/G	A/G	A/P		
Fortress		G		P	
Kobra	G		G	G	
Manson		G	G		
Oceane					
Rocna	A	G			
Sarca	A/G	G			
Spade	G	G	G		
Wasi Bugel					
West Marine Performance 20					
Fisherman	P				

Table 2 Re-setting ability

5.4. Findings

1. The Spade and Kobra yielded consistently good results across the different tests. The Delta was consistently average.
2. The Spade, Kobra and Manson showed consistently high holding power, with Delta and Britany consistently medium-high.
3. The Fortress results were mostly good but inconsistent and the CQR results were mostly poor but inconsistent

4. The tests conducted on the Delta show it to be a good all-rounder, though never outstanding. This could explain its popularity.
5. The Claw/ Bruce-style anchors did not perform well and there is no evidence to support the oft held view that they are superior to other anchors when short scope is used. It would appear that the scaling down of oil rig anchoring technology (where the Bruce came from) does not work as well as might be expected.
6. The poor old CQR didn't fare very well except in one test. Perhaps the new designs really have overtaken this "tried and tested" design that originated way back in 1933. (As an irrelevant aside, the CQR inventor G.I. Taylor was an eminent scientist whose research in hydrodynamics won high acclaim.)

5.5. Influence of sea bed type

There is often more variation between test results for a single anchor than the variation in results between different anchors. This variability in results goes a long way towards explaining why there are so many different anchor designs and why there is so much apparently conflicting advice out there. Whilst the holy grail is an anchor that performs consistently well, the reality is that an anchor can be very useful for certain circumstances even if it performs badly in others. The fisherman anchor is an excellent example – fairly hopeless in sand and mud but excellent for those rare occasions when you have to anchor in weed.

Seabed type	**Hardness**	**Shear strength**	**Anchor type**
Mud	Very soft – soft	Weak	flat are best, claw OK, plough not so good
Silt	Soft – medium	Medium	All Ok
Gravel	Soft (between pebbles)	Weak	New gen (large surface area + tip weight)
Clay	Medium	High	Heavy old ones and new gen
Sand	Medium-hard	Medium-high	New gen good. Flat and plough can skid on hard sand
Rock	Impenetrable	Very high	Fisherman
Weed	-	-	Difficult - Flat and/or sharp-tipped

Table 3 match anchor to seabed. Source: YM Feb 14

5.6. The 2011/12 Rocna controversy

A batch of Rocna anchors were made with a shank of sub-standard steel between 2009 and 2010. None were reported to have bent or broken under use, but tests proved they were sub-standard yet no product recall was issued. In 2011 the licensed manufacturer (Holdfast) went into liquidation. There was lots of mud-slinging in the yachting press. The products from the subsequently licensed manufacturer (Canada Metals Pacific) seem to be fully up to standard. The only remaining uncertainty is the quality of some of the second hand anchors made in 2009-2010. I would not consider this saga relevant when selecting a new anchor.

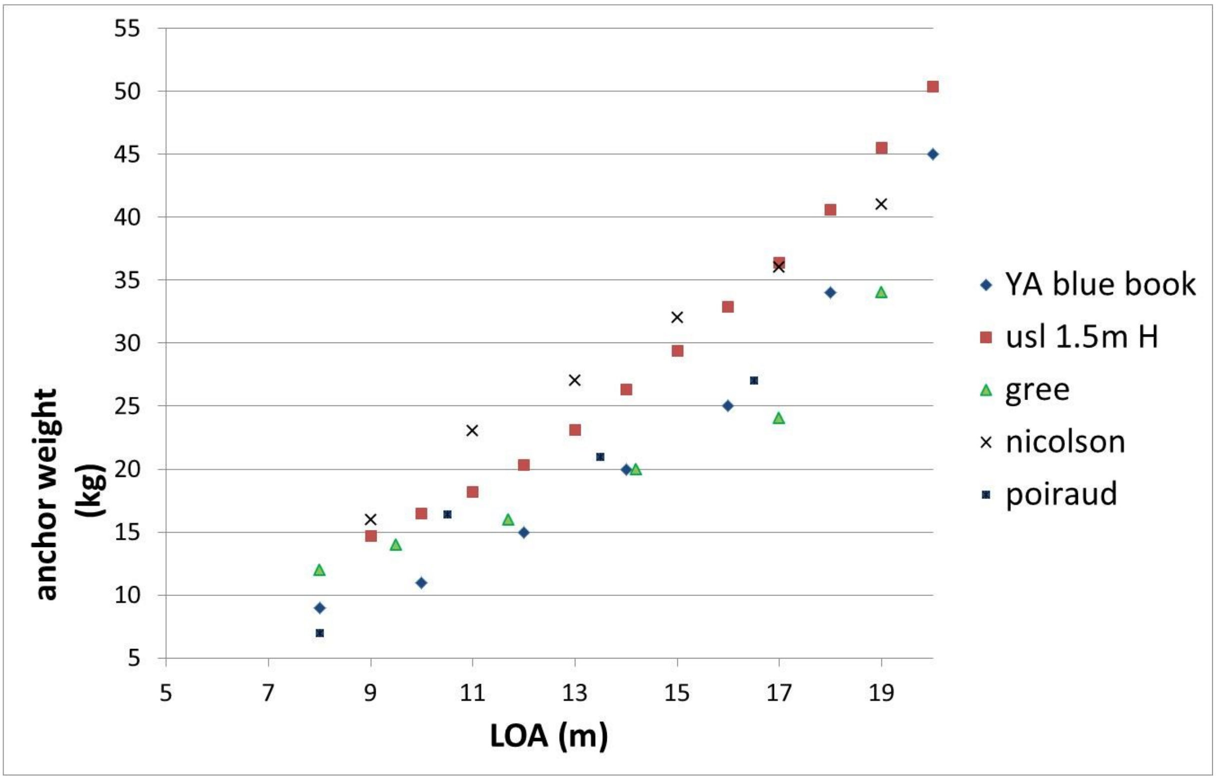
5.7. Other things

Do not use a cheap copy! They may be either weak or the wrong shape.

Beware of re-galvanising an anchor that uses lead to balance it (e.g. CQR, Delta) – the lead melts in the galvanising bath and has to be replaced.

5.8. Recommended sizes of anchor

Size – always buy bigger than you think you need. A large anchor helps you sleep at night.



Analysis of size recommendations from 5 different sources yields best fit of:

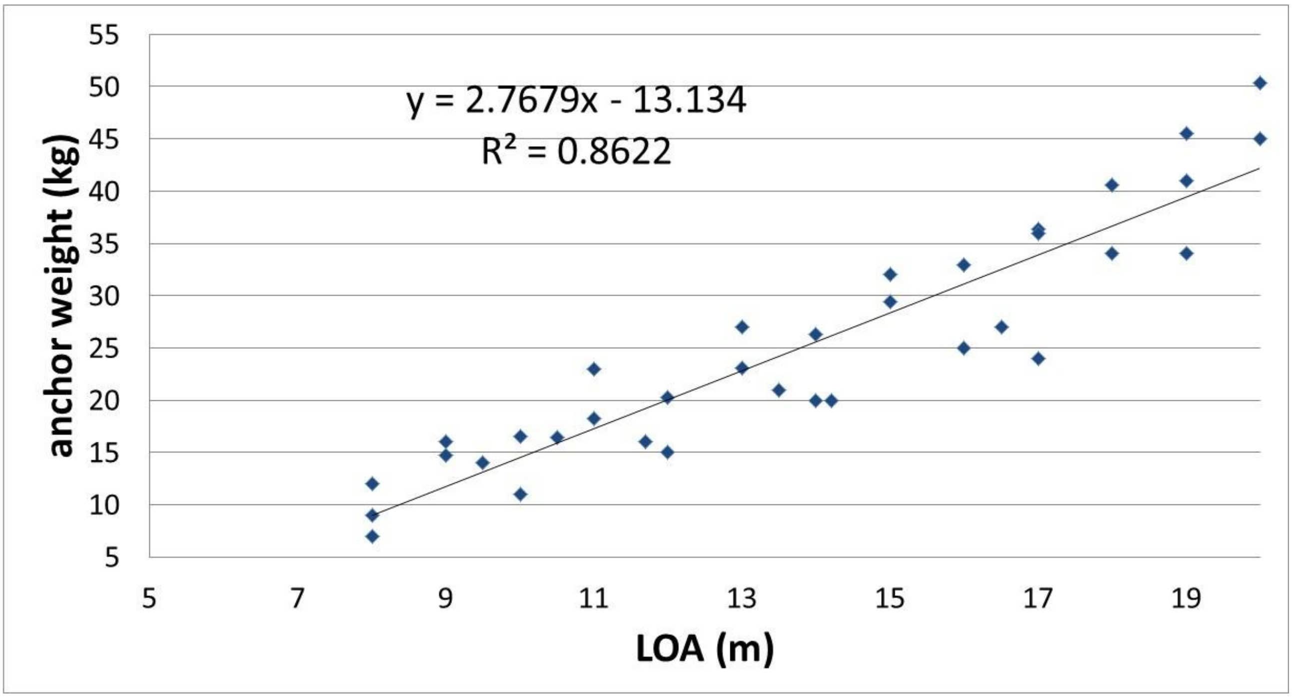
y = 2.7679x - 13.134 with a regression coefficient of 0.86 .

I have simplified this to produce the "*Klaka anchor weight guide*":

Anchor weight (kg) = 3x LOA(m) – 16

e.g. for a 10m yacht you need a 14kg anchor

This is for a typical CQR/Danforth/Bruce anchor on a typical cruising yacht anchoring in typical reasonable holding ground in wind and waves less than storm conditions.



6. CHAIN OR ROPE?

This is a debate about the trade-off between strength, weight, stretch and chafe. It is a topic with plenty of conflicting advice. Two reasons for this are:

- The best option depends on your cruising destinations and your anchoring technique.
- It is all about compromises and where you decide to sit on the scale in the various trade-offs.

Note on terminology: The chain and/or rope connecting the anchor to the boat is called the anchor *rode*.

6.1. Strength

Some definitions

Minimum Breaking Load (MBL) is the force at which the rode breaks. Clearly we need a safety margin or safety factor (SF), which leads to the more useful definition

Safe Working Load (SWL), also called Working Load Limit (WLL) = MBL/SF

The Safety Factor (SF) usually used for anchor chain is 4. The SF for anchor rope is about 5 or 6, sometimes more. It is bigger because rope degrades easier (chafe, sunlight etc.). The choice of Safety Factor is not an exact science, and makes direct strength comparisons a bit difficult.

Galvanised chain

Selecting the right type of chain can be very confusing due to different grading systems, link sizes etc.

The strength of chain for a particular diameter is determined by its Grade. The old system used a number e.g. “Grade 30”, where the definition of that number is, if you are interested:

Grade= 1/10 of the minimum breaking force in newtons divided by two times the nominal cross sectional area in square mm.

Grade 30 is the most common grade used for anchor chain. Some of the cheaper chain around is Grade 20 or even Grade 10. The highest grade galvanised chain is Grade 70; galvanising chain above Grade 80 can cause serious metallurgical problems.

There is a move by many suppliers towards using letters instead of numbers.

- Grade L (mild steel low strength) is most common, and is the equivalent of about Grade 30.
- Grade M is about grade 40
- Grade P (high tensile) is roughly Grade 70 or 80 (conflicting advice). It is difficult to find below 10mm diameter.

So, is it better to have a long length of light chain or a shorter length of heavy chain of the same strength and all-up weight? The answer is that both have same energy absorption (see Annex A), so there is not much point in using high strength chain as it corrodes quicker. Besides, it’s a false dilemma – best of all is to use a long length of heavy chain!

Note: galvanizing can reduce strength by about 20%.

Stainless steel chain

Stainless looks pretty but it is expensive and unreliable. Stainless chain has a breaking strength about the same as Grade L chain but suffers work hardening and crevice corrosion problems (so needs a bigger Safety Factor).

So it is usually cheaper and safer to regalvanise (or replace) ordinary Grade L chain than to select stainless steel chain. A similar argument applies to stainless steel anchors.

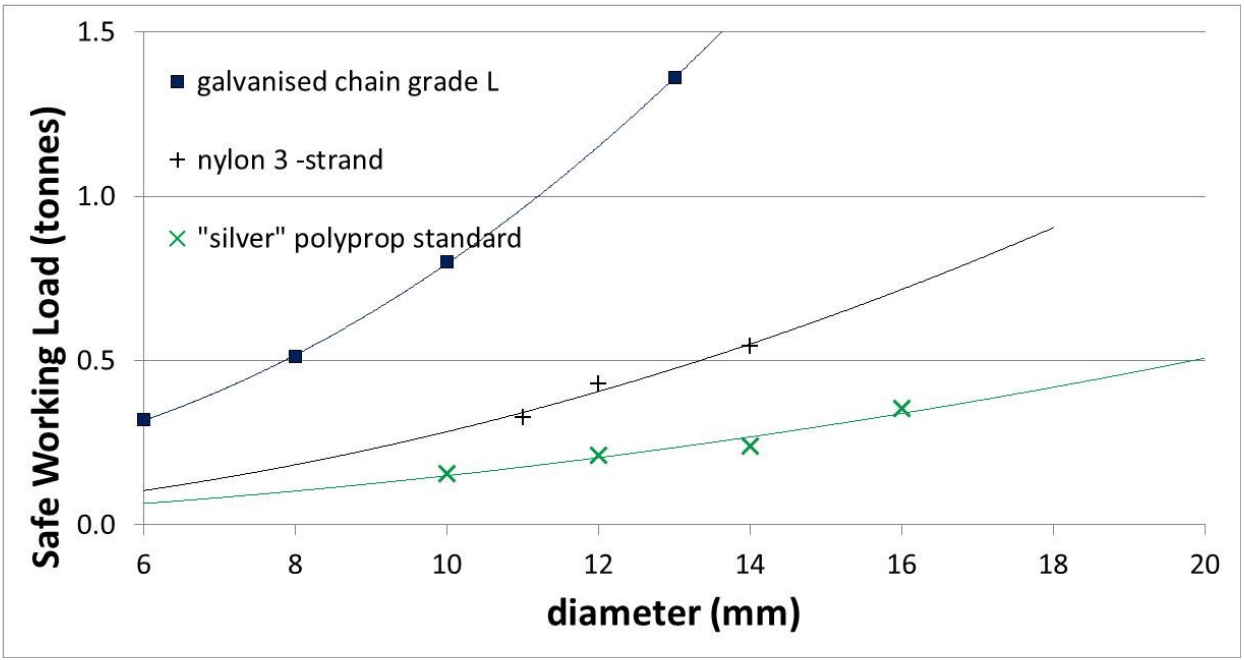
Rope

You will always have to have some length of chain connected to the anchor (see later under “chafe”), but you may choose to use a mix of chain and rope for the complete rode. You need to ensure the rope has at least the same strength as the chain. The graph below gives you a guide. In using it you need to be aware that there are lots of different types of rope. Even if it is called ”nylon” or “silver” or “ polypropylene”, there are big variations under each heading depending on how it is made, the exact material, whether it is wet or dry etc.

The materials selected are intended to be representative of what is commonly found on many yachts:

- Chain is L grade galvanised
- Nylon is 3-strand of a type not too much affected by moisture.
- Silver is standard (not high-strength) good quality 3-strand.

Silver is nasty stuff for anchor rode – it is weak and it floats. Nevertheless people still insist on using it because it is cheap, so I have included it here.



Strength of chain and rope. Sources: Bullivants and Engineering Toolbox

From the above graph, if we want to match say, 8mm chain, then we need to use 13mm nylon or 20mm silver rope. To illustrate the very general nature of this graph, some reliable sources say that 11mm nylon has the same strength as 8mm chain.

6.2. Stretch

But does strength matter? It is the shock load that breaks a chain, so the key is to reduce the shock load by introducing stretch (with rope) or catenary (chain weight). Catenary is simply the amount of curve or bow in the chain as it hangs from the boat to the anchor. If it is stretched taut into a straight line then there is no catenary.

The key to providing stretch is that you simply must have *some* rope in the system somewhere. Why can't you rely solely on the chain catenary to absorb the shock loads? Because at some point (high wind speed or waves, or short scope), the chain will stretch taut; and once it is taut it has no ability to absorb any more energy, so it will either break or pull the anchor out of the sea bed.

So the question is not whether to have rope, but how much? You must therefore have either a mix of chain and rope, or use a snubber. If you go for a mixed rope/chain rode, the answer to "how much chain" is given later – rather surprisingly when we discuss chafe.

Snubbers
The snubber is a vital component of your anchor gear if you use all-chain rodes .It is a length of stretchy rope maybe 10m long, tied round the bow mooring cleat at one end and attached to the mooring chain underwater at the other

- It takes the load off the windlass and
- it provides some stretch in the system.

Snubbers are best made of nylon because it stretches and is also strong.

The amount of stretch is directly proportional to length and inversely proportional to the square of the diameter e.g.

- A 6m long snubber stretches twice as much as a 3m long snubber.
- An 11mm diameter snubber stretches twice as much as a 16mm diameter snubber.

A 12mm diameter nylon snubber has about the same breaking strength as 8mm Grade L chain when new.

So a small diameter nylon snubber is strong enough and provides the stretch you need; whereas a large diameter snubber defeats its purpose.

6.3. Chafe

One of the biggest drawbacks to using rope is its susceptibility to chafe. However, you must have rope somewhere in the system so you simply have to deal with the problem.

There are two main chafe points on the anchor system

Sea floor chafe
If your rode has any catenary at all (and it must), then the first few metres will sit on the sea floor. As the boat yaws and surges it will drag those few metres over the seabed. If there is anything sharp on the sea bed e.g. limestone or coral, it will chafe the rode. This will just rub some of the galvanising off chain, but will destroy rope very quickly. The only way of preventing this is to have the first few metres of rode as chain. How many metres is “a few”? It depends on your anchoring technique. You must adjust your scope so that the rope cannot touch the seabed when there is no load on the anchor rode. If you follow this logic, the length of rope in the rode must never exceed the water depth! So you are going to need a lot of chain, which leans you towards having an all-chain rode with the stretch provided by the separate anchor snubber.

Bow-fitting chafe
You will risk chafing at the bow fitting regardless of whether you are using a combination rope/chain rode or an all chain rode with a snubber. The two solutions to adopt are:

- Remove any sharp corners on the bow fitting. Remember that the rode doesn't just lead forwards, it can lead at 90 degrees to the bow when the boat is yawing around in wind gusts and swell.
- Put an anti-chafe cover over the rope at the bow fitting . This needs to be fixed so it cannot slide away from the chafe point. I use a 500mmm length of fire hose slid over the snubber, which has a 3mm rope at each end of the hose which I tie to the pulpit to keep the hose in its position at the stemhead. If I change the length of the snubber line it just slides inside the hose.

6.4. Weight

Below is an accurate but extremely misleading table that shows the weight of nylon v chain

size	Weight(kg/m)
13mm nylon (about same strength as 8mm chain)	0.106
5/16" (approx. 8mm) chain	1.5
3/8" chain	2.4
½" chain	4.2

Table 4 chain weight v. nylon . Source: CH Nov 13, Bullivant & Engineering Toolbox

So chain weighs 15 times nylon rope of the same strength – wow! Lets go for rope!. Hang on a minute, let's consider two things:

- We must look at the weight of the entire anchoring system (See later), not just the rode.
- If you accept my comments on seafloor chafe, a long rope rode is not an option, so the weight savings of using a rope/chain combination rode are not that great. If you never anchor on sharp seabeds then a combination rode does start to become significantly lighter, but you are limiting your anchoring options.

Maybe a compromise is to have 50m of chain then use rope for beyond the 50m mark? – gives more stretch for a given weight and has only a small chance of touching the seabed when there is any load on it.

7. THE ENTIRE ANCHORING SYSTEM

7.1. Windlasses

- Electric or manual? It's a trade off between personal fitness, battery power and reliability.
- Powered lowering as well as raising? Gives more control but is slower.
- Vertical or horizontal axis?

A vertical axis model has better chain grip and more versatile positioning. A horizontal axis model requires shorter chain fall, so is better for shallow chain lockers.

Combined chain/rope units are handy but it is difficult getting the rope to fall into the chain locker.

You must not hang the boat off the windlass, it will probably void the windlass warranty - use a snubber.

Pulling power
Rule of thumb: windlass pull power should be 3x weight of entire gear. (70m of 8mmm chain weighs 90kg, then add the anchor weight)

Electric current
The current will be very big (at least 100 Amps) so you need big wires – even bigger than alternator ones.

A dedicated circuit breaker (fuse) must be fitted - next to the battery not the winch (it is there to protect the wires not just the windlass).

Installation
You need a straight, level run from roller to windlass (compare vertical or horizontal axis models).

You need a big strong underdeck backing plate (for the cleats too). A bulkhead or frame attachment is good.

Ensure there is a waterproof barrier between the windlass gearbox and the anchor chain, but allow for maintenance access. Waterproofing to IP67 standard is preferred.

Should you have a dedicated windlass battery near the windlass, or use the house batteries? A dedicated battery at the windlass means smaller cables but weight forward is bad. It also needs separate battery monitoring. On the plus side of the argument, a flat windlass battery doesn't affect any of the other electrics on the boat.

The windlass MUST be maintained as per the manual.

Make sure you have a good bow roller – low friction under load, strong for downloads *and* lateral loads.

And how are you going to deploy and recover that second anchor?

Use for anchor retrieval
Do not wind the boat up to the anchor with the windlass; it is not designed for this and you will burn the motor out. Gently motor the boat up to the anchor, using the windlass to take up the slack chain. Once the rode is "up and down", if the anchor doesn't break out from the seabed, again do not use the windlass to do this. Simply let the boat drift back with the wind (or motor gently back if no wind); the vertical pull

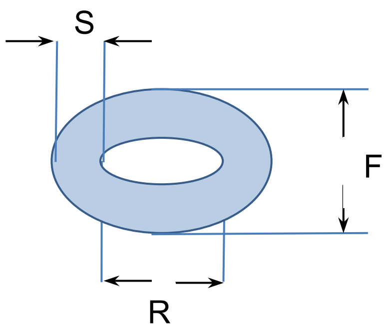
of the rode will break the anchor out unless it is snagged (in which case you have a problem that won't be cured with the windlass).

Note: if you adopt good practice for recovering the anchor then the loads on the windlass will be low, so perhaps there is no need for an electric windlass if you have a smaller boat (<12m)?

A note on chain link size

It is essential to match the windlass gypsy to the chain. Why?

a) All standards are different e.g. European DIN 766 and ISO 4565 standards have same chain size except for 10mm! USA ISO G30 and G43 (grade 40) standards are different from each other and different from European standards sizes.



Chain type	**S**	**R**	**F**
AS2321 Short link Grade L (Bullivants)	8	23.8	27
DIN 766/ISO 4565 (YM Sum 13)	8	24 (+0.4 – 0.2)	25.6
AS2321 Short link Grade L (Bullivants)	10	29.8	34.3
DIN 766 (YM Sum 13)	10	28	32
ISO 4565 (YM Sum 13)	10	30	34

Table 5 Chain link size variations

Of 13 samples supplied as "calibrated DIN 766", more than half were outside the size tolerances (YM summer 2013).

So take a sample of the actual chain to the actual windlass before buying either!

7.2. The weight problem

Weight in the bow is not good for boat performance and handling heavy gear can cause back injury. So weight is not good, but a heavy anchoring system will give you better holding than a light one. Let's look at the weight of the entire anchoring system.

1. Windlass weighs about the same as the anchor.
2. Battery weighs about the same as the anchor.
3. Chain weighs more than (anchor + windlass + battery) combined.

item	Weight (kg)
Anchor	15
Windlass	15
Battery	20
60m 8mm chain	90
snubber	5
Total weight	145 kg

Typical values for a 10m LOA 5 tonne yacht:

i.e. same as about two people on the bow; 3% of total displacement - and this is just for the primary anchor.

Total weight of anchors and rodes will be about 350kg or 7% of total boat weight i.e. about the same as full water tanks, and much more than the engine.

If you go for a new generation anchor, you might reduce its weight by up to 5kg – is it really worth it in the scheme of things? Your call.

If we change from 60m of chain plus 5m snubber to 20m chain and 35m nylon i.e. same total length (but note earlier comment on seabed chafe), we save about 60kg per anchor rode. i.e. 38% or somewhat less than one person. This is certainly useful, but is it worth the limitation it places on the type of seabed you can anchor in? Again, your call.

I use all chain on my primary anchor and a chain/rope mix on my secondary and tertiary anchors. I do this because my second and third anchors and their rodes are stored in an aft locker and have to be manhandled to the bow, so they can't be heavy. I try to rationalise the compromise by thinking that I only use them in addition to the primary anchor, so if they do chafe through then I still have the primary anchor holding me. It's not a very strong argument, but in my defence the secondary and tertiary rodes have not shown any serious signs of chafe in 15 years' light use.

8. NOTES ON MULTIHULLS

- Don't use boat displacement as a guide for anchor size – multihulls have proportionally much more windage.
- Multihulls are very weight sensitive, so mixed chain/rope rodes become more attractive than on a monohull. Alloy anchors might save you a bit of weight, but it's the rodes that make up most of the weight.

- The good news is that on a catamaran it is easier to bring the chain (locker) back to the mast, reducing the pitching from weight in the ends. No such luck with a trimaran.
- The snubber for a multihull will be a bridle, which also reduces yawing.

9. CONCLUSIONS

- The new generation anchors are better than the older ones, but the older ones are OK.
- The first 50m of rode should be chain.
- If you have all-chain rode then you must use a snubber.
- Learn how to use your anchor system.

10. REFERENCES

*Those marked with an asterisk * and italicised are highly recommended.*

10.1. General

Beggs G. (2011) "Anchoring" Kindle e-book April 2011.

Gree A. (1984) "Anchoring and Mooring" Adlard Coles Ltd.

Klaka K. (2003) " How to anchor a boat" Fremantle Sailing Club seminar November 2003.
http://www.fsc.com.au/cproot/443/3/How%20to%20anchor%20a%20boat_publ.pdf

Lynn D. (2014) "The complete guide to anchors and anchoring" Kindle e-book August 2014.

**Poiraud A., Ginsberg-Klemmt A., & Ginsberg-Klemmt E. (2008) "The complete anchoring handbook" International Marine/McGraw Hill. Also Kindle e-book.*

Wells D. (2013) " Anchor anywhere" Yachting Monthly December 2013.

Chains Ropes and Anchors (NZ) http://www.chainsropesandanchors.co.nz/advice accessed 6 Nov 2014

10.2. Anchors

Allisy D. (2009) "Which anchor is best?" from Voiles et Voiliers, reprinted in Yachting Monthly November 2009.

Anon (2012) "Rocna roulette update" Cruising Helmsman September 2012.

Cox V. (2012) "We test a Rocna anchor to destruction" Yachting Monthly April 2012.

Cox V. (2014) " How well will my anchor hold here?" Yachting Monthly February 2014.

**Hodges T. & Springer W. (2006) "Ultimate holding power" Yachting Monthly December 2006, also in Sail magazine.*

Moser J. Power and Motoryacht February 2007. http://www.powerandmotoryacht.com/boat/anchors-aweigh accessed 18th Aug 2014

Neeves J. (2011) "Head to head of anchors" Cruising Helmsman October 2011.

Neeves J. (2012) "Rocna roulette" Cruising Helmsman July 2012.

Neeves J. (2013) "High performance anchors for mutlis" Cruising Helmsman June 2013.

Sezerat A. (2003) "The ultimate anchor test" from Voiles et Voiliers May 2003, reprinted in Yachting World January 2004.

10.3. Chain and rope

Cox V. (2013) " How to choose chain that won't jam or slip in your windlass" Yachting Monthly summer 2013.

Cox V. (2013) " How to choose anchor chain you can trust" Yachting Monthly January 2013.

National Association of Chain Manufacturers (2010) "Welded steel chain specifications". http://www.nacm.info/Downloads/NACM_Welded.pdf accessed 5 Nov 14

Putt J. (2004) "Anchor Chain Selection, Regalvanising and a case of Caveat Emptor"

Fremantle Sailing Club Cruising Section 10th June 2004. http://www.fsc.com.au/cproot/2690/3/Anchor%20chain%20selection.pdf accessed 18th Aug 2014

Selkirk D. (2013) "From A to zinc: caring for your ground tackle" Cruising Helmsman November 2013.

Bullivants " Handling Safety Handbook" 4th Edition

- Chapter 2 " Fibre rope" pp30-37 http://www.bullivants.com/FlippingBooks/02FibreRope/files/assets/common/downloads/publication.pdf
- Chapter 3 " Chain and fittings" pp38-79 http://www.bullivants.com/FlippingBooks/03ChainAndFittings/files/assets/common/downloads/publication.pdf *(Note: the units for chain weight are incorrect; they should be m/100kg not kg/100m)*

Engineering Toollbox " Nylon rope strength" http://www.engineeringtoolbox.com/nylon-rope-strength-d_1513.html accessed 19th August 2014.

10.4. Windlasses

Barrell E. (2012) "Anchor windlasses" Yachting Monthly November 2012.

Champion J. (2013) “ Heavy metal and how to move it part 1” Cruising Helmsman November 2013.

Champion J. (2013) “ Heavy metal and how to move it part 2” Cruising Helmsman December 2013.

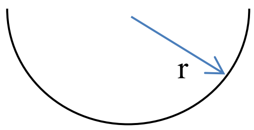
Green K. (2010) “ Weighing up windlasses” Cruising Helmsman September 2010.

11. ANNEX A: ENERGY ABSORPTION OF CHAIN RODE

Modelling the physics and geometry of a real anchor/cable combination is a surprisingly complicated problem – certainly too complicated for me to do quickly. However, we can gain insight by simplifying the problem .

Version (a)

Consider a chain hanging from two lampposts, and assume the catenary describes an arc of a circle (it doesn't, but the logic is true for any shape of curve and the maths is simpler for a circle). Next, let's just consider the energy absorption of the bit of chain at the mid-point (again, the principle holds true at any point along the chain, it just makes the sums simpler to look at the mid-point).



Let the mass per metre = m and the length of the chain be L

The length $L = \pi r$

The potential energy PE of a small length of chain δL at the mid point is $mgr\delta L$

i.e. PE is proportional to mL

Now for a given total weight of chain, $m_{heavy}L_{heavy} = m_{light}L_{light}$

So the potential energy is the same for both the short heavy chain and the long light chain of the same total weight.

Version (b)

Consider the anchor cable to be chain in the lower part and rope in the upper part. The rope is assumed light enough to ignore.

Let the length of rope be just equal to the water depth and the length of the chain be an order of magnitude greater than the water depth i.e. the length of the rope is negligible in comparison. (This is a fairly good representation of reality e.g. in 3m water depth I often use 30m of chain and 3m of rope.) When there is no load applied by the boat then all the chain is sitting on the seabed and the rope sits vertically in the water column. This is the condition of minimum PE.

```
_____________________________________________ sea surface
                              | rope
(--oooooo-chain-oooooooo.|__________________ sea bed
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The condition of max PE is when the entire system is taut and straight (no catenary) and lies at some (irrelevant) angle y to the seabed.

To achieve this the end of the chain has risen the entire water depth from the seabed to the sea surface (less the tiny amount of rope x sin y where y is quite small) and the mid-point has therefore risen by half this amount i.e. half the water depth. Seeing as we are considering this as a statics problem there is no catenary and we can consider the chain as a solid rod. The centre of mass has risen by half the water depth regardless of the actual length of chain or its mass per metre. So the PE is Weight* depth/2 and is the same for a short heavy chain as it is for a long short chain.

END