Corbin 39 Study – Theoretical Analysis
An assessment of stability index (STIX)

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1 Working document

This is a working document setting out the results of a study into various aspects of the Corbin 39. Conceptually this document is the last in the planned series:

1. A study of the anecdotal evidence in respect of weather helm.
2. A theoretical analysis of weather helm and various options for owners.
3. A reproduction of the lines plans, the hull form, and analyses of displacement, trim, and static stability.
4. A study of the sailing performance, including results of Velocity Prediction Programs (VPPs).
5. **This document** is a study of the dynamic seaworthiness using the ISO **stability index (STIX).**

The authors are the same three as explained in the previous studies, with the vast bulk of the work being carried out by Jean-Francois Masset. This is also the first full use of Jean-Francois Masset's new "SA-STIX" and comparison with other STIX-assessments from commercial software packages.

2 Summary

The Corbin 39 had a 1970s design intent of "ocean" conditions. In 2020, we can both ask and answer the question, *"how does Robert Dufour's design meet seaworthiness standards set 40-years later*".

For a Corbin 39 results are obtained for two loadcases for the mk2 49' mast sailplan, corresponding firstly to an operating displacement of 14,000 kg (30,865 lbs) with a Centre of Gravity ("Zg") placed 3.8cm above the Design Waterline (this is just below the saloon table top is); and secondly for an extra 1-tonne of mass placed low in the cabin, raising Zg marginally. **In general terms this suggests the Corbin 39 design would meet ISO design category 'A' for ocean use,** according well with the practical experiences of many Corbins and their owners sailing worldwide over the years.

Mk2 49' Displacement	CoG (Zg)	STIX	Downflooding Angle (PhiD)	Angle of Vanishing Stability (AVS)	Area Ratio
14,000 kg (30,865 lbs)	3.8 cm	40.7	97.06°	127.3°	6.3
15,000 kg (33,069 lbs)	5.2 cm	40.1	94.70°	127.4°	6.6

The effect of loading that same extra 1-tonne higher in the vessel, are obvious:

Mk2 49' Displacement	CoG (Zg)	STIX	Downflooding Angle (PhiD)	Angle of Vanishing Stability (AVS)	Area Ratio
15,000 kg	5.2 cm	40.1	94.70°	127.4°	6.6
15,000 kg	11.0 cm	37.0	94.70°	123.6°	5.0
15,000 kg	20.2 cm	32.0	94.70°	117.3°	3.2

Similar results are obtained for all the other sailplans, as shown here by the STIX values:

STIX for 7 sailplans and 2 loadcases	Mk1 46'	Mk1 51'	Mk1 ketch	Mk2 49'	Mk1 46' bowsprit	Mk1 51' bowsprit	Mk1 51' shortboom
D 14 t / Zg 0,038 m	42.0	41.0	41.9	40.7	41.5	40.3	41.9
D 15 t / Zg 0,052 m	41.1	40.4	41.1	40.1	40.9	39.7	41.1

3 Background:

This builds on the previous studies of the Corbin 39 yacht, of which there is a single moulded hull form and several common sail arrangements in use all over the world. Ideally owners and purchasers would like insight into the dynamic seaworthiness of the Corbin 39 design in a way that can be compared with more recent yacht designs available in the market. Such a study also gives an improved understanding of the practical consequences of choosing to operate a Corbin 39 in a particular way, or to modify it in any given way.

According to Marius Corbin when he commissioned Robert Dufour the design of the Corbin 39 was intended to take its owners "*safely and comfortably around the world*" in a package of "*about 40 feet, comfortable, giving good performance to windward and in light air, strong enough for around-the-world cruising, an interior layout suitable for two persons or a small family, and built to the highest specs*."

In 1977 when he founded Corbin Les Bateaux Inc to build these yachts the 1979 Fastnet Race yacht disaster had not happened. Nevertheless Robert Dufour incorporated in the design many elements to achieve this overall objective.

The first Corbin 39 was moulded in January 1979. Later that year, in August 1979, a violent storm wreaked havoc on the Fastnet Race. Of the 303 vessels to start, only 86 finished. There were 194 retirements and 24 abandonments (five of which were "lost believed sunk"). Some 15 sailors died, at least 75 boats capsized, and five boats sank. This prompted the race organisers, the Royal Ocean Racing Club (RORC) to commission an enquiry into what happened, and what lessons to learn.

An outcome from this inquiry was the progressive development of various assessments of a yacht's overall seaworthiness. These included, but were not limited to, the static stability and important efforts were also made to formally assess more general seaworthiness including dynamic stability. In the 1980's the RORC and RYA created a metric known as the Safety & Stability Screening System number (SSSN). In time, as other significant yacht-racing tragedies have happened the assessments evolved to better address dynamic stability and were incorporated into various racing rules and now also into international design standards (ISOs) that are referenced in product requirements such as the European Union Recreational Craft Directive (the EU RCD). Therefore lessons learned in racing in extreme conditions have become incorporated in designs of cruising yachts.

The latest evolution of this is the Stability Index (STIX) which is a single number representing the perceived 'seaworthiness' of the design, with again a higher value reflecting a more 'seaworthy' boat. A boat's STIX can be calculated in accordance with the international standard ISO 12217-series by the combination of factors related to dynamic stability, inversion recovery, knockdown recovery, displacement-length, beam-displacement, wind moment and downflooding, using the relevant data and methods. The **ISO 12217-2 : 2015** "**Small craft — Stability and buoyancy assessment and categorization**" is for sailing boats of hull length greater than 6m, i.e. well suited for a Corbin 39.

Every few years the ISO standards are updated, the latest being the third edition ISO 12217-2:2015 with the first edition being :2001 and the second edition :2013. A fourth edition is due soon. This is relevant because with each edition adjustments are made as results come in from experiments, research, and practical experience.

In general terms the seaworthiness of a boat design is assessed, and a STIX rating number is computed, e.g. "19.5", provided that all aspects of a boat conform. Such a STIX number can then allow a boat to be assigned to a design category ranging from A to D, corresponding to a set of envisaged use conditions as generally set out in the table below. The example design with a STIX of "19.5" would therefore likely be suited for no more than coastal usage. Such "coastal" conditions may be encountered on exposed inland waters, in estuaries, and in coastal waters in moderate weather conditions, and of course we are aiming for more than that in a Corbin's design.

In particular a Corbin would hope to achieve category ‘A’ for ocean use. *“A boat given design category A is considered to be designed to operate in winds of Beaufort force 10 or less and the associated wave heights, and to survive in more severe conditions. Such conditions may be encountered on extended voyages, for example across oceans, or inshore when unsheltered from the wind and waves for several hundred nautical miles. Winds are assumed to gust to 28 m/s.”*

Colloquial description	Ocean	Offshore	Coastal	Local
ISO Design Category	A	B	C	D
Significant wave height (metres)	Approx 7	4	2	0.5
Wind speed (Beaufort) (m/s) (knots)	 to F10 28 54	 to F8 21 41	 to F6 17 33	 to F4 13 25
Minimum STIX	32	23	14	5
Minimum AVS *(where m = weight of boat in kg)*	130-0.002*m always ≥ 100° *(102-deg for 14t)*	130-0.005*m always ≥ 95°	90°	75°
ISAF SR Category	1-2	3	4	N/A

Note that for category 1 offshore races in Australian waters, like Sydney-Hobart typically, a minimum STIX of 35 is required : https://orcv.org.au/safety/stability-requirements .

As well as the STIX number some other numbers are very important. The **Angle of Vanishing Stability (AVS) which** is the angle beyond which the boat will naturally roll to the fully inverted position, which we must remember is an undesirable but stable outcome for most yacht designs. The **area ratio** between the area under the GZ curve when upright, versus the area in the inverted position. This area ratio is a good indicator of how much energy is required to peturb the inverted hull enough for it to flip back upright, ordinarily due to wave action. As yet the area ratio is not directly referenced in the ISO standard, but various racing rules (such as the Imoca rules), especially after the terrible capsizes during the Vendée globe events in the 1990’s, are very concerned by this aspect and added the requirement for the area ratio to be > 5 for open ocean racing and so we too apply it to the Corbin 39 in this study. The **downflooding angle** is also important as described later.

4 Tools used

A STIX assessment tool, in the form of a spreadsheet application named SA-STIX, was written by Jean-Francois Masset, firstly based on formulations given by « Principles of Yacht Design » L.Larsson & R.E. Eliasson, 2nd edition 2000, and then compared with the results of a commercial proprietary software. Some slight differences occurred, were understood and corrected thanks to the clarifications described in a Boatdesign Forum, in particular this thread page 6/ quote#88 and page 22 / quote#326 :
https://www.boatdesign.net/threads/sailing-boats-stability-stix-and-old-ratios.13569/page-6
https://www.boatdesign.net/threads/sailing-boats-stability-stix-and-old-ratios.13569/page-22#post-407872

Then, the accordingly revised SA-VPP now gives exactly the same values as the commercial proprietary software for the Corbin 39 loadcases, and this was also checked using another example available in the spreadsheet attached to the quote#326 above.

A little bit of information about two of the programs is given below. The third is a piece of professional proprietary software which we had access to, but we are unable to give the name, however we can confirm that the results correspond well with everything in these study reports.

Multisurf : A professional 3D design tool for complete marine design as used by Alain Lebeau for the hull definition. See http://aerohydro.com/.

SA-STIX : Developed by retired naval architect Jean-Francois Masset is the SA-STIX application, using the OpenOffice spreadsheet tool. In its current state of development it is dedicated to the Corbin 39, meaning that the GZ curves data for the loadcases 14 t and 15 t (according to the Multisurf definition of its hull geometry) and the corresponding first downflooding angles (assuming the main hatch top corner is the first opening) are embedded in the spreadsheet. But the user has the possibility to input, for each case D 14t and D 15t, either another sailplan (parameters As and ZCE) or another height of the gravity centre (parameter Zg in the second set of columns).

Ultimately, SA-STIX can be made public within a more general form to cope with any other boat, providing that its GZ curve with a given Zg can be available. In due course this will be available at the Boatdesign software forum (https://www.boatdesign.net/forums/design-software/).

5 Process

As inputs this study uses the results from the previous studies. In particular it uses the static stability assessment that resulted in two defined loadcases, one for a Corbin 39 with a displacement of 14,000 kg (30,865 lbs) which was thought to be a typical cruising displacement, and a slightly greater displacement of 15,000 kg (33,069 lbs) to investigate a more heavily laden condition. The brochure displacements of 9,979 – 10,342 kg (22,000 – 22,800 lbs) were not used for reasons set out fully in the static stability assessment report, i.e. primarily we consider them to be too light (and therefore generally too optimistic) compared with normal operating displacements. Secondly the weight and location of the sails and spars have to be taken into account, and although there is only one Corbin 39 hull there are several sailplans. Therefore the seven different sailplans defined in the sailing performance (VPP) study and the weather helm study were used.

During the study the effect of placing the additional 1-tonne of mass at different heights within the vessel were explored. These correspond to the best condition of internal stowage low down, progressing to the more severe effect of above-deck placement of mass, such as radars, solar panels, expedition paraphernalia, etc.

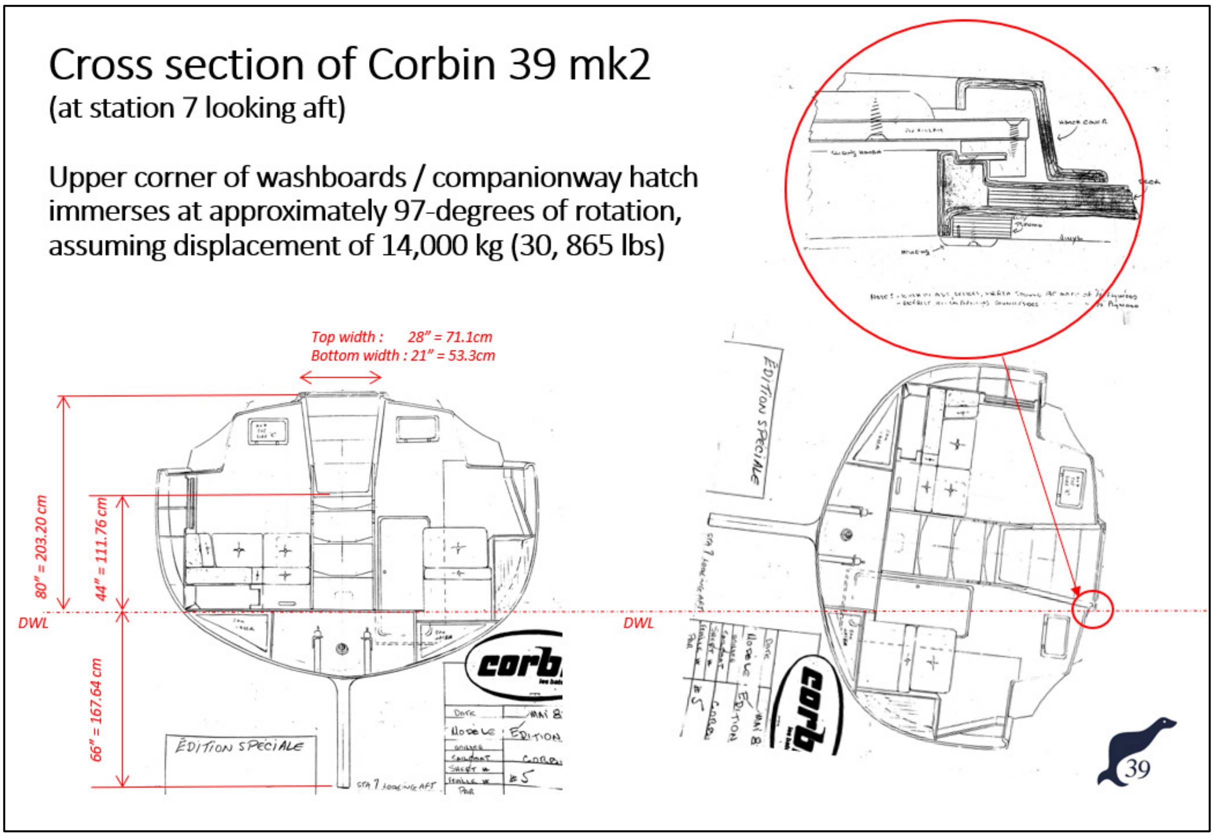
Two STIX assessments were carried out using the dedicated spreadsheet application SA-STIX and by another professional software package which we cannot name, both using the input data derived from the Multisurf definition of the hull. All results were found to be in good agreement. The baseline boat was assumed to be in general terms compliant with any detail required in any seaworthiness standards, though this is of course a matter for verification in any individual Corbin 39 boat. Some specific items are noted below.

Downflooding angle

The downflooding angle, is the angle of heel at which a non-watertight aperture will dip beneath the water surface allowing water to flood uncontrollably into the interior.

In a Corbin the companionway was considered to represent the first risk in this respect, and the co-ordinates were calculated for the mk2 aft-cockpit version. When these were rotated about the centre of buoyancy it was observed that the upper hatch corner was the first non-watertight item to enter the water.

The exact angle of heel at which this occurs obviously depends on the displacement, but it was observed to be 97.1 degrees in the 14-tonnes displacement loadcase, and 94.7 degrees in the 15-tonnes displacement loadcase. It is worth recalling that in general terms a Corbin does not significantly pitch in fore-and-aft trim towards either the bow or the stern as the hull rolls over, so this means all the longitudinal edge of the hatch would immerse at the same moment.



Graphical depiction of downflooding angle in Corbin 39 mk2 aft cockpit

For the mk2 aft-cockpit the following hatch & washboard coordinates were used

Upper companionway/hatch : x=291.465cm, y= 35.75cm, z=203.20cm.

Lower companionway corner : x=291.465cm, y= 26.65cm, z=111.76cm

The mk1 aft-cockpit has slightly different coordinates as the pilothouse roof is slightly lower, and the companionway narrower. The centre cockpits are more varied. Therefore for the purposes of this study we treated all hulls/sailplans/loadcases as if they were mk2 aft-cockpit for the purposes of downflooding.

Companionway and hatch on #155, "Blue Run" (ex "Reverence")

General layout photo of #155, "Blue Run" (ex "Reverence"), a mk2 aft-cockpit cutter

Cockpit flooding

No account was taken of the mass of a flooded cockpit or the self-draining capabilities of the cockpit. It was assumed that the cockpit itself is watertight (which it should be, if properly built), and it was assumed that the cockpit drains were adequate.

Sail locker(s) & cockpit lockers

No account was taken of the forward sail lockers in the bow. They were assumed to not flood and to self-drain.

No account was taken of the cockpit lockers. Note that in some aft-cockpit Corbins one side of the cockpit accesses a deep locker, and that ought to receive greater attention in a more detailed assessment, where it exists. All the other cockpit lockers are very small, and do not seem material in an assessment of this nature.

Deck structures

No account was taken of the volume of the pilothouse. All hulls were assumed to be simple flush-decked forms. This is a slight simplification, but it was considered that the volume of the pilothouse was a greater benefit that the volume of the cockpit, and so this would be a reasonable simplification.

Deck openings

Apart from the companionway and/or main hatch all hatches and vents were assumed to be watertight, or any leakage in the inverted or knocked-down position to be minimal and manageable with handpumps. This is a reasonable assumption as all dorades/vents and deck hatches on a Corbin can be closed tight and well-sealed by the crew (if properly built & maintained).

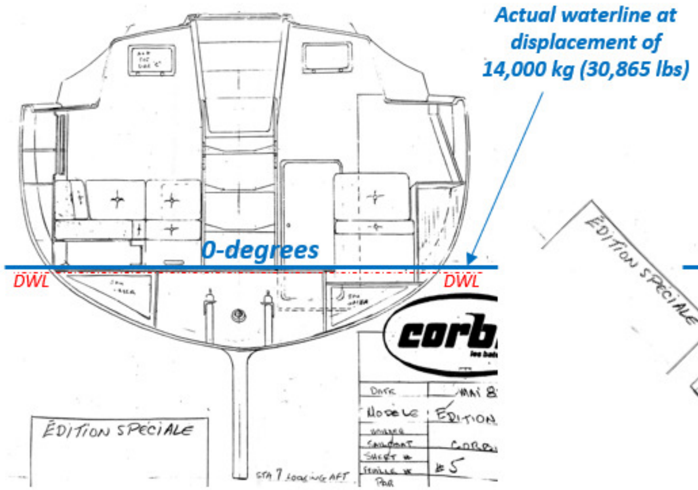
Deck/hull joint

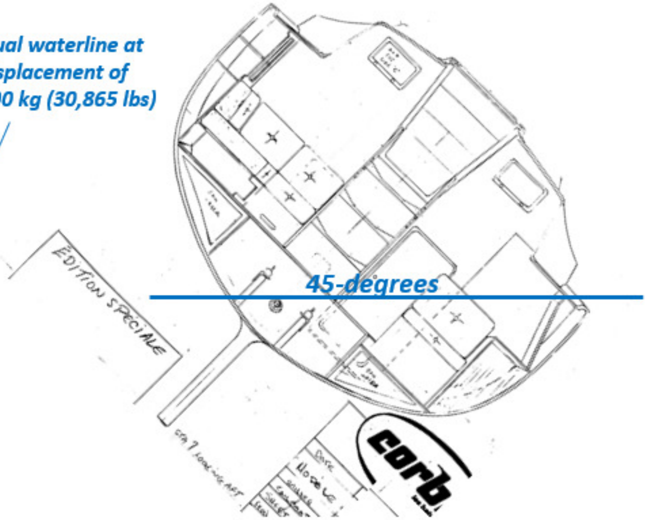
The deck/hull joint was assumed to be well sealed.

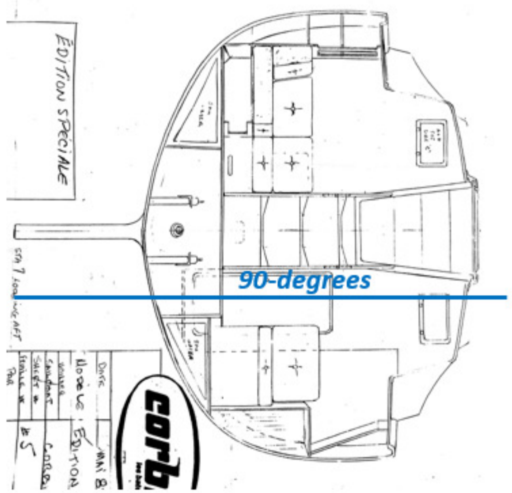
Top hamper

No specific account was taken of any other unusual top hamper excepting the stated sailplans with their corresponding allowances for masts, spars, sails, and standing & running rigging. In the basic 14,000 kg (30,865 lbs) displacement loadcase there is an allowance for liferaft, etc (~200kg at Zdeck + 0.3m), but not for large arches, large solar panel arrays, etc.

As a comment the effect of taking quantities of water onto the boat is not directly evaluated. As water (or snow & ice) comes onto the deck, or onto the sails it will load the boat. This is both a static effect (the boat sinks a bit deeper in the water) and a dynamic effect (as the water mass decelerates, so the boat accelerates in one direction or another). This could be from rain, or spray, or waves sweeping across a deck. Therefore a consequence of adding top hamper to a boat is that such wave etc action will be more consequential. An ideal boat would be sleek and shed water rapidly. This is the self-evident 'bare' form design intent of a Corbin 39, and we compromise it if we add 'draggy' top hamper. It is of course most consequential in the more extreme conditions we hope & seek never to encounter, but nevertheless it is worth mentioning & considering.

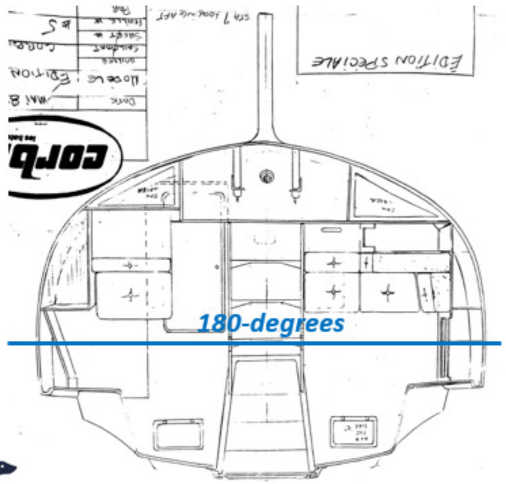


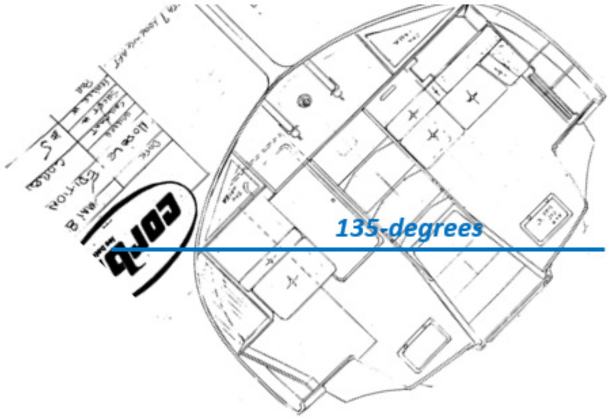


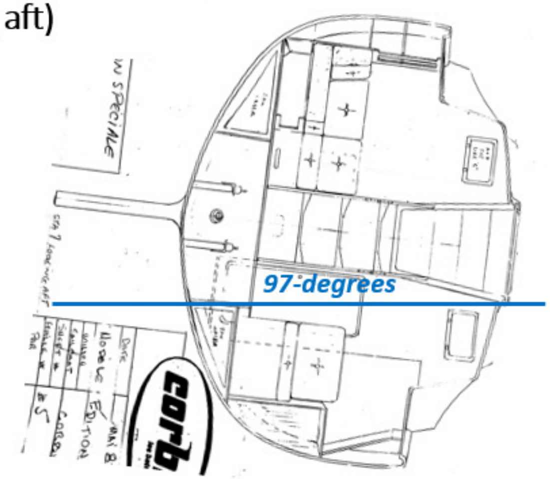


Cross section of Corbin 39 mk2

(showing rotation at station 7 looking aft)







6 Cautionary words

This is not a formal seaworthiness assessment by a competent and professional certification body against all the relevant standards. It is merely an informal academic exercise carried out in their spare time by retired or non-practicing amateurs (for that is what we are in this respect).

The development of and codification of the ISO 12217-series and the STIX is not without criticism. The whole matter of what is, and what is not, a seaworthy boat has very many aspects, of which the dynamic stability is only one small part. As one example of a technical issue, the ability of the boat to make way and hold a course, and to manoeuvre effectively so as to meet seas to best advantage, is not taken into account. Another example is that of vessel motion, whether it be 'kindly' to a crew, or an 'unkindly' ride that prematurely fatigues the crew physically and mentally. Therefore just because a boat has a good STIX score does not necessarily mean it is in every respect ideal and seaworthy.

The build standard, upkeep, and maintenance of the boat also have an important role to play. Examples are that if the hatches and vents will not close and fasten securely to provide a good seal then they are merely giving a false sense of security. Or if the standing rigging has not been well kept and/or renewed then the boat could be dismasted at the worst possible moment. There are many other examples, too numerous to mention.

This assessment has relied upon a number of assumptions, the most important of which are what is the actual displacement of any particular as-built Corbin 39, and how the mass is distributed in the boat so as to set the Centre of Gravity (Zg). Furthermore we are of course very unsure how and where additional masses might be added to any individual boat to load it for a voyage.

The ability of the crew, and the manner in which they conduct themselves is perhaps the most important aspect not taken into account in seaworthiness assessments of a boat. A wise crew, operating harmoniously, will never encounter severe weather, because they will have sailed a course to avoid the worst storms whilst still achieving their destination.

As with every human endeavour in the natural world we must remember how puny we are. The sea has a vote, and it does not care. It does not obey human rules, and will not show compassion. Just because the ISO standard defines the significant wave height for a category 'A' ocean-rating as being 7-metres, does not mean that one day the boat may not be called upon to meet two much larger breaking waves crossing each other, combined with boiling foam that further reduce buoyancy, visibility, and control.

So always exhibit caution and seamanship, and this begins in harbour with preparing yourselves and the boat and understanding the limitations of both, and the demands of the environment.

7 Formal STIX assessment, and personalised assessments

In order to carry out a formal STIX (etc) conformity assessment to ISO 12217-2:2015 a representative Corbin needs proper measurement, weighing, and for an inclining test to be conducted in a well-documented condition. This can then be the baseline Corbin against which other Corbins can be assessed as sister-ships. Ideally such as assessment should be conducted by notified body, or an official measurer.

Other load cases ought to also be considered. As an example the "end-of-voyage" condition when most tanks are empty, but a full crew onboard ought to be assessed.

The downflooding points of the mk1 aft cockpit, and the centre cockpit ketches, also ought to be identified and assessed.

8 Spreadsheet for personalised assessment

As with the static stability assessment Jean-Francois Masset has kindly set up a spreadsheet which any Corbin owner could use to assess his/her own Corbin. It is available for download on the Corbin 39 Association website (http://corbin39.org/).

9 Further Reading

If you want to read more about STIX workings then **"Principles of Yacht Design"** by R. Larsson & E. Eliasson has a good introduction. Read the full results report (see below) by Jean-Francois Masset & Alain Lebeau to identify some differences between the calculation in PYD and that of the ISO. Then for further insight the **ISO 12217-2 : 2015 "Small craft — Stability and buoyancy assessment and categorization"** can be purchased from the online ISO webstore **(** https://www.iso.org/store.html), though check if there is a more recent edition at the time of your purchase.

10 Full results

The full report :

Corbin 39 – the STIX issue – as for 22 06 2020, by Jean-Francois Masset & Alain Lebeau

is available for download on the Corbin 39 Association website (http://corbin39.org/) along with the accompanying spreadsheet :

SA-STIX final_2020 06 22

Once again we in the Corbin community owe an enormous debt of gratitude to Jean-Francois Masset and Alain Lebeau for their fantastic volunteer support, so willingly given.