Yacht Stability

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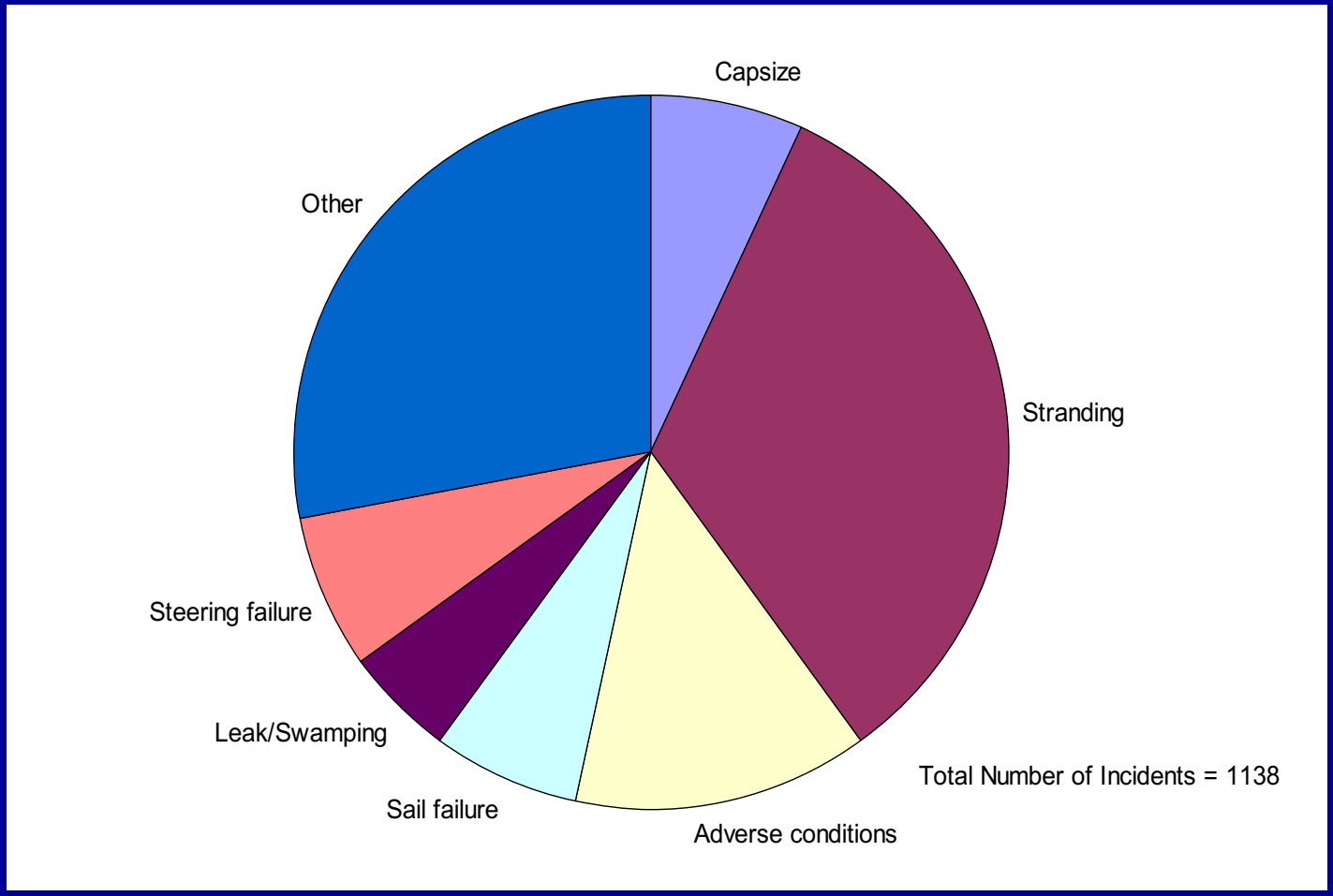
Session Contents

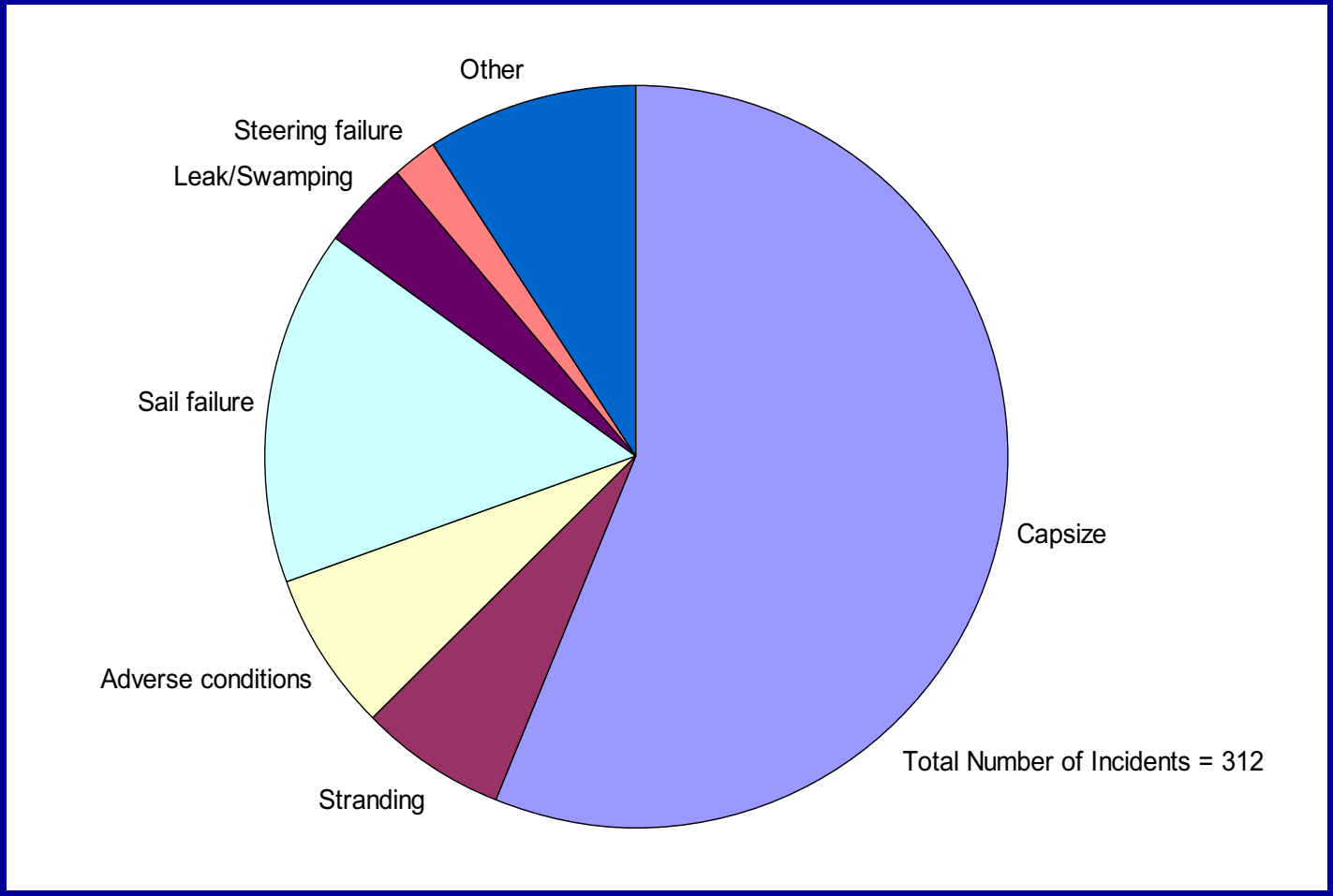
- What is stability?
- Basic concepts –righting moment and “GZ curve”
- Large angle stability
- Things that affect stability
- The STIX number
- Guidelines for choosing a design
- Challenging some assumptions

Monohull - Casualty Statistics



RNLI lifeboat launches (5 year period)

Multihull - Casualty Statistics



RNLI lifeboat launches (5 year period)

What is stability?

1. Normal sailing:

Stability = power to carry sail

2. Extreme conditions:

Stability = ability to resist capsize

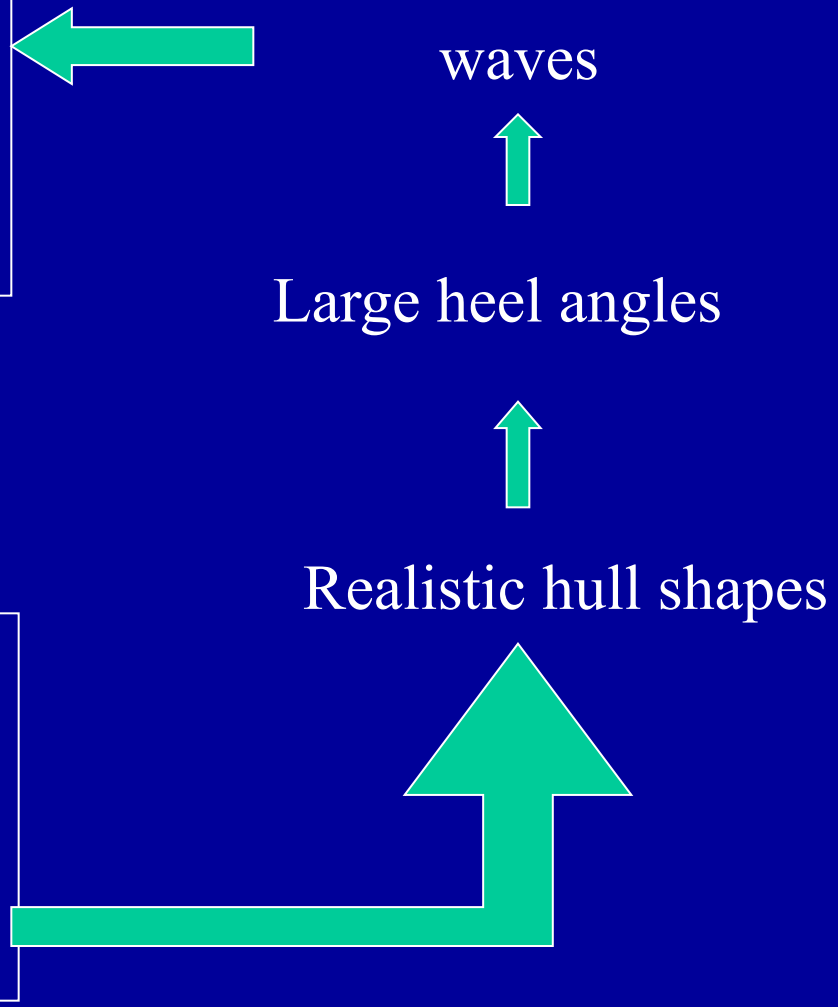
How stability is studied

Real world:

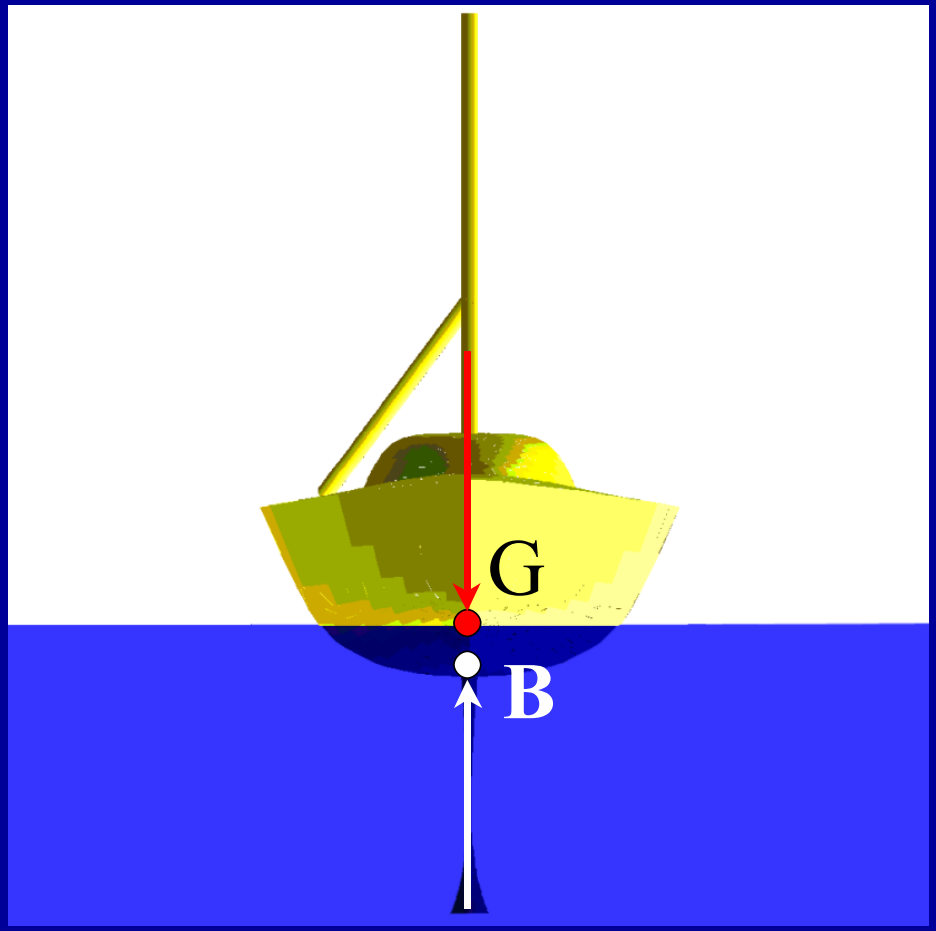
- Waves
- Roll motion
- Large heel angles

simplify

- Calm water
- Small angles
- “quasi-static”



Generation of Righting Moment



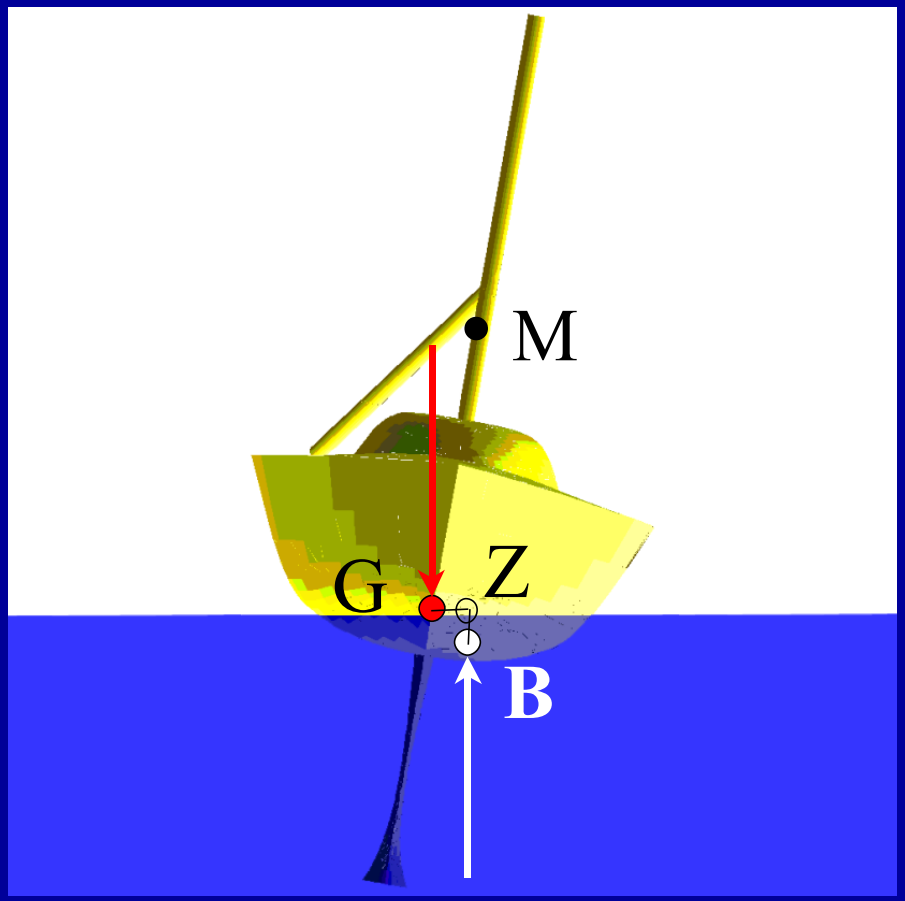
Yacht upright & in equilibrium

Mass of yacht in air is equal to mass of fluid displaced

Buoyancy force acts upwards

Displacement force acts downwards

Generation of Righting Moment



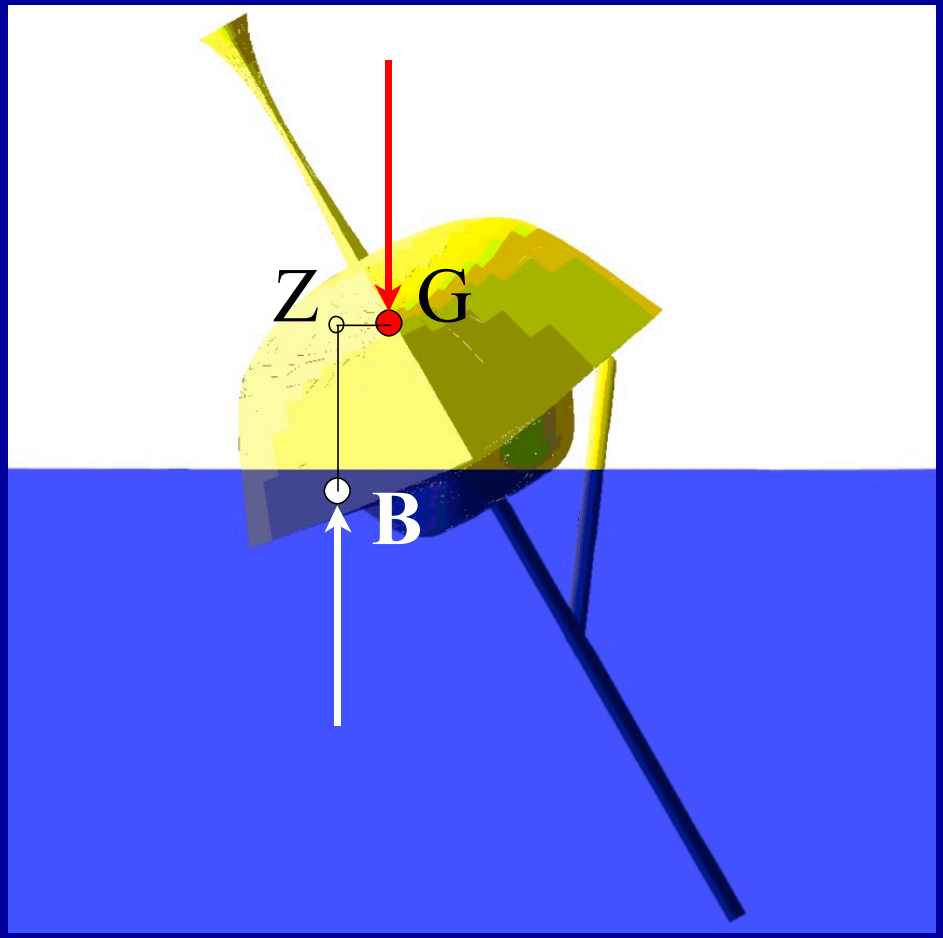
Yacht heels & B moves to one side

G remains in constant position

Intersection of B line of action and centreline is Metacentre

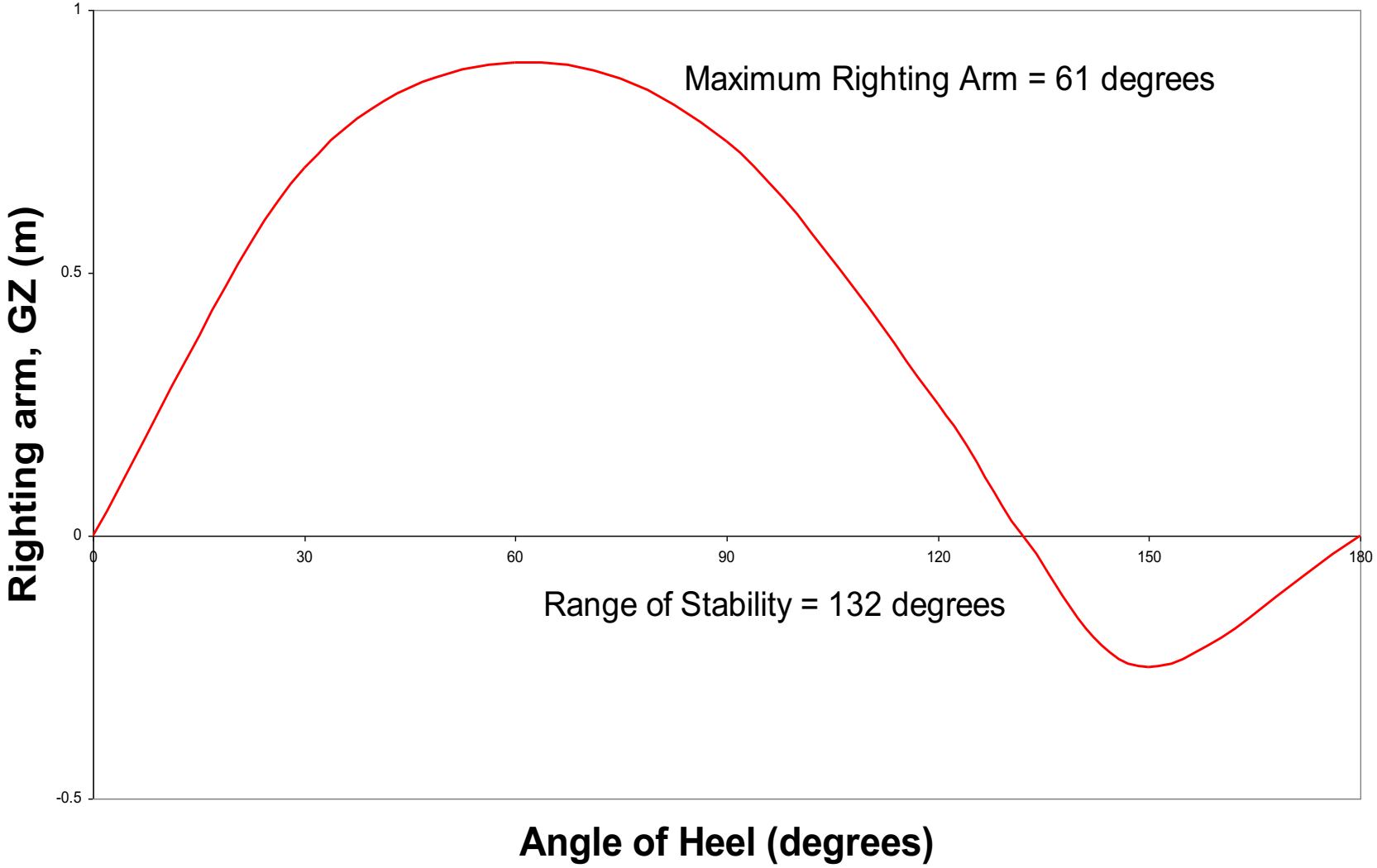
Yacht will return to upright since GZ, righting moment, is positive

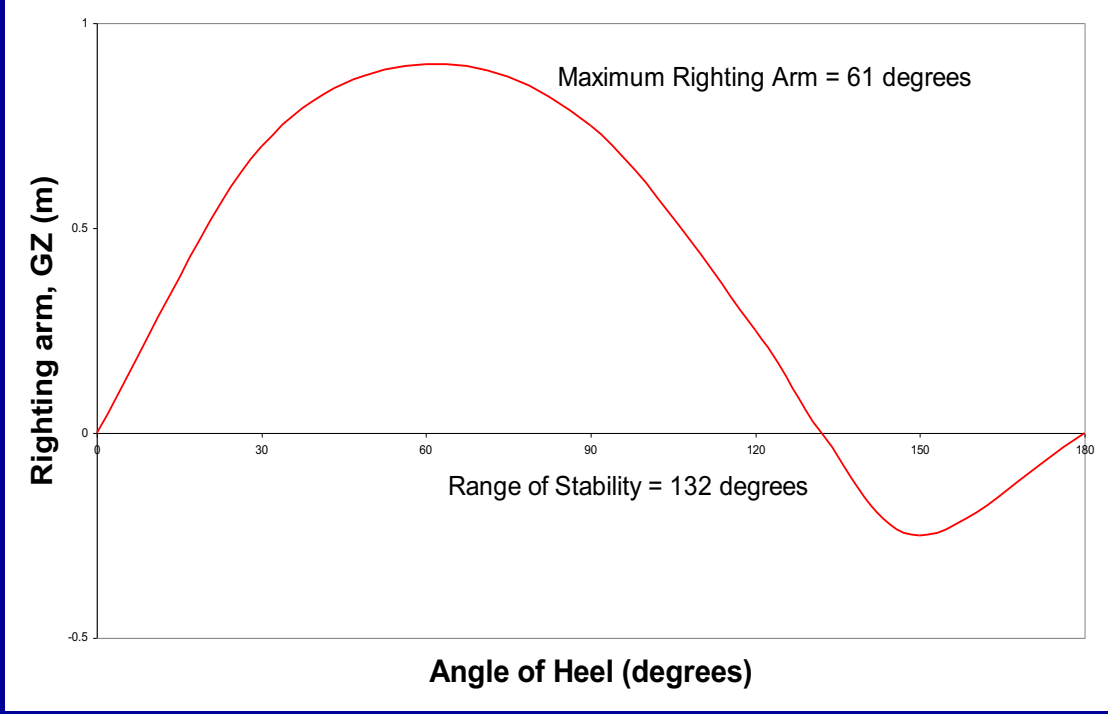
Generation of Righting Moment



GZ is negative & yacht will continue to roll and will capsize

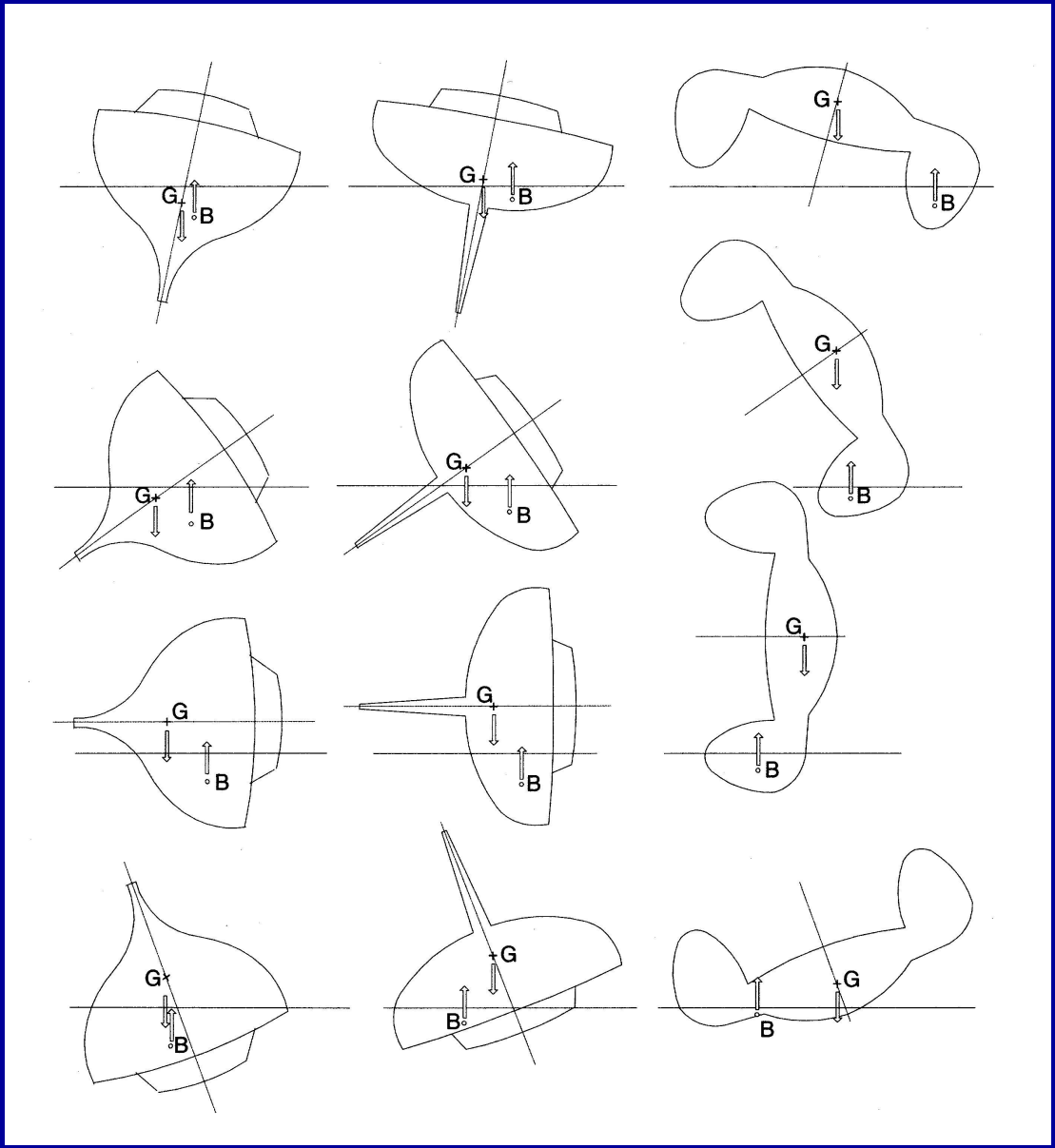
Righting Arm or GZ curve



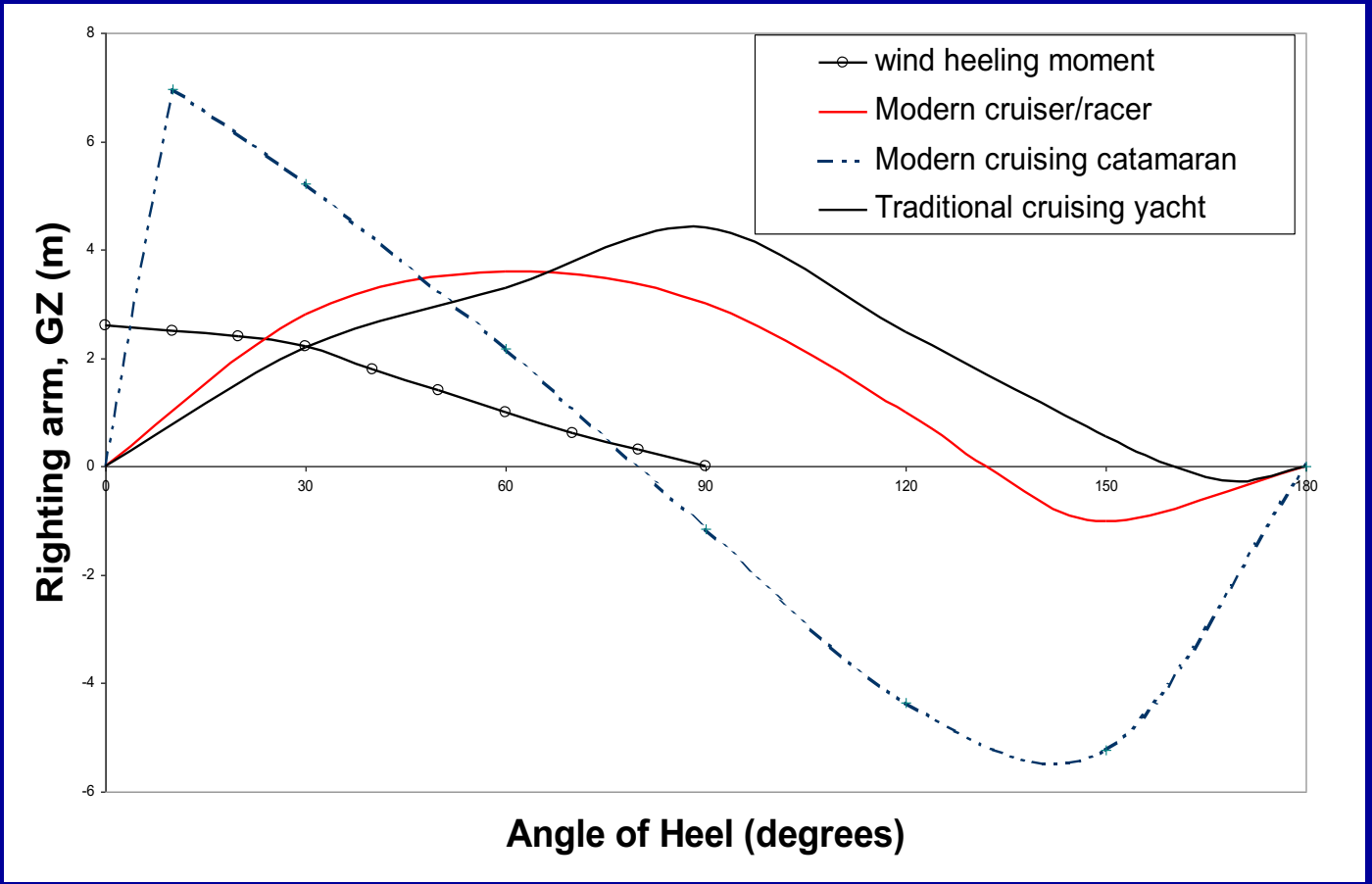


- as heel angle increases, G & B separation increases to maximum
- GZ then reduces to zero at limit of positive stability
- If yacht released at angle less than limit it will return to upright
- If yacht released at angle greater than limit it will capsize
- If range of stability 180 degrees, it is self-righting
- GZ curve used to compare designs and assess against regulations

Different Hull Forms



Righting moment curves for different Yachts



For identical rigs:

traditional yacht heel = 30 degrees

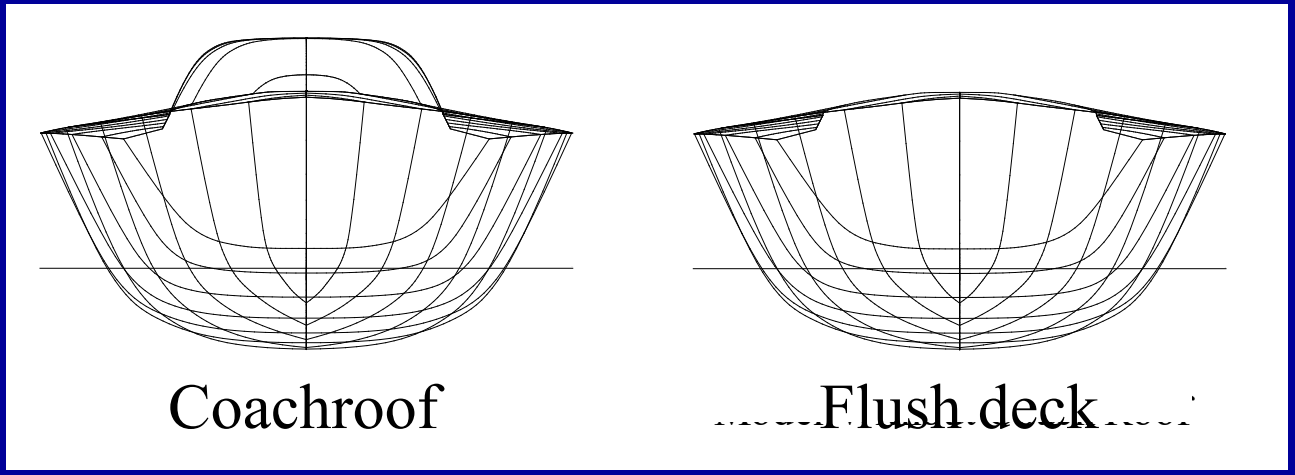
modern yacht heel = 25 degrees

catamaran heel = 5 degrees

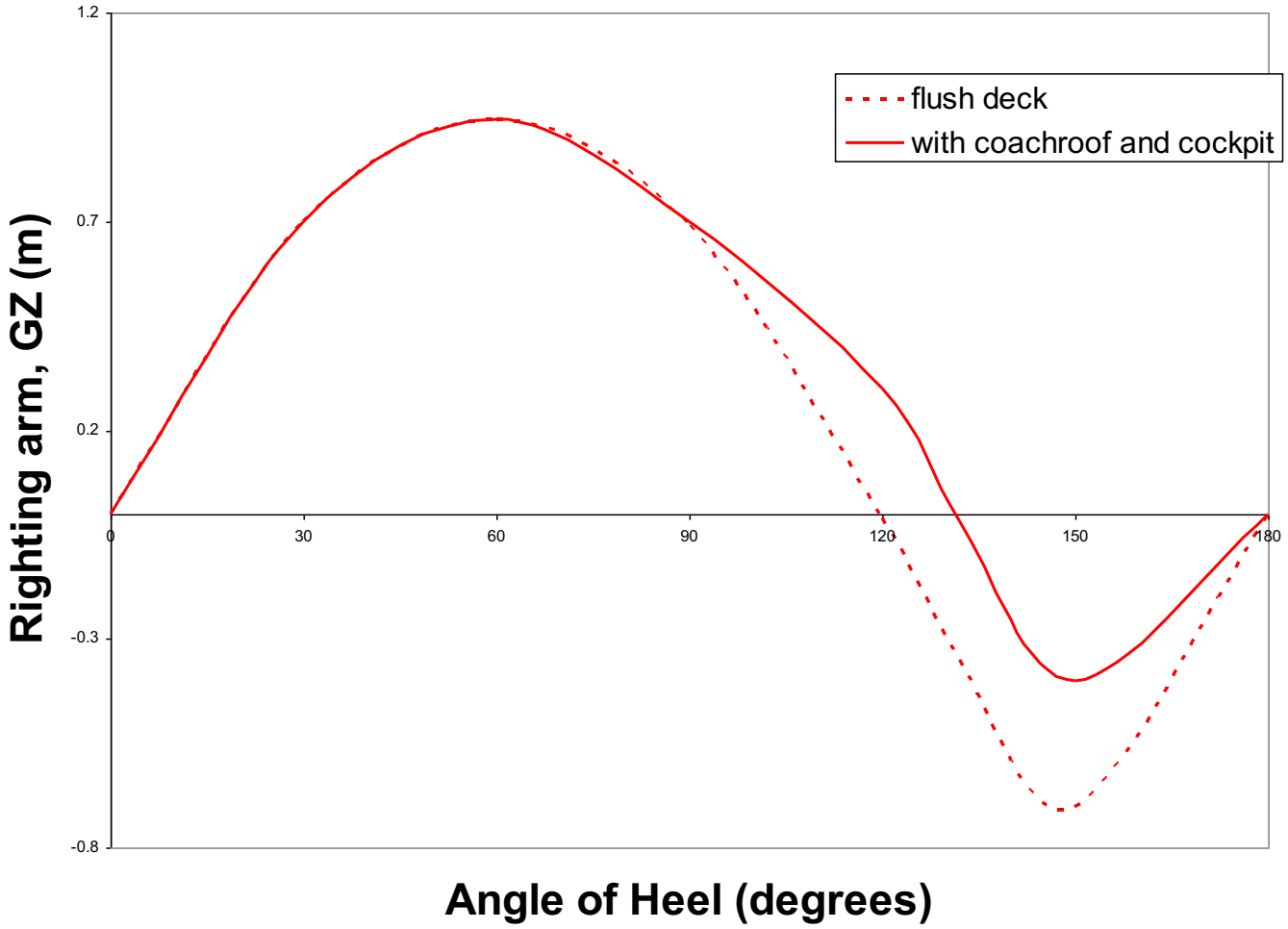
Coachroof & Cockpit Volumes

A large coachroof increases distance between buoyancy and C of G & hence increases stability at 90 degrees. It will also aid re-righting.

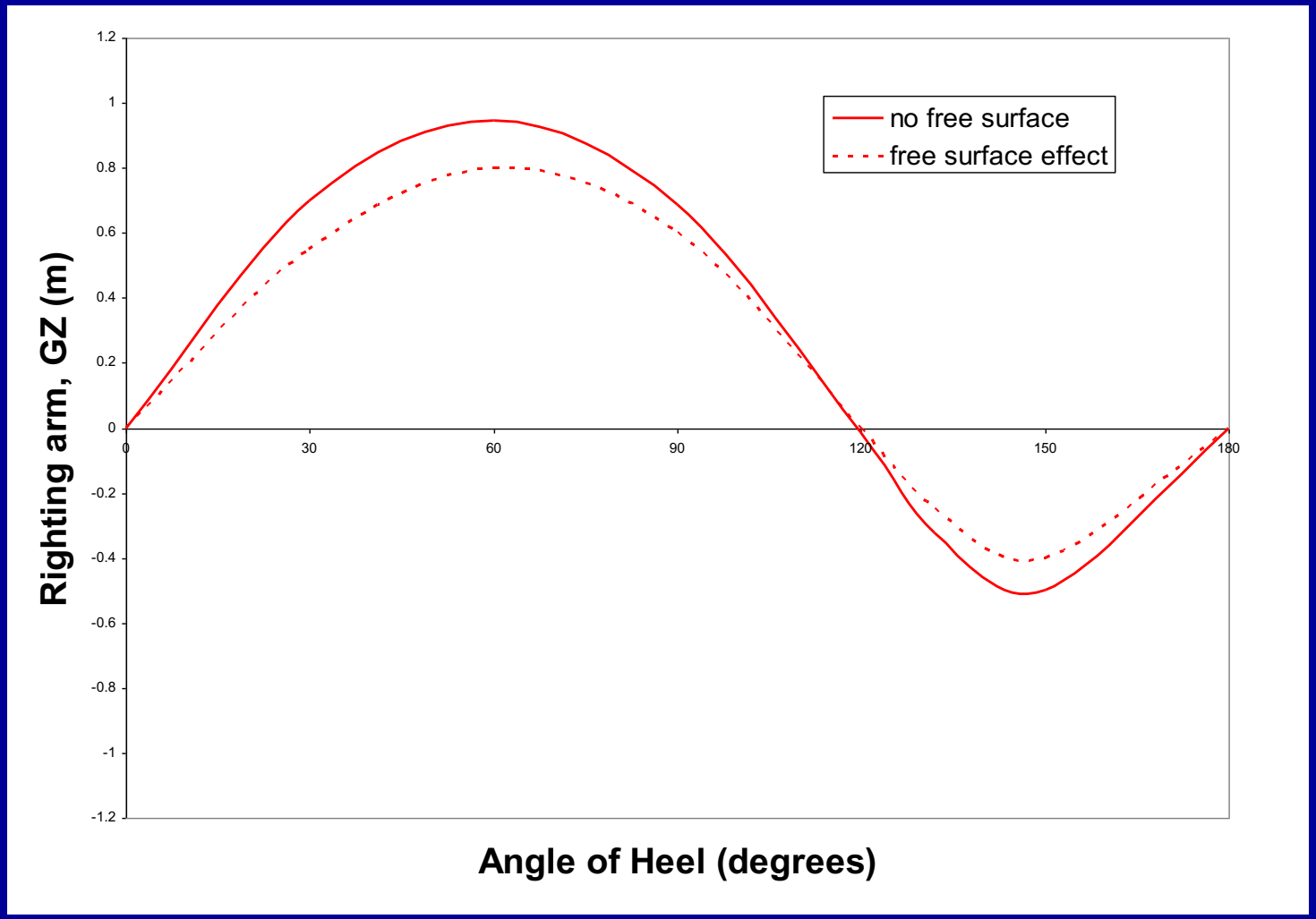
Cockpit has little effect on stability because remains above waterline at most angles



Coachroof & Cockpit Volumes

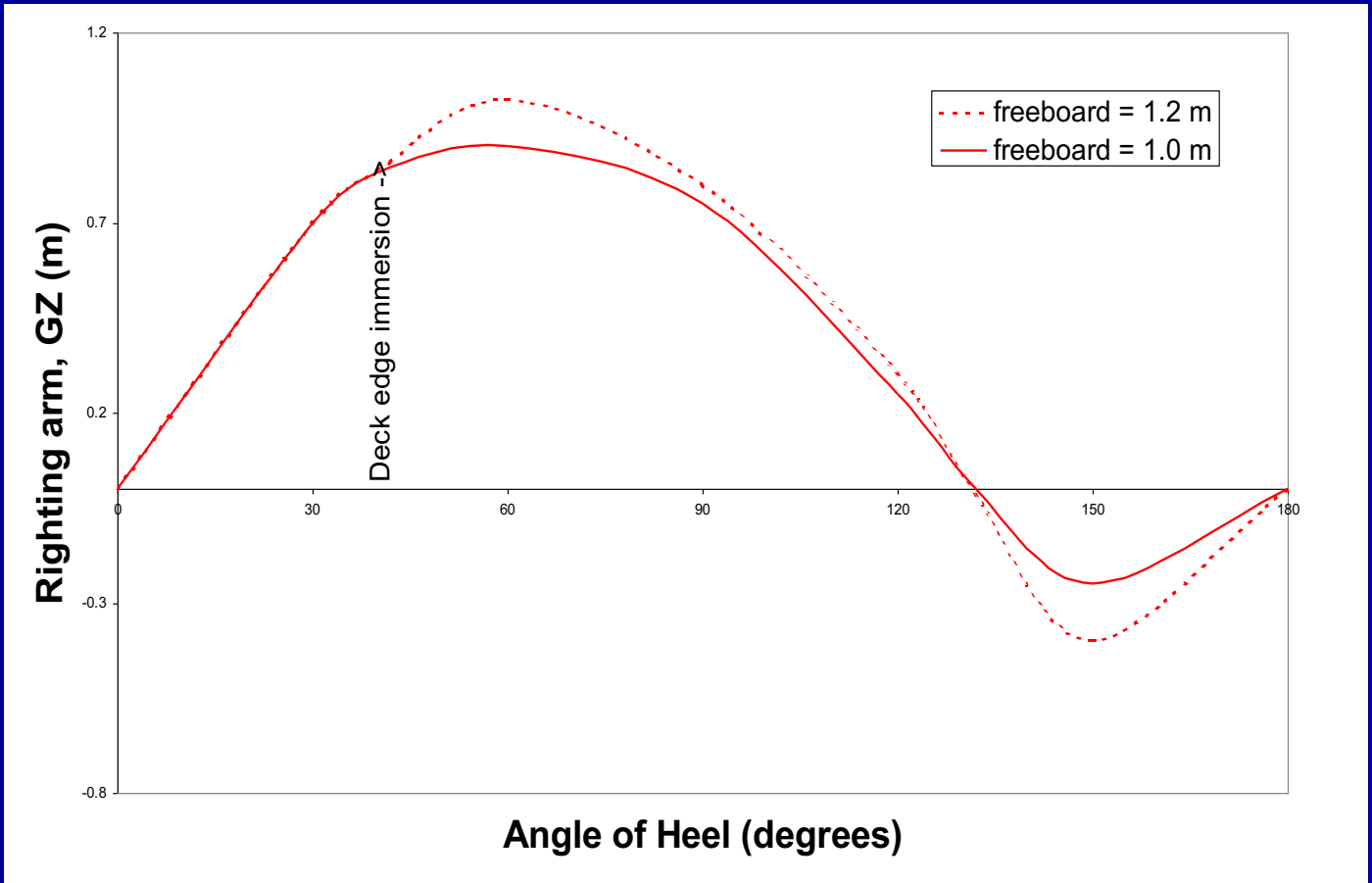


Free surface effect – tanks, bilge water etc



Freeboard

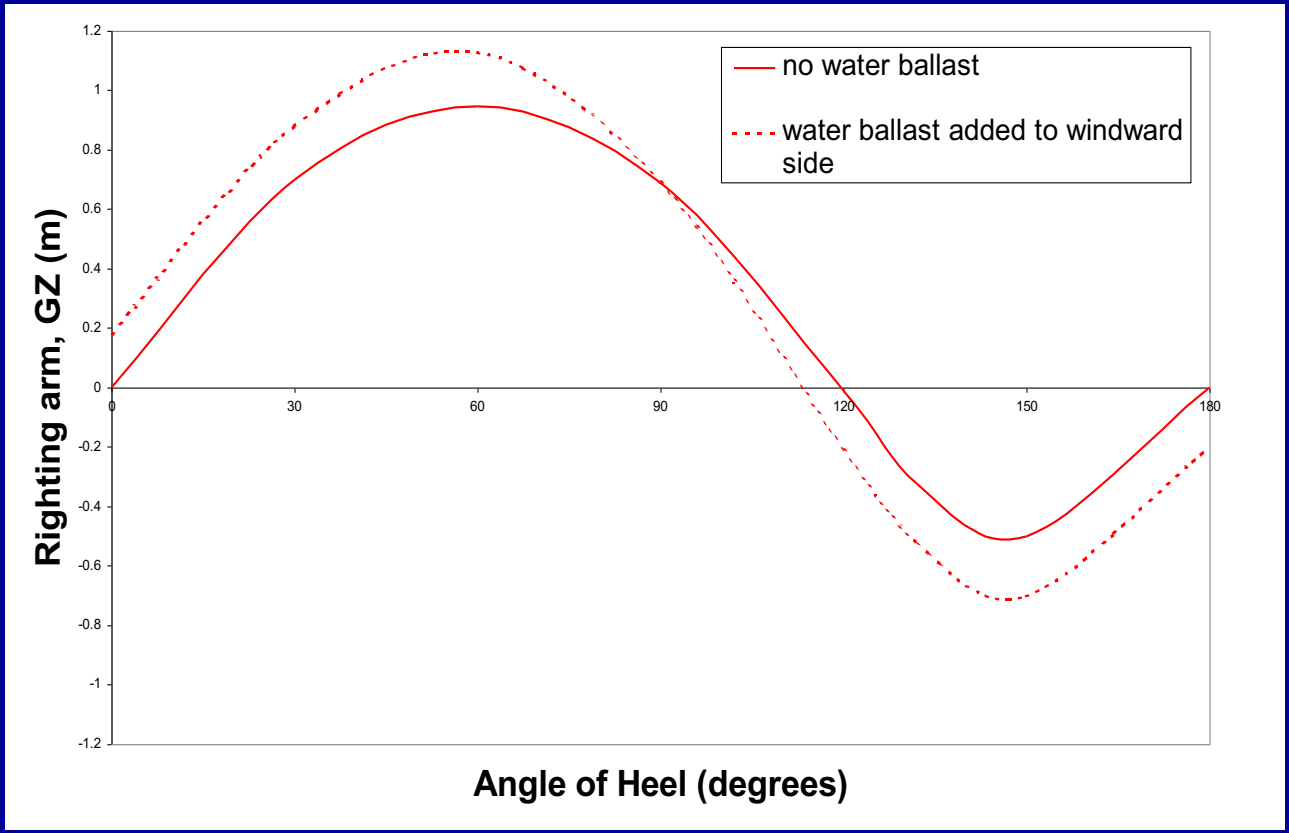
Freeboard has significant effect on stability at angles greater than deck edge immersion



Movable Ballast

To improve sailing performance by a reduction in heel angle, ballast is frequently moved, or added to the windward side of the yacht.

eg. moving crew, swinging keel or water tanks



Downflooding angle

Heel angle at which water starts to enter boat:

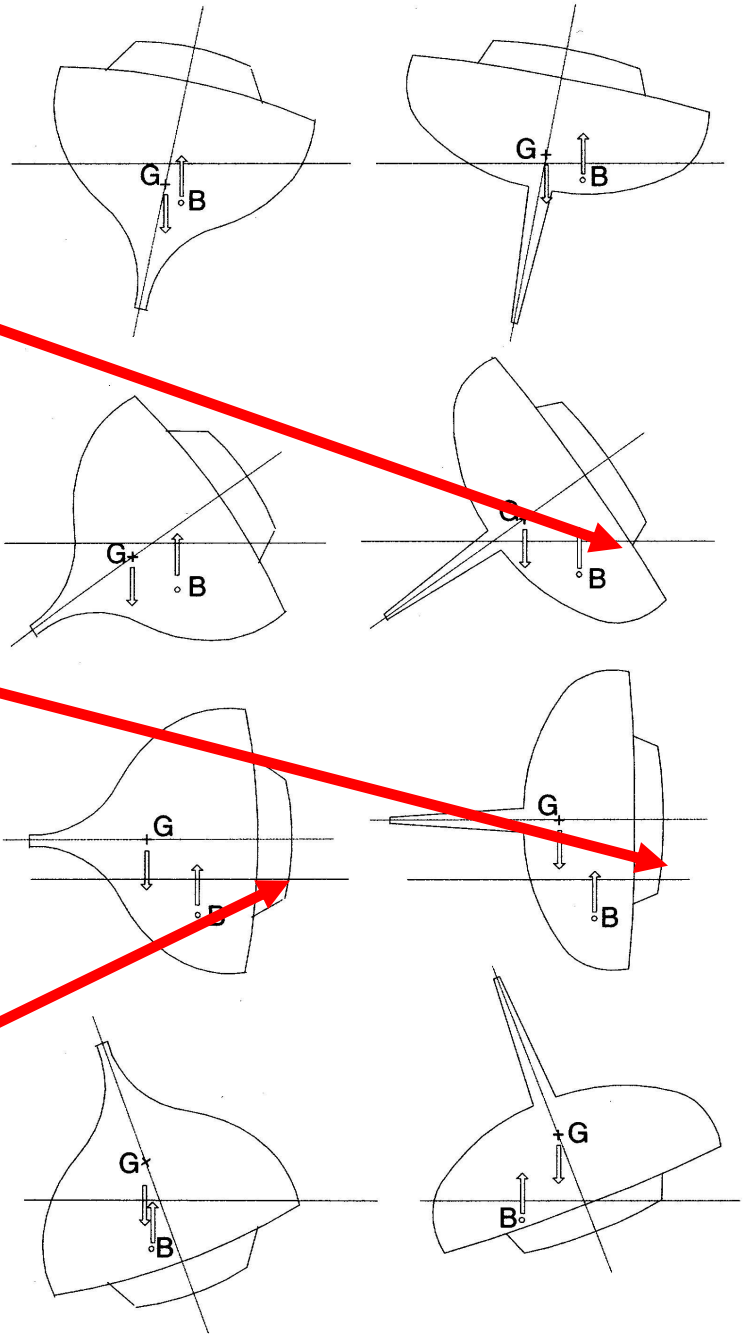
- Open hatch
- Ventilator
- Tank breather
- Cockpit locker lid

Stability curve after downflooding angle becomes irrelevant!

Cockpit locker

ventilator

Main hatch



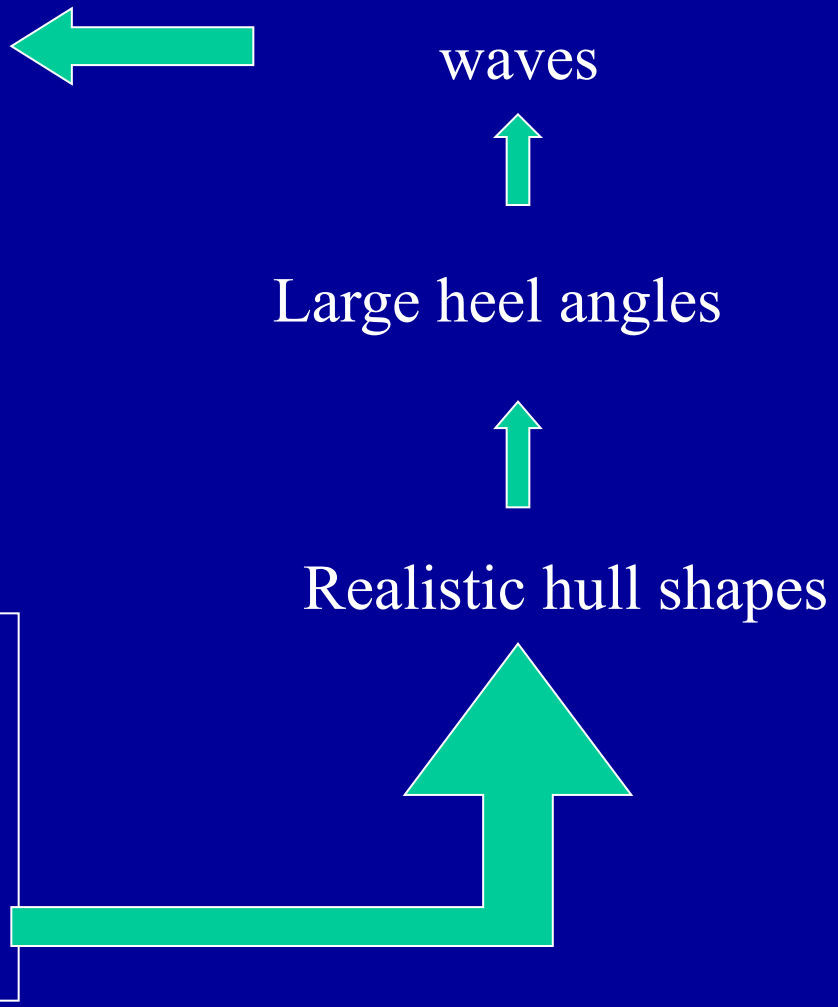
How stability is studied

Real world:

- Waves
- Roll motion
- Large heel angles

simplify

- Calm water
- Small angles
- “quasi-static”

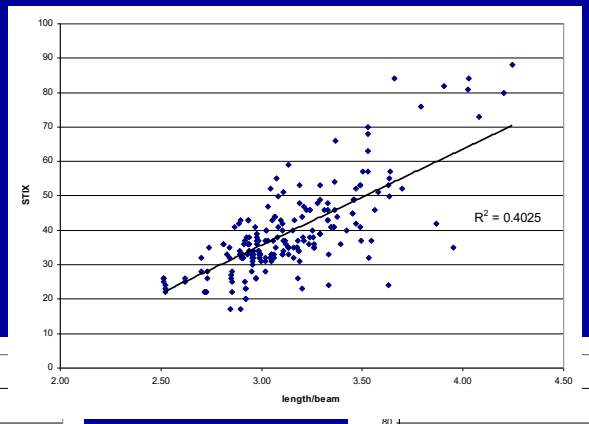


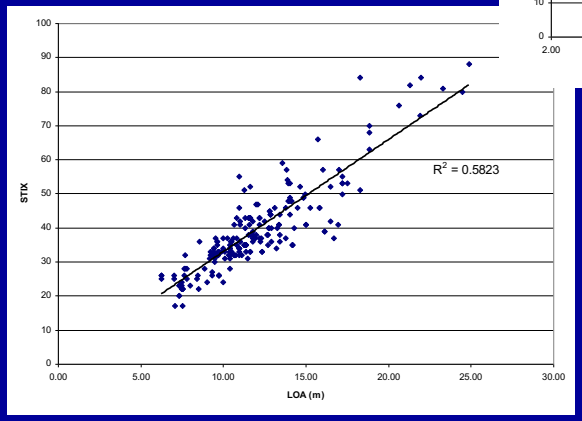
The STIX number combines:

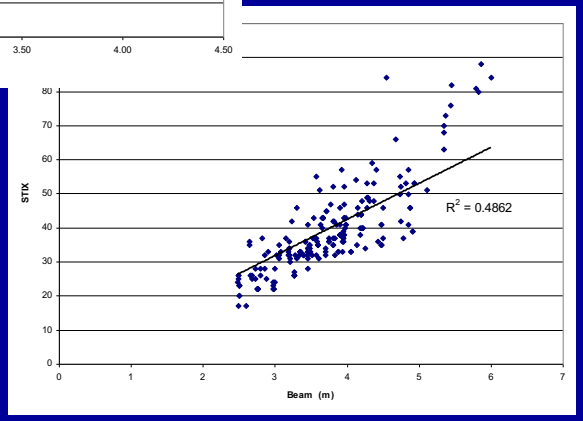
- Length
- Length/mass
- Beam/mass
- Wind heel moment
- Angle of Vanishing Stability (AVS)
- Area under curve up to AVS
- Downflooding angle

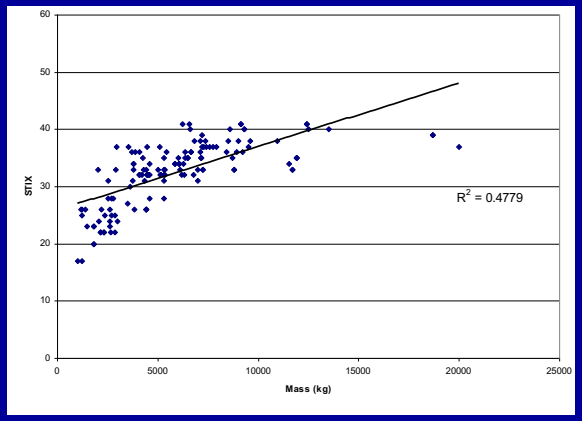
STIX number

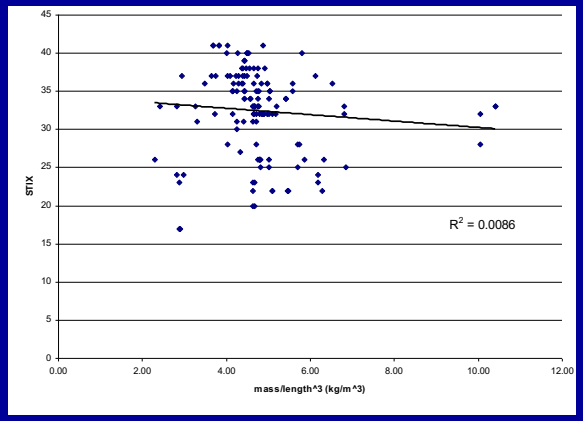
EU category	Min STIX	V_{wind} max (kn)	H_{sig} (m)
A	32	55	7
B	23	40	4
C	14	27	2
D	5	16	0.5

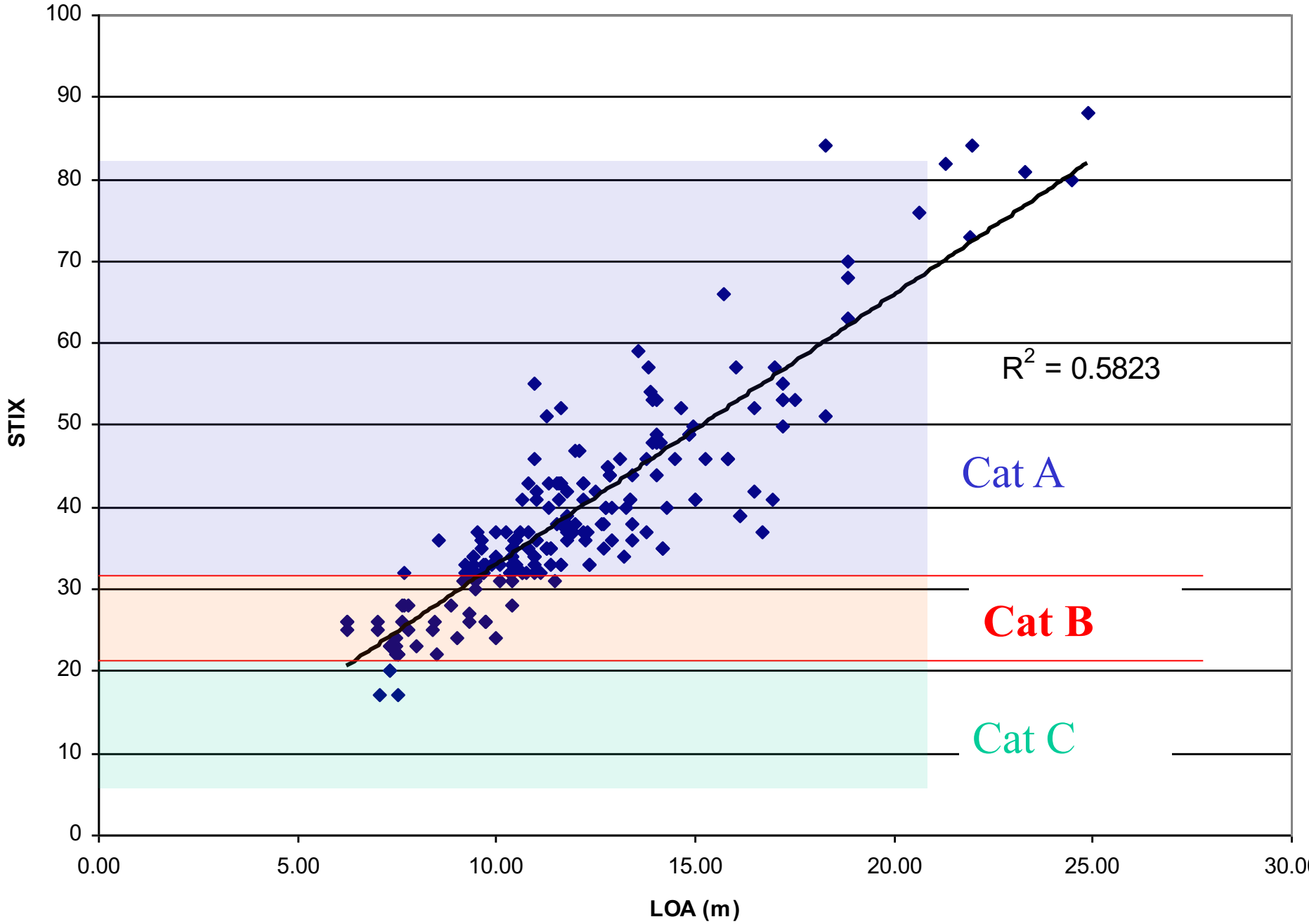

STIX
length/beam
R^2 = 0.4025

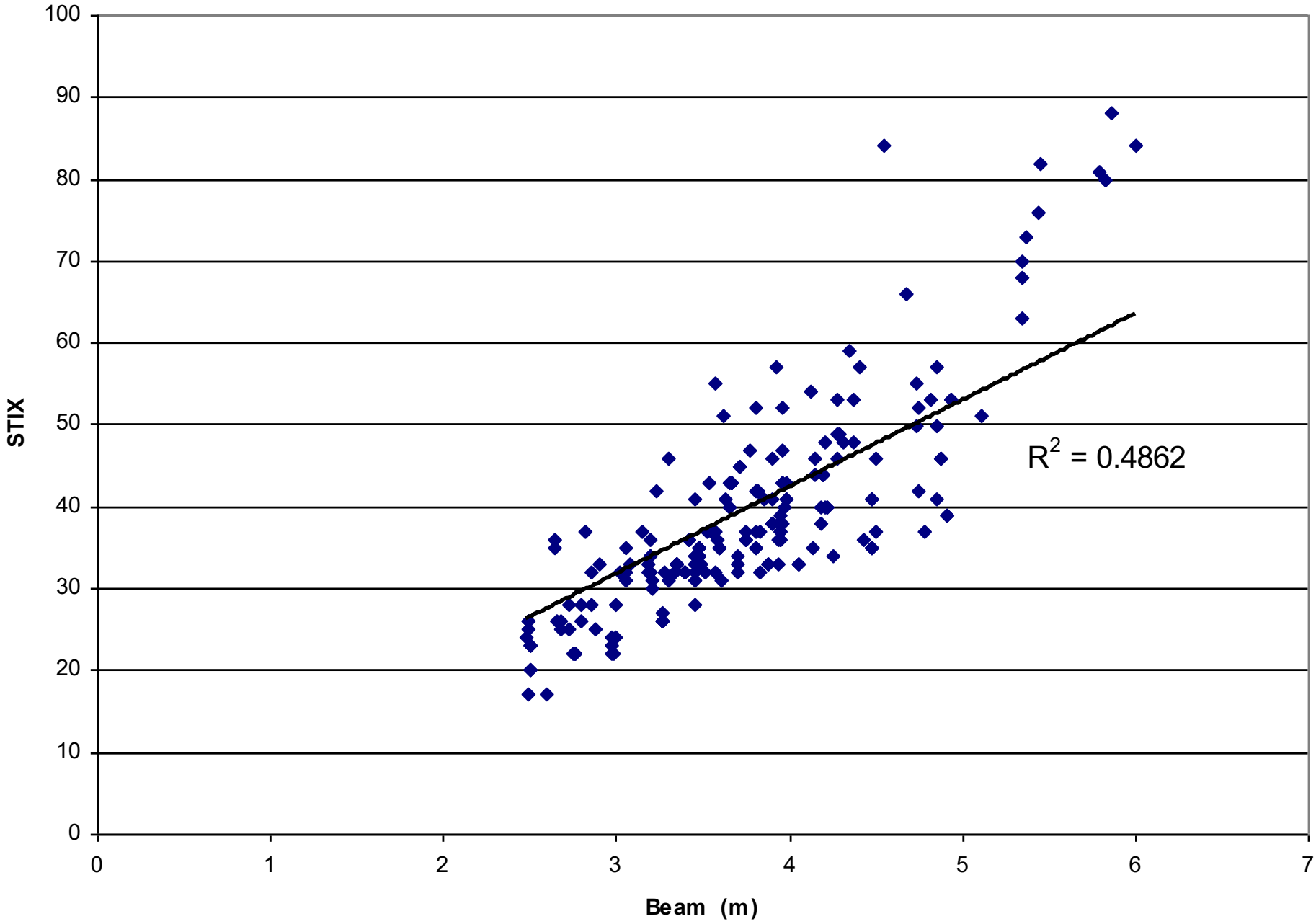

STIX
LOA (m)
R^2 = 0.5823


STIX
Beam (m)
R^2 = 0.4862


STIX
Mass (kg)
R^2 = 0.4779


STIX
mass/length^3 (kg/m^3)
R^2 = 0.0086


100
90
80
70
60
50
40
30
20
10
0
STIX
0.00
5.00
10.00
15.00
20.00
25.00
30.00
LOA (m)
R2 = 0.5823
Cat A
Cat B
Cat C


100
90
80
70
60
50
40
30
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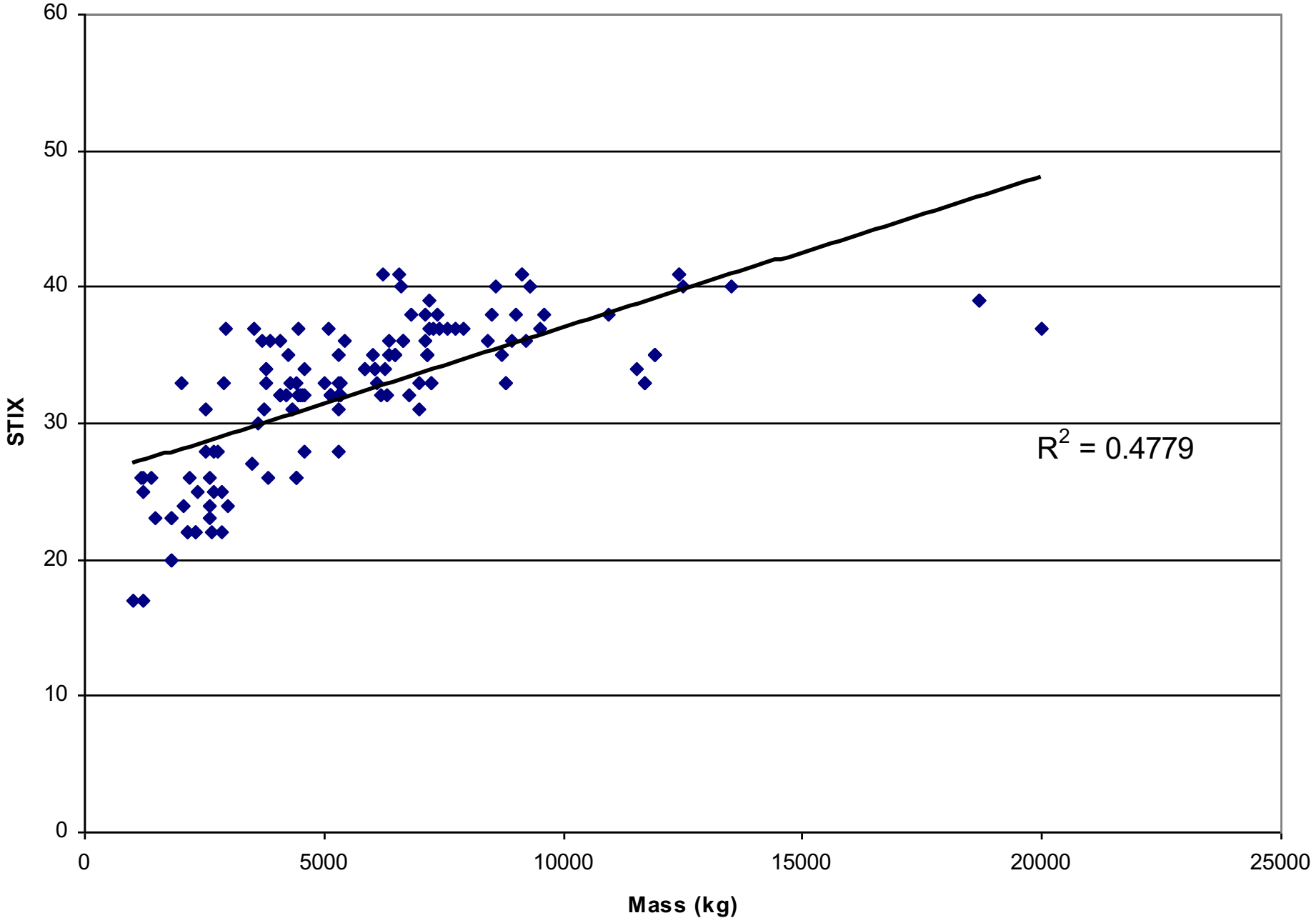
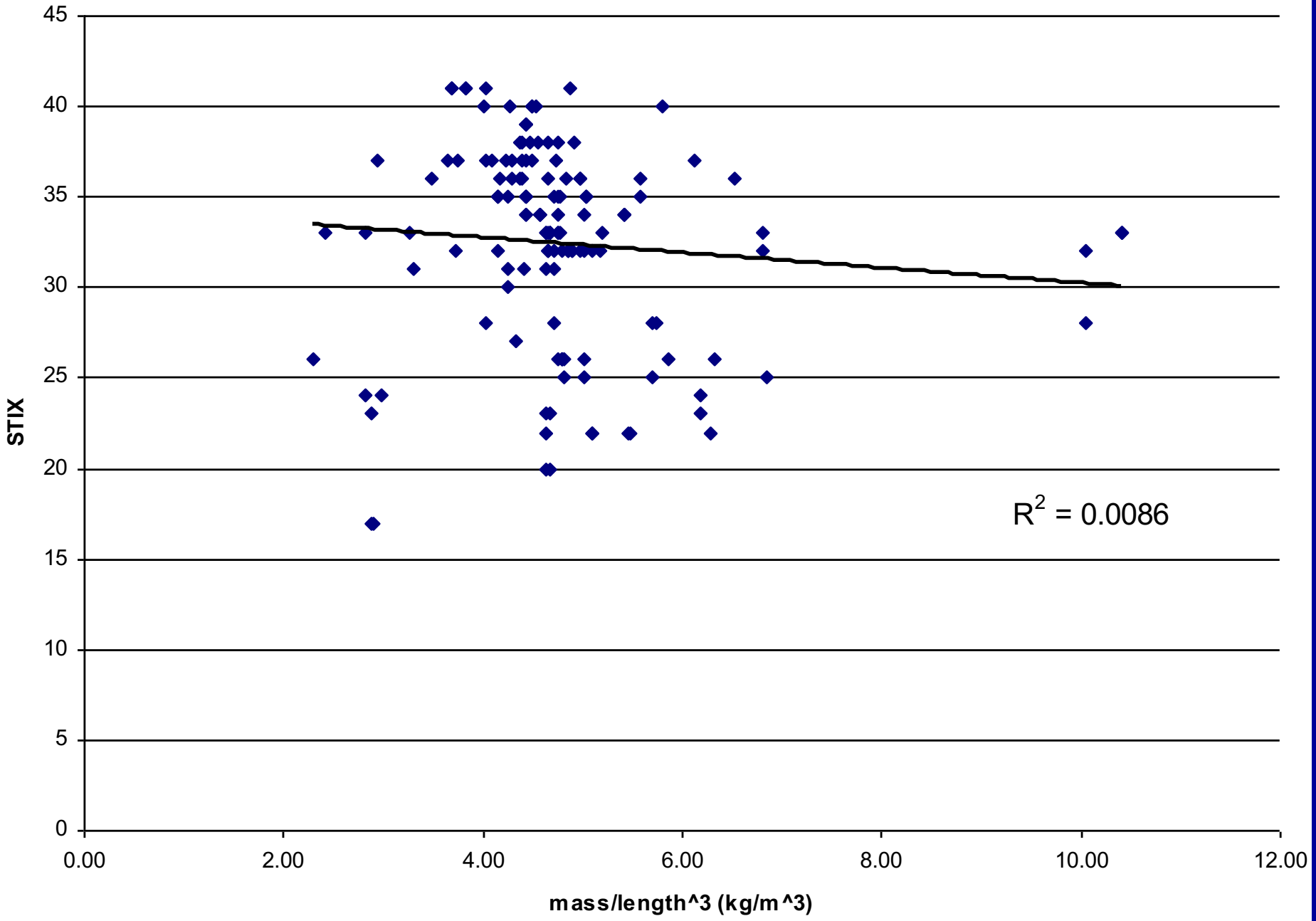
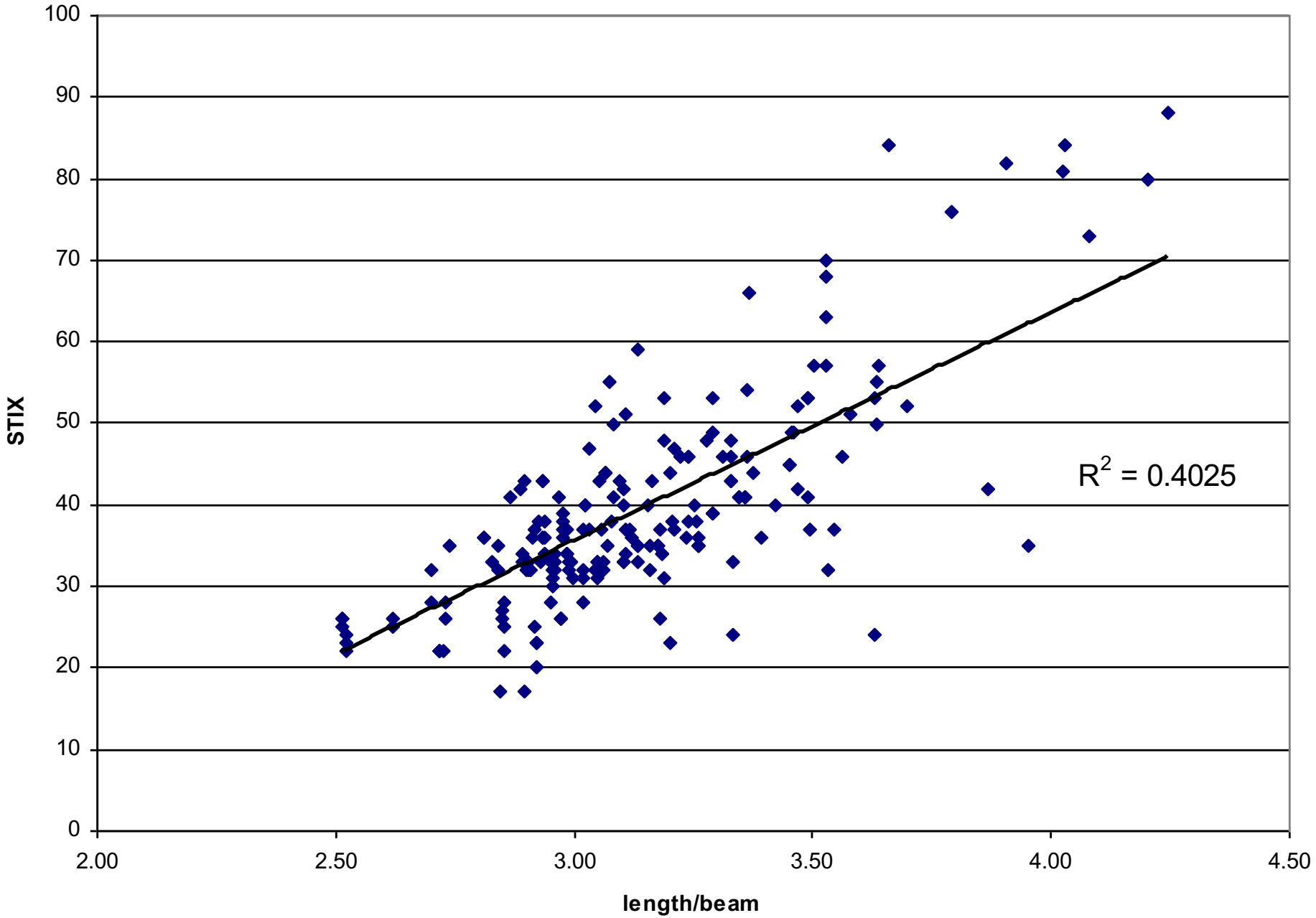
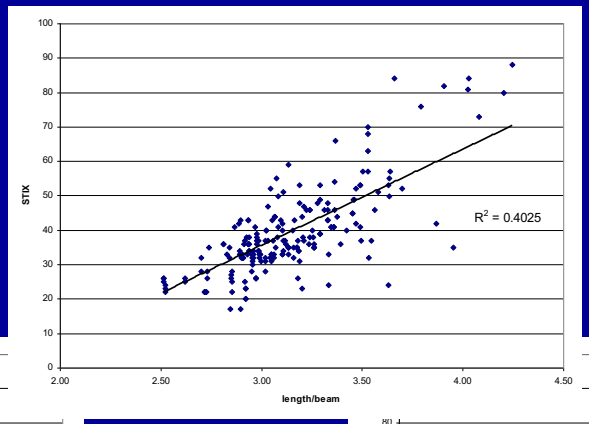
10
0
STIX
0
1
2
3
4
5
6
7
Beam (m)
R2 = 0.4862


60
50
40
30
20
10
0
STIX
0
5000
10000
15000
20000
25000
Mass (kg)
R2 = 0.4779


45
40
35
30
25
20
15
10
5
0
STIX
0.00
2.00
4.00
6.00
8.00
10.00
12.00
mass/length^3 (kg/m^3)
R2 = 0.0086


100
90
80
70
60
50
40
30
20
10
0
STIX
2.00
2.50
3.00
3.50
4.00
4.50
length/beam
R2 = 0.4025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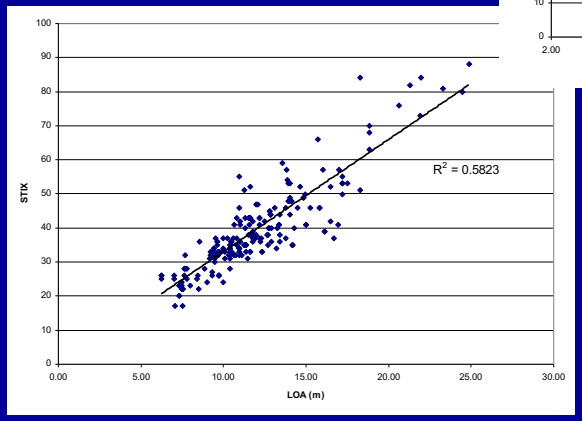
R^2 = 0.4025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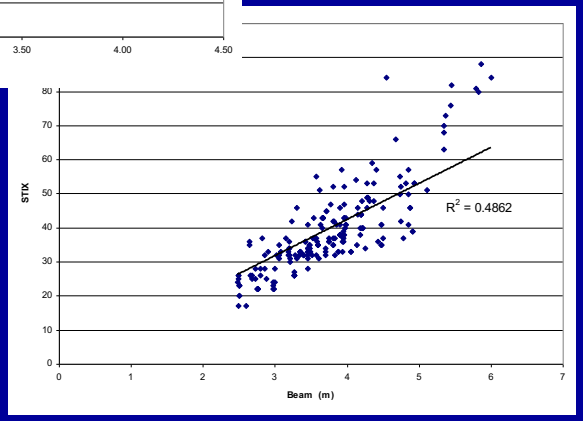
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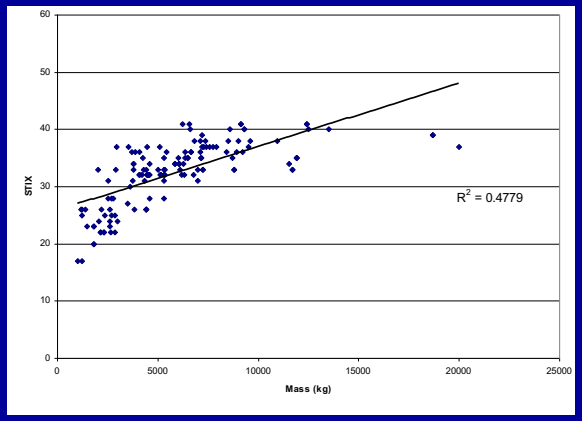
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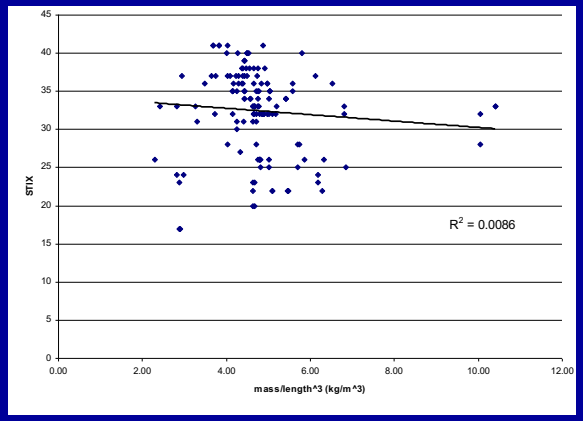
STIX
mass/length^3 (kg/m^3)
R^2 = 0.0086

Guidelines for selecting a design

"good" features for resisting capsize:

- Long
- Heavy
- Narrow

"good" features for speed, comfort and cost:

- Short
- Light
- Wide

Guidelines for selecting a design

- Decide type of sailing (coastal, offshore, ocean, extreme)
- Obtain stability curve, STIX or similar design data
- Compare with known designs
- Decide if OK (you choose, or consult a naval architect)

Guidelines when building a boat

- Avoid adding weight high up (e.g. in-mast furlers, radar, thicker deck plating)
- Avoid adding weight to keel without reviewing strength
- Avoid adding weight!
- Do not add tanks without lateral baffles
- Do not add off-centre openings (hatches, breathers, ventilators)

Summary: do not change designer's specs