Germanischer Lloyd

Excessive Accelerations Criteria

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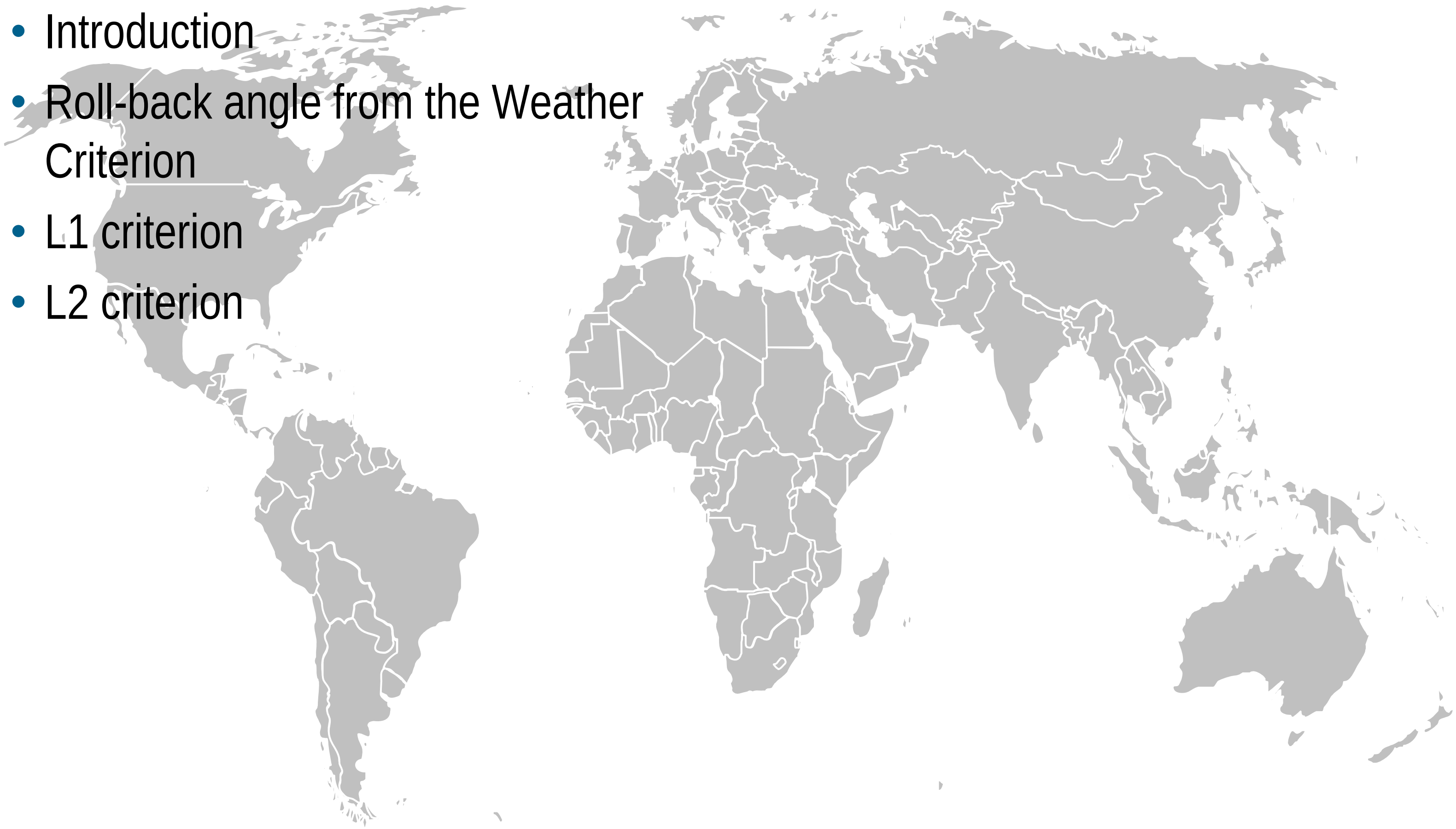
Overview

- Introduction
- Roll-back angle from the Weather Criterion
- L1 criterion
- L2 criterion



Introduction

- Introduction of Excessive Accelerations criteria was proposed by Germany, following fatal accidents onboard Chicago Express and MSC Guayas
- When standards are selected, these accidents should be taken into account
- Cargo security is addressed by Classification Rules, IMO CSS Code etc., people safety against excessive accelerations is not addressed
- Excessive accelerations due to parametric roll, pure loss & broaching are somehow addressed by criteria for these modes (large roll angle)
- Thus, only excessive accelerations due to synchronous roll with large *GM* needs to be addressed:

$$a_y \sim \varphi_a \left(g + h\omega_\varphi^2 \right)$$

Tested Ships

Ship	Lpp [m]	B [m]	Td [m]	D [m]	Δ(Td) [t]	Abk [m²]	$100A_k/(L_{wl}B)$ [-]
CV 14000 TEU	348.0	51.0	13.9	30.0	177045	61.6	0.347
CV 9200 TEU	319.5	45.4	12.9	27.3	120554	60.0	0.414
CV 8600 TEU	317.5	42.6	12.9	24.6	118428	64.2	0.475
CV 7500 TEU	302.5	42.6	12.9	24.0	112838	60.0	0.466
CV 5600 TEU	263.5	40.1	11.9	23.6	74234	59.0	0.559
CV 4800 TEU	280.1	32.1	11.9	20.9	75088	51.0	0.568
CV 2500 TEU	193.9	29.6	11.3	15.9	44031	38.0	0.663
CV 2500 TEU	193.5	29.6	10.0	15.9	36873	45.0	0.786
CV 1700 TEU	179.6	27.6	10.4	15.9	34747	36.5	0.737
Tanker 318 ktdw	317.5	59.7	20.9	29.9	334267	57.8	0.305
Tanker 113 ktdw	238.5	43.7	14.7	20.5	132997	37.2	0.357
Bulk Carrier 175 ktdw	279.3	46.4	16.4	24.0	187520	90.0	0.695
Bulk Carrier 118 ktdw	252.4	42.7	12.9	20.1	122615	76.2	0.707
Bulk Carrier 48 ktdw	178.5	31.9	9.4	16.6	54067	51.3	0.900
OSV 5970 tdw	103.30	21.8	6.4	8.0	10779	11.5	0.511

Using Roll-Back Angle from WeC

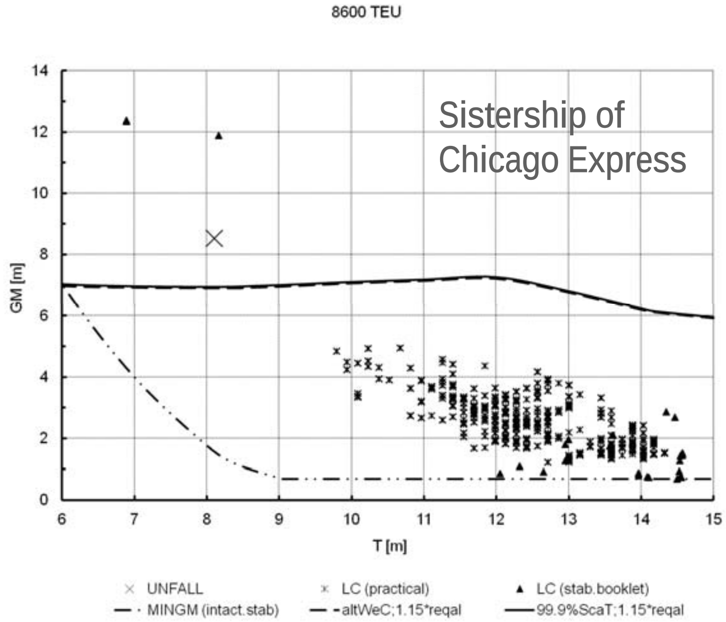
- Because roll-back angle in WeC considers synchronous roll in beam waves, it may be directly used to calculate corresponding accelerations
- Wave steepness s_W from Alternative WeC, MCS.1/Circ.1200
- h = height of the bridge above the roll axis
- ω_φ is the natural roll frequency: from roll period T_φ in the WeC
- Standard for a_y is set according to accident onboard Chicago Express: [0.92*g*]

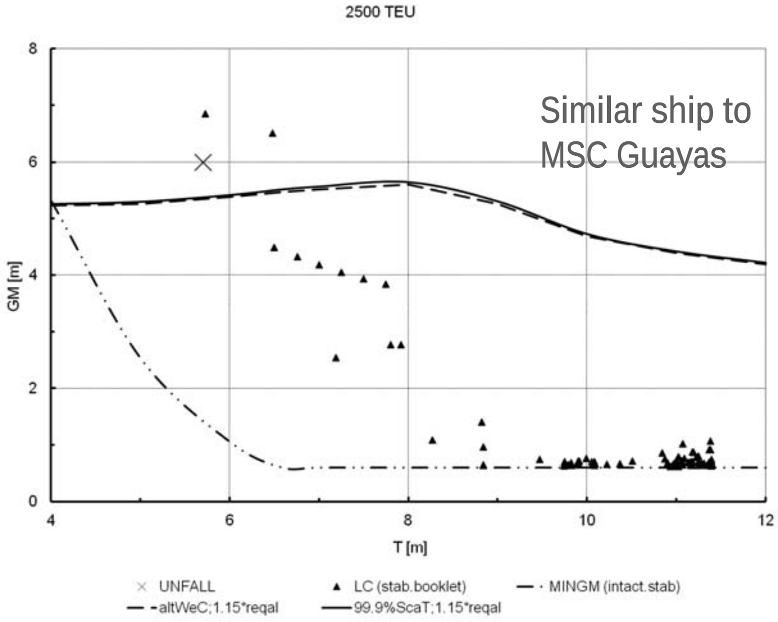
$$\varphi_1 = 109 k X_1 X_2 \sqrt{r s_W}$$

$$k = k\left(\frac{100 A_k}{L_{wl} B}\right)$$

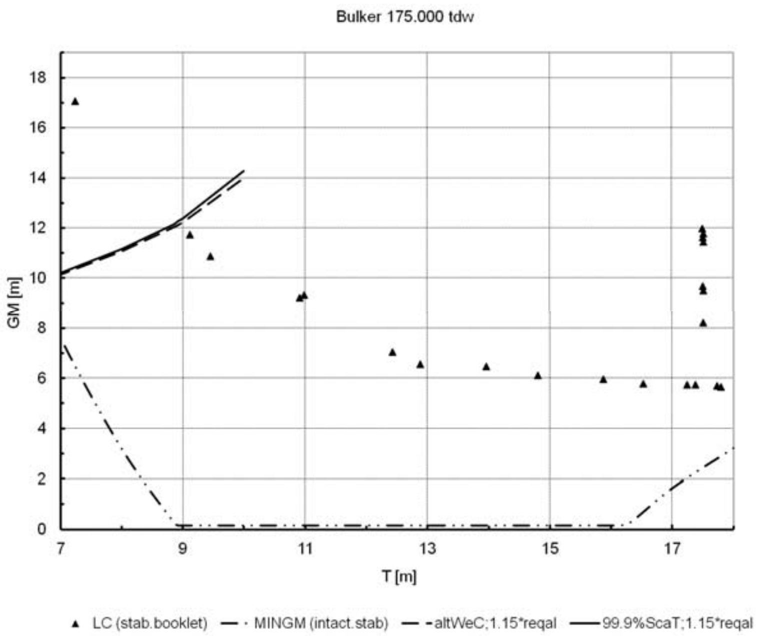
$$a_y = \varphi_1 \left(g + h\omega_\varphi^2\right)$$

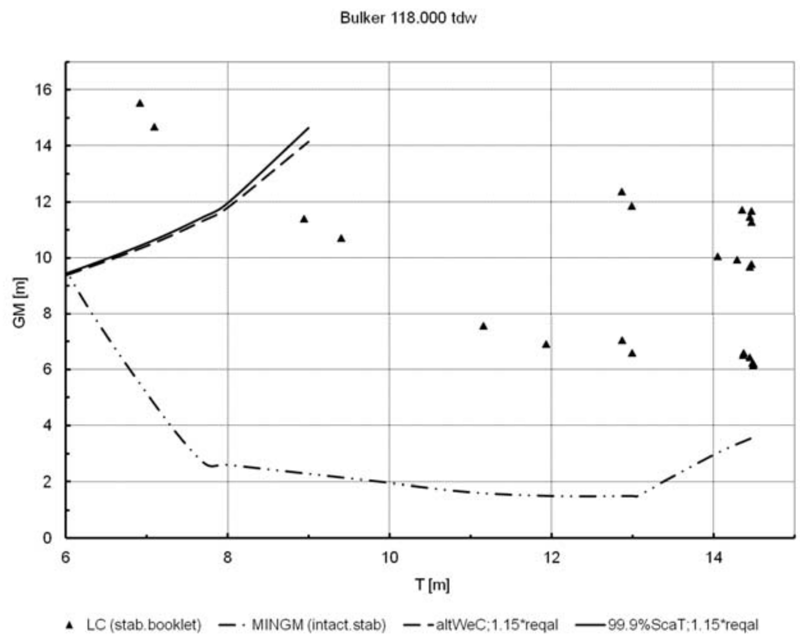
Results: Container Ships





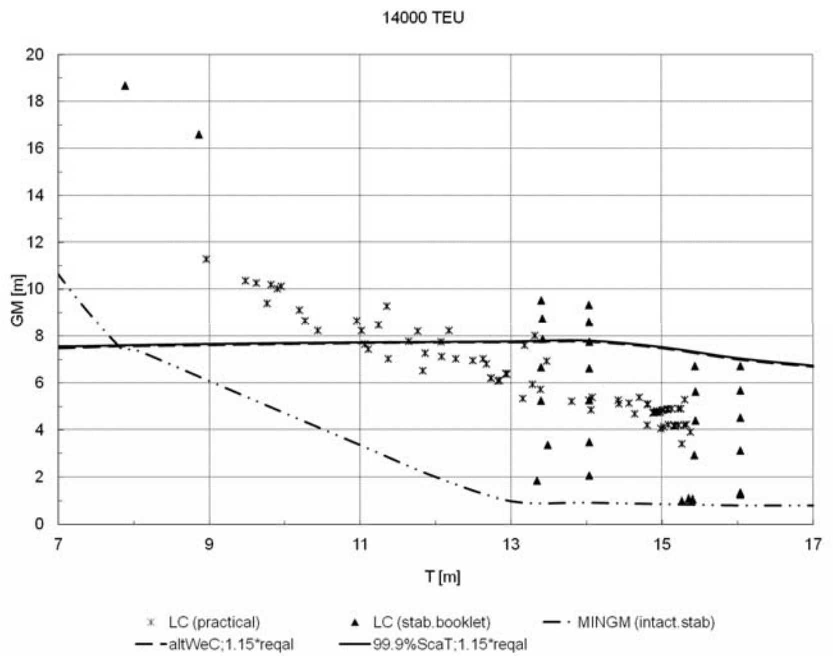
Results: Bulk Carriers

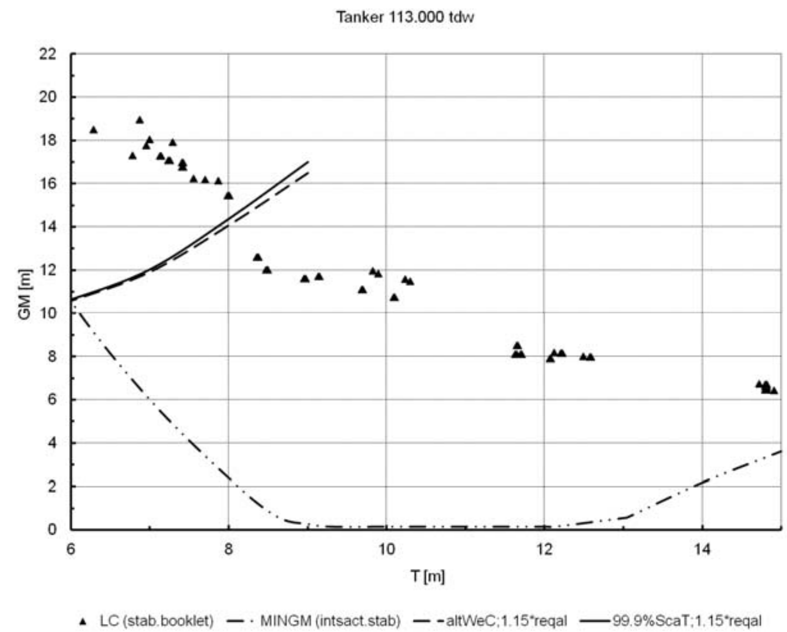




- Practically encountered load cases are not concerned
- Ballast load cases (both light & heavy for bulk carriers) may be of concern
- Ballast (container ships) and heavy ballast (bulk carriers) are seagoing conditions

Critical Ships

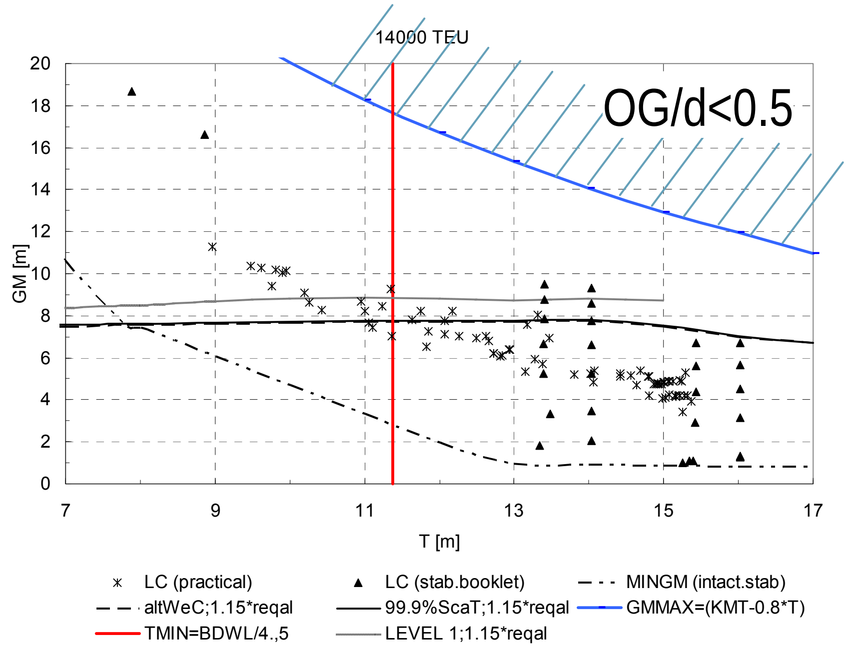




- Loading conditions from the stability booklet are concerned
- As well as practical loading conditions registered by the loading computer
- In both cases, bilge keel area is small compared to other vessels

L1 Criterion: Introduction

- The tests show that parameters of the vessels and loading conditions are very often outside of applicability limits of Weather Criterion:
    - effective wave slope formula
    - natural roll period formula
- Using these formulae outside of their applicability range is believed to lead to conservative errors
- Besides, WeC in the present form will be updated later anyway



L_1 Criterion: Solution Method

- Roll amplitude is found from a simplified solution of 1 d.o.f. roll equation:
- $s_W=h_W/\lambda_W$ wave steepness, h_W wave height, λ_W wave length, δ_φ logarithmic decrement of free roll decay, $\zeta_{\%}$ effective linear damping as percentage of critical damping
- To define:
  - effective wave slope r
  - wave steepness s_W
  - roll damping $\zeta_{\%}$
  - natural roll period $T_\varphi=2\pi\omega_\varphi$
  - standard for σ_{ay}

$$\sigma_\varphi = \frac{0.07 r h_w \omega_\varphi^2}{\sqrt{\delta_\varphi}} \equiv \frac{4.3 r s_W}{\sqrt{\delta_\varphi}}$$

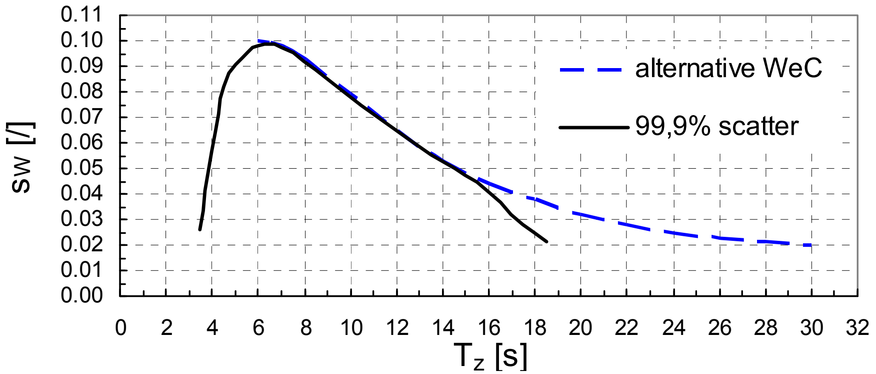
$$\zeta_{\%} = \frac{\delta_\varphi}{2\pi} \cdot 100\%$$

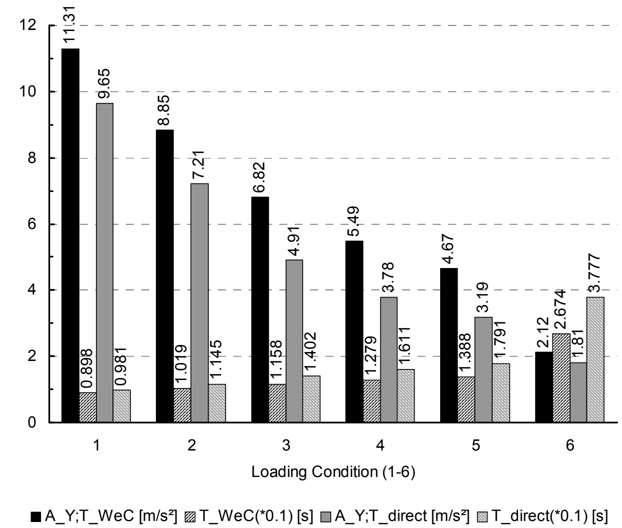
$$\delta_\varphi = \delta_0 + 1.88 \sigma_\varphi \frac{d\delta_\varphi}{d\varphi_a}$$

$$\sigma_{ay} = \sigma_\varphi k_L \left(g + h\omega_\varphi^2 \right)$$

L_1 Criterion: Problems

- wave steepness s_W: as $h_s=f(T_z)$ with a given exceedance frequency
- roll damping $\zeta_{\%}$: proposals for parametric roll (plus quadratic term)
- natural roll period $T_\varphi=2\pi\omega_\varphi$: the formula in WeC or existing alternative proposals
- standard for σ_{ay}: by adjustment to loading conditions in accidents
- effective wave slope r: empirical formulation is required, with an extended applicability range compared to WeC-formula





L_2 Criterion: Method

- Sway-roll coupling is cancelled with roll diffraction moment $\Rightarrow$ roll can be modelled without coupling with other motions if exciting moment is calculated without diffraction
- Then wave excitation can be pre-computed with a hydrostatic software
- Simulations of roll motions:
  - Simulations are performed over a given scatter table
  - For each combination of $[h_s, T_z]$, integral needs to be calculated to compute σ_φ
  - Using spectral moments and sum over all seaways produces a_y^{max}
  - Standard is tuned by accident loading conditions

$$\sigma_\varphi^2 = I_1 \frac{\omega_\varphi^4}{g^2} \int_0^\infty \frac{r^2 \omega^4 S_\zeta d\omega}{(\omega_\varphi^2 - \omega^2)^2 + (\omega_\varphi \omega \delta_\varphi / \pi)^2}$$

I_1 = const, taking into account spreading and course-keeping

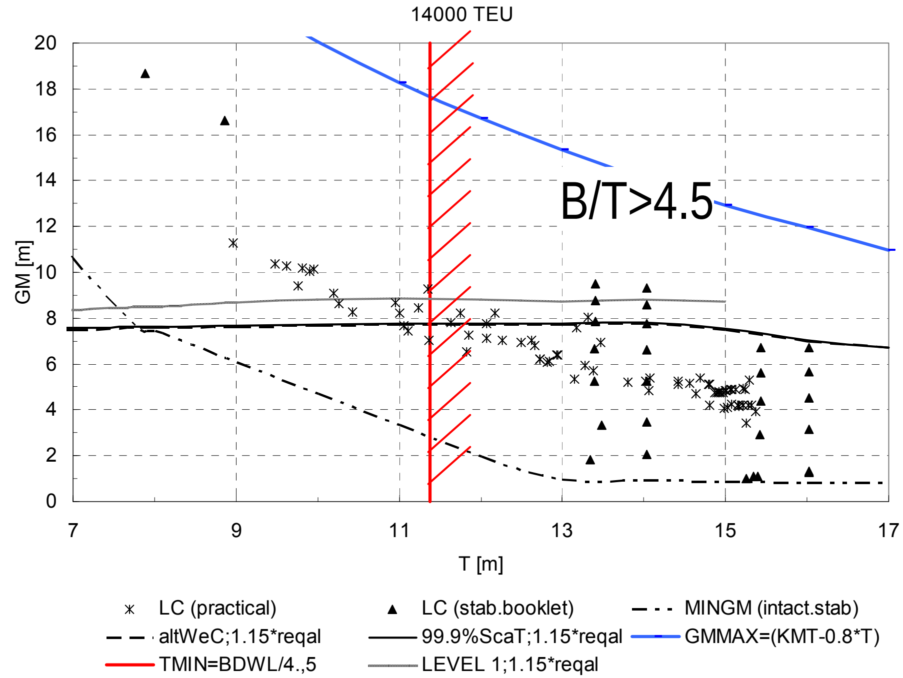
S_ζ = wave energy spectrum

r = effective wave slope: pre-computed for regular waves and stored in lookup-tables

δ_φ = logarithmic decrement of roll decay

L_2 Criterion: Problems

- Simplified Ikeda method for roll damping works for B/T ≤ 4.5 ⇒ *does not work for ballast conditions*
- new empirical formula for natural roll period is to be defined
- Computational requirements:
  - hydrostatic preparation (tables of effective wave slope r): 1 hour overnight with a NAPA script
  - Simulations over a scatter table (NAPA-macros or Excel-scripts): overnight per 1 vessel (all loading conditions)



Conclusions and Outlook:

Ongoing developments:

- L_1 criterion:
  - empirical formulation for roll damping (especially higher order)
  - empirical formula for natural roll period &
  - empirical formula for effective wave slope r with extended applicability range compared to WeC
- L_2 criterion:
  - simplified formulation for linear and quadratic roll damping, working for B/T > 4.5
  - empirical formula for natural roll period

Design considerations:

- Ballast load cases are of concern for all considered vessels
- For ships with low roll damping, also other practical loading conditions are concerned
- Possible design solutions:
  - increase bilge keel area
  - bridge design, handles, fastening etc.

Thank you for your attention. Questions?

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