COPENHAGEN OFFSHORE WIND

International Conference & Exhibition 26 – 28 October 2005

Concrete Foundations for Offshore Wind Energy Converters subjected to fatigue loading

Prof. Dr.-Ing. Jürgen Grünberg
Dipl.-Ing. Joachim Göhlmann

Institute of Concrete Construction

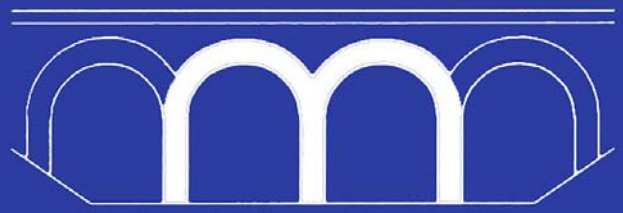


Table of Contents

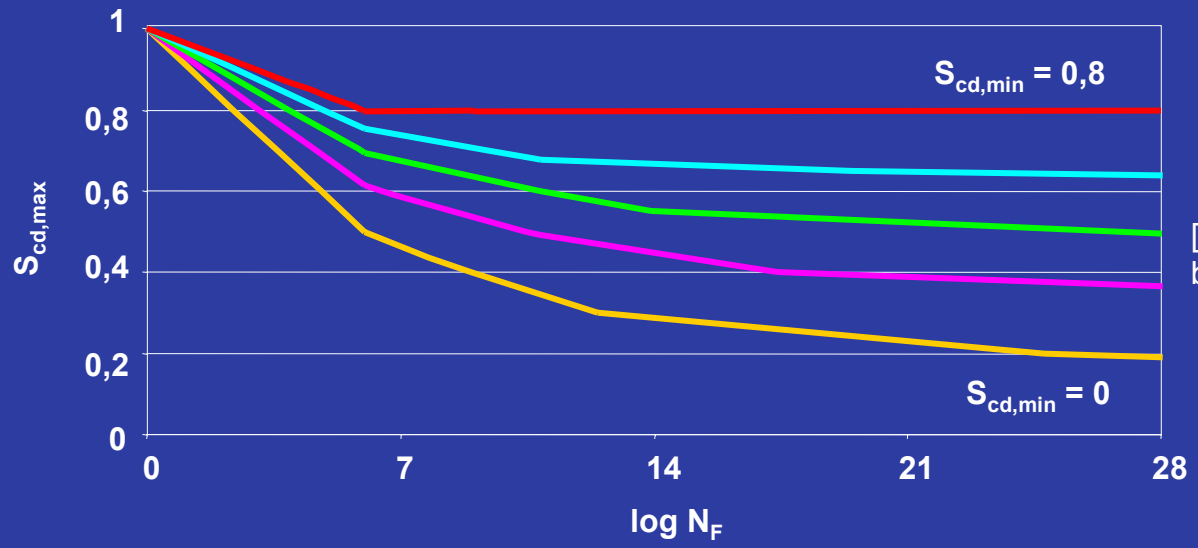
1. Introduction and Motivation

Hybrid Tower Bremerhaven

Nearshore Foundation Emden

1. Introduction and Motivation

Cumulative damage law by Palmgren and Miner



[S – N curves
by Model Code 1990]

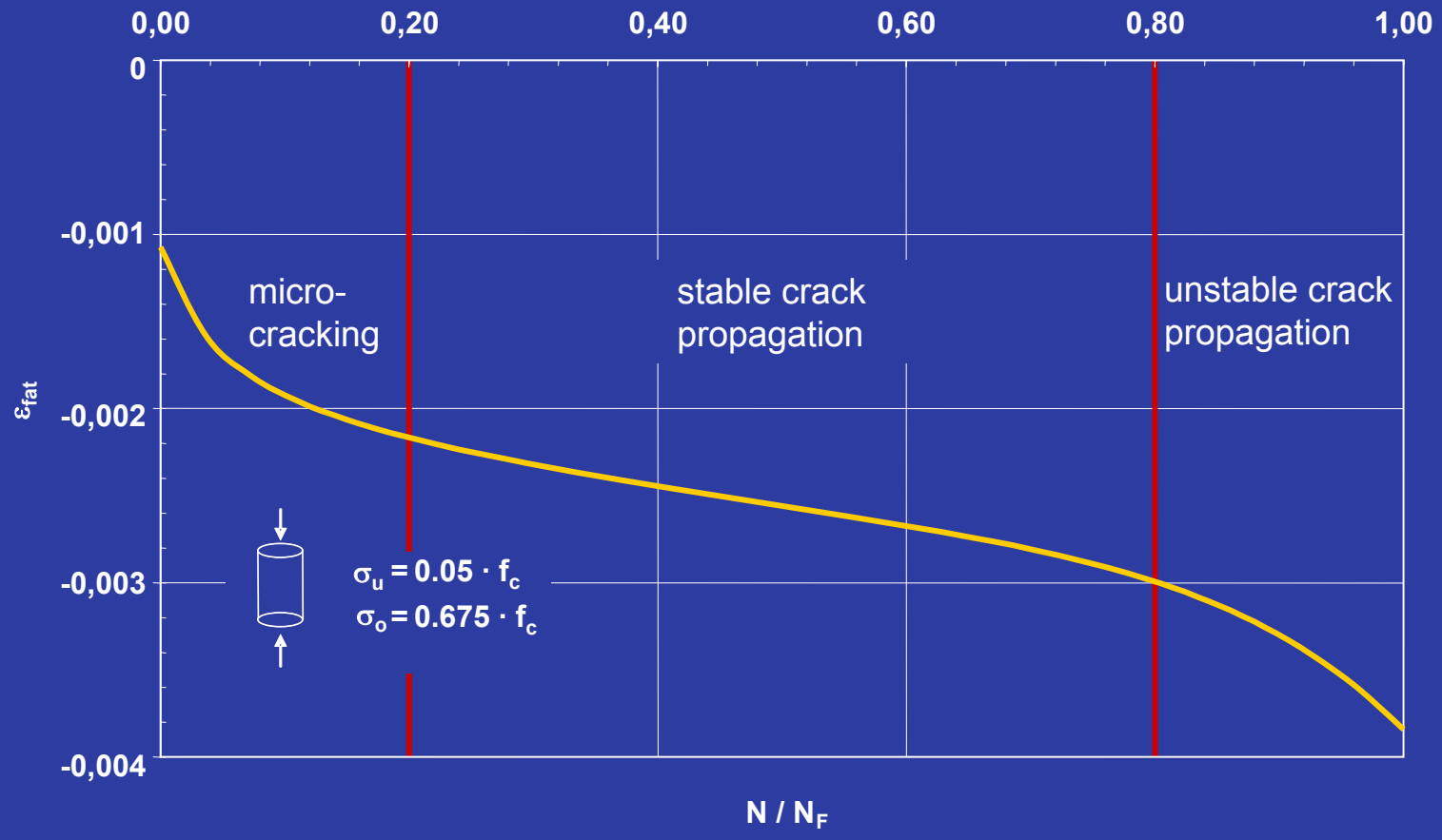
Linear accumulation:

$$D = \sum_{i=1}^{j} \frac{N_i}{N_{Fi}} \leq D_{lim} = 1$$

N_i = Number of load cycles with the same amplitude and range

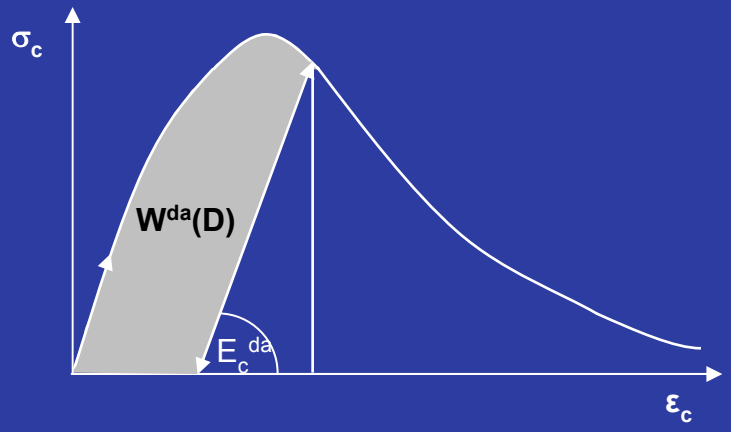
N_{Fi} = Corresponding total number of cycles to failure

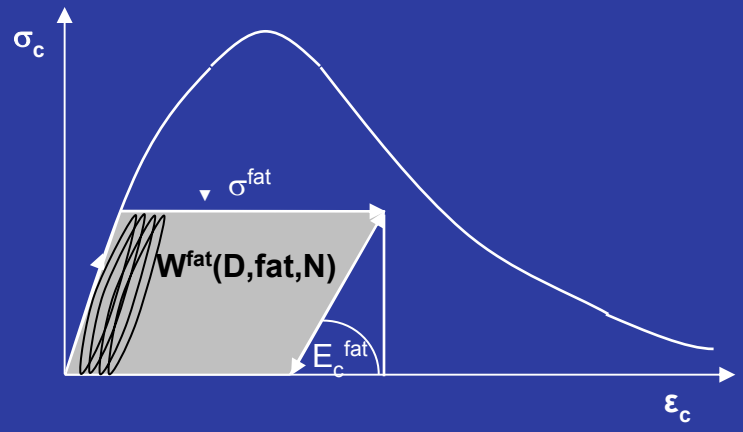
Strain evolution under constant fatigue loading



Energetic fatigue damage model by Pfanner

Assumption:



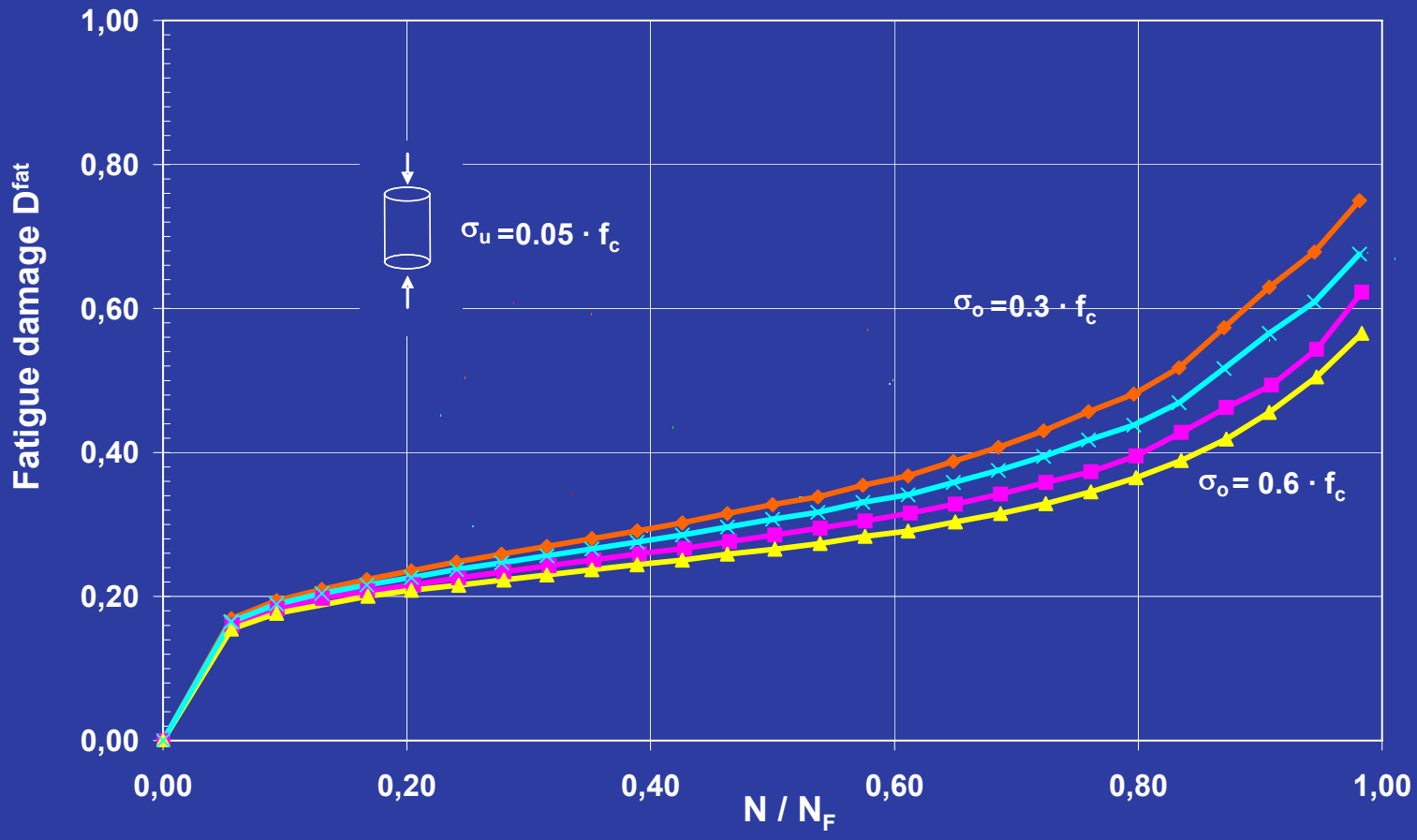


$$W^{da}(D) \stackrel{!}{=} W^{fat}(D, \sigma^{fat}, N)$$

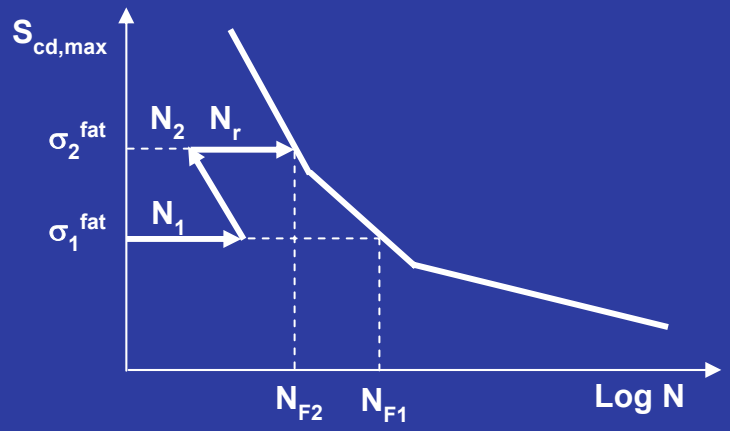
$$E_c^{da} = E_c^{fat} = (1 - D) \cdot E_c$$

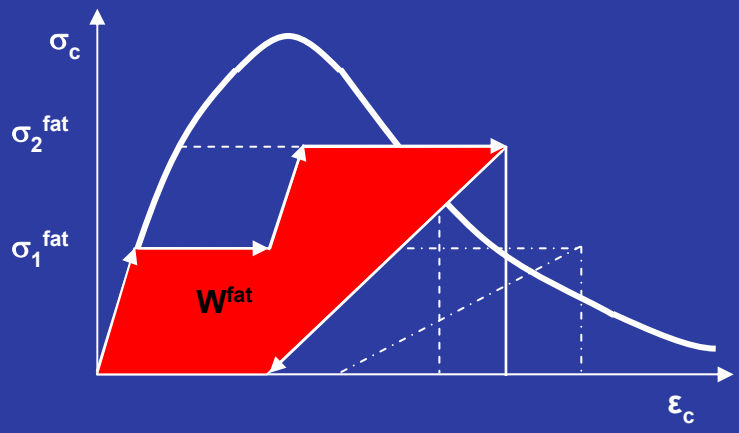
The mechanical work, which have to be applied to obtain a certain damage state in the fatigue process, is equal to the mechnical work under monotonic loading to obtain the same damage state.

Damage evolution under constant fatigue loading computed by a user – subroutine of ABAQUS



Extended approach for multi - stage fatigue loading

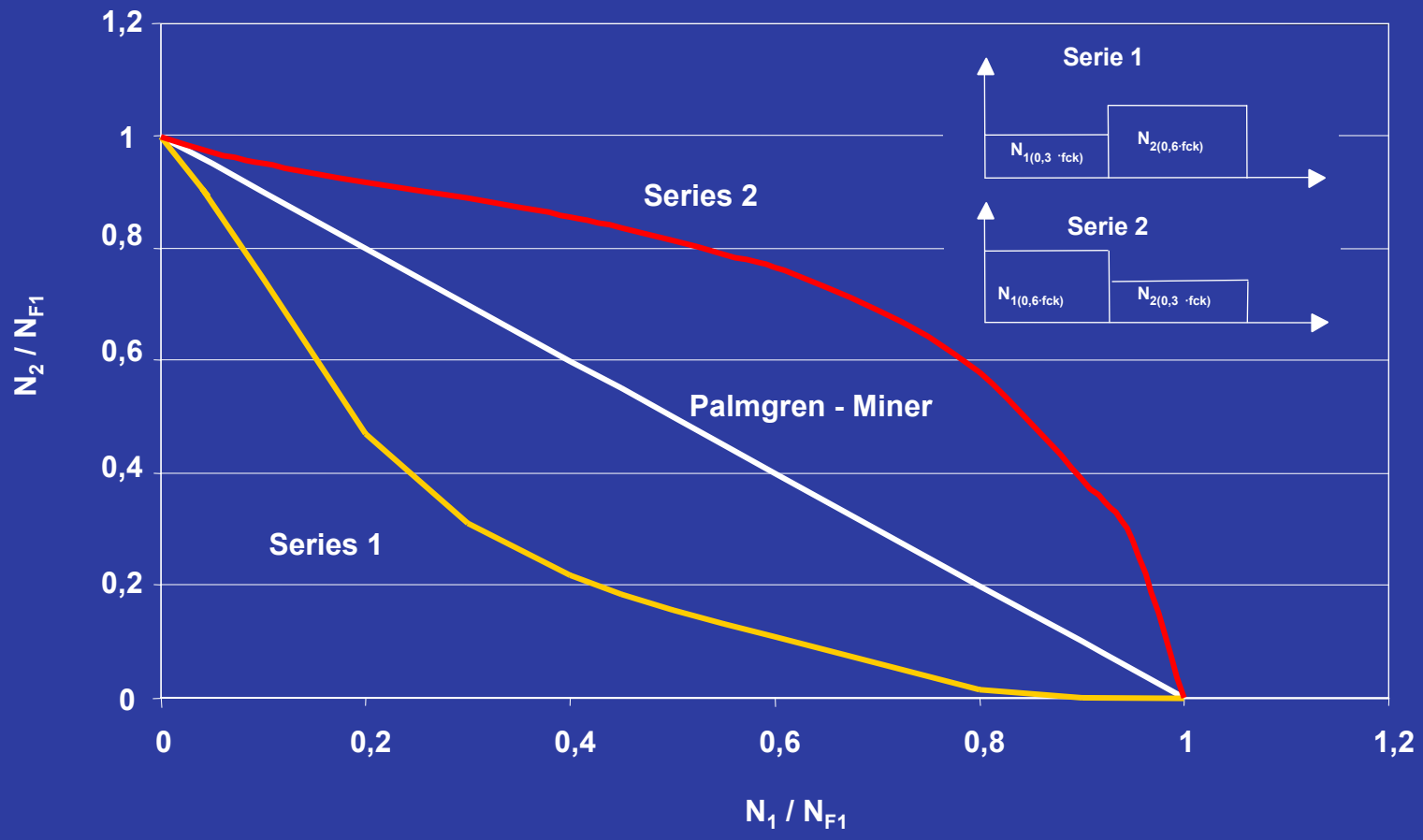




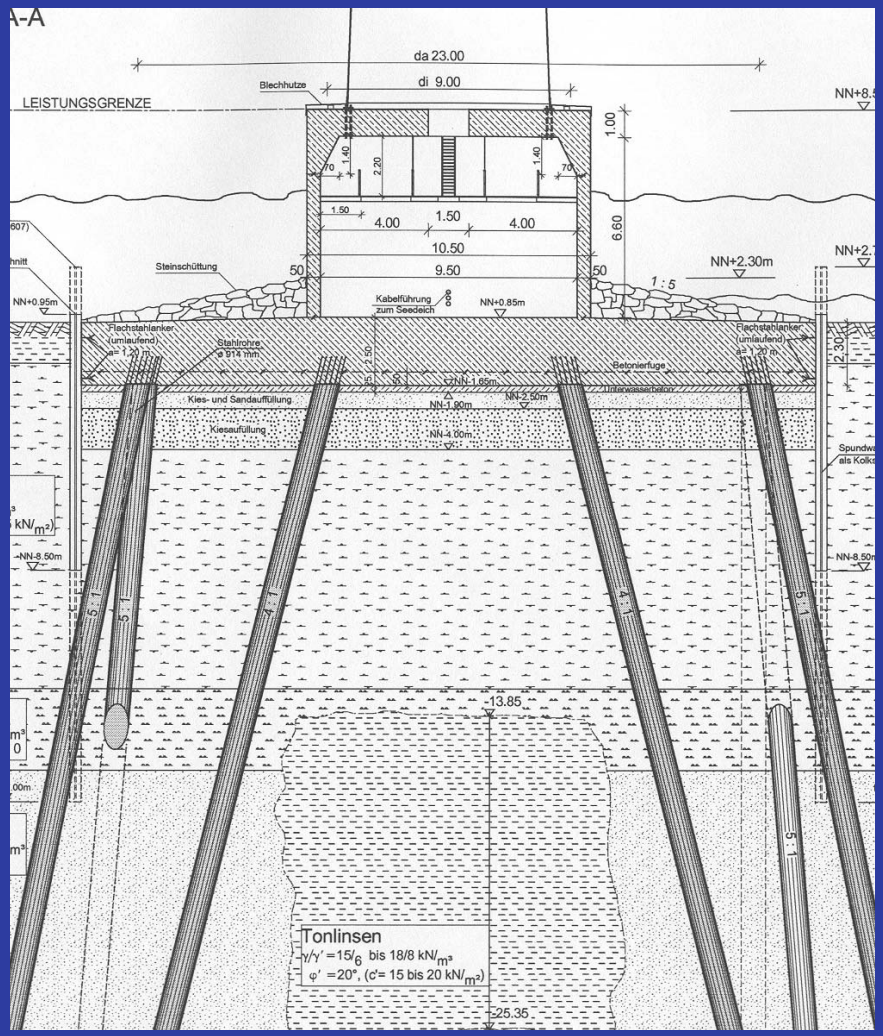
Assumption for a two – stage fatigue process:

$$N_2\left(\sigma_2^{\,fat}, W^{fat}(D)\right) \stackrel{!}{=} N_1\left(\sigma_1^{\,fat}, W^{fat}(D)\right)$$

Life cycle of a two - stage fatigue process

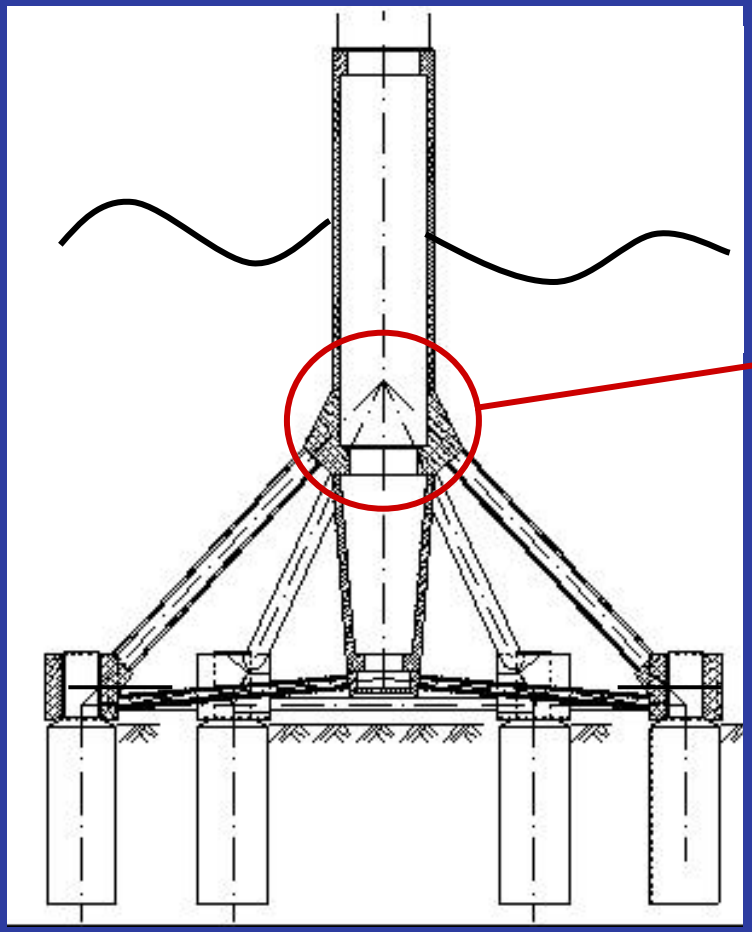


Nearshore – Gravity Foundation

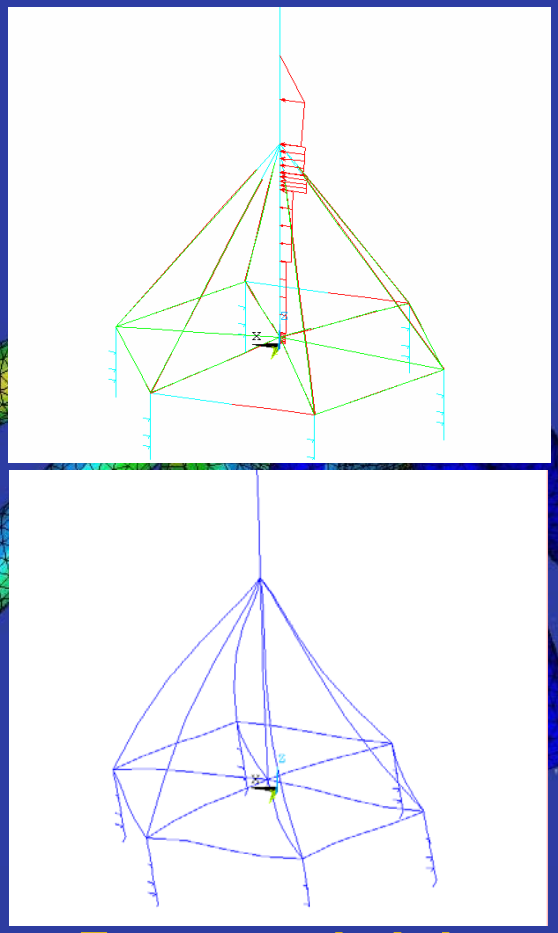


Design:
G + S Planungsgesellschaft mbH
Hamburg, www.gus-ing.de

Offshore – Framework Foundation „HEXAFIX“

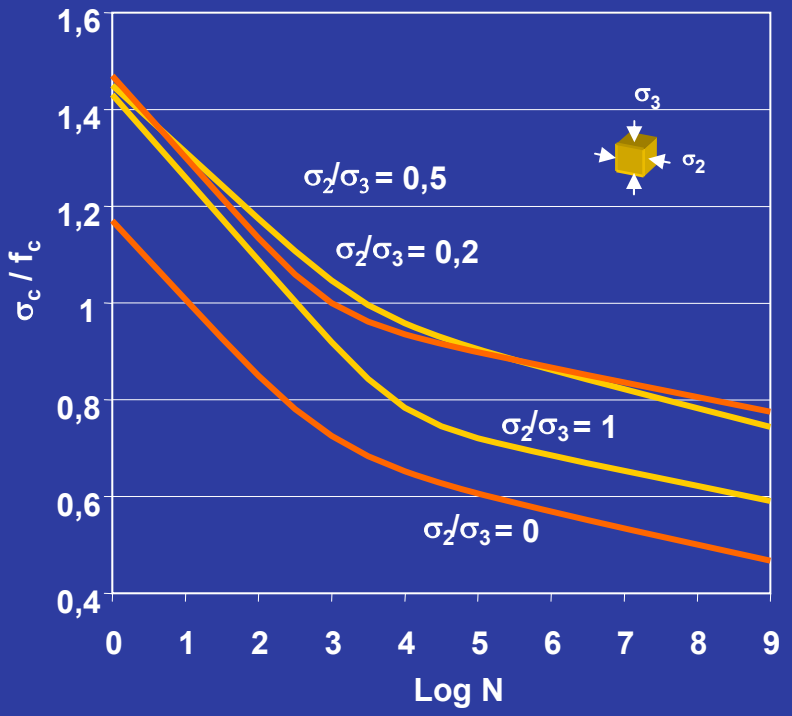


Design:
Oevermann GmbH & Co. KG, Münster

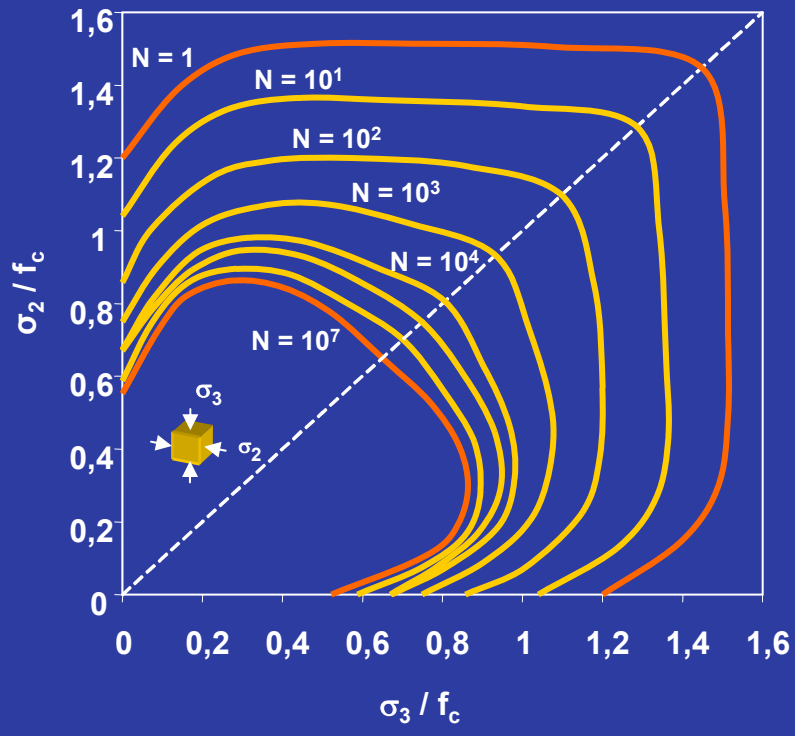


Framework Joint

Failure curves for fatigue in biaxial compression

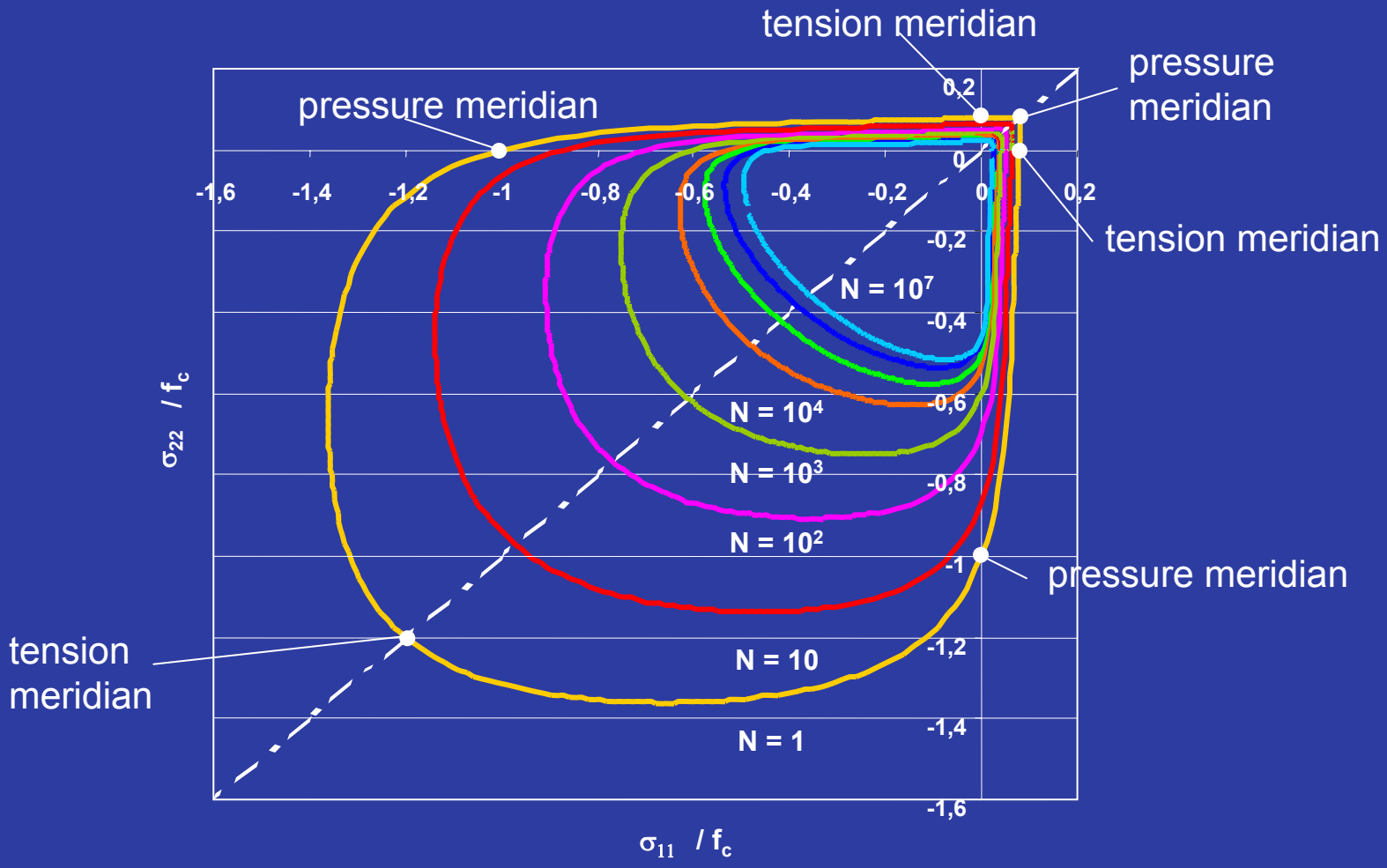


S – N curves by Su/Hsu

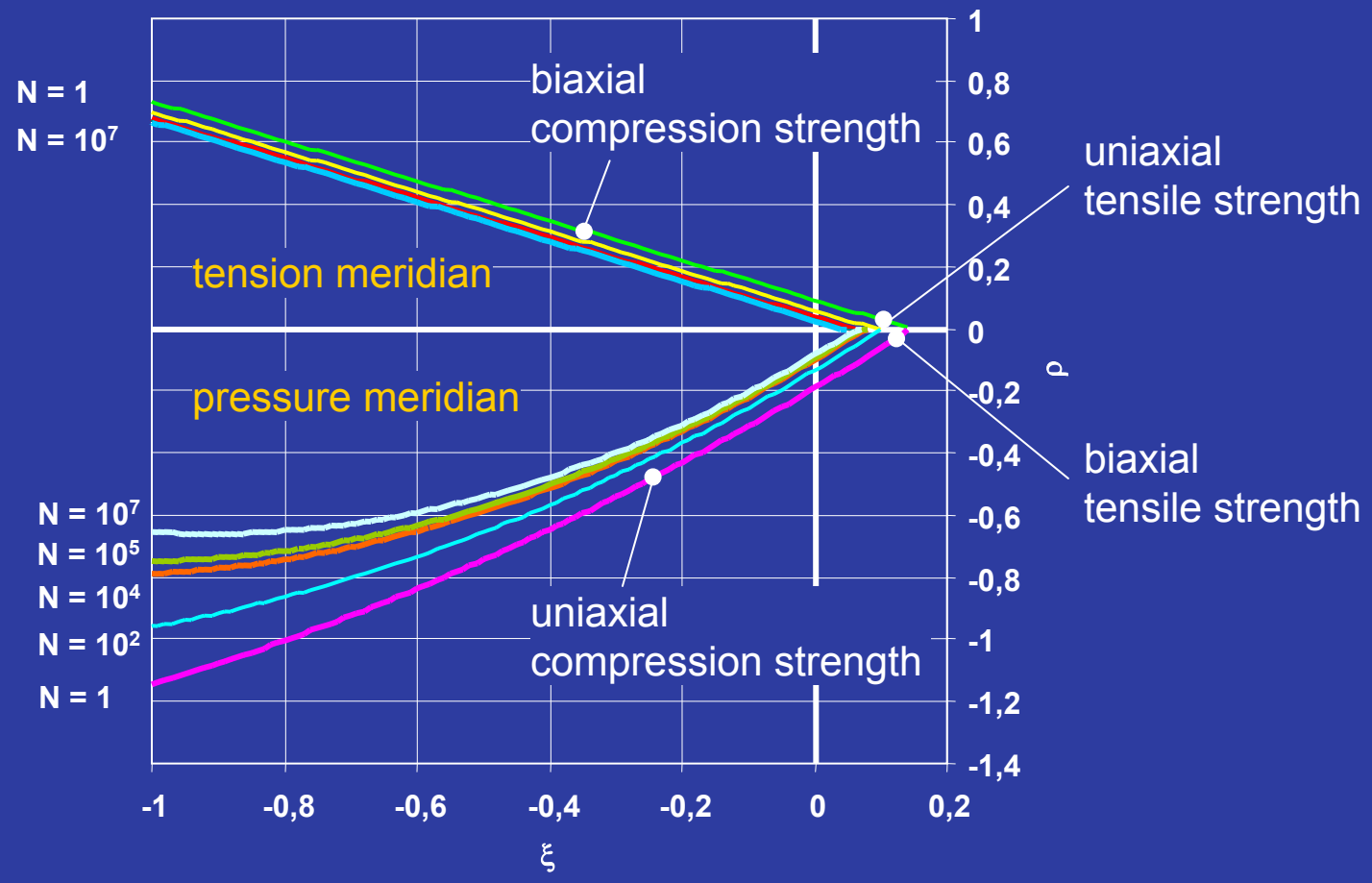


Failure curves by Su/Hsu

Anisotropic damage approach



Boundary curves of fatigue damage in the main meridian section



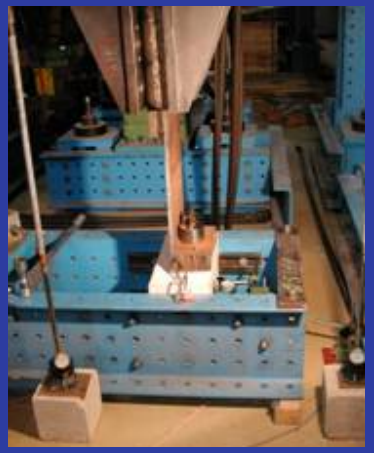
5. Summary and Further Work

- The simplified damage accumulation law by Palmgreen and Miner could lead to unsafe or uneconomical constructions
- A new fatigue damage approach, based on regarding fracture engery, could realistically compute the damage evolution in concrete and could be extended for multi-stage fatigue loading
- The introduced damage model could be successfully associated with a finite - element program
- Purpose: Development of damage parameters to consider the influence of multiaxial fatigue loading in structural analyses

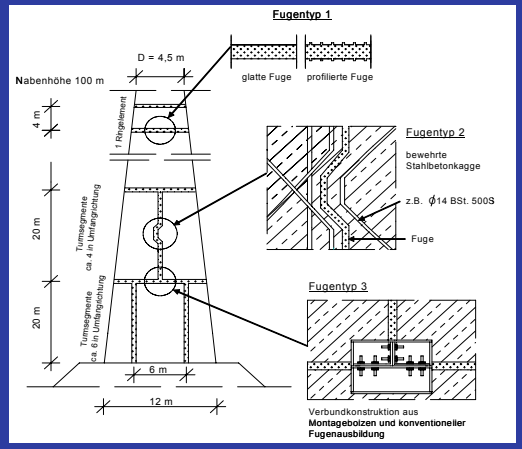
Acknowledgement

ForWind
Center for Wind Energy Research

In - situ measurements at a concrete tower



Testing of load transfer joints



Fatigue tests of mortar gaps

COPENHAGEN OFFSHORE WIND

International Conference & Exhibition 26 – 28 October 2005

Concrete Foundations for Offshore Wind Energy Converters subjected to fatigue loading

Prof. Dr.-Ing. Jürgen Grünberg
Dipl.-Ing. Joachim Göhlmann

Institute of Concrete Construction