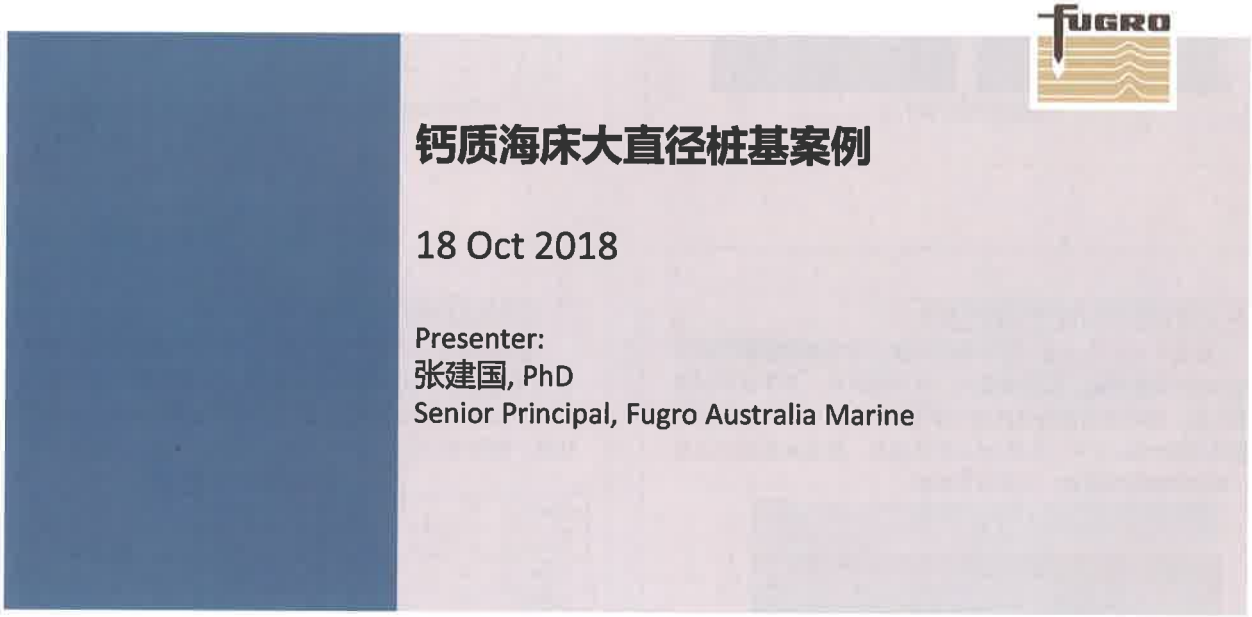
演讲嘉宾介绍

张建国 博士 1985 年毕业于天津大学水利系并留校工作。1997 年加入西澳大利亚大学海洋地基系统研究中心，授业于国际著名土力学与海洋岩土工程专家 Mark Randolph 教授，2001 年获得博士学位。2001 年至今一直在 Advanced Geomechanic - Fugro AG - Fugro Australia Marine 从事海洋岩土工程咨询与地基基础设计工作，积累了丰富的工程实践经验。现任职为 Fugro Australia Marine 岩土工程咨询部的资深主任工程师和资深项目经理，是该公司岩土数据解读与地基设计技术权威之一。



Outline

致谢

Organizing Committee

Dr Michael O'Neill
Senior Principal

Dr Ian Finnie
Technical Authority – Integrated Geoscience

Mr Carl Erbrich
Technical Director

Prof. Mark Randolph
Technical Advisor

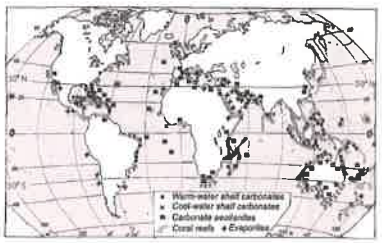
Fugro Australia Marine

- 背景介绍
- 传统桩基设计方法
- 钙质海床桩基竖向承载力
- 竖向荷载桩设计实例
- 水平荷载与位移关系
- 水平荷载桩设计实例
- 打桩过程中的桩头变形
- 结语

背景介绍

Distribution of carbonate sediments

- Mainly between 40°S and 40°N
- Mostly formed in warm water environment
- Cover 35% of the ocean floor
- Widely distributed along 海上丝绸之路

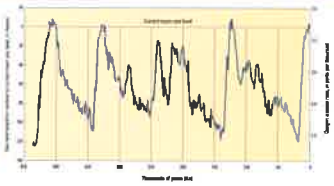


I. P. Martini (2014). General considerations and highlights of low-lying coastal zones: passive continental margins from the poles to the tropics. Information on the figure from Nelson 1988 Perlish 1998, Brooks 2001; Short 2005; Warren 2010).

背景介绍

Sea level variations

U.S. Dept of Interior, U.S. Geological Survey (1998). "Sea Level Change - Lessons from the Geologic Record", Fact Sheet FS-117-98



Thomas W. D. et al (2016). "Sea-Level Rise Modeling Handbook: Resource Guide for Coastal Land Managers, Engineers and Scientists" U.S. Dept of Interior, U.S. Geological Survey, Professional Paper 1815.

钙质沉积物简介

API RP 2GEO / ISO 19901-4; Annex B

- Biogenic in nature composed of skeletal remains
- Highly angular particles
- High crushability due to low hardness of 'calcium carbonate'
- High compressibility due to large porosity
- Prone to natural process, such as cementation when exposed to air
- High variability
- Highly degradable/ high sensitivity


Sand


Calcarenite


Silty sand

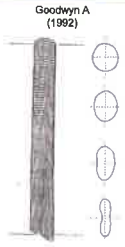

Muddy silt

钙质海床桩基设计难点

API RP 2GEO / ISO 19901-4; Annex B

- Low axial capacity for driven open ended pipe piles
- Extremely high capacity reduction under cyclic loading
- Common t-z and p-y curves do not exist
- Pile free fall when driving in uncemented layers (e.g., 0 to 64 m then 72 to 114 m, 1.83 m OD piles at NRA, 1982)
- Hard driving/ pile buckling / deformation when driving through cemented layers (10 m to 40 m long lower section of 2.65 m OD, 45 mm WT primary piles at GWA, 1992).

Goodwyn A (1992)



Barbour & Erbrich, 1994

www.fugro.com

Outline

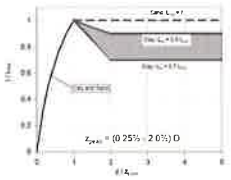
钙质海床
大直径桩基工程案例

- 传统桩基设计方法

传统桩基设计方法

API RP 2GEO / ISO 19901-4 design method

- Applicable in silica sand (drained response) and clay (undrained response)
- Applicable to driven steel pipe piles
- API t-z curves for siliceous sand and clay
  - $\tau_{max} = \alpha \times s_u$ in clay
  - $\tau_{max} = \beta \times \sigma_{v0}'$ in sand



Outline

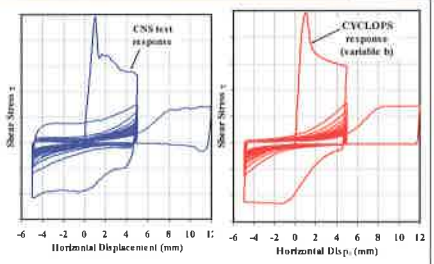
钙质海床
大直径桩基工程案例

- 钙质海床大直径桩竖向承载力
- 竖向荷载桩设计实例

钙质海床桩基竖向承载力_ CYCLOPS

Alternative pile types

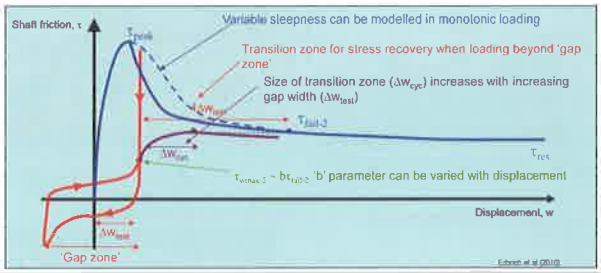
- Driven-drilled-grouted piles
- Drilled & grouted piles



Erbrich et al (2016)

钙质海床桩基竖向承载力 _ CYCLOPS

Details of CYCLOPS t-z Load Transfer Curve

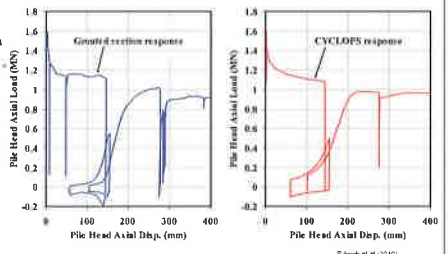


Erbrich et al (2016)

钙质海床桩基竖向承载力_ CYCLOPS

Overland Corner Field Test

- GST 400S2
- Grouted Diameter = 482mm
- Grouted Length = 2.4 m

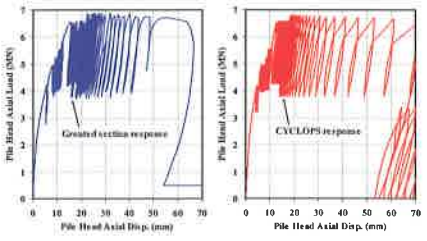


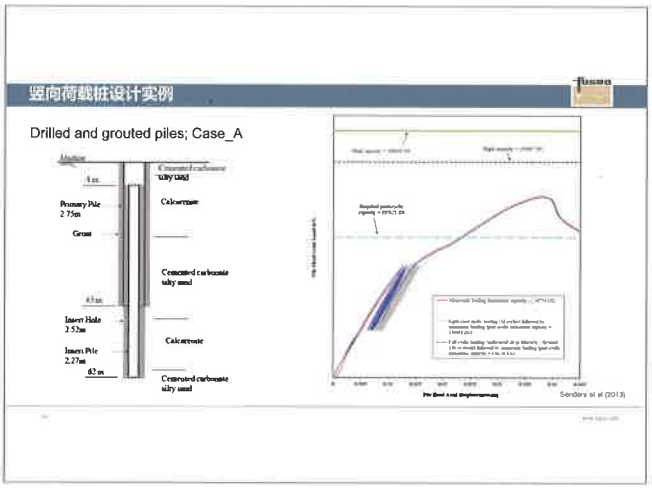
Erbrich et al (2016)

钙质海床桩基竖向承载力 _ CYCLOPS

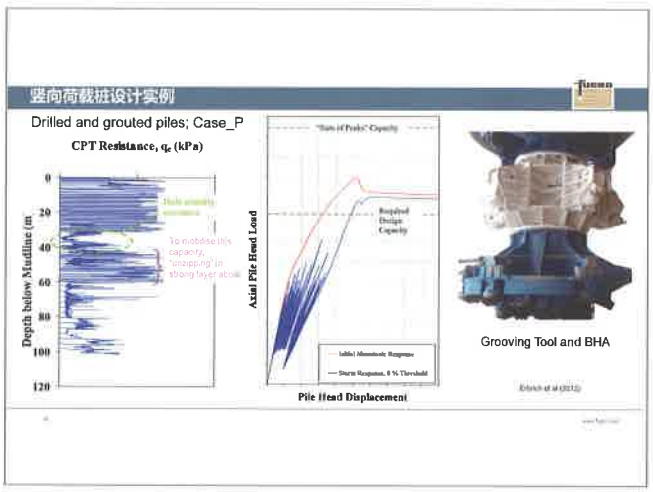
Overland Corner Field Test

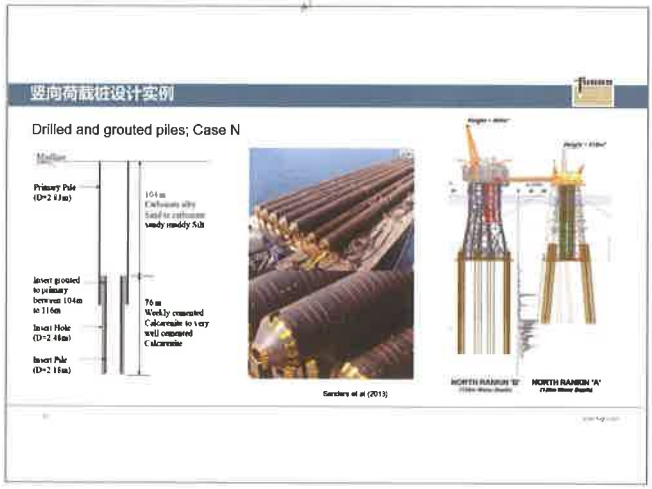
- GST 400L
- Grouted Diameter = 446mm
- Grouted Length = 15.6 m

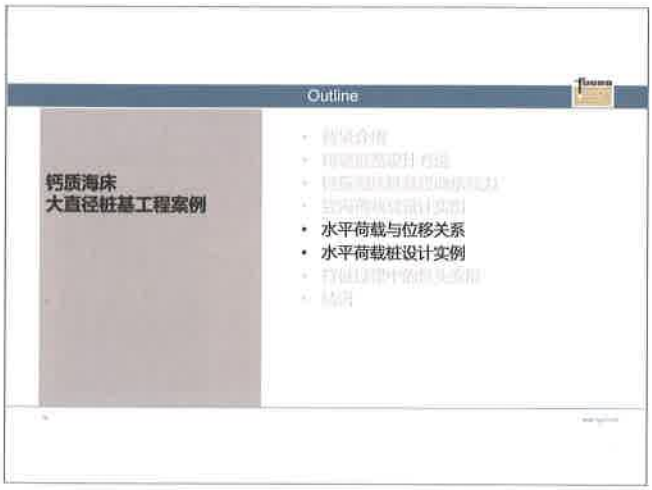


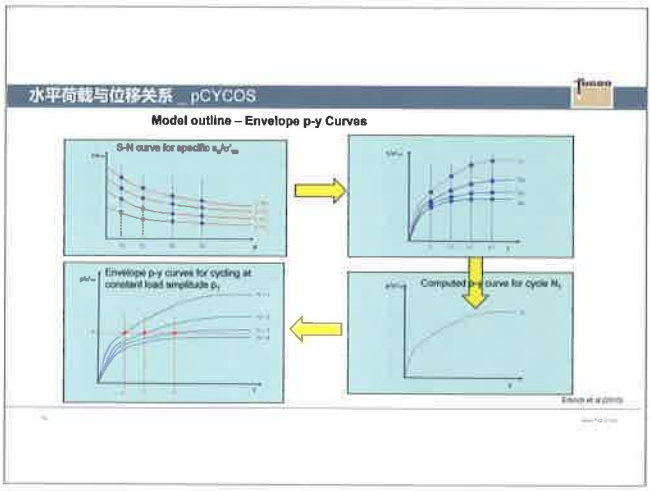

竖向荷载桩设计实例
Drilled and grouted piles; Case_A
Primary Pile 2.75m
Grout
Calcarenite
Cemented carbonate silty sand
Insert Hole 2.52m
Insert Pile 2.27m
62 m
Sanders et al (2013)


竖向荷载桩设计实例
Drilled and grouted piles; Case_A


竖向荷载桩设计实例
Drilled and grouted piles; Case_P
CPT Resistance, q_c (kPa)
Depth below Mudline (m)
Axial Pile Head Load
Pile Head Displacement
Grooving Tool and BHA


竖向荷载桩设计实例
Drilled and grouted piles; Case N
Primary Pile (D=2.41m)
Invert Hole (D=2.46m)
Invert Pile (D=2.18m)
76 m
Sanders et al (2013)

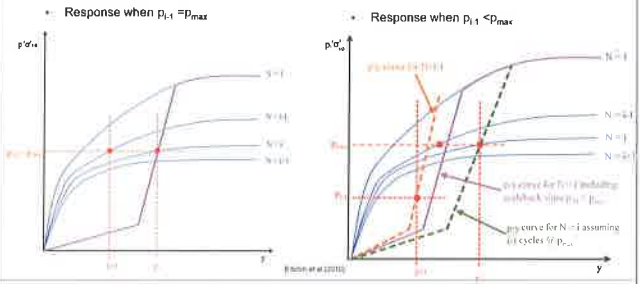

Outline
钙质海床
大直径桩基工程案例
水平荷载与位移关系
水平荷载桩设计实例


水平荷载与位移关系 pCYCOS
Model outline – Envelope p-y Curves
S-N curve for specific
Envelope p-y curves for cycling at constant load amplitude
Computed p-y curve for cycle

水平荷载与位移关系_ pCYCOS

p-y Curves; N > 2

- Response when $p_{i-1} = p_{max}$
- Response when $p_{i-1} < p_{max}$



大直径锚桩设计实例

Large, heavy FLNG anchor piles

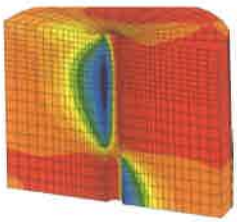
- 48m long 5.5m OD
- 500t self weight
- Up to 2,500t lateral loads

Driven open ended steel tubular

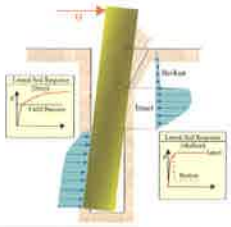
Holand et al (2013)

胶结层中大直径桩水平响应_ CHIPPER

Piles in calcarenite



P-y curve from CHIPPER

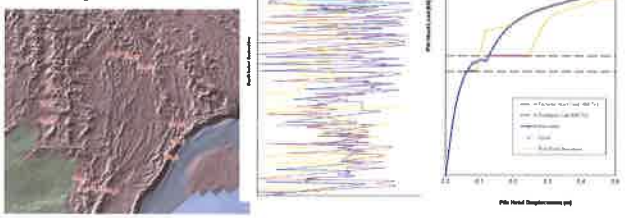


胶结层中大直径水平荷载桩设计实例

MODU anchor piles

- 12m long 2.5m OD
- Up to 500t lateral loads

Drilled and grouted steel tubulars



Outline

钙质海床
大直径桩基工程案例

- 打桩过程中的桩头变形

BASIL 方法

BASIL method

- Models 'extrusion' of pile through soil
- Captures progressive growth of small pile imperfections

Method originated from 1994

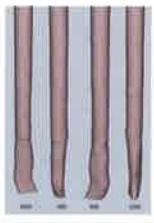
- Precipitated by Goodwyn pile collapse in 1992

Used for design of thin walled Bucket Foundations

- Sleipner SLT
- Draupner (Europipe) 16/11E

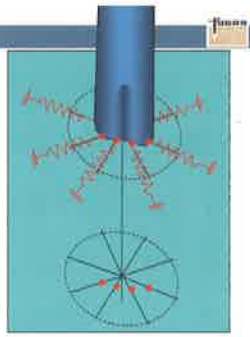
Never actually used to model piles before Valhall

Valhall P7
quite similar to Goodwyn A



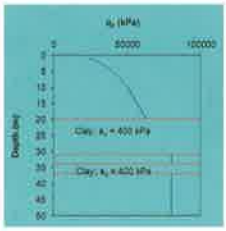
BASIL 用户单元

- A 'brush' of 'hairs' radiating from pile centre line
- Pile 'penetrates' to first row of 'hairs'
- Intersection of skirt tip with 'hairs' defines spring origin
- Pile 'penetrates' to next row of 'hairs'
  - Springs from first row are loaded if any radial displacement
  - Pile deflects as required
- Intersection of skirt tip with next row of 'hairs'
- And so on .....

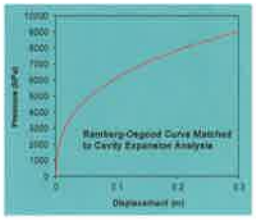


土性参数 – '密砂'

Soil Profile

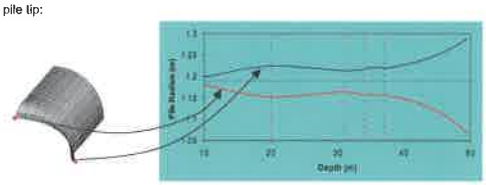


Basil Spring (Very Dense Sand q_c = 60 MPa)



典型工况

- 10 mm radial imperfection
- First mode shape (assuming chamfer ring load)
- Pile pushed from depth of 10 m to 50 m
- Track of pile tip:



结语

- Carbonate sediments have unique characteristics, conventional pile design methods do not apply
- Site specific geophysical and geotechnical data must be acquired to facilitate pile design
- Advanced analytical and numerical analyse tools have been developed through many years of piling in carbonate sediments practice, based on the unique soil response
- Fugro has used these tools for many projects, either engaged by Operators or Contractors
- Design reports (methods/ analyses) have been reviewed/ verified by Lloyd/ DNV
- High quality products were delivered to client satisfactory

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Thank You