Workshop Proceedings:

Improving Modular Construction: Management & Technical Advancements

- Tues 14 October 2014
Workshop on

Improving Modular Construction: Management & Technical Advancements

Tuesday 14 October 2014

Loughborough University,
Loughborough, UK
Workshop on Modular Construction: Management & Technical Advancements

Tues 14 October 2014

Attendees List

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<td>Alessandro Palmeri</td>
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<td>Alistair Gibb</td>
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<td>Andrew Till</td>
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<td>Brian Champkins</td>
<td>M+W Group UK</td>
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<td>Bruce Douglas</td>
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<td>Callum Alderton</td>
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<td>Chris Goodier</td>
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<td>Danny Leighton</td>
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<td>David Adamson</td>
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<td>David Yates</td>
<td>Franklyn Yates Engineering Limited</td>
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<td>Diego Gil</td>
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<td>Federico Perotti</td>
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<td>Gytis Juodzevicius</td>
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<td>Iain MacPhee</td>
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<td>Michael O’Connor</td>
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<td>Tony Goddard</td>
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Workshop on Modular Construction: Management & Technical Advancements

Tues 14 October 2014

PROGRAMME

09:30  Registration and Coffee
       Welcome

10.00  Introduction to Workshop & ECI
       James Bishop, ECI

       Presentation 1 - Paul Sloan, Sellafield

10:45  Coffee and Networking break

       Presentation 2 - Patrick Pady, Fluor
       Presentation 3 - Mark Sadler, Mammoet

12:15  Networking Lunch

       Presentation 4 - Federico Perotti, Politecnico di Milano
       Presentation 5 - Alistair Gibb, Loughborough University

14.15  Group Discussion Session

15.15  Feedback Session

16.15  Closing Remarks
Presentation slides for Paul Sloan Sellafield
Workshop on Modular Construction: Management & Technical Advancements

Tues 14 October 2014

Paul Sloan
Head of Construction
Sellafield Limited

Paul is a mechanical engineer with experience of project delivery from both Client and Contractor perspective. He has held roles across the whole project lifecycle, having previously worked within Design organisations, managed manufacturing contracts, led construction and installation of active cells, commissioned major projects and been successful in winning and delivering works in the nuclear decommissioning sector.

Paul is native West Cumbrian and has worked on the Sellafield site since 1986, having previously worked in the manufacturing industry. He is currently Sellafield Limited Head of Construction, where he is responsible for establishing and maintaining construction procedures, introducing/utilising Knowledge Management to bring about project delivery improvements and also responsible for the standards applied to Construction Management roles across Sellafield project management organisation.
Modularisation

A Client Perspective

Date: October 2014
Modularisation - A Client Perspective

• Sellafield – Currently UK’s Largest Construction Site.
• Why?
  – Responsible for the ‘Aftercare and Clean Up’ of the UK Nuclear legacy
  – Ageing Storage and Treatment facilities to be replaced
  – Continued commitment to reprocessing contracts
  – Ever changing environment

Modularisation - A Client Perspective

• Sellafield Ltd (SL) Project Drivers
  – Time - Ageing Facilities/Reprocessing Capacity
  – Cost - Efficient use of UK Taxpayer monies
  – Quality – Nature of Materials drives exacting standards
Modularisation - A Client Perspective

• SL Project Drivers (Sub)
  – Complexity of Design
  – Access to Site
  – Capacity & Capability of Local Supply Chain
  – Site Constraints/Build Sequence
  – Proximity to adjacent ‘live’ facilities
  – Etc

Modularisation - A Client Perspective

• Evaporator D
  – Schedule Driven Project
Modularisation - A Client Perspective

- Evaporator D
- Where does this take the decision process?
  - Modularisation allows parallel activities/multiple workfronts
  - Build Remote from Site – Local Capacity/Capability?
  - Road network in West Cumbria
  - Rail network in West Cumbria
  - Sea Transportation – most viable option

Modularisation - A Client Perspective

- Evaporator D
  - Engineering
    - Extensive Temporary works
    - Increased duty due to transportation stresses
    - Reduced clearance in-cell for installation phase
    - Build Sequence & access arrangements – limits flexibility
Modularisation - A Client Perspective

• Evaporator D
  – Intelligent Customer Oversight
    • Temptation to treat as ‘simple procurement’ exercise
    • Far from simple – Sub Project
    • Internal ‘scarce resource’ now located at works

• Evaporator D
  – Stakeholder Management
    • Internal – site roads and infrastructure, safety case – impact with adjacent operational facilities
    • External – multiple – Police/Highways Agency, Rail Networks, Port Authorities, Local Land Owners
Modularisation - A Client Perspective

• Sludge Packaging Plant 1
  – Balance of Risk

Modularisation - A Client Perspective

• Proximity of construction site – close to ‘active facility’.
  – Safety case – dropped load (module) onto active facility (high consequence) balanced against ‘stick build’ (personnel dose uptake)
Modularisation - A Client Perspective

- Sellafield Product & Residues Store (SPRS)
  - Maximise Commissioning Opportunities – Time, Cost & Quality Driven.

  - Complex mechanical handling plant
  - Assemble at works – parallel to main civil build
  - Assemble at works – implement Integrated Works Testing
    - ‘Flush Out’ problems early and fix at works
    - Familiarise with assembly
    - Train operators
Modularisation - A Client Perspective

• Conclusions
  – Benefits are multiple and across all project drivers
  – Providing…….
    • Modularisation is designed into the whole project delivery strategy
    • All parties understand their role in delivery
  – It isn’t the silver bullet to all project problems and requires careful forethought/planning
Patrick Pady is the Department Manager for the Civil, Structural and Architectural Group at Fluor UK, Farnborough and is responsible for the technical execution of a range of global FEED and EPC Projects within the Oil & Gas, Power, Industrial and Mining sectors. These include many projects featuring various types of modular construction.

Prior to joining Fluor, Patrick was Chief Civil/Structural Engineer at Shaw Stone and Webster in Milton Keynes and Principal Civil/Structural Engineer at Foster Wheeler Energy, Reading.

Patrick is a graduate of University College Swansea and a Chartered Civil Engineer.
Workshop on Modular Construction: Management & Technical Advancements

Tues 14 October 2014

Diego Martín Gil
Area Lead / Core Team Senior Engineer
Fluor UK

Diego Martín Gil is Area Lead / Core Team Senior Engineer at CSA Department, FLUOR UK. He specialises in Oil & Gas Modularisation projects.

Prior to joining FLUOR, Diego coordinated international projects across other Oil and Gas companies such as Técnicas Reunidas and Foster Wheeler Iberia. In another professional experience at Isolux Corsán, in the position of Building Division Director, he ruled the commercial and residential company activities.

Diego started his career focused in FE, collaborating in the development of CivilFEM ANSYS module at Ingeciber and as a FE tunnel design engineer at Geoconsult.

Diego obtained his PhD from Madrid Polytechnic University, where he worked as an Associate Professor for 12 years.
Modularisation: Best Practice

Fluor – Corporate Executive Overview

- One of the world’s leading publicly traded engineering, procurement, construction, maintenance, and project management companies
- #110 on the FORTUNE 500 list in 2013
- Over 1,000 projects annually, serving more than 600 clients in 79 different countries
- 40,000 employees executing projects globally
- Offices in 31 countries on 6 continents
- Celebrated 100 years in 2012
Fluor UK Overview

- Farnborough is a leader in innovative EPC contracting and project execution strategies for mega projects
  - Full service offering:
    - Conceptual/FEED/Detailed Engineering
    - Procurement
    - Construction Management
    - Start-Up
    - Commissioning
  - UK, Europe, Africa, Middle East, Former Soviet Union and Kazakhstan
  - Energy & Chemicals, Power, Mining & Metals, Industrial Services
  - 1800 staff
  - Proven distributed execution platform
  - Joint Ventures
  - Reimbursable and Lump sum
  - Modularisation Expertise
  - FSU Regulatory Expertise

Modularisation: Best Practice

CONTENTS

- 1. Modularisation in Fluor - Recent Experiences
- 2. Factors Driving Fluor Modular Construction Decision
- 3. Fluor Modularisation Methods - Examples
  - I. Pre assembled structures.
  - II. Mega Modules.
  - III. 3rd Generation Modules.
- 5. Q&A.
1. Modularisation in Fluor - Recent Experiences
1. Modularisation in Fluor - Recent Experiences

- Fluor has utilised modularisation on projects since 1970’s
- Many global module projects with water access + VLMS
- Globally some remote landlocked project locations use modules
- Alberta Oil sands projects; landlocked locations commonly use 3rd Generation modular execution

2. Factors driving Fluor modular construction decision
2. Factors driving Fluor modular construction decision

- Main factor groups to be analysed are as follows:
  - Organization's Readiness
  - Owner's Willingness
  - Economic drivers
  - Module-related drivers
  - Fabrication/quality issues
  - Logistics and equipment drivers
  - Location specifics / regulations
  - Labour considerations
  - Specific Project risks
  - Environmental requirements

- Factors that support module design:
  - Remote site
  - Severe site climate constraints
  - Schedule improvements
  - Plot Plan constraints
  - Limited availability of regional skilled labour / imported construction labour / man camps
  - Extensive Factory Acceptance Testing (FAT) desired
  - High module potential / repeatability
  - High density piping, cabling
Modularisation: Best Practice

2. Factors driving modular construction decision (Example)
   – Plot Plan constraints

3rd Generation Modularised Unit Plot Plan

FLUOR.
3. Fluor Modularisation Methods - Examples

- I. Pre-assembled structures
- II. Mega Modules
- III. 3rd Generation Modules

To consider:
- Every project has unique requirements
- Every module fabricator has unique methods / capabilities
- Every Client has unique preferences
- Every engineer has a unique way to design a module.
3. Modularisation methods (I). Pre-assembled structures

- Middle Eastern EPC Project
  - Offsites & Utilities Petrochemicals Facility Project
  - Common Facilities Interconnecting Pipe Racks
  - Multiple Projects, Multiple Contractors
  - Congested Site, Limited Laydown on site
  - Large Labour Force
  - Climate
- FEED featured stick-built, bolted steel structures
- Fluor Challenge – to offer project the advantages of modularisation at no extra cost
3. Modularisation methods (I).

Pre-assembled structures.

- Method Adopted
  - Outdoor Pre-assembly yard adjacent to site, 3km
  - Fabricated steelwork delivered piece-small to pre-assembly yard.
  - Bolted construction
  - Optimised design process, weight saving. NO additional bracing or transportation steel
  - Structures erected on stools in yard including piping, cable trays, ladders, handrail etc.
  - Controlled SPMT load out, transportation and placement strategy developed in close consultation with transportation contractor
  - 4 point support to avoid instability
  - PAR’s Placed onto Precast Concrete columns

- Other Applications
  - Pipe Support Structures
  - Equipment Skids
  - Pancakes
  - Prefabricated Buildings
  - Package Substations, Switchgear Rooms
  - Pre-dressed columns and vessels

3. Modularisation methods (II). Mega Modules

- Constraints
  - Module definition. Limits related to weight (>600t) and dimensions. (Land+ Sea transportation)
  - Heavy Haul contractor input at the early stages: accelerations, grillage concept, hog/sag...
  - Requirements related to vessels / Infrastructure
  - Feasible fabrication locations
  - Module standardisation vs. material saving
  - Stacked /Non Stacked transportation
Modularisation: Best Practice


Modularisation: Best Practice


Fluor has developed a 3rd Gen Modular Execution Methodology, considering:
- Past modular projects and Offshore design methods
- Facility interconnections
- Power and control distribution

Key factors:
- Minimise site labour. Relocate 90% field hours to fabrication yard
- “Modularization Drives Layout” not “Layout Drives Modularization”
- Schedule/Vendor interdependencies are critical to success
- Minimise foundations activities
- Avoid piperacks- integrate into structures
- 95%steel & 95%piping on modules
- 85%electrical & 95%instruments on modules
- Cabling, wiring & testing at fabrication yard
- Equipment commissioning at fabrication yard

NOTE: Percentages are specific for each project

2nd Generation MCCs in Substations

- Power cables for each load run back to Substations along Piping racks
- 2nd Generation: 20% Electrical Equipment and Wiring on Modules

3rd Generation MCCs - part of the Process Blocks

- Smaller Main Substation
- Connected with U/G Power Feeders
- One feeder cable per MCC
- 3rd Generation: 85% Electrical Equipment and Wiring on Modules Terminated (Excluding UG HV Distribution)
Modularisation: Best Practice

  - Direct Craft Staffing Comparison
    - Managing and achieving a steep manpower decline in the shop is easier than in the field.

- **3rd Generation enables module assembly to start later**
  - Eases pressure on Structural engineering
  - Shorter field work duration

![Graph showing comparison of Modularisation methods](image-url)

4. Best Current Practice - Fluor Experience
4. Best Current Practice - Fluor Experience

4.1. General

- Understand the implications of modularization on engineering work processes
  - Piping and Structural are usually aligned and understand the level of effort required
  - Electrical, Control Systems and HVAC may have to accelerate their work
  - Process and Mechanical to recognise the restrictions caused by modularization

- Contingency Plans
  - Bear in mind that something will go wrong along the way
  - Consider different scenarios
  - Identify risks and contingency measures

4.2. Early engagement with Logistics and their contractors

- Logistics
  - Firmly define any geometric/weight restrictions (max envelope / weight)

- Naval Architect/Marine Warrantor
  - Transit Routes, Metocean Data and Marine Transport Analyses
  - Project documentation for warrantor

- Marine Contractor
  - Vessel types and availability
  - Verify method of Load out
  - Coordinate on Grillage and Seafastening designs

- Heavy Haul Contractor
  - Transport/Transit Routes
  - Transporter Types

- Heavy Lift Contractor
  - Craneage and rigging capabilities
  - Lift plans & space required
4. Best Current Practice - Fluor Experience

4.3. Early engagement with Fabricator
- 75% of engineering finished before fabrication starts
- Client/project taskforce to understand selected fabricators work history and tendencies
- Achieve alignment on project specifications and standards
  - Material finish including Galvanising and Fireproofing
  - Miscellaneous Supports
- Achieve alignment on work processes
  - 2D drawings or 3D model transfer
  - Dimensional Control Procedures
- Achieve alignment on commissioning philosophy
- Achieve alignment on preservation philosophy
- Develop EPC schedule around fabricator capabilities
- Maximise understanding of contractual obligations to minimise potential future claims

4.4. Early engagement with Construction
- Early definition of construction strategy
- Define staging and storage areas
- Develop on-site transport routes
- Coordinate with logistics contractors on module installation procedures
- Coordinate with surveyors and dimensional control representatives
- Define inter-module hook-up philosophy
- Local Labour Regulations
- Modules onsite ideally 3 months prior to placement
4. Best Current Practice - Fluor Experience

4.5. Develop and implement Weight Control Program

- Establish weight reporting format and cycles
- Establish datum and tolerable centre of gravity locations
- Establish weight shedding guidelines and other contingency measures
- Coordinate with engineering, fabricator and logistics contractors on physical weighing procedures
- Ensure Client and project taskforce are aware of the purpose and criticality of formal weight control programs

4.6 Problems to AVOID!

- Modularization strategy and plan developed too late
- Modules incomplete at shipment
- Late engineering deliverables or late revisions
- Instrument, electrical,... materials late
- Modules delivered late and/or in wrong sequence
- Shop workload exceeds capacity
THANKS FOR YOUR ATTENTION.

Q&A
Presentation slides for Mark Sadler Mammoet
Workshop on Modular Construction: Management & Technical Advancements

Tues 14 October 2014

Mark Sadler
Senior Commercial Manager – Projects
Mammoet

Mark Sadler became Senior Commercial Manager for Mammoet in Jan 2014. He joined the company in 2008 as an engineer after graduating from the University of Hertfordshire in Aerospace engineering. His early career was spent on various different projects within the UK which covered the full range of services which Mammoet offer. From replacing large columns and vessels on different petrochemical sites to installation of new bridges around the UK.

He built up a good knowledge of the market and moved to a projects engineer/management role within the company in 2010. Engineering and organising the projects he was involved with from an operational point of view he built up a network of key personnel within both the Mammoet organisation and our customer base.

In 2011 he was asked to move into Mammoet’s sales department as a commercial manager. Earlier this year he was made responsible for the UK Projects sales business. He enjoys keeping up to date with the technological advances which Mammoet are making in Heavylift and transport bringing new innovation to the market.
MAMMOET IN BRIEF

- Mammoet is a global specialist in heavy lifting & transportation projects
- Assist clients in delivering improved construction efficiency and optimize the operational time of their plants, facilities & installations with services and solutions for the safe lifting, transporting, installing and decommissioning of large or heavy structures
- More than 1,600 cranes ranging from 5te to 3,600te capacity
- More than 4,000 axle lines of modular transporter providing a total capacity in excess of 120,000te
- In total some 110,000te capacity of hydraulic jacking & skidding equipment
- Employees: 5,000

MAMMOET IN BRIEF

‘LONDON EYE’

‘THE KURSK’

Employees: 5,000
COMMON CHALLENGES

- Historically construction always via ‘stick built’ piece small approach
- No heavy load route / infrastructure available for oversize modules
- No quayside at site for direct shipment
- Stakeholders with limited knowledge and understanding of modular build
- Stakeholders with limited knowledge of heavy lift and transportation technology available within the global market
COLLABORATION

• Early involvement is key

• Team work philosophy

• Commitment & trust between parties

• Open approach;
  o Shared values
  o Client's aspirations
  o Project drivers
  o Risks
  o Common objectives

Perform as an integrated team

COLLABORATION

• Supply chain requirements

• Value engineering & optimisation

• Achieved programme certainty and price confidence

• Risks are identified, mitigated wherever possible with the residual risk managed by the best placed party

• Opportunities & innovation realised
INNOVATION

- Minimised the need for infrastructure improvements
- Minimised impact on Site operations, the environment and the local community
- Allowed an optimised construction schedule to be realised
INNOVATION

- Heavy lifting services
- Heavy transport services
- Shutdown management
- Site wide construction services
- Modular construction
- Factory-to-foundation/logistics
- Emergency response & wreck removal
- On- and offshore decommissioning

SUPPLY CHAIN PARTNER
THANK YOU FOR YOUR TIME
Presentation slides
for
Federico Perotti
Politecnico di Milano
Workshop on Modular Construction: Management & Technical Advancements

Tues 14 October 2014

Federico Perotti
Professor at the Department of Civil and Environmental Engineering
Politecnico di Milano

Federico is a Professor at the Department of Civil and Environmental Engineering at the Politecnico di Milano. Previously, he has also been Associate Professor at the Department of Civil Engineering at the University of Brescia. He has taught on programmes including ‘Earthquake Engineering Analysis and Design’ and ‘Theory of Structures for Mechanical Engineering Students’, and has been Dean of the School of Civil and Environmental Engineering at the Politecnico di Milano.

His research activity has been mainly in the fields of Structural Dynamics and Earthquake Engineering.

His professional and consulting activity have been focused on applications in Seismic Engineering and vibration problems in Civil Engineering. This includes: seismic analysis of structural and equipment components in nuclear power plants; design input and general criteria for the seismic analysis of the Messina Strait crossing; dynamic analysis of large submerged structures under hydrodynamic and seismic excitation; and structural analysis and design of a number of complex structures such as large turbine generators, printing systems and long span beams/decks under dynamic loading.
Structural aspects of modularization

Federico Perotti and Raffaele Ardito
Department of Civil and Environmental Engineering

The White Book on modularization

Is the result of the work of the ANIMP-ECI Task Force “Modularization”

In Chapter 3 “Structural design aspects: a case study” some general considerations are attempted, though based on a single case study performed, at DICA – PoliMi, with the help of MS students (2 MS Theses completed + 1 under development)

A quite comprehensive report of the case study is given in Appendix B, while developments of research are treated in the WB Conclusions
**Aim of the case study:** investigate issues related to structural design which affect the feasibility and affordability of modularization

**Issues treated in the WB**
- on site loading conditions (wind, earthquakes, PSV operation)
- structural design (general + seismic)

**More recent activity**
- loads due to marine transportation
- fire design of columns

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**Structural modularization**

**Basic CB analysis**

"Direct" costs

- Larger structural cost (material/weight, detailing, etc) due to additional loading conditions (transportation, lifting, etc)
- Transportation costs
- Need for larger installation means (cranes, etc)
**Basic CB analysis**

“Indirect” costs

- More complex structural design
- Need to complete structural design in a shorter time
- Need of early interface with transportation/lifting contractor

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**Basic CB analysis**

“Direct” benefits

- Reduction in the construction cost
- Reduction of risks associated to onsite construction
- Reduction of project delivery time
Basic CB analysis

“Indirect” benefits

• Better performance (e.g. in terms of stiffness) of the modularized structure
• Better durability (reducing maintenance)
• Better flexibility with respect to equipment development and/or renovation

White Book: case study

In analyzing the case study (typical pipe rack) some design proposals have been formulated aiming to

• **Reduce weight** (especially at transportation)
• **Introduce some standardization** (versatility?)
• **Improve functionality** (or, at least, preserve)
Design proposals aiming to Reduce weight

To reduce the weight of a structure two main areas of intervention can be explored:

(a) classical **structural optimization**, which can be obtained both by varying the structural layout and by working on structural element sizes though preserving the layout. The first option can easily conflict with equipment layout and has been disregarded here. The second has been pursued, even though code provisions have set constraints such to inhibit, in practice, the optimization process.

(b) **reduction of loads**, which can be obtained either by adopting more sophisticated analysis procedures or by adopting design solutions which are rewarded by the code with a more favorable load level, the latter case being typical of seismic loading; both options have been investigated here.
Design proposals aiming to

Reduce weight - loads

note that the reduction of loads coming from the equipment (weight, operation and thermal effects) has not been attempted, even though some considerations have been formulated on the loading condition due to the PSV (Pressure Safety Valves) action. Preliminary activity was performed regarding transportation loads, with special reference to standard barges operation, showing that a better insight on loading conditions can be obtained with reasonable effort.

Design proposals aiming to

Introduce standardization

Standardization is the key for addressing the need for a more complex design to be performed in a shorter time; in this light, standardization can be related either to the actual structure or to the design process itself. It can be argued that it is practically impossible to standardize civil structures given the wide spectrum of variable loading combinations that are to be applied according to equipment, seismicity, wind conditions, transportation etc.
Design proposals aiming to

**Introduce standardization**

It can be argued that…

In such setting to standardize a structure means to make it easily adaptive to loading conditions of increasing level by simply adding structural elements and/or modifying a limited number of existing ones.

*Note: is “versatility” the key word?*

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Design proposals aiming to

**Improve functionality**

*(see “Indirect” benefits list)*

• Better performance (e.g. in terms of stiffness) of the modularized structure
• Better durability (reducing maintenance)
• Better flexibility with respect to equipment development and/or renovation
Note: the pipe rack assembly is constrained almost in the same way on the barge and in its final installation. In spite of this additional stiffening is often provided during transportation

Question: should these stiffeners be introduced in the design, given that loading conditions (i.e. seismic vs barge-roll) are similar?

Case study: g.i. – horizontal bracing

Question: should these stiffeners be introduced in the design, given that loading conditions (i.e. seismic vs barge-roll) are similar?

The question is directly related, for example, to the problem of horizontal bracing which, given the results here obtained, should be provided at least at the top level of the pipe rack. 

But the issue seems to be a more general one.
Case study: general issues – stiffness

Note: columns are often encased in r.c. for fireproofing; r.c. is not taken as structural, for equipment development reasons

Proposal: steel hollow sections, filled with structural r.c. on site could be used, providing additional stiffness and resistance (and good functionality). Their fire performance, with or without additional protection is investigated.

Case study: g.i. – seismic design

Note: when Ultimate Limit States are considered the problem of structural coefficients (q or behavior factor) is crucial

A question arises on how to balance the need for higher coefficients (to reduce load/weight) and the necessity of

1. preserving the (irregular) layout, which affects equipment layout

2. trying to standardize and simplify the structural design
**Case study: g.i. – sacrificial elements**

**Note:** seismic design is often governed by serviceability more than by ultimate behaviour (stiffness again …)

**Proposal:** introduction of structural elements (typically diagonal braces) which are accounted for in terms of stiffness for SLS, but disregarded in ULS checks. They must not obey to provisions for ductile behavior.

**Case study: g.i. – welded joints**

Note: the possibility, intrinsic to modularization, of extensive use of shop welding pushes towards the use of **welded joints**, which can be lighter and can meet high ductility requirements wrt seismic loads

A question arises about the possibility of designing **standardized welded joints**, with particular reference, to **Moment Resisting Frames**, typically introduced as transverse frames in pipe racks.
Dynamic loading during sea transportation (standard barge)

- Use of simple models (linear theory, rigid-body ship model,...) and commercial software
- Evaluation of design sea-state according to route and season

Estimation of dynamic loading on a module and comparison with codes and other loading conditions

Comments

General issues

- Standardization of the structure
  from standardization to versatility
- Interaction between structural and equipment designers
  workflow of the structural and equipment design
- More detailed analysis of loading conditions
  interdisciplinary activity on sea transportation
Future research developments

- A complete non linear analysis of the pipe rack behaviour under strong seismic actions seems to be advisable, also in view of the possible upgrade to a “high ductility” structural systems in light of Eurocode 8.
- A test campaign in the Wind Tunnel seems to be necessary for better calibrating local wind loading and spatial correlation
- *An investigation on structure-equipment interaction (?)*
Presentation slides
for
Alistair Gibb
Loughborough University
Workshop on Modular Construction: Management & Technical Advancements

Tues 14 October 2014

Alistair Gibb
ECI Royal Academy of Engineering Professor of Complex Project Management

Alistair is the ECI Royal Academy of Engineering Professor of complex project management and is responsible for knowledge creation and best practice assimilation within and on behalf of ECI across the European organisation.

Alistair is a Chartered Engineer and Chartered Builder. He joined Loughborough University in 1993 following a career in civil engineering and construction management, especially in complex projects.

He has been closely involved with ECI since the mid-1990s, mainly as Project Director of the Safety, Health & Environment task force. Internationally he is coordinator of the Conseil Internationale de Batiment (cib) working commission on construction health & safety. He has led many health and safety research projects funded both by UK and US Governments and industry. He also has an impressive research track record in technical innovation – particularly in offsite construction. He is a founding member of the influential UK industry body Buildoffsite and has led several overseas trade missions.
Something new under the sun?

Modularisation in Engineering Construction
2014 Research Update

Alistair Gibb

Director: European Construction Institute
Royal Academy of Engineering Professor

What has been will be again, what has been done will be done again; there is nothing new under the sun

Ecclesiastes 1:9 (The Bible)
There is nothing new under the sun, but there is something old we do not know

— Laurence J. Peter —

www.StatusNxt.com
Potential Advancements within Industrial Modularization

Alistair Gibb
Director: European Construction Institute
Royal Academy of Engineering Professor
September 2014
What we do…

• Design as ‘stick-build’
• Then decide to ‘go modular’

Or, we do…

• Decide early to ‘go modular’
  – Sometimes for well thought-out, logical reasons
  – Sometimes not
• Then… throw our brains out of the window thinking that modular, by definition, will solve all of our problems
Or, we do...

- Decide early to ‘go modular’
- Then… get enticed by the desire to use the biggest module ever used

www.watchismo.com/promotions/bigger-better-banner.jpg
How long is innovation innovative?

- **Technology trigger**
- **Peak of inflated expectations**
- **Trough of disillusionment**
- **Plateau of productivity** (i.e., acceptance of technology)
- **Slope of enlightenment**
- **Repeat peak of inflated expectations**
- **Repeat trough of disillusionment**
- **Repeat plateau of productivity** (i.e., acceptance of technology)

*After Gartner, USA*
Hype Cycle

Continuously repeated peaks of inflated expectations

Continuously repeated troughs of disillusionment

Slope of enlightenment ?????

Gibb After Gartner, USA

After ‘Crossing the Chasm’ – Geoffrey A Moore

Bringing innovations to market
Crossing the chasm
THE COMING BOOM

Skills shortages
Investment opportunity
Early completion
Expensive labour

THE COMING COLLAPSE

Cheap labour
Fixed factory costs
Tight margins
No long term investment
Achieving Project Success Through Modular Construction

Mauro Mancini
Politecnico di Milano, MIP
Chairman of ANIMP Construction Section
(Italy)

http://animp.it/prodotti_editoriali/Advances_in%20plant_modularisation.php?codice=AB57842
Do we already reach the full potential of a modular approach?

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Phonebloks</th>
<th>Modular LNG</th>
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<tbody>
<tr>
<td>Modules design</td>
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<td>x</td>
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<tr>
<td>Modules standardisation</td>
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<tr>
<td>Interfaces design</td>
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<td>x</td>
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<tr>
<td>System physical decomposition</td>
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<td>System functional decoupling</td>
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<td>Platform design</td>
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<tr>
<td>Bus architectures</td>
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<tr>
<td>Modules Sharing</td>
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<td>x</td>
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<tr>
<td>Modules swapping</td>
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<tr>
<td>Minimise inter-module interactions</td>
<td>x</td>
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<tr>
<td>Aggregation into cell modules</td>
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<tr>
<td>Modular consortium</td>
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<tr>
<td>Sectional modularity</td>
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</tr>
<tr>
<td>Interfaces Standardisation</td>
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<td>x</td>
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<tr>
<td>Design for Postponement</td>
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</tbody>
</table>
Main Characteristics of Plant Modularization

Transfer as much of construction site works as possible to a more controlled and favorable environment, i.e. fabrication yards.

Profound effect on the way the engineering work is defined and scheduled

Need of progressive fundamental decisions at the early FEED (that cannot be significantly changed into an EPC Company)

(On site?) construction workload: modular vs stick build SAIPEM 2013
Taxonomy in Plant Modularization

Self-Propelled Modular Trailer
Taxonomy in Plant Modularization

Load in of a module in detail

Taxonomy in Plant Modularization

Load out of a module in detail  Load out of a 2000 ton living module
### Modularisation benefits

<table>
<thead>
<tr>
<th>Schedule Savings</th>
<th>Higher Safety</th>
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<tbody>
<tr>
<td>Improved quality</td>
<td>Higher Security</td>
</tr>
<tr>
<td>Social/Environmental Impacts reduction</td>
<td>Lower Manpower costs</td>
</tr>
<tr>
<td>Reduction of weather impacts</td>
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</tbody>
</table>

### Modularisation drawbacks

<table>
<thead>
<tr>
<th>Higher engineering effort</th>
<th>Higher structural costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher transportation costs</td>
<td>Higher need for infrastructure</td>
</tr>
<tr>
<td>Local content impacts</td>
<td>...</td>
</tr>
</tbody>
</table>

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**Literature**

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**Companies Involved**

- eni
- Saipem
- Technip
- Rosetti Marino
- Fagioli

**Roles Interviewed**

- Engineering
- Procurement
- Construction
- Tendering
- Project management

**Numbers of Interviews**

- [ ]
- [ ]
- [ ]
- [ ]
- [ ]
### Companies Involved

<table>
<thead>
<tr>
<th>CLIENT</th>
<th>EPC</th>
<th>SERVICE PROVIDER</th>
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<td>SG Group</td>
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<td>SELLWOOD</td>
<td>MORGAN SINDALL</td>
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<tr>
<td>HOME INTERNATIONAL</td>
<td>FLUOR</td>
<td>GROUPCYTEK</td>
</tr>
</tbody>
</table>

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Head of Project Management  
Project Development Director  
Principal Project Manager  
Project Advisor  
Project Development Manager  
Chief of Civil Engineering  
Responsible Engineer  
Project Manager  
Construction Engineer  
Director, Process & Engineering  
Operations Director  
Technical Sales  
Managing Director  
Sales Manager  
Senior Project Engineer  
Senior Principal Engineer  
Design and Engineering Manager
Drivers (Client vs EPC)

Open-ended question – suggested items then scored 1-100

Constraints (Client vs EPC)

Open-ended question – suggested items then scored 1-100
Drivers & Constraints (UK-EPC vs Italian-EPC)

What has been will be again, what has been done will be done again; there is nothing new under the sun

Ecclesiastes 1:9 (The Bible)
Involvement in project life cycle (Clients vs EPC)

Five solution elements for increasing the use of modularization on industrial projects:

1. business case process
2. execution plan differences
3. critical success factors (CSFs)
4. standardization strategy
5. modularization maximization enablers

Addresses the following modularization issues:

- assessment of benefits and costs of the modular approach;
- determination of the optimal level of modularization on a project;
- methods and timing of modular implementation;
- isolation of the CSFs that drive modular success;
- use of standardized modules versus the modular standardized plant
- strategies for overcoming industry-wide barriers to higher levels of modularization.
The challenge…

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Alistair Gibb