Industrial Doctoral Centre for Offshore Renewable Energy

ICOE 2018 INTERNATIONAL CONFERENCE ON OCEAN ENERGY

Quoceant Innovation Offshore

ADVANCED CONCRETE MATERIALS FOR OFFSHORE FLOATING STRUCTURES

CONTEXT

Reinforced concrete (RC) is well suited for the offshore environment, with good strength and stiffness properties at a low unit cost. However, there are a number of issues with using the material in its conventional form for floating structures:

- **Concrete is heavy**, *with minimum wall thicknesses driven by the practicality of fitting in internal steel rebar with adequate cover to ensure durability - can be an issue for floating structures;*
- **Concrete cracks under tension** – *reduced permeability of cracked concrete can be an issue for reinforcement durability and watertightness. Additional prestressing is often required to keep structure in compression.*
- *Dynamic, multi-axial force regimes result in* **complex internal reinforcement requirements**; *rebar is a high cost item for RC structures.*
- *Complex shapes require* **complex formwork;** *also a high cost item.*

This work investigates the potential of advanced fibre reinforced concrete (FRC) materials to overcome these issues, using the buoyant Node structure from the Albatern WaveNET array as a case study (Figure 2).

MATERIALS

Two different FRC materials have been considered (Figure 3):

1: Ultra high performance fibre reinforced concrete (UHPFRC)

- *up to 5% volume of fibres, with residual tensile strength up to 10x that of RC.*
- *Main benefit: to eliminate internal reinforcement in areas of high tensile stress, and reduce overall section thickness.*

2: Strain hardening cementitious composites (SHCC)

- *up to 2.5% volume of fibres, residual tensile strength up to 2x that of RC, and strain-hardening behaviour (characterised by formation of micro-cracks) under increasing tensile strain. Permeablity of cracked material = permeability of uncracked material.*
- *Main benefit: to use in areas where lower tensile stresses occur through the full section thickness (risk of formation of through thickness cracks if using conventional RC), to ensure watertightness of structure and eliminate need for post-tensioning.*

This work compares an FRC solution, (using UHPFRC in high stress areas, and SHCC in lower stress areas) against conventional materials for two different WaveNET array scales:

- *Reference material for 12S array: conventional RC*
- *Reference material for 6S array: Steel, and GFRP*

COST ESTIMATES

Baseline, optimistic and pessimistic cost estimates for the different options are shown in Figure 1.

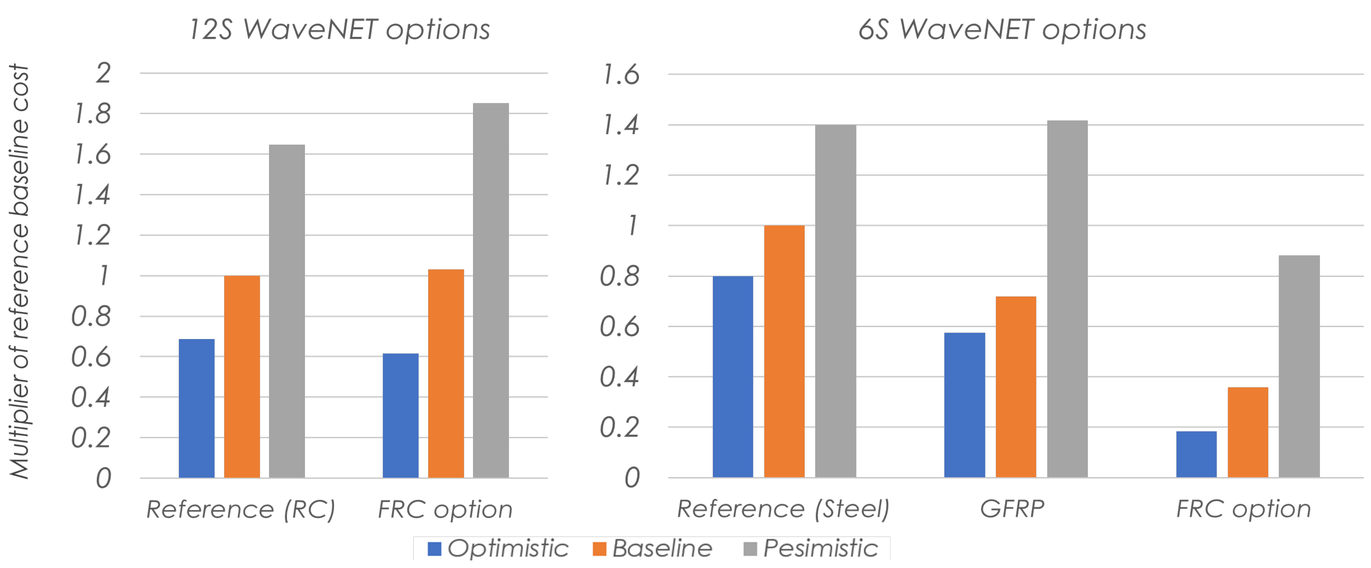
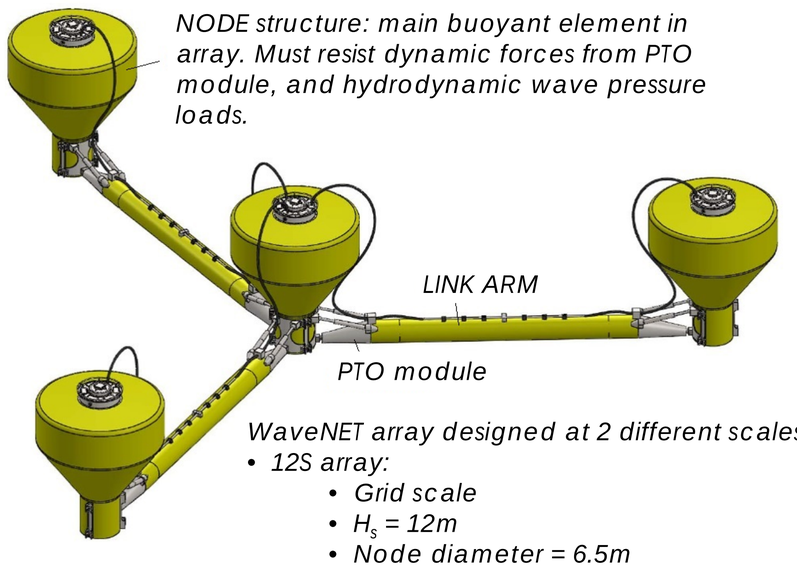


Figure 1: *Cost estimates*



NODE structure: main buoyant element in array. Must resist dynamic forces from PTO module, and hydrodynamic wave pressure loads.

WaveNET array designed at 2 different scales.

- *12S array:*
  - *Grid scale*
  - *H_s = 12m*
  - *Node diameter = 6.5m*
- *6S array:*
  - *Off-grid application*
  - *H_s = 6m*
  - *Node diameter = 3.25m*

Figure 2: *Albatern WaveNET array overview*

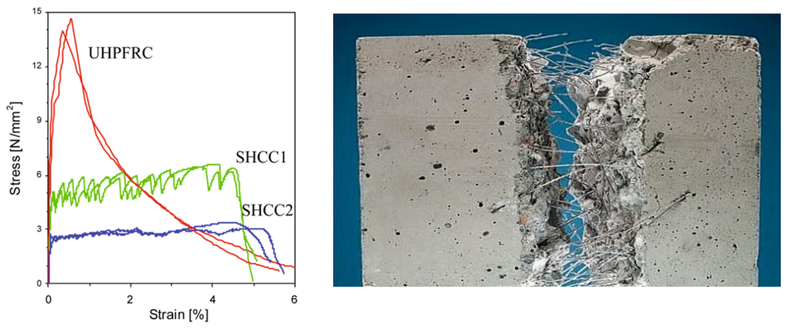


Figure 3: *FRC materials; stress-strain curve, and visualisation of fibres*

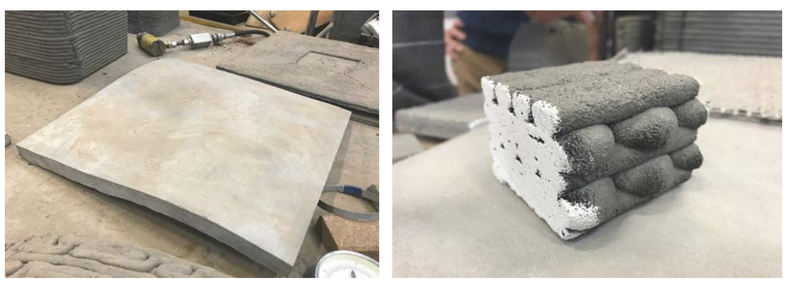


Figure 4: *Examples of 3D printed concrete (Loughborough 3DCP Centre)*

SUMMARY OF COST BENEFIT

- *12S array:* **FRC could be 60% of the cost of the RC option.**
- *6S array:* **FRC could be as little as 20% of cost of the reference steel design, and 25% of the GFRP option.**

POTENTIAL FOR 3D PRINTING *(Figure 4)*

- *Costs presented in Figure 1 assume the use of traditional formwork for all options.*
- *Current research work [1] shows that additive manufacturing methods (i.e 3D printed concrete) could reduce manufacturing costs further, by eliminating need for external formwork.*

CONCLUSIONS

- *Advanced concrete materials have potential to significantly reduce the cost offshore structures when compared to conventional materials.*
- *This offers great benefits both to wave energy structures, and the wider offshore industry.*

Acknowledgements: Work has been carried out as part of the IDCORE programme, funded by the ETI and RCUK Energy programme (grant no EP/J500847/1), alongside the ACE-WEC project, funded by Wave Energy Scotland, and led by Quoceant

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Reference [1]: ACE-WEC Public report MC11_QUO_WES, Quoceant, 2018 (soon to be published)