Qualification of Composite Components

ELÄSS - Pula

Ramin Moslemian & Philippe Noury

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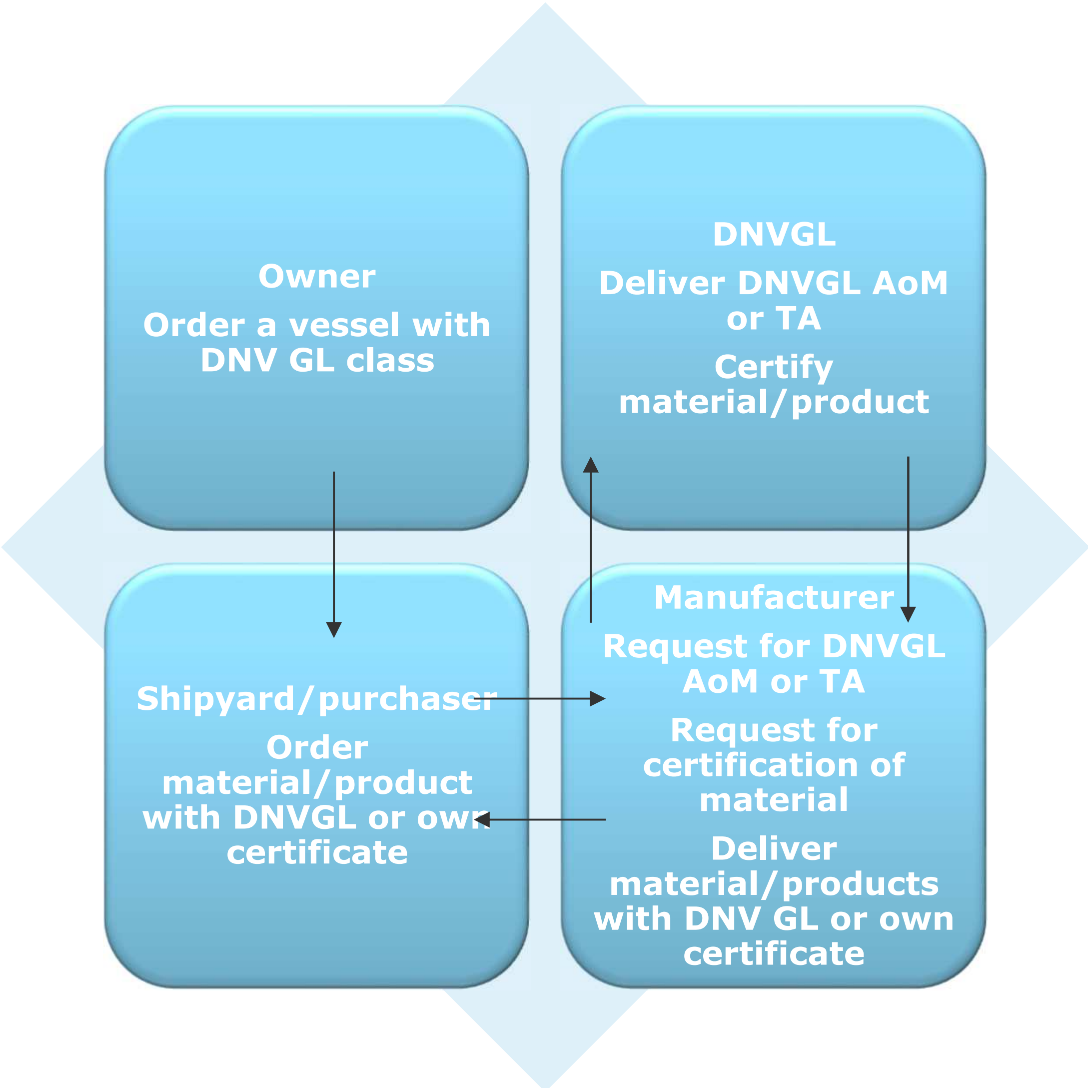
Material innovation in maritime

- Putting into practice new technology e.g. new type of material introduces uncertainties that imply risk for its developers, manufacturers, vendors, operators and end-users

- Development of new materials or technology will need to be proven and qualified prior to be set in production and operation

Current certification regime for materials and components



Qualification according to DNGL-OS-C501

- DNVGL-C501 is probably one of the few generic offshore multi-scale standards which their scope is not limited to a specific components
- The generic comprehensive approach of DNVGL-OS-C501 has advantages & disadvantages:
  - As it is generic and does not target a specific product it is attractive to the new technologies which there is a lack of reliable standard covering them. Coupled with DNVGL-RP-A203 on technology qualification it offers a robust road map to qualification of new composite technologies
  - Being generic comes with the cost of complexity which makes the standard difficult to use compared to other composite standards written for specific applications

OFFSHORE STANDARD
DNV-OS-C501

Composite Components

NOVEMBER 2013

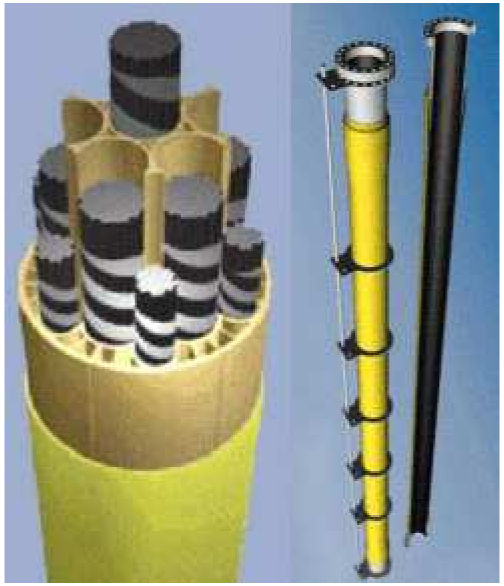
RECOMMENDED PRACTICE
DNV-RP-A203

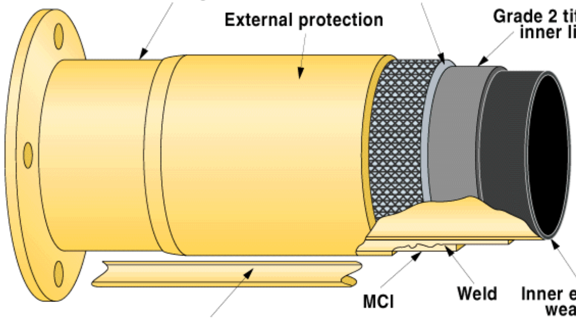
Qualification of New Technology

JULY 2011

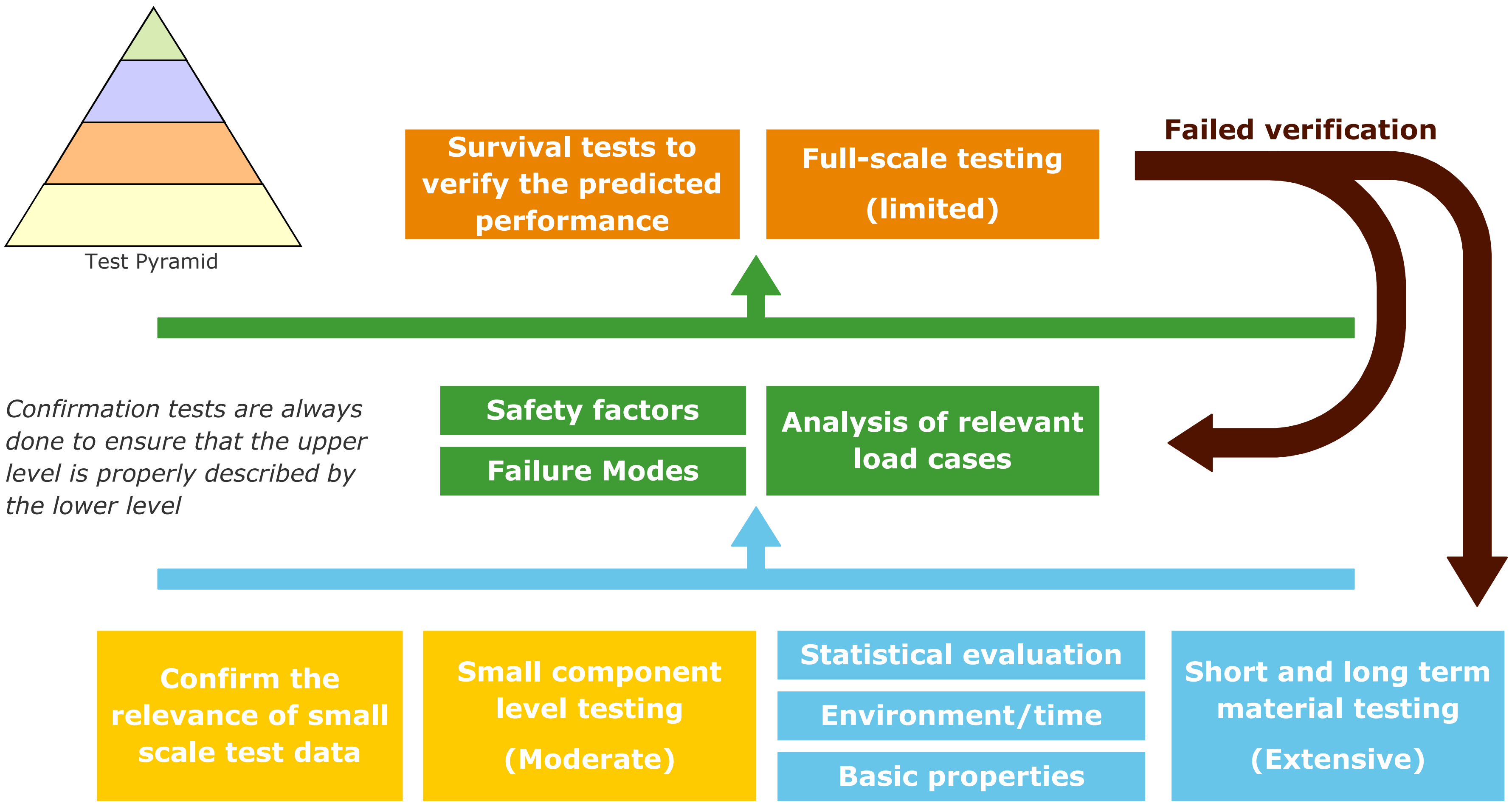
Qualification of new technologies

- The combination of DNVGL-OS-C501 and DNVGL-RP-A203 has been used in the qualification of various new composite technologies mostly for offshore applications:
  - Tethers
  - Composite risers
  - Chock and kill lines
  - Booster lines
  - Subsea clamps
  - Drilling pipes
  - Pressure vessels
  - Subsea cables
  - Bridges



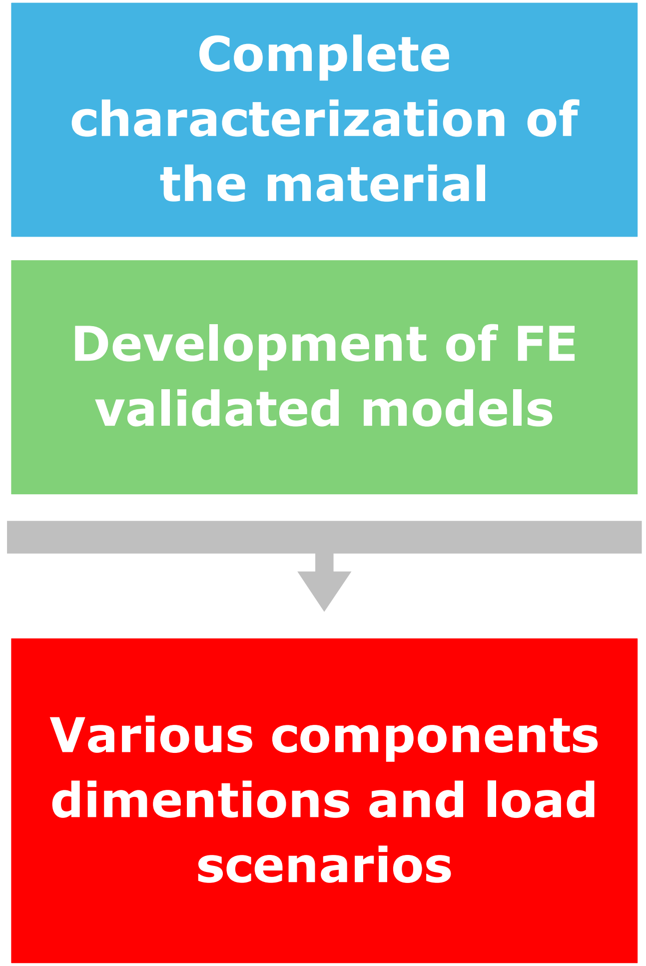


Qualification according to DNVGL-OS-C501



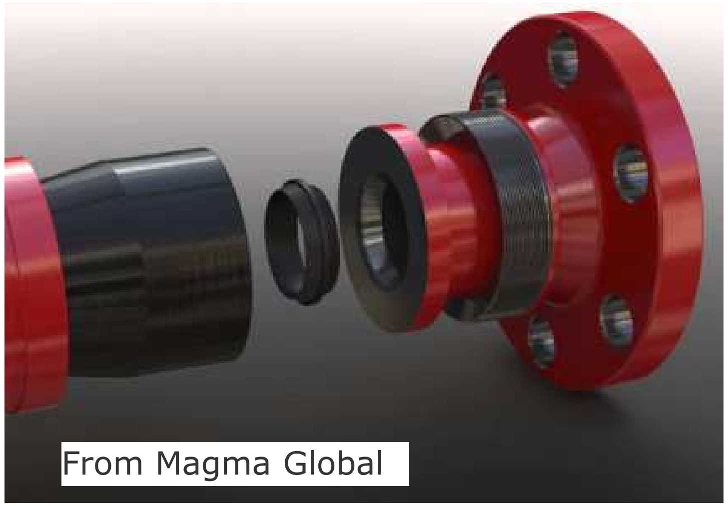
Is it worth it?

- The main advantage of the approach advocated in DNVGL-OS-C501 is its flexibility.
  - As it is adopting a multiscale approach the results from smaller scales can be reused for various applications with different load scenarios
  - It offers room for innovation by possibility of defining new failure modes and innovative solutions for addressing them
  - It is costly and complex in the beginning but pays off later by offering flexibility



Example: Fibre-reinforced thermoplastic composite pipes

- Fully bonded flexible pipe typically consisting of a non-reinforced polymeric liner, fiber reinforced thermoplastic polymer layer and outer jacket
- Their weight is less than half of similar capacity steel pipes with much better corrosion resistance and pressure rating
- Their working environment is one of the most extreme for composite components with high temperatures up to 150 C and exposure to various chemicals from H2S to hydrocarbons
- A new long-term failure mechanisms compare to other composite component: static fatigue



From Magma Global

Which design criteria can and should be targeted.

1. Fibre dominated ply failure
2. Matrix cracking
3. Delamination
4. Laminate failure

Design Criteria's following DNVGL-OS-C501 Short-term Design Criteria's

3. Fluid tightness – permeability
4. Non-reinforced polymer fracture
5. Plastic deformation, yielding of isotropic materials
6. Maximum deformation
7. Debonding
8. Crazing, cracking
9. Impact
10. Puncturing, scratches and point loads
11. Wear and tear

10. Chemical degradation
11. Swelling or shrinkage
12. Leaching of additives
13. Rapid gas decompression - blistering resistance
14. UV exposure
15. Thermal softening or hardening
16. Morphology change

Long-term design criteria

Cyclic fatigue

1. Fibre dominated failure
2. Through thickness delamination and debonding
3. Matrix cracking
4. Laminate Failure
5. Non-reinforced Polymer fracture of liner and cover
6. Thermal fatigue
7. Low cycle fatigue

- ***Characteristic curve***
- ***Goodman Diagram***
- ***Miner Sum***
- ***All critical failure mechanisms***

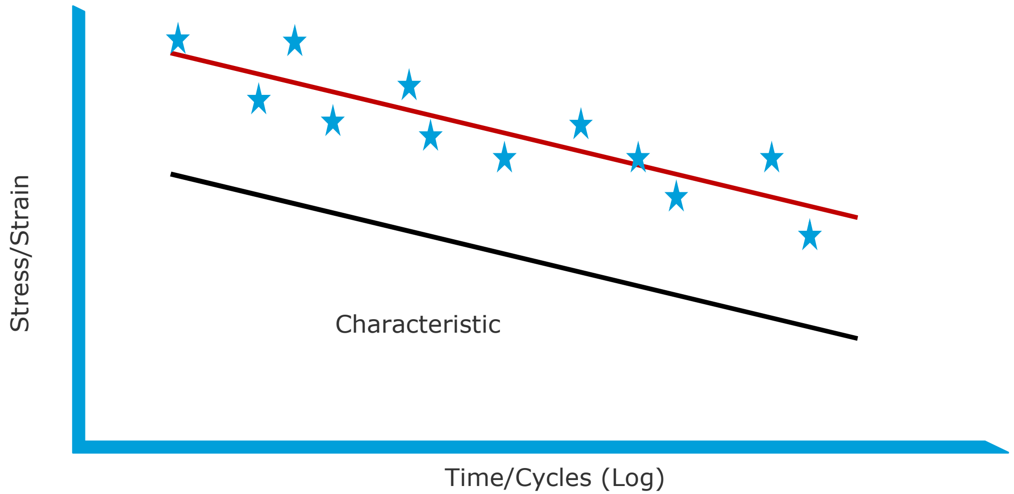
Stress rupture

1. Fiber dominated failure
2. Through thickness delamination and debonding
3. Matrix cracking
4. Laminate Failure
5. Non-reinforced Polymer fracture of liner and cover

- **Every relevant design criteria will be addressed through FEA/testing**
- **Safety factors**

Short and long term small-scale material testing

- Statistically determined characteristic values are use
- Long-term material strength are determined by small-scale testing
- Depending on the number of test points a more conservative characteristic S-N curved is recommended to be used
- Expensive and time consuming testing for stress rupture/static fatigue tests
- Valid only for a given media and a given temperature



Short term testing

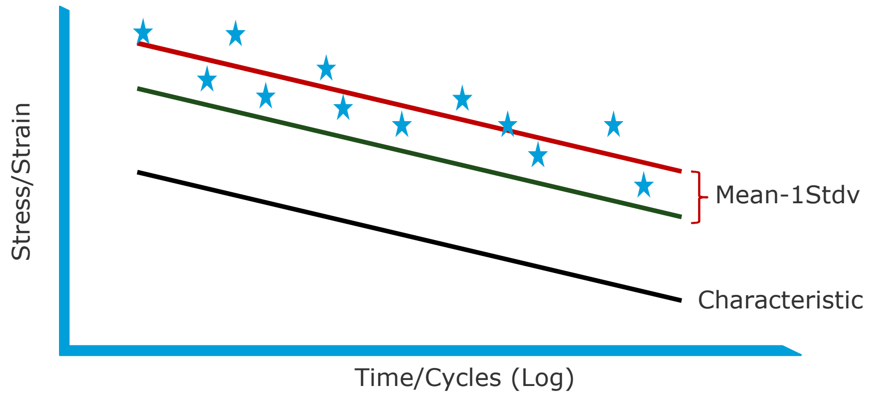
Long term testing

Temperature & Media

Confirmation testing on representative pipes

- To ensure the relevance of material tests/FEA to the actual pipe
- Tests can be performed on pipes with diameter up to 50% smaller than the targeted pipe
- Static tests: stresses/strains to failure should be within one standard deviation of the predicted mean stresses/strains
- Long-term tests: time/cycles to failure should be within one standard deviation of the predicted mean time/cycles

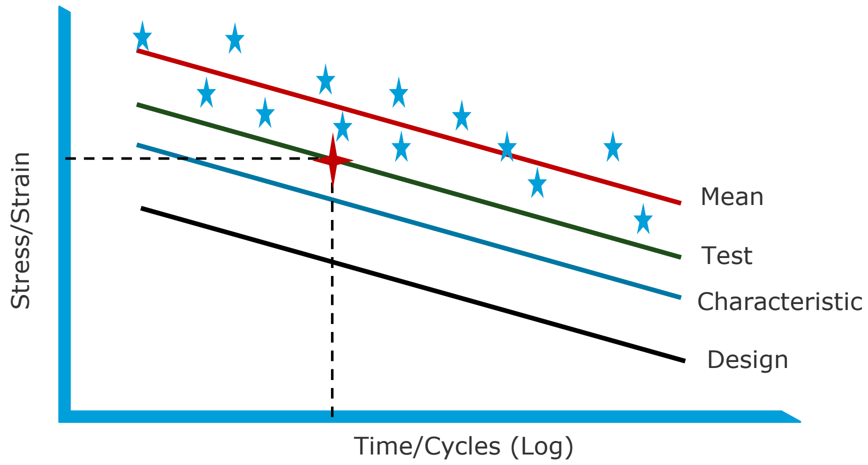
Test type	Load case
Static Tests	Axial Compression
	Internal Pressure
	Hoop Strength
	Crushing ring
Long-Term Tests Cyclic Loads (10^5 Cycles)	Axial Compression
	Axial Tension
	Internal Pressure
Long-Term Tests Stress rupture (1000 hours)	Axial Compression
	Internal Pressure



Prototype testing: long-term survival testing

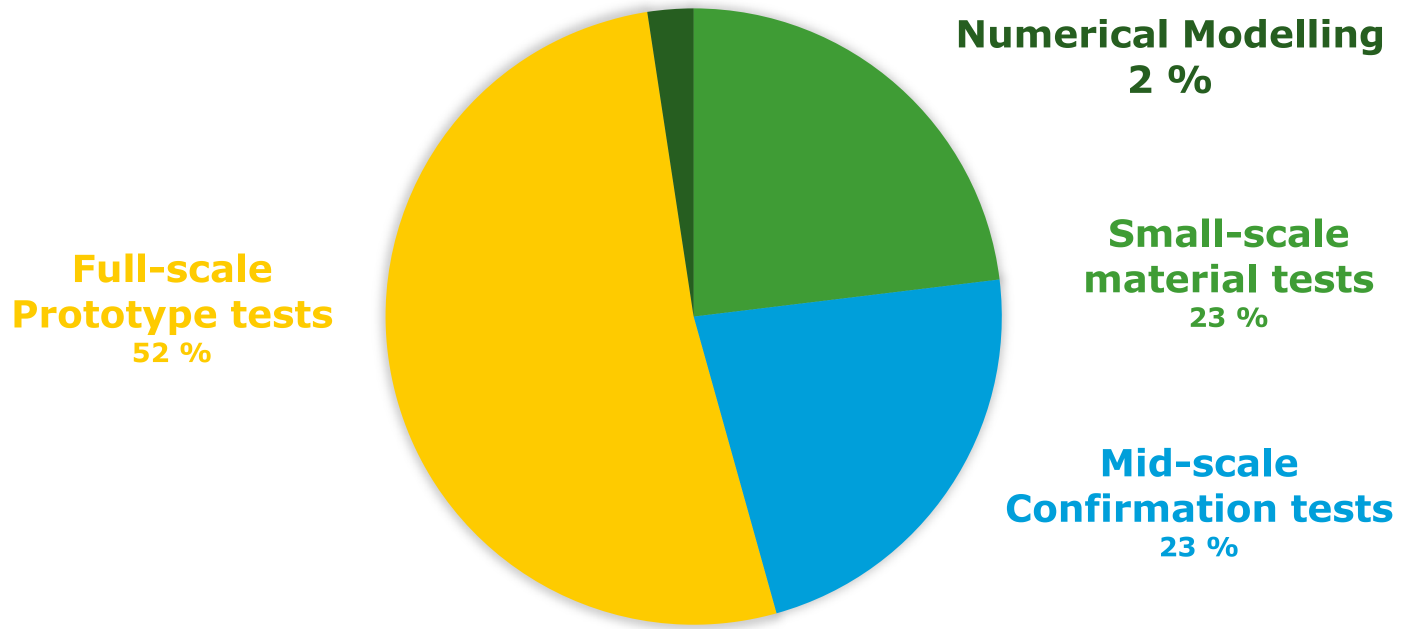
- Survival tests are required to verify the long-term strength calculations
- Required only for high- & medium-safety classes
- Should be performed for the loads which TCPs are expected to experience
- 2 survival tests for high-safety class for each load case
- 1 survival tests for medium-safety class for each load case
- The test specimen should survive the test

Survival Tests **Cyclic Loads** **(10^5 Cycles)**	**Axial Fatigue Test** **Bending Fatigue Test** **Internal Pressure Fatigue Test**
Survival Tests **Stress Rupture** **(1000 Hours)**	**Axial Fatigue Test** **Bending Fatigue Test** **Internal Pressure Fatigue Test**



Is it worth it?

- DNVGL cost study shows a typical qualification campaign for a composite pipe system costs more than 3 m$ if the qualification plan is executed effectively
- Only 2% of the total qualification cost is attributed for predictive models
  - A negligible number; probably much less than other industries such as wind energy, maritime and aeronautics, which also use composites



Thank you!

Philippe.Noury@dnvgl.com
Ramin.Moslemian@dnvgl.com

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