2010-108-01

BOEMRE Comparison of Offshore Standards - M10PC00108 – TA&R Project No. 677

Progress Meeting No. 3

31 March 2011

MANAGING RISK DNV

Agenda

- Introductions
- Work To-date
- Tasks and Schedule
- Summary/Recap

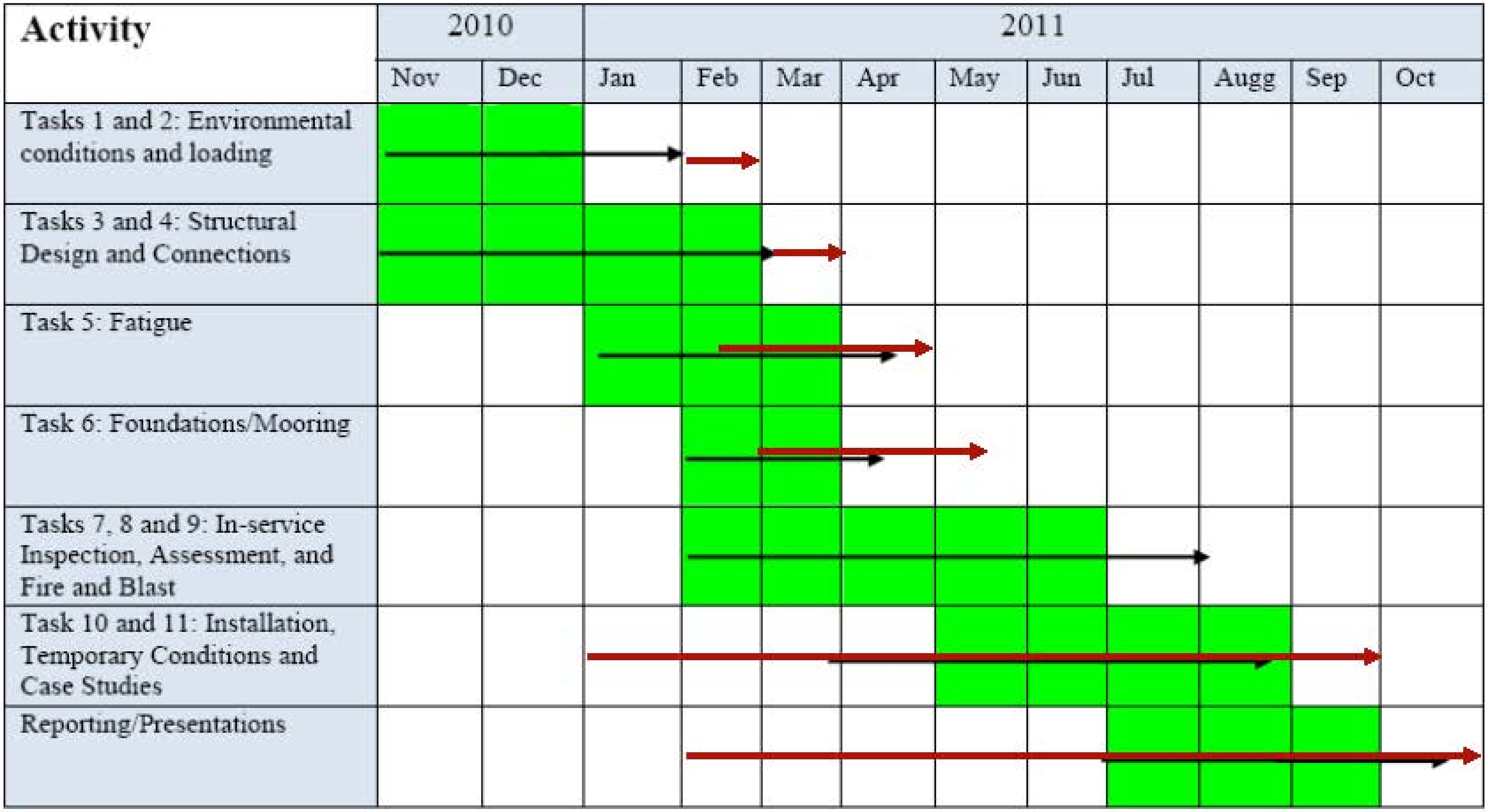
Work to-date

- Review of standards and TA&R reports
- Comparison - fixed structures:
  - Environmental criteria and loading recipe
  - Member and joint design
  - Foundation design
  - Seismic
  - Fatigue
- Comparison - floaters:
  - Environmental criteria and loading recipe
- Jacket case study preliminary results
- Calculation Sheets Developed for Member and Joint Checks
- Floater case study TLP/SPAR (?)

Tasks

1. Environmental Load Recipes	☑
2. Loading Conditions	☑
3. Structural Steel Design	☑
4. Connections	☑
5. Fatigue	
6. Foundation Design	
7. In-service inspection and maintenance	
8. Assessment of existing platforms and floaters	
9. Fire, blast and accidental loadings	
10. Installation, Temporary Conditions, and Case Studies	
11. Reporting	
12. Project Management	

Schedule



Activity
2010
2011
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Augg
Sep
Oct
Tasks 1 and 2: Environmental conditions and loading
Tasks 3 and 4: Structural Design and Connections
Task 5: Fatigue
Task 6: Foundations/Mooring
Tasks 7, 8 and 9: In-service Inspection, Assessment, and Fire and Blast
Task 10 and 11: Installation, Temporary Conditions and Case Studies
Reporting/Presentations

Scope for Floater Case Study

High Level Scope of Case Study for TLP/SPAR:

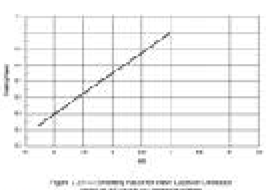
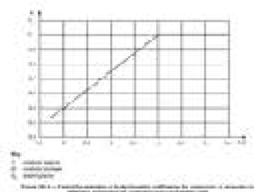
- Verify the computer model in SESAM suite of programs to ensure imported model is ready for analysis
- Run in place analysis for extreme (survival) load case
- Run analysis to verify acceptance with criteria as set in API RP-2T/2FPS, ISO 19904-1, and NORSOK N-004
- Compare the results of the analyses
- Summarize the results

Assumptions:

- The case study is intended to be an exercise in acceptance criteria for primary structural members of the hull. Topsides, tendons and foundations are not included as part of this evaluation.

Examples of Code Comparison

- Environmental criteria

	API RP 2A/API 2INT MET	ISO 19901-1/ISO 19902	NORSOK N-003
Waves	Section 2.3.1	Annex A8	Section 6.2.1
Wave Kinematics factor	0.85 to 0.95 for tropical storms 0.95 to 1.00 for extra-tropical storm 0.88 for GoM Hurricanes	0.88 for tropical cyclones 1.0 for winter storms (ISO 19902 A.24.7.3)	0.95 for North Sea Conditions
Marine Growth	1.5" (38mm) from MHHW to -150 ft in GoM	Table C.1 for UK Sector Table C.2 same as NORSOK for Areas offshore Norway; GoM: LAT +3m to -50 m: 38mm Offshore southern and central California: 200mm are common	Area Offshore Norway only Water Depth (m) / 56° to 59° (mm) / 59° to 72° (mm) Above -2: 0 / 0 -2 to -40: 100 / 60 Under -40: 50 / 30
Drag and Inertia Coeff.	smooth C_d=0.65; C_m=1.6 rough C_d=1.05; C_m=1.2 Applicable to $U_{mo}T_{app}/D$ > 30.	smooth C_d=0.65; C_m=1.6 rough C_d=1.05; C_m=1.2 Applicable to $U_{mo}T_i/D$ > 30.	smooth C_d=0.65; C_m=1.6 rough C_d=1.05; C_m=1.2 Applicable to $U_{max}T/D$ > 30.
Conductor Shielding Factor	Figure 2.3.1-4, applicable to $U_{mo}T_{app}/S$ > 5π (extreme waves); For less severe waves, with Umo/Tapp/S < 5π as in fatigue analyses, there may be less shielding 	Figure D.5-2, applicable to $U_{mo}T_{app}/S$ > 5π (extreme waves); For less severe waves, with Umo/Tapp/S < 5π as in fatigue analyses, the shielding shall not be invoked. 	6.2.4.2, referred to ISO 19902
Wind	Section 2.3.2 Wind	Annex A7	Section 6.3 Wind
Wind profiles and Gusts	$u(z,t) = U(z) \times [1-0.41 \times I_u(z) \times \ln(t/t_0)]$ $U(z) = U_0 \times [1 + C \times \ln(z/32.8)]$ $C = 5.73 \times 10^{-2} \times (1+0.0457 \times U_0)^{1/2}$ $I_u(z) = 0.06 \times [1+0.0131 \times U_0] \times (z/32.8)^{-0.22}$ where U_0 (ft/s) is the 1 hour mean wind speed at 32.8 ft	$U_{w,T}(z,t) = U_{w,1h}(z) \times [1-0.41 \times I_u(z) \times \ln(T/T_0)]$ $U_{w,1h}(z) = U_{w,0} \times [1 + C \times \ln(z/z_r)]$ $C = 5.73 \times 10^{-2} \times (1+0.15 \times U_{w,0})^{1/2}$ $I_u(z) = 0.06 \times [1+0.043 \times U_{w,0}] \times (z/z_r)^{-0.22}$ where $U_{w,0}$ (m/s) is the 1 hour mean wind speed at z_r = 10 m; All in SI units	$u(z,t) = U(z) \times [1-0.41 \times I_u(z) \times \ln(t/t_0)]$ $U(z) = U_0 \times [1 + C \times \ln(z/32.8)]$ $C = 5.73 \times 10^{-2} \times (1+0.15 \times U_0)^{1/2}$ $I_u(z) = 0.06 \times [1+0.043 \times U_0] \times (z/10)^{-0.22}$ where U_0 (m/s) is the 1 hour mean wind speed at 10m. All in SI units
Wind Spectra	$S(f) = [3444 \times (U_0/32.8)^2 \times (z/32.8)^{0.45}]/(1+\tilde{f}^n)^{5/3n}$ $\tilde{f} = 172 \times f (z/32.8)^{2/3} \times (U_0/32.8)^{-0.75}$ where n = 0.468 S(f) (ft²/s²/Hz) = spectral energy density at frequency f (Hz) z(ft) = height above sea level Uo (ft/s) = the 1 hour mean wind speed at 32.8 ft above sea level	$S(f,z) = [320\ (m/s)^2 \times (U_{w,0}/U_{ref})^2 \times (z/z_r)^{0.45}]/(1+\tilde{f}^n)^{5/3n}$ $\tilde{f} = 172 \times f (z/z_r)^{2/3} \times (U_{w,0}/U_{ref})^{-0.75}$ where n = 0.468, U_{ref} = 10m/s S(f) (m²/s²/Hz) = spectral energy density at frequency f (Hz) z(m) = height above mean sea level Uw0 (m/s) = the 1 hour mean wind speed at z_r	$S(f) = [320 \times (U_0/10)^2 \times (z/10)^{0.45}]/(1+\tilde{f}^n)^{5/3n}$ $\tilde{f} = 172 \times f (z/10)^{2/3} \times (U_0/10)^{-0.75}$ where n = 0.468, U_{ref} = 10m/s S(f) (m²/s²/Hz) = spectral density at frequency f (Hz) z(m) = height above sea level Uw0 (m/s) = the 1 hour mean wind speed at 10m above sea level

Examples of Code Comparison Table

- Load recipe

Design Loading Combinations

API RP 2A - WSD

The loading conditions should include environmental conditions combined with appropriate dead and live loads in the following manner:

1. Operating environmental conditions combined with dead loads and maximum live loads appropriate to normal operations of the platform.
2. Operating environmental conditions with dead loads and minimum live loads appropriate to the normal operations of the platform.
3. Design environmental conditions with dead loads and maximum live loads appropriate for combining with extreme conditions.
4. Design environmental conditions with dead loads and minimum live loads appropriate for combining with extreme conditions.

API RP 2A - LRFD

Design Conditions	D_1	D_2	L_1	L_2	W_o	W_e	D_n
Factored Gravity Loads	1.3	1.3	1.5	1.5		-	-
Operating Wind Wave and Current Load	1.3	1.3	1.5	1.5	1.2	-	1.5
Extreme conditions when the actions effects due to permanent and variable actions are additive	1.1	1.1	1.1	-	-	1.35	1.0075
Extreme conditions when the actions effects due to permanent and variable actions are oppose	0.9	0.9	0.8	-	-	1.35	1.6875

D_1 = self weight of the structure

D_2 = the load imposed on the platform by weight of equipment and other objects

L_1 = the load including the weight of consumable supplies and fluids in pipes and tanks

L_2 = the short duration force exerted on the structure from operations

W_o = the owner defined operating wind wave and current load

W_e = the force applied to the structure due to the combined action of the extreme wave (typically 100-yr return period) and associated current and wind

D_n = [illegible] to the structure, W_e

ISO 19901-1/ISO 19902

Design Condition	Partial action factors					
	γ_{G1}	γ_{G2}	γ_{Q1}	γ_{Q2}	γ_{Ew}	γ_{Ee}
Permanent and variable actions only	1.3	1.3	1.5	1.5	0.0	0.0
Operating situation with corresponding wind, wave, and/or current conditions	1.3	1.3	1.5	1.5	$0.9\gamma_{E,o}$	0.0
Extreme conditions when the actions effects due to permanent and variable actions are additive	1.1	1.1	1.1	0.0	0.0	γ_{E}
Extreme conditions when the actions effects due to permanent and variable actions are opposed	0.9	0.9	0.8	0.0	0.0	γ_{E}

F_d = [illegible]

where,

G_1, G_2 are the permanent actions defined in [illegible]

Q_1, Q_2 are the variable actions defined in [illegible]

E_o [illegible]

D_o [illegible]

E_e [illegible]

D_e is the equivalent quasi-static action representing dynamic response defined in [illegible]

γ_{G1}, γ_{G2}, γ_{Q1}, γ_{Q2} are the partial action factors for the various permanent and variable actions [illegible] given in Table above.

[illegible] given in table above.

[illegible]

NORSOK N-001, N003

Limit State	Action combinations	Permanent actions (G)	Variable actions (Q)	Environmental actions (E)[e]	Deformation actions (D)[e]
ULS	a[a]	1.3	1.3	0.7	1.0
ULS	b	1.0	1.0	1.3	1.0
SLS	Abnormal effect[d]	1.0	1.0	1.0	1.0
ALS	Damaged condition[c]	1.0	1.0	1.0	1.0
FLS		1.0	1.0	1.0	1.0

a For permanent actions and/or variable actions, an action factor of 1.0 shall be used where this gives the most unfavourable action effect

b Actions with annual probability of exceedance = 10^{-2}

c Environmental actions with annual probability of exceedance = 10^{-2}

d Earthquake shall be handled as environmental action within the limit state design for ULS and ALS (abnormal effect)

e Applicable for concrete structures.

Combination of environmental actions with expected mean values and annual probability of exceedance 10^{-2} and 10^{-4}

Limit State	Wind	Waves	Current	Ice	Snow	Earthquake	Sea Level
Ultimate Limit State	10^{-2}	10^{-2}	10^{-1}				10^{-2}
	10^{-1}	10^{-2}	10^{-2}	-	-	-	10^{-2}
	10^{-1}	10^{-1}	10^{-1}	10^{-2}	-	-	m
	-	-	-	-	10^{-2}		m
	-	-	-	-	-	10^{-2}	m
Accidental Limit State	10^{-4}	10^{-2}	10^{-1}	-	-	-	m+
	10^{-2}	10^{-4}	10^{-1}	-	-	-	m+
	10^{-1}	10^{-1}	10^{-4}	-	-	-	m+
	-	-	-	10^{-4}	-	-	m
	-	-	-	-	-	10^{-4}	m

m – Mean sea level

m+ - mean water level, including the effect of possible storm surge

Seismic response analysis should be carried out for the most critical water level

Environmental Conditions

API RP 2A

1. Typically, a 1-year to 5-year winter storm is used as an operating condition in the Gulf of Mexico.
2. Earthquake load, where applicable, should be imposed on the platform as a separate environmental loading conditions.

ISO 19901-1/ISO 19902

One of three methods is normally used for defining an environment that generates the extreme direct action Ee and generally also the extreme action effect, caused by the combined extreme wind, wave and current conditions:

a) 100 year return period wave height (significant or individual) with associated wave period, wind and current velocities;

b) 100 year return period wave height and period combined with the 100 year return period wind speed and the 100 year return period current velocity, all determined by extrapolation of the individual parameters considered independently;

c) any reasonable combination of wave height and period, wind speed and current velocity that results in
- the global extreme environmental action on the structure with a return period of 100 years, or
- a relevant action effect (global response) of the structure (e.g. base shear or overturning moment) with a return period of 100 years.

Method a) has been used for Gulf of Mexico designs

b) has been used in the North Sea and many other areas

c) is a more recent development, suitable when a database of joint occurrences of wind, waves and current is available.

Examples of Code Comparison Table

- Seismic

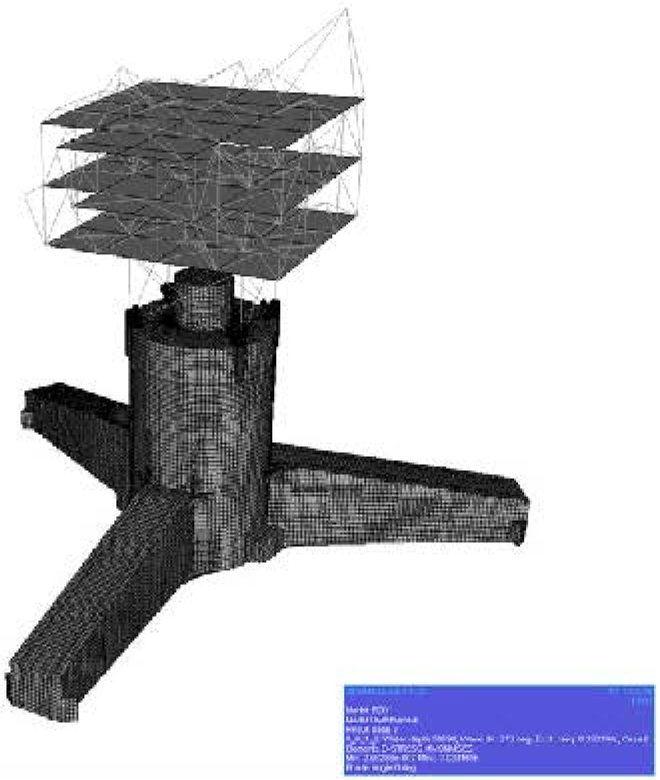
	API RP 2A	ISO 19901-2	NORSOK N-003 & N-004
Provisions Purpose	1. The strength requirements are presented to provide resistance to moderate earthquake, which have a reasonable likelihood of not being exceeded during the life of the platform, without significant structural damage. 2. To prevent collapse of the platform in the event of rare intense earthquake ground motions.	1. The seismic ULS design event is the extreme level earthquake (ELE). The structure shall be designed such that an ELE event will cause little or no damage. The ULS requirements are intended to ensure that no significant structural damage occurs for a level of earthquake ground motion with an adequately low likelihood of being exceeded during the design service life of the structure. 2. The ALE (abnormal level earthquake) requirements are intended to ensure that the structure and foundation have sufficient reserve strength, displacement and/or energy dissipation capacity to maintain the overall structural integrity and avoid structural collapse.	1. ULS (strength) check of components based on earthquakes with an annual probability of occurrence of 10^{-2} and appropriate action and material factors; 2. ALS check of the overall structure to prevent its collapse during earthquakes with an annual probability of exceedance of 10^{-4} with appropriate action and material factors 3. This provisions mainly focus on Norwegian continental shelf
Structural Modeling (Section 2.3.6.c2)	1. The analysis model should include the three dimensional distribution of platform stiffness and mass 2. Earthquake loading should be combined with other simultaneous loadings such as gravity, buoyancy, and hydrostatic pressure; Gravity loading should include the platform dead weight (comprised of the weight of the structure, equipment, appurtenances), actual live loads and 75% of the maximum supply and storage loads. 3. In computing the dynamic characteristics of braced, pile supported steel structures, uniform modal damping ratios of five percent of critical should be used for an elastic analysis.	1. Design Action $F_d = 1.1G_1 + 1.1G_2 + 1.1Q_1 + 0.9E$ where E: the inertia action induced by the ELE ground-motion and determined using dynamic analysis procedures such as response spectrum or time-history analysis; G_1 and G_2: permanent actions; Q_1: variable action; and shall include actions that are likely to be present during earthquake. When contributions to the action effects due to weight oppose the inertia actions due to the earthquake, $F_d = 0.9G_1 + 0.9G_2 + 0.8Q_1 + 0.9E$ where G_1, G_2 and Q_1 shall include only actions that are reasonably certain to be present during an earthquake. 2. The mass used in the dynamic analysis: - the permanent actions G1 and G2 - 75% of the variable actions Q1 - the mass of entrapped water, and the added mass 3. A modal damping ratio of 5% of critical may be used in the dynamic analysis of the ELE event	1. The number of vibration modes in the analysis should represent at least 90% of the total response energy of all modes. 2. In the absence of more accurate information, a modal damping ratio of 5% of critical may be used. 3. Earthquake shall be handled as environmental action within the limit state design for ULS and ALS (abnormal effect) ULS (a): 1.3G + 1.3Q + 0.7E ULS (b): 1.0G + 1.0Q + 1.3E
Strength Requirement – Response Analysis (Section 2.3.6.c3) / Extreme Level Earthquake Design – Response Analysis / ULS – Response Analysis	1. Response spectrum method – one design spectrum is applied equally in both horizontal directions. An acceleration spectrum of one half that for the given zone should be applied in the vertical direction. The complete quadratic combination (CQC) method may be used for combining modal responses and the square root of the sum of the squares (SRSS) may be used for combining the directional response. At least two modes having the highest overall response should be included for each of the three principal directions plus significant torsional modes. 2. Time history method – the design response should be calculated as the average of the maximum values for each of the time histories considered.	1. In both methods, the base excitations shall be composed of three motions, i.e. two orthogonal horizontal motions and the vertical motion. 2. Response spectrum method - When responses due to each directional component of an earthquake are calculated separately, the responses due to the three earthquake directions may be combined using the root of the sum of the squares method. Alternatively, the three directional responses may be combined linearly assuming that one component is at its maximum while the other two components are at 40% of their respective maximum values. 3. Time history method – a minimum of 4 sets of time history records shall be used to capture the randomness in seismic motions. The ELE design is satisfactory if the code utilization maxima are less than 1.0 for half or more of the records; a scale factor of 1.05 shall be applied to the records if less than 7 sets of records are used.	1. Earthquake motion can be described by two orthogonal horizontal motions and the vertical motion action simultaneously. 2. One of the horizontal excitations should be parallel to a main structural axis, with the major component directed to obtain the maximum value for the response quantity considered. Unless more accurate calculations are performed, the orthogonal horizontal component may be set equal to 2/3 of the major component and vertical component equal to 2/3 of the major component referred to bedrock. 3. Time history method - the load effect should be calculated for at least three sets of time histories. The mean values of the calculated action effects from the time history analyses may be taken as basis for design
Strength Requirement (3.0.d & 2.3.6e) / Extreme Level Earthquake Design / ULS	1. The structural members should not exceed yielding of the complete section or buckling. 2. For strength requirement, the basic AISC allowable stresses and those presented in Section 3.2 (Allowable Stresses for Cylindrical Members) may be increased by 70 percent. 3. For combined earthquake loading and hydrostatic pressure, the suggested safety factors for local buckling and interaction formula are as follows: Axial Tension 1.0	1. All primary, secondary structural and foundation components shall sustain little or no damage to the structure. Limited non-linear behaviour (e.g. yielding in steel) is permitted, but brittle degradation (e.g. local buckling in steel) shall be avoided. 2. The internal forces in joints shall stay below the joint strengths, using the calculated (elastic) forces and moments. 3. Masts, derricks and flare structures shall be capable of sustaining the motions transmitted via the structure with little or no damage. 1. For the design of piles for ELE event, a partial resistance factor of 1.25 shall be	Material Factor γ_M = 1.15

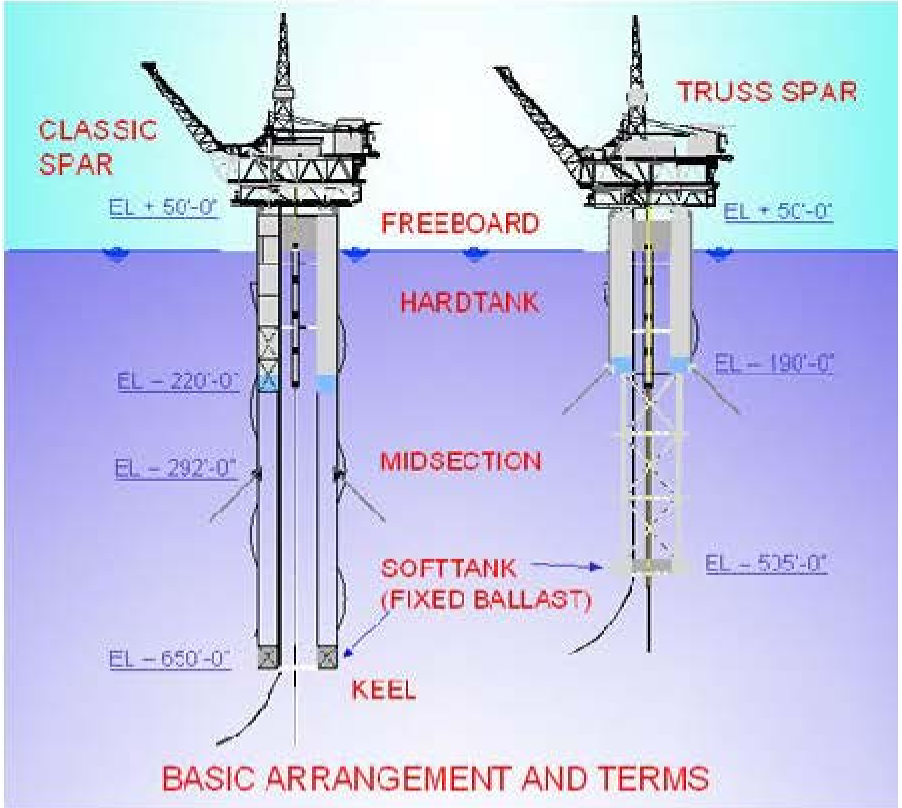
Examples of Code Comparison Table

- Pile capacity

API WSD	API LRFD	ISO 19902	NORSOK N-004
3.3.1.b Cylindrical Piles [illegible] < 1.0 F_{xc} = F_y[1.64 − 0.23 (D/t)[illegible]] ≤ F_{xe} 60 < D/t < 300, t ≥ 6 mm F_{xc} = F_y [illegible] **3.3.1.c Pile Overload Analysis** P/A − 2/π [arc sin((M/Z)/F_{xc})] ≤ 1.0 where the arc sin term is in radians and A = cross-sectional area, in^2 (m^2) Z = plastic section modulus, in^3 (m^3) P, M = axial loading and bending moment computed from a nonlinear analysis, including the (P-Δ) effect F_{xc} = Critical local buckling stress with a limiting value of 1.2F_y considering the effect of strain hardening	**D.3.2.2 Piles** 1-cos[(π/2)(...)] + [illegible] ≤ 1 where ϕ_c = 0.85 ϕ_b = 0.95 f_{by}, f_{bz} should include secondary moments or P-Δ effects		
6.3.4 Pile Penetration The allowable pile capacities are determined by dividing the ultimate pile capacity by appropriate factors of safety which should not be less than the following values: Load condition — Safety Factor 1. Design environmental conditions with appropriate drilling loads — 1.5 2. Operating environmental conditions during drilling operations — 2 3. Design environmental conditions with appropriate producing loads — 1.5 4. Operating environmental conditions during producing operations — 2 5. Design environmental conditions with minimum loads (for pullout) — 1.5	**G.4.2 Foundation Capacity** The axial pile capacity should satisfy the following conditions: P_{DE} ≤ ϕ_{E} Q_D P_{DO} ≤ ϕ_{O} Q_D where Q_D = ultimate axial pile capacity determined from a coupled linear structure and nonlinear foundation model using factored loads ϕ_E = pile resistance factor for extreme environmental conditions (= 0.8) ϕ_O = pile resistance factor for operating environmental conditions (= 0.7)	**17.3.4 (b) Pile Axial Resistance** The axial pile capacity should satisfy the following conditions: $P_{d,e}$ ≤ Q_d = Q_r/γ_{R,P_e} $P_{d,o}$ ≤ Q_d = Q_r/γ_{R,P_o} where Q_d = design axial pile capacity Q_r = the representative value of the axial pile capacity $P_{d,e}$ = design axial action on the pile determined from a coupled linear structure and non-linear foundation model using the design actions for extreme conditions $P_{d,o}$ = design axial action on the pile, determined from a coupled linear structure and non-linear foundation model using the design actions for permanent or variable actions or the design axial action for operating situations γ_{R,P_e} = the pile partial resistance factor for extreme conditions (= 1.25) γ_{R,P_o} = the pile partial resistance factor for permanent and variable actions or operating situations (= 1.50)	**K.6.2.1 Axial Pile Resistance** For determination of design soil resistance against axial pile loads in ULS design, a material factor γ_M = 1.3 is to be applied to all characteristic values of soil resistance.
6.10 Pile Wall Thickness For piles that are to be installed by driving where sustained hard driving (250 blows per foot [820 blows per meter] with the largest size hammer to be used) is anticipated, the minimum piling wall thickness used should not be less than: t = 0.25 + D/100 or t = 6.35 + D/100 (Metric Formula) where t = wall thickness, in. (mm) D = diameter, in. (mm)	**G.10.6 Minimum Wall Thickness** For piles that are to be installed by driving where sustained hard driving (250 blows per foot [820 blows per meter] with the largest size hammer to be used) is anticipated, the minimum piling wall thickness used should not be less than: t = 0.25 + D/100 or t = 6.35 + D/100 (Metric Formula) where t = wall thickness, in. (mm) D = diameter, in. (mm)		

TLP/SPAR for Floater Case Study (?)





Summary

- Reviewed project progress to date
- Case studies status
- API, ISO, and NORSOK Standards applied to a Jacket platform case study Preliminary results presented.
- Tasks 5 and 6 Underway
- Next deliverable
- Next Progress GoToMeeting – April 28th 2011.

Further comments

Safeguarding life, property and the environment

www.dnv.com

MANAGING RISK