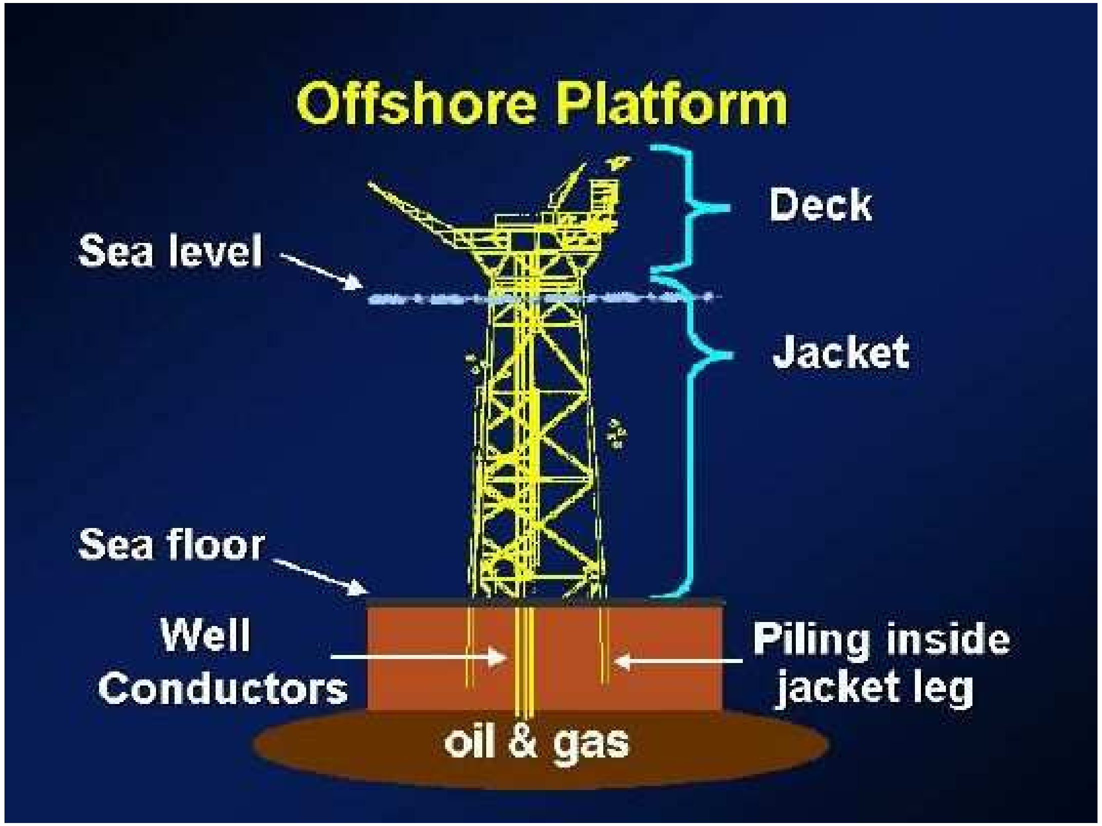
Offshore Structural Design

Detail Engineering

Fixed Platforms

M.ANBARASAN

Components of Fixed Platforms



Design of structures

In-place Phase (Piles, Jacket ,Deck Integral)

Three types of analysis are performed:

- Survival state----- wave/current/wind attack with 50 or 100 years recurrence period.
- Operational state--- wave/current/wind attack with 1 or 5 years recurrence period, under full operation.
- Fatigue assessment for design life.
- Accidental.

Above analyses are performed on the complete and intact structure.

- Assessments at damaged structures, e.g. with one member deleted, and assessments of collision situations are occasionally performed.

Design of structures(contd)

- Majority of structural analyses are based on the linear theory of elasticity for total system behaviour.
- Dynamic analysis is performed for the system behaviour under wave-attack if the natural period exceeds 3 seconds.

Structure Geometry

Jacket configuration depends

1. Size of deck
2. Water depth
3. Geotechnical reports
4. No. of conductors
5. Appurtanances : They are

   Risers , Boat Landing , Barge bumpers

   Riser guards, Pumps or Caissons.

Computer Model Preparation- Jackets

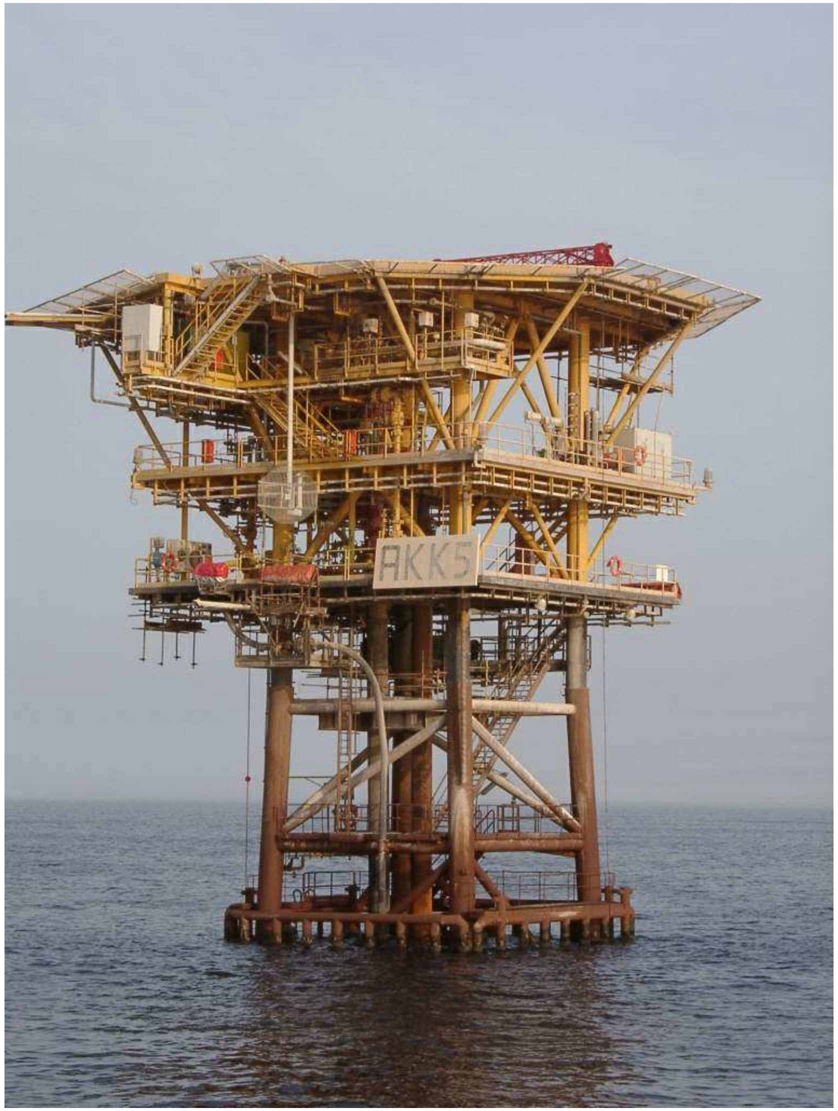
Jacket structure shall be modelled as a 3D space frame. All primary and secondary

- tubular members shall be modelled.
- *Risers & Caissons* shall be modelled as structural elements that attract wave loads
- (without contribution to the jacket stiffness). They should be linked to the jacket in
- a way that is consistent with their guide and anchor arrangements.
- *Conductors* shall be modelled down to mudline level where they can be assumed
- pinned. Linear dependencies shall be provided at relevant guide levels such that
- conductors do not contribute to the structural stiffness of the jacket.
- *Boat landing* primary members shall be modelled such that they attract wave
- loads. The effects of secondary members shall be considered by modelling
- additional masses and modifying the hydrodynamic coefficients of primary
- members. Boat landing models shall be connected to the jacket models such that
- they correctly reflect the state of the connection/releases between two structures.

Computer Model Preparation- Jacket (contd.)

- *Jacket Appurtenances* including mudmats, anodes, walkways, ladders and fenders shall be modelled as either structural masses or increased density on associated members. The contribution of these members to hydrodynamic forces shall be considered by modifying drag and mass coefficients of main members
- *Grouted pile sleeves* and members with ring stiffeners shall be modelled as equivalent members with similar stiffness and correct structural mass.
- *Joint eccentricities* shall be modelled based on the requirements of API-RP2A .

Well Head Platform



Codes and Standards

- API-RP2A: American Petroleum Institute Recommended practice for planning, designing and constructing fixed offshore platforms The structural offshore code,

  Regulations of a major certifying authority.
- DnV: Rules for the classification of fixed offshore installations.
- AISC: Specification for the design, fabrication and erection of structural steel for buildings. American Institute of Steel Construction . Widely used structural code
- AWS D1.1-90: Structural Welding Code - Steel.

  American Welding Society 1990. The structural offshore welding code.
- Marine Operations: Standard for insurance warranty surveys in marine

  operations. Regulations of a major certifying authority.
- ABS: Rules for building and classing offshore installations, Part 1 Structures.

  American Bureau of Shipping 1983.Regulations of a major certifying authority.
- BV: Rules and regulations for the construction and classification of offshore platforms. Bureau Veritas Regulations of a major certifying authority.

Data Requirement

Environment

- water depth at location
- soil, at sea bottom and in-depth
- wind speed, air temperature
- waves, tide and storm surge, current
- ice (fixed, floes, icebergs) (not applicable for this part of world)
- Earthquakes
- Deck loads (Operating & Extreme)
- Dead loads,
- Live Loads,
- Equipment Loads

Platform Data(Typical)

Design life 25 years

Wind loads Inplace of Jacket ---- 1Hr average

Deck Inplace ---------- 1 Min Average

Modules/Frame local- 3Sec Gust

Cantelever struct ----- 3 Sec Gust

Zones: Atmospheric ----- +6.00 upwards

Splash ----- -1.8 to +6.0

Submerged ------ -1.8 to Mudline

Plat form location Northing Easting Ref.Point

Water depth 55.0 m from MSL

Lowest Astronomical Tide ----- -0.183m

Extreme Storm Parameters

Direction (From)	Tide (M)		Maximum Wave		Current (M/Sec)					Wind (km/h)
	AT	Storm	Height (M)	Period (Sec.)	Bottom	Y-1/4	Y-1/2	Y-3/4	Surface	1-Hour Average
North	4.0	0.61	15.32	13.7	0.457	0.914	1.341	1.341	1.585	161.3
North East	4.0	0.61	11.03	12.2	0.274	0.670	1.005	1.005	1.249	161.3
East	4.0	0.61	9.51	11.5	0.243	0.640	0.944	0.944	1.158	161.3
South East	4.0	0.61	11.64	12.7	0.304	0.884	1.067	1.067	1.280	161.3
South	4.0	1.31	17.71	14.3	0.457	0.944	1.158	1.371	1.615	161.3
South West	4.0	1.31	17.10	13.9	0.335	0.731	0.884	1.036	1.249	161.3
West	4.0	1.25	16.50	13.5	0.274	0.640	0.792	0.944	1.127	161.3
North West	4.0	0.85	15.88	13.45	0.335	0.731	0.884	1.036	1.249	161.3

Operating Storm Parameters

Direction (From)	Tide (M)		Maximum Wave		Current (M/Sec)					Wind (km/h)
	AT	Storm	Height (M)	Period (Sec.)	Bottom	Y-1/4	Y-1/2	Y-3/4	Surface	1-Hour Average
All Directions	4.0	0.655	11.58	11.0	0.457	0.762	0.944	1.097	1.280	100.0

Installation Parameters

Tide (M) Astronomical	Wave Height (M)	Period (Seconds)	Current (M/Second)		Wind (KM/H)
			Surface	Bottom	1 Minute Sustained
4.0	1.829	8.3	0.701	0.426	48.27

Envormental Parameters for Fatigue design

WAVE HEIGHT RANGE (M)	PERIOD (SEC.)			
	S	SW	W	NW
0 - 1.523	8.7	9.6	8.3	6.6
1.524 - 3.047	9.2	10.1	8.7	7.4
3.048 - 4.571	9.5	10.3	9.2	7.9
4.572 - 6.095	9.7	10.4	9.6	8.4
6.096 - 7.619	9.9	10.5	10.0	8.9
7.620 - 9.143		10.6	10.3	
9.144 - 10.667		10.8	10.6	
10.668 - 12.192		11.0	10.9	

Wave exceedance data (Fatigue design)

WAVE HEIGHT (M)	NUMBER OF WAVES EXCEEDING SPECIFIED HEIGHT IN 1-YEAR				
	S DIR	SW DIR	W DIR	NW DIR	CUMULATIVE
0	1,276,045	770,535	1,015,713	1,220,511	4,282,804
1.524	61,704	219,347	220,985	69,788	571,824
3.048	3,132	37,929	31,902	3,764	76,727
4.572	167	5,878	4,073	177	10,295
6.096	11	869	493	8	1,381
7.620	0	126	59	0	185
9.144		18	7		25
10.668		2	1		3
12.192		0	0		0

Notes: 1. Wave directions are directions from which wave approaches the platform.

Material Properties

Design properties of steel shall be taken as follows:

- Density (ρ) 7850 kg/m3
- Modulus of Elasticity (E) 210 x 106 kN/m2
- Shear Modulus (G) 80.9 x 106 kN/m2
- Poisson’s Ratio (v) 0.3
- Coefficient of Thermal Expansion (α) 12.0 x 10 – 6 /℃

Steel Types

Allocations of the steel types for offshore jackets are shown in Table 6.2. In sp circumstances, use of higher grade steels like 450EM or 450EMZ (as defined ir 7191) is also possible, however, approval of QP must be obtained in advance.

Steel Type	Grade	Allocated Members
Primary (Type I)	355 EM	Jacket primary members, legs, braces, piles, and pile sleeves.
Special (Type II)	355 EMZ	Jacket primary members with high stress concentrations like jacket nodes, lifting padeyes, trunnions, pile heads, clamps and components subject to lamellar tearing.
Miscellaneous (Type V)	275 D/E	Jacket secondary members, miscellaneous brackets, pipe supports, cable tray supports, stairs and handrails.
Secondary (Type VI)	355 D/E	Secondary members where higher strength is required (mudmats, caissons, risers, J-tubes, seafastening, installation aids, boat landings, grillage and ladders).

Corrosion allowance

Additional wall thickness in the form of corrosion allowance shall be provided for the jacket members in the splash zone

- Jacket legs, bracing, conductor and caissons 12mm
- Pipe casings and sump caissons (wrapped) 12mm wrapped plate
- Fenders, bumpers and boat landing members 6 mm

Note: The extra thickness for corrosion allowance shall not be included in calculating

- stresses in members or joints. For these members/joints, the allowance shall be
- deducted from the outside diameter of the tube. In general, the tubular member wall
- thickness in the splash zone shall not be less than 25mm.
- Alternatively Monel sheathing provided in Splash zones.

Cathodic Protection

All jacket members below the water line shall be protected against corrosion using sacrificial anodes. The protection system shall be designed based on the requirements of DNV-RP B401

Anode properties as per specification

Loads

- The following loads shall be considered when a platform is in permanent condition:
- *Dead Loads:* Weight of the platform structure and appurtenances, permanent
- equipment and pipes, dead weight of modules, cranes and helideck.
- *Functional Loads:* Loads induced by platform operation like weight of the liquids in
- pipes/tanks, thermal loads, drilling loads, loads induced by helicopter landing and
- vessel mooring, dynamic loads due to vibration of equipment and loads due to crane
- operation.
- *Live Loads:* Weight of the personnel, movable equipment and loads due to material
- handling.
- *Environmental Loads:* Loads induced by the action of waves, currents, winds,
- earthquake, and temperature fluctuations**.**
- *Accidental Loads:* Loads induced by accidental vessel collision, fire, explosion, wave
- slam and dropped objects.

Typical Deck Loading

I. **Deck Plating Design**

S.No.	Item/Location	Uniformly distributed area live loads	Remarks
1.	Deck Plating of Well and Process Platform	1500 kg/m^2	Check and reinforce if required for higher local loads.
2.	Building Module Floor	1000 kg/m^2	

II. **Grating Design** = 500 kg/m^2

III. **Live loads for local beam design**

S.No.	Item/Location	Uniformly distributed area live loads	Remarks
1.	Plated areas of Well Platform	1500 kg/m^2	All beams should be checked for the case of (actual equipment and piping dead weight + operating contents weight + 500 kgf/m.sq. on open area) and reinforced if required.
2.	Plated areas of Process Platform	2000 kg/m^2	
3.	Module areas where module skids are supported directly onto the deck main trusses/framework	Actual	
4.	Potable Water Storage tank area	Actual	
5.	Access hatches	1500 kg/m^2	Access hatches shall be checked for appropriate concentrated loads also.

Wind Load calculations

Wind loads act on the portion of a platform above the water level, as well as on any equipment, housing, derrick, etc. located on the deck. An important parameter pertaining to wind data is the time interval over which wind speeds are averaged. For averaging intervals less than one minute, wind speeds are classified as gusts. For averaging intervals of one minute or longer they are classified as sustained wind speeds.

The wind velocity profile may be taken from API-RP2A [2]:

$V_h/V_H = (h/H)^{1/n}$ (1)

where:

V_h is the wind velocity at height h,

V_H is the wind velocity at reference height H, typically 10m above mean water level,

1/n is 1/13 to 1/7, depending on the sea state, the distance from land and the averaging time interval. It is approximately equal to 1/13 for gusts and 1/8 for sustained winds in the open ocean.

From the design wind velocity V(m/s), the static wind force F_w(N) acting perpendicular to an exposed area A(m^2) can be computed as follows

Wind loads (cont.)

Fw = (1/2) r V2 Cs A (2)

where:

r is the wind density (r » 1.225 Kg/m3)

Cs is the shape coefficient (Cs = 1,5 for beams and sides of buildings,

Cs = 0,5 for cylindrical sections and Cs = 1,0 for total projected area of platform).

Shielding and solidity effects can be accounted for,by designer's judgement

For combination with wave loads, the DNV and DOE-OG rules recommend the most unfavourable of the following two loadings:

a. 1-minute sustained wind speeds combined with extreme waves.

b. 3-second gusts.

API-RP2A distinguishes between global and local wind load effects. For the first case it gives guideline values of mean 1-hour average wind speeds to be combined with extreme waves and current. For the second case it gives values of extreme wind speeds to be used without regard to waves.

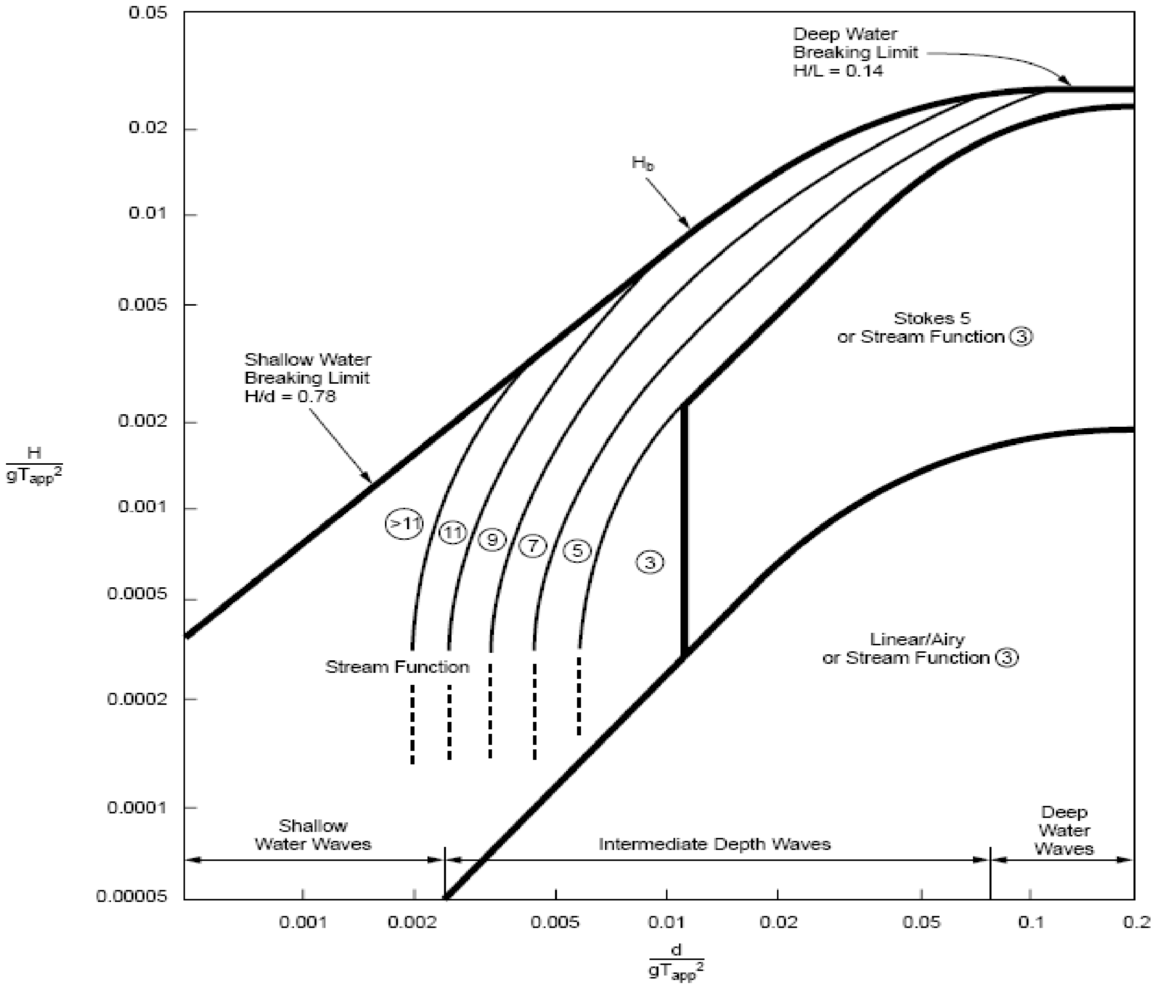
Wave Slam (Misc')

Wave slam shall be considered for members in the splash zone. The wave slam load

- shall be calculated based on the equation presented below. The API allowable stresses can be increased by 33% for the design of members and connections.
- F = 0.5 ρ.Cs.Us2 where
- Us Velocity of the water surface normal to the member surface (m/s)
- Cs Slam coefficient (3.5 for tubulars, 5.0 for flat plates)
- ρ Water density (kg/m3)
- In designing the members for wave slam, consideration shall be given to dynamic
- amplifications due to wave impact. In this case a minimum dynamic amplification of
- 2.0 shall be used in calculating the bending moments at the member ends and midspan.

Wave Loads

The wave loading of an offshore structure is usually the most important of all environmental loadings for which the structure must be designed. The forces on the structure are caused by the motion of the water due to the waves which are generated by the action of the wind on the surface of the sea. Determination of these forces requires idealisation of the wave surface profile and the wave kinematics given by an appropriate wave theory. The computation of the wave forces on individual members and on the total structure, from the fluid motion.



H/gT_{app}^2: Dimensionless wave steepness
d/gT_{app}^2: Dimensionless relative depth
H: Wave height
H_b: Breaking wave height
d: Mean water depth
T_{app}: Wave period
g: Acceleration of gravity

Figure 2.3.1-3—Regions of Applicability of Stream Function, Stokes V, and Linear Wave Theory
(From Atkins, 1990; Modified by API Task Group on Wave Force Commentary)

Current

There are tidal, circulation and storm generated currents. When insufficient data in criteria, current velocities may be obtained from various sources, e.g. Appendix A of DNV. In platform design, the effects of current superimposed on waves are taken into account by adding the corresponding fluid velocities vectorially. For slender members, cyclic loads induced by vortex shedding may also be important and should be examined locally.

Other parameters

- **Marine Growth**

  Marine growth is accumulated on submerged members. Its main effect is to increase the wave forces on the members by increasing not only exposed areas and volumes, but also the drag coefficient due to higher surface roughness. In addition, it increases the unit mass of the member, resulting in higher gravity loads and in lower member frequencies.

Marine growth consideration	+3.00m to -30.00 m	10 cm
	-30.0m to Mudline	5 cm

- **Tides**

  Tides affect the wave and current loads indirectly, i.e. through the variation of the level of the sea surface. The tides are classified as:
  (a) astronomical tides

  (b) storm surges - caused by the combined action of wind and barometric pressure differentials during a storm. The combined effect of the two types of tide is called the storm tide.

Earthquake

Offshore structures in seismic regions are typically designed for two levels of earthquake intensity:

The strength level and the ductility level earthquake. For the strength level earthquake, defined as having a "reasonable likelihood of not being exceeded during the platform's life" (mean recurrence interval ~ 200 - 500 years), the structure is designed to respond elastically. For the ductility level earthquake, defined as close to the "maximum credible earthquake" at the site, the structure is designed for inelastic response and to have adequate reserve strength to avoid collapse.

Preservice condion loads

Loadout Forces

These are forces generated when the jacket is loaded from the fabrication yard onto the barge. If loadout is done by skidding the structure onto the barge, a number of static loading conditions must be considered, with the jacket supported on its side. Such loading conditions arise from the different positions of the jacket during the loadout phases, from movement of the barge due to tidal fluctuations and from possible support settlements. Since movement of the jacket is slow, all loading conditions can be taken as static. Typical values of friction coefficients for calculation of skidding forces are the following:

- steel on steel without lubrication... 0,25
- steel on steel with lubrication.. 0,15
- steel on teflon... 0,10
- teflon on teflon.. 0,08

Preservice condion loads(cont.)

- **Lifting Forces**

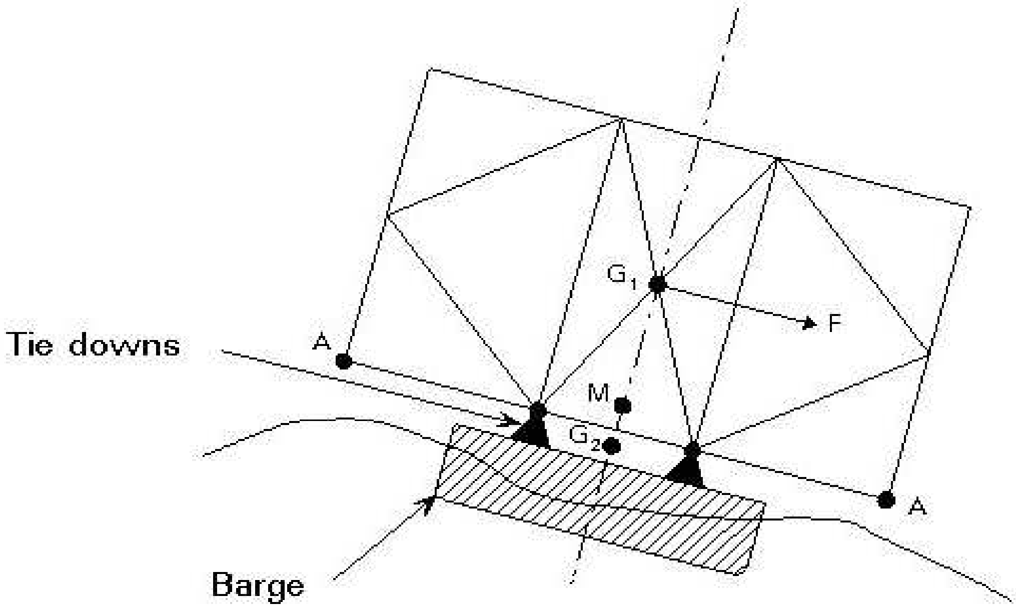
  Lifting forces are functions of the weight of the structural component being lifted, the number and location of lifting eyes used for the lift, the angle between each sling and the vertical axis and the conditions under which the lift is performed . All members and connections of a lifted component must be designed for the forces resulting from static equilibrium of the lifted weight and the sling tensions. API-RP2A recommends that in order to compensate for any side movements, lifting eyes and the connections to the supporting structural members should be designed for the combined action of the static sling load and a horizontal force equal to 5% this load, applied perpendicular to the padeye at the centre of the pin hole. All these design forces are applied as static loads if the lifts are performed in the fabrication yard. If, however, the lifting derrick or the structure to be lifted is on a floating vessel, then dynamic load factors should be applied to the static lifting forces.

  Lifts made offshore API-RP2A recommends two minimum values of dynamic load factors: 2,0 and 1,35. The first is for designing the padeyes as well as all members and their end connections framing the joint where the padeye is attached, while the second is for all other members transmitting lifting forces..

Preservice condion loads(cont.)

Transportation Forces

These forces are generated when platform components (jacket, deck) are transported offshore on barges. They depend upon the weight, geometry and support conditions of the structure (by barge or by buoyancy) and also on the environmental conditions (waves, winds and currents) that are encountered during transportation. The types of motion that a floating structure may experience are shown schematically in Figure.



F = Component of gravity plus inertia
G_1 = Centre of gravity of jacket
G_2 = Centre of gravity of the tow
M = Metacentre of the tow
A = Areas of potential impact

Transportation forces are generated by the motion of the tow, i.e. the structure and supporting barge. They are determined from the design winds, waves and currents. If the structure is self-floating, the loads can be calculated directly.

According to API-RP2A [3], towing analyses must be based on the results of model basin tests or appropriate analytical methods and must consider wind and wave directions parallel, perpendicular and at 45° to the tow axis. Inertial loads may be comput ed from a rigid body analysis of the tow by combining roll and pitch with heave motions, when the size of the tow, magnitude of the sea state and experience make such assumptions reasonable.

For open sea conditions, the following may be considered as typical design values:

- Single - amplitude roll: 20°
- Single - amplitude pitch: 10°
- Period of roll or pitch: 10 second
- Heave acceleration: 0,2 g

Weight Control

A detailed weight control report shall be developed, maintained and updated throughout the Jacket/Deck design. The report shall include detailed weight, centre of gravity and summary reports. The reports shall contain (but not limited) to the following information:

- Dry Weight
- Operating Weight
- Load-out Weight
- Transportation Weight
- Lift Weight
- Maximum Allowable Lift weight