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Analytical Study on Offshore Platform Using SACS

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Abstract

Offshore structures exist in a variety of forms, and they are used for a variety of functions in varied sea depths. These structures are designed for particular circumstances and sea depths. For the uses of these nine offshore structures, many steps for appropriate equipment selection, platform type design, and drilling/production procedures are necessary. The main objective is to give a broad understanding of the many procedures involved in designing, building, loading out, transporting, and installing offshore platforms. There were some debates about the design criteria, such as water depth and environmental factors. Risk assessment and the creation of an inspection plan depend on the structural integrity of six platform components under operational loads and weather storm conditions. The 10 effective and secure maritime platform designs.

***Keywords:** offshore structures, designing, building, loading out, transporting, and installing offshore platforms.*

INTRODUCTION

Offshore Structure

The oil and gas industry is rising rapidly in the worldwide since 50 years ago. The offshore structure used for exploration and production of oil and gas have been extended from shallow to deep water. The common design life for the offshore structure is between 15-25 years, depending on the capacity of the reservoir. The offshore structure can be classified into two types; fixed and floating (Chakrabarti, 2005). The analysis and design of fixed offshore structure have three main phases which are feasibility studies, preliminary design and final design (Chakrabarti, 2005). All the analysis and design procedure must be referred to the recommendation by the American Petroleum Institute (2007) or the International Organization for Standardization (2007). Offshore structures are engineered

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installations designed to operate in marine environments, typically in the open sea or coastal areas. These structures are critical for various industries such as oil and gas exploration, renewable energy production (e.g., offshore wind farms), telecommunications, and marine transportation. They serve as platforms for drilling, production, storage, and transportation of resources, as well as for research and communication purposes.

Fig 1 Offshore Structure

Generally, the installation of the offshore structure depends on the water depth such as fixed structure usually used in shallow water. When the water depth increase, the compliant structure which is a bounded-structure are more practical for water depth between 450m to 900m (refer Figure 1). For deeper water, the floating structure such as spar and semi- submersible are more suitable.

During the operation, the offshore structure is exposed to several types of environmental loads such as wave, wind and current. In order to use the Morison’s equation for computing the wave load, the appropriate wave theory is required to determine the water particle kinematics such as linear wave theory, Stokes theory, Cnoidal theory, etc. (Chakrabarti, 2005; Wilson, 2003; Chandrasekaran, 2015). In reality, the dominant load is commonly due to the wind- generated random wave that can be achieved by using probabilistic method (Najafian & Burrows, 1994). Therefore, the capability to predict the extreme offshore response during the service life will be a very significant to the designer.

TYPES OF OFFSHORE STRUCTURES:

Offshore Oil and Gas Platforms: These structures are used in the exploration and extraction of oil and natural gas reserves beneath the ocean floor. They come in various forms, including fixed platforms, floating platforms, and subsea systems. Fixed platforms are anchored to the seabed, while floating platforms are moored in place using buoyant structures.

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Fig 2 Offshore Oil and Gas Platform

Offshore Wind Farms: Offshore wind structures consist of wind turbines installed in shallow or deep waters to harness wind energy for electricity generation. These wind farms can be fixed to the seabed or floating, depending on the depth and conditions of the location

Fig 3 Offshore Wind Frame

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Offshore Telecommunication Towers: These structures support antennas and satellite dishes for transmitting data and signals across long distances, enabling global communication networks.

Fig 4 Offshore Telecommunication Towers

Offshore Research Platforms: Scientists and researchers use these platforms as floating laboratories to conduct studies on marine life, oceanography, and climate change. They often have specialized equipment and facilities to support scientific investigations.

Fig 5 Offshore Research Platform1.2

JACKET

A "jacket" is a specific type of offshore structure commonly used in the oil and gas industry and for offshore wind farms. It is a type of platform that supports various facilities and equipment above the water surface in shallow to intermediate water depths. The term "jacket" comes from the structure's resemblance to a coat or jacket, with vertical legs and diagonal braces forming a lattice-like framework. A jacket is a welded tubular space frame with three or more near vertical tubular chord legs with a bracing system between the legs. The jacket provides support for the foundation piles, conductors, risers, and other appurtenances. A jacket foundation includes leg piles which are inserted

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through the legs (Figure 10) and connected to the legs either at the top, by welding or mechanical means, or along the length of the legs, by grouting.

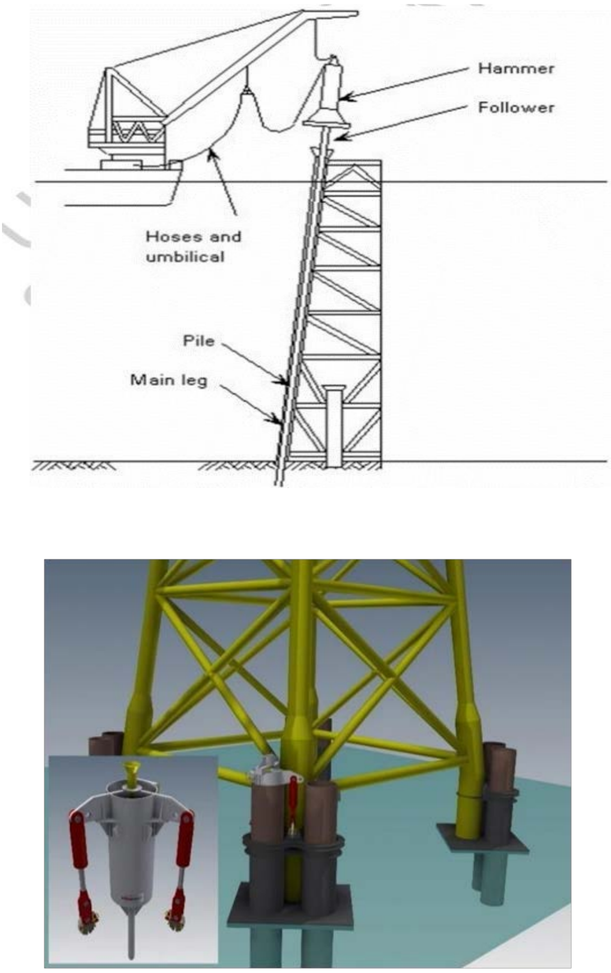

Fig.7 Jacket Showing Driving of Pile through Jacket Leg

Additional piles, called skirt piles, can be inserted through and connected to sleeves at the base of the structure. Leg and skirt piles jointly anchor the structure and transfer both vertical and horizontal actions to the seabed. Where the piles are only connected to the legs at the jacket top, the forces are transferred to the piles at the connection and the jacket "hangs" from the piles. Where the piles are connected by full length grouting, the jacket behavior is similar to that of a tower (Section 2.3), with the legs and piles acting together as composite components.

The jacket structure consists of a steel framework that resembles the shape of a jacket, with vertical legs (also known as piles or tubular members) supporting a horizontal deck. The legs are driven into the seabed to secure the platform in place. The jacket's design provides excellent stability and resistance to wave, current, and wind forces, making it suitable for various water depths, including shallow and deep waters. The vertical legs are driven deep into the seabed to create a sturdy

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foundation. These piles provide the necessary support to keep the platform upright and stable, even in challenging environmental conditions. he horizontal deck, supported by the vertical legs, houses the drilling and production equipment, living quarters for personnel, and other facilities necessary for offshore operations. The term "topsides" refers to all the facilities and equipment located on the deck of the jacket structure. This includes Leg and skirt piles work together to secure the building and transmit both horizontal and vertical motions to the seafloor. When the piles are only attached to the legs at the top of the jacket, the jacket "hangs" from the piles because the forces are passed to the piles at the connection. The behavior of the jacket is similar to that of a tower (Section 2.3) when the piles are joined by full length grouting, with the legs and piles acting as a single composite component.

TOWER

Additionally, the tower has a braced, welded tubular space frame with three or more nearly vertical tubular chord legs. The tower supports the topsides, conductors, risers, and other auxiliary equipment.. The corner legs of a tower are often supported by cluster piles that are inserted through and linked to sleeves. The skirt piles, which come in addition, can be put through the sleeves at the base and around the outside of the structure. Another foundation technique, such as bucket foundations, can sustain a tower in place of piles by supporting the tower at its base. Anchoring the structure and transmitting both vertical and horizontal actions to the bottom are cluster and skirt piles or another foundation system. With all activities being communicated to the foundation system at the foot of the tower, a tower behaves generally like a vertical cantilever.

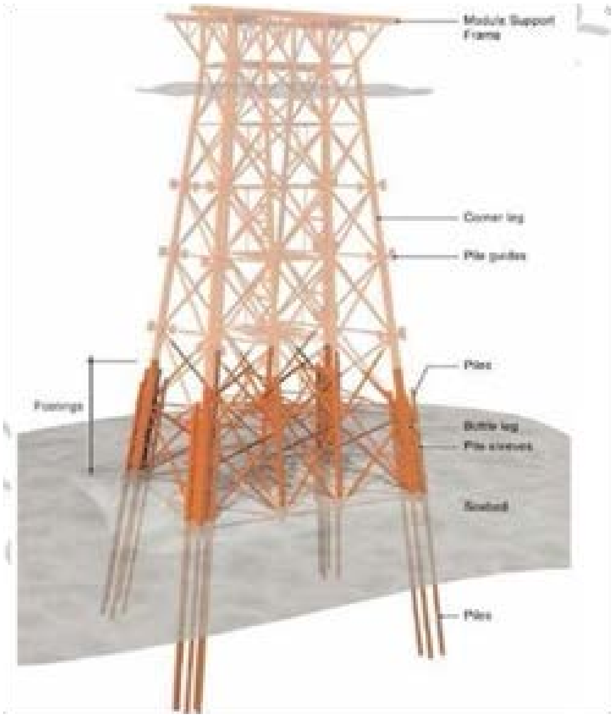

Fig.8 Tower Structure Showing Cluster Piles

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JACK-UP drilling rigs, processing units, living quarters, and other modules essential for oil and gas production and living conditions for the workforce. The vertical legs are transported to the offshore location and driven into the seabed using large hammers. The pile driving process secures the jacket to the seabed, providing a stable foundation. The deck and topsides are connected to the jacket using welding or other structural connections to ensure they function as an integrated platform. Jacket structures have been widely used in the offshore industry for many decades due to their robustness and ability to withstand harsh marine environments. They are particularly common in regions with water depths ranging from approximately 30 meters to 150 meters, where other types of platforms may not be as practical or cost-effective

Fig.9Jack-ups in the elevated positions

A jack-up consists of a floating hull and three or more movable legs that are attached to the hull. By lowering the legs to the water's surface and then elevating the hull to the necessary elevation, it can operate. The legs are supported at their bottom ends by spud cans and are independently movable (Figure 1.2.3). The spud cans are driven into the seabed before elevating the hull, a procedure referred to as ‘preloading’ Preloading pre-compresses the soil to lower the likelihood of punch-through, which can partially or completely undermine the platform if it occurs.

The majority of jack-ups are constructed for temporary use at various sites throughout the world. Such jack-ups must be evaluated for each specific area because met-ocean and foundation the majority of jack-ups are constructed for temporary use at various sites throughout the world. Such jack-ups must be evaluated for each specific area because met-ocean and foundation characteristics vary between locales. A small number of jack-ups are constructed with the intention of being used for production in a single place, though this is not always the case. Characteristics vary between locales. A small number of jack-ups are constructed with the intention of being used for production in a single place, though this is not always the case.

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COMPLAINT TOWER

A compliant tower is a flexible construction containing flex elements, primarily flexible legs or axial tubes, to manage mass and stiffness properties and lessen the effects of recurring wind, wave, and current forces. Natural periods are typically longer than 25 seconds, which puts them outside of wave periods.

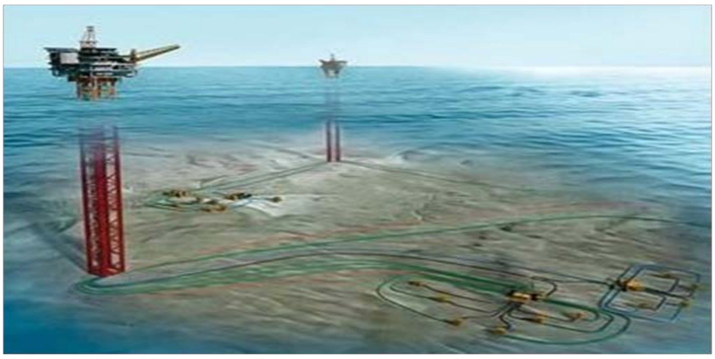

Fig.10 Compliant Tower

Whereas compliant towers are comparatively slim compared to jacket/tower constructions, they require a significant amount of steel and have greater installation costs. With dry trees, they can support a lot of wells (more than 40), as well as a heavy payload.(Figure

GRAVITY STRUCTURE

Gravity structures, also known as gravity-based structures, are fixed structures that are only held in place against environmental forces by their weight and the weight of any contained ballast, as well as foundation resistance. from their weight and lateral resistance from any skirts. Gravity structures (or any skirts' weight and lateral resistance Gravity structures, also known as gravity-based structures, are fixed structures that are only kept in place against environmental forces by their weight and the weight of any contained ballast, as well as foundation resistance brought on by their weight and lateral resistance from any skirts. Almost all gravity constructions are made of concrete. (Figure 1.2.5)

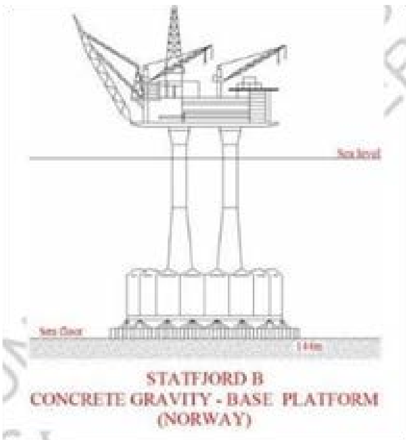

Fig.11 gravity structure

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MONOTOWER

A mono-tower is a fixed structure in which the topsides are supported by a single tubular or framed vertical column that spans the whole structure, or at least the upper portion of it. (Figure 12).

Fig.1.2 mono-tower – here with only one deck with helipad on top This type of mono-tower is known as a "free-standing caisson" or simply "caisson" when it is made up of a single vertical column that extends the entire height of the structure and continues into the seabed as the foundation pile. A mono-tower known as a "braced caisson" has one or more inclined braces between the column and one or more foundation piles that support the lower half of the column laterally.

SEMI SUBMERSIBLE

Semi-submersible vessel is majorly used in marine operations carried out in the high seas like oil drilling and production platforms for oil. In addition, Semi-submersible ships are also used as heavy duty cranes.

Fig.13 semi-submersible

TENSION LEG PLATFORM

A TLP refers to the platform that is held in place by vertical, tensioned tendons connected to the sea floor by pile-secured templates. TLPs consist of floating rigs tethered to the seabed in a manner that

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eliminates most vertical movement of the structure. The platform is buoyant and held in place by a mooring system. TLPs are similar to conventional FPs except that the platform is maintained on location through the use of moorings held in tension by the buoyancy of the hull. The mooring system is a set of tension legs or tendons attached to the platform and connected to a template or foundation on the seafloor. The template is held in place by piles driven into the seafloor. This method dampens the vertical motions of the platform, but allows for horizontal movements.

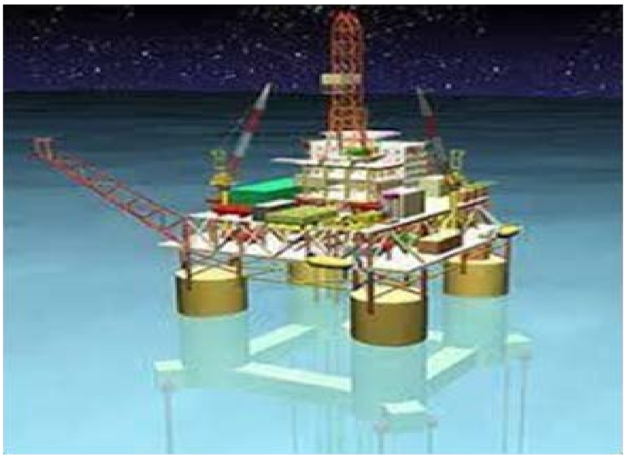

Fig.14 tension leg platform

SPAR

Spar platform is a kind of offshore floating product unit with relatively large aspect ratio (draft over diameter). Such kind of floating structures are subject to vortex-induced motions (VIM) when exposed in current with certain speed. The large amplitude oscillating motion is a critical issue for the fatigue failure and safety operations. To mitigate VIM, helical strakes are designed and installed on the surface of main spar hull. A truncated cylindrical hard tank with three-start helical strakes of a truss spar scaled at 1:22.3 is selected for study (Finnigan and Roddier, 2007). Truss structure and keel tank are ignored in the simulation.

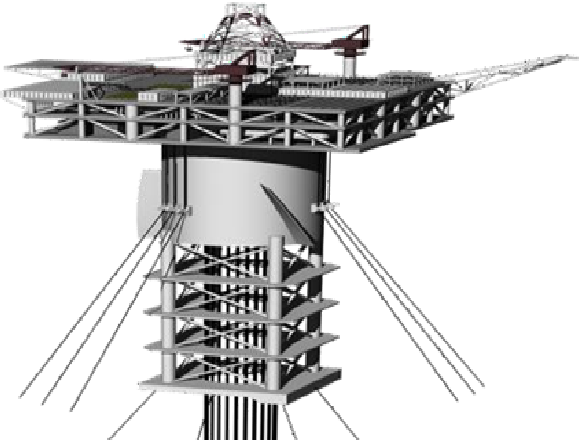

Fig.15 spar structure

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SACS (Structural Analysis Computer System)

INTRODUCTION TO BENTLY SACS V15.1

SACS (Structural Analysis Computer System) is a comprehensive suite of software tools developed by Bentley Systems, Inc., specifically designed for the analysis and design of offshore structures in the oil and gas industry. It is widely used by engineers and designers to perform structural analysis, design, and assessment of various offshore structures, including oil and gas platforms, wind turbines, and other marine structures.

Offshore engineering involves the design, analysis, and construction of various complex structures, such as offshore platforms and jackets, which play a crucial role in the oil and gas industry. To ensure the safety and efficiency of these structures, engineers rely on advanced software tools that can handle the complexities of offshore environments. One such tool is SACS (Structural Analysis Computer System), developed by Bentley Systems, Incorporated. This essay explores the significance of SACS software in offshore engineering, highlighting its capabilities, benefits, and its impact on the industry.

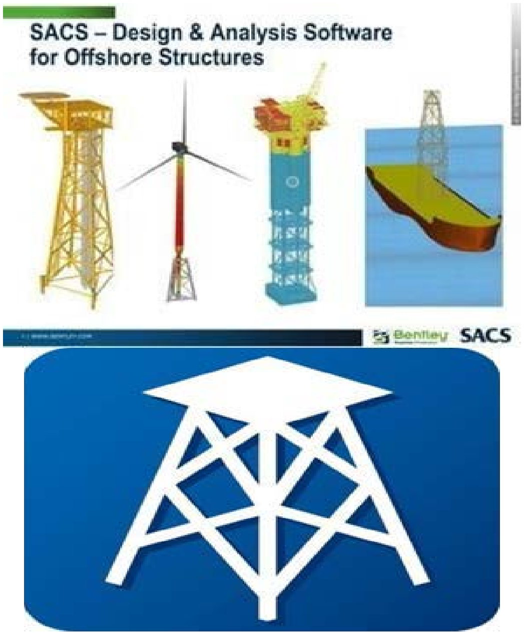

Fig 16 Structural Analysis Computer System

SACS is a comprehensive software suite designed specifically for structural analysis and design in the offshore and maritime industries. It provides engineers with powerful tools to model, analyze, and optimize various offshore structures.

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The software encompasses a wide range of features, including 3D structural modelling, static and dynamic analysis, fatigue assessment, and design optimization. One of the key strengths of SACS is its advanced structural modeling capabilities. Engineers can create intricate models of offshore platforms, topsides, and subsea structures, incorporating all necessary components and loadings. These models consider environmental conditions, such as wave, wind, and seismic forces, to accurately simulate real-world scenarios. For structural analysis, SACS employs sophisticated algorithms to assess the behavior of these complex structures under different loading conditions. This helps engineers identify potential weaknesses, stress concentrations, and modes of failure, allowing them to make informed design decisions Offshore structures are subject to dynamic loads, including waves, currents, and vessel impact. SACS can conduct dynamic analysis to evaluate the structural response to these time-varying loads. This analysis ensures that the structures can withstand the harsh environmental conditions they may encounter during their operational lifespan. the software incorporates fatigue assessment, which is crucial for offshore structures that experience cyclic loads. Fatigue analysis helps determine the potential accumulation of damage over time, enabling engineers to design structures with sufficient fatigue resistance and prolong their service life.

SACS supports design optimization by allowing engineers to evaluate multiple design alternatives quickly. The software can automate the process of modifying parameters and assessing their impact on the structural performance. Through this optimization process, engineers can achieve more cost-effective and efficient designs while meeting safety and regulatory standards. SACS streamlines the engineering process, saving time and resources. Its advanced analysis capabilities help engineers make informed decisions and ensure the accuracy of their designs.

The software supports various industry standards and guidelines, ensuring that offshore structures comply with relevant codes and regulations. Engineers can use SACS to optimize the design of offshore structures, considering various factors such as material usage, structural performance, and safety requirements. By conducting comprehensive analyses, SACS helps identify potential structural weaknesses and risks, allowing engineers to implement measures to enhance safety and mitigate risks during the design phase.

SACS plays a critical role in the offshore engineering industry by providing a comprehensive and reliable software solution for the analysis and design of complex offshore structures. Its advanced features, coupled with its integration capabilities, make it an essential tool for engineers and designers involved in offshore projects, contributing to the safety, efficiency, and success of offshore operations worldwide.

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SACS software has become an indispensable tool in the field of offshore engineering. Its advanced capabilities in structural modelling, analysis, and design optimization have revolutionized the way engineers approach the design and construction of offshore structures. By enhancing safety, reducing costs, and promoting innovation, SACS plays a vital role in ensuring the success and sustainability of the offshore industry in an ever-evolving and challenging environment. Key features and capabilities of SACS include:

Structural Analysis: SACS allows engineers to perform advanced structural analysis and finite element analysis (FEA) to assess the behavior of offshore structures under various loads and environmental conditions.

Design and Optimization: The software provides tools for designing and optimizing various structural components, ensuring that the offshore structures meet safety and industry standards while maximizing efficiency.

Load Combinations: Engineers can apply a range of load combinations, such as wave, wind, seismic, and temperature loads, to simulate real-world scenarios and assess the structural response.

Fatigue Analysis: SACS includes fatigue analysis capabilities to evaluate the fatigue life of structural components, which is crucial for offshore structures subjected to cyclic loading.

Buckling Analysis: The software can perform buckling analysis to identify potential instability and critical failure modes in the structure.

Connection Design: SACS offers tools for designing and analyzing connections between structural members, ensuring they can withstand the required loads and maintain integrity during the life of the structure.

API and ISO Standards Compliance: SACS complies with industry standards set by the American Petroleum Institute (API) and International Organization for Standardization (ISO) for offshore structural analysis and design.

Integration with Other Software: SACS can integrate with other software applications like Auto PIPE and MOSES, further enhancing its capabilities and versatility in the offshore engineering domain. It's worth noting that software tools like SACS are continuously updated and improved, so newer versions might have additional features and enhancements. If you are using or considering using SACS for your projects, it is advisable to check the official Bentley Systems website for the

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most up-to-date information and documentation. offshore oil and gas industry, providing a versatile, cost-effective, and efficient solution for hydrocarbon production, processing, storage, and offloading in challenging marine environments. Over the years, FPSOs have become an integral part of the offshore industry, offering several advantages and contributing to the development and exploitation of remote and deepwater oil and gas reserves FPSOs have demonstrated their significance in various ways, making them a preferred choice for operators seeking to optimize production and reduce project development costs. The following are key aspects that highlight the importance of FPSOs in the offshore oil and gas industry FPSOs have become indispensable assets in the offshore oil and gas industry. Their flexibility, cost- efficiency, reduced environmental impact, risk mitigation, and ability to unlock remote and deepwater reserves make them a preferred choice for offshore field development. As technology continues to evolve and the industry embraces sustainability, FPSOs will play a pivotal role in meeting the world's energy needs while addressing environmental concerns. Their adaptability and versatility ensure that FPSOs will remain a key component of the offshore oil and gas industry for years to come.

MODELLING PIPE RACK USING SACS SOFTWARE STRUCTURAL DESIGN OF PIPE RACK

Details Are As Follows

The pipe rack structure described has a height of 14.45 meters, making it a substantial installation designed to support and organize various pipes and cables in an offshore or industrial setting. Along the edges of the structure, a handrail stands at a height of 1 meter, providing safety for personnel working in the vicinity. The bay width, measuring 5.21 meters, allows sufficient space between the frames to accommodate the pipes and cables efficiently. This pipe rack comprises six frames, which are essential components supporting the overall structure. Frames are horizontal sections that connect the vertical columns, forming the backbone of the pipe rack. Each frame is carefully engineered to withstand the loads imposed on the structure and ensure structural this implies that the pipe rack is designed to support the additional loads of cables running along its length. Cable trays and supports are strategically placed to manage these cables, ensuring proper organization and reducing the risk of damage to the cables integrity throughout its lifetime.

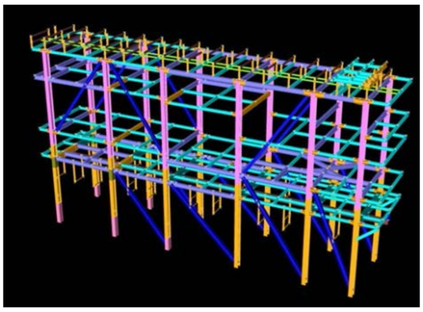

Fig 17 Pipe Rack Model

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Considering the total weight of the structure to be 708 kilonewtons, it is evident that the design accounts for substantial loads, indicating its use in handling heavy pipes, equipment, or cables. Offshore environments can be harsh, with unpredictable weather conditions, so the design and material selection must adhere to stringent safety and reliability standards. The cable dry weight on the structure is given as 9.5 kilonewtons per meter. This implies that the pipe rack is designed to support the additional loads of cables running along its length. Cable trays and supports are strategically placed to manage these cables, ensuring proper organization and reducing the risk of damage to the cables. Pinned supports are considered for all columns, indicating that the columns are allowed to rotate at their base connections, acting as pivots under certain load conditions. Pinned supports offer some flexibility to the structure, allowing it to respond to external forces and distribute loads efficiently. The use of pinned supports must be carefully calculated to ensure structural stability while maintaining safety.

The combination of a well-engineered design, careful material selection, and consideration of various loads and support conditions ensures the pipe rack's longevity and reliability. Proper maintenance and periodic inspections are crucial to guarantee that the structure continues to operate safely and efficiently in its intended environment. In conclusion, the described pipe rack structure represents a robust and well-designed installation for managing pipes and cables in an offshore or industrial setting. Its height, bay width, frames, and pinned supports are all integral components that contribute to its stability, functionality, and safety. With proper care and adherence to industry standards, this pipe rack will continue to serve its purpose effectively, supporting vital operations in the offshore industry or other industrial applications.

In conclusion, the described pipe rack structure represents a robust and well-designed installation for managing pipes and cables in an offshore or industrial setting. Its height, bay width, frames, and pinned supports are all integral components that contribute to its stability, functionality, and safety. With proper care and adherence to industry standards, this pipe rack will continue to serve its purpose effectively, supporting vital operations in the offshore industry or other industrial applications.

4.5 BRACINGS

In offshore steel structures, "K bracing" refers to a specific type of bracing system used to provide lateral support and stability to the structure. It is a commonly used bracing arrangement to resist horizontal loads, such as wind and wave forces, and prevent lateral movement or sway. K bracing takes its name from its shape, which resembles the letter "K." It consists of diagonal members that form a V- shape, and a horizontal member connects the two diagonals at the midpoint. The bracing is typically arranged in pairs on opposite sides of the structure to balance the lateral loads.

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The diagonal members of the K bracing are oriented at an angle to the vertical and horizontal members of the structure. These diagonals are tension members, meaning they primarily carry tensile forces that arise due to lateral loads. he horizontal member connects the two diagonals at the center, forming the "V" shape. It provides additional rigidity to the bracing system and helps to distribute lateral loads evenly between the diagonals.

K bracing provides significant stiffness and stability to the offshore structure, minimizing lateral movement and sway caused by wind and wave forces. he arrangement of K bracing in pairs on opposite sides of the structure provides redundancy, ensuring that the structure remains stable even if one bracing member is damaged or fails. bracing offers effective lateral support while requiring relatively less space compared to other bracing systems, making it suitable for offshore structures with space constraints.

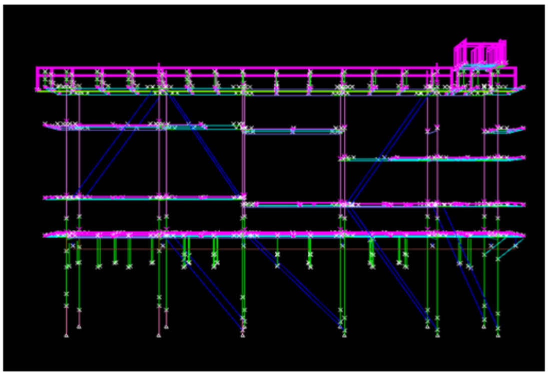

Fig 18 K Bracings

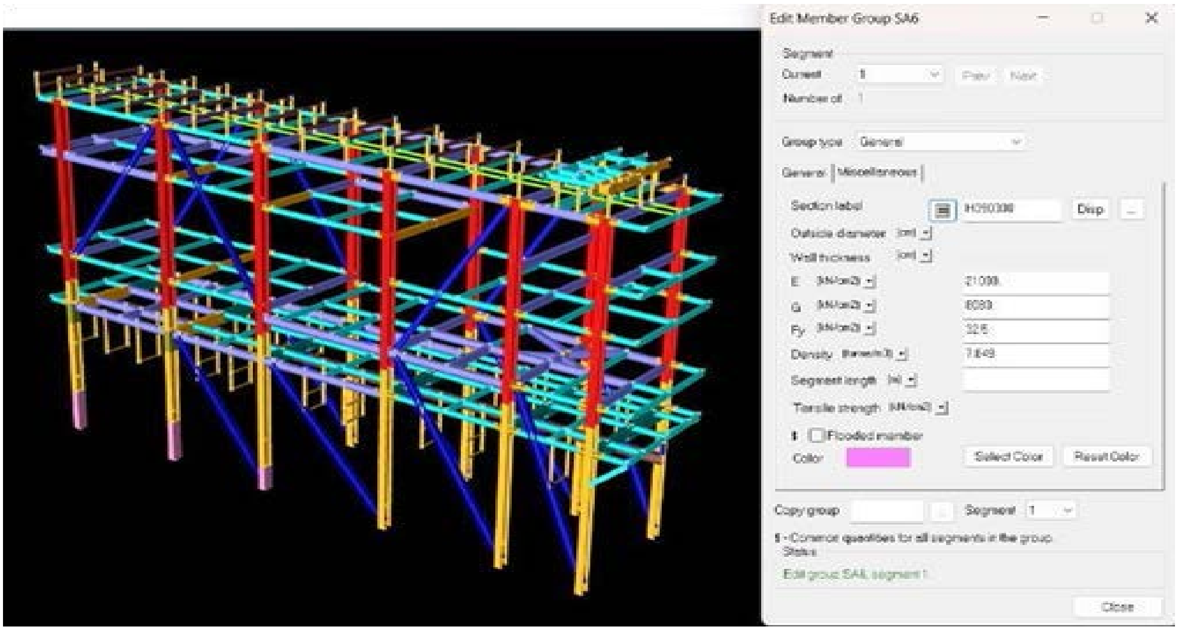

Fig 19 Member Property

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Loading

Fixed offshore platforms are unique structures as they are located in the sea or ocean and their main function is to carry industrial equipment that services oil and gas production and drilling.

The robust design of fixed offshore structures is dependent on define all the applied loads. Most loads that affect laterally the platform, such as wind and waves, are variables which depend on the met ocean data for the location of the platform. The structure design depends on the strength of materials used and the applied load.

In general the loads which act on the platform are as follows:

- gravity loads;
- wind loads;
- wave loads;
- current loads;
- earthquake loads;
- installation loads;
- other loads

Gravity Load

The gravity load consists of the dead load and the live (imposed) load. The dead load is the weight of the platform itself and in addition to that the weight of machines such as pump, compressors, and electrical generators, and static equipment like separators, in addition to piping which is a major item. gravity loads still refer to the force exerted on the structure due to the Earth's gravitational pull. However, in offshore engineering, the consideration of gravity loads becomes more complex due to the unique environmental conditions and the floating or fixed nature of the platforms.

Gravity loads in offshore structures can be categorized as follows:

Structural Weight: The weight of the offshore structure itself, including the platform's hull, topsides, equipment, and all permanent fixtures, constitutes the structural dead load. This includes the weight of the topside facilities, living quarters, helidecks, processing equipment, and other infrastructure.

Ballast and Buoyancy: Offshore structures, especially floating platforms like Spars, FPSOs, and Semi- submersibles, use ballast and buoyancy systems to control their stability. Ballast tanks are filled or emptied with water or other materials to control the platform's draft and maintain a proper balance between weight and buoyancy.

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Payload: The payload of the offshore structure includes temporary loads related to oil and gas production, drilling operations, equipment, and personnel. These variable live loads can change during the operational phase as the platform's activities and personnel count fluctuate.

Environmental Loads: Offshore structures are subject to additional environmental loads beyond gravity loads, including wave, wind, current, and ice loads. These forces act on the structure and contribute to the overall loading conditions.

While designing offshore structures, engineers perform detailed structural analysis to account for all the gravity loads, environmental loads, and their combinations. Safety factors and load cases are considered to ensure that the platform can safely withstand the various loads it will experience during its service life. The design must comply with strict industry standards and regulations to ensure the structural integrity and safety of the offshore facility.

Dead load

The “dead load" refers to the static or permanent weight of the structure itself and any fixed components permanently attached to it. Dead load is one of the primary types of gravity loads that must be considered during the design and construction of offshore platforms. The dead load is the overall weight of the platform structure in air, including piling, superstructure, jacket, stiffeners, piping and conductors, corrosion anodes, decking, railing, grout, and other appurtenances. Sealed tubular members are considered either as buoyant or flooded, whichever produces the maximum stress in the structure analysis.

The dead load of an offshore structure includes the weight of various components, such as:

Hull: For floating platforms like FPSOs (Floating Production, Storage, and Offloading), Spars, or Semi-submersibles, the hull's weight is a significant portion of the dead load. The hull is the main body of the floating platform that provides buoyancy and stability.

Topsides: The topsides refer to the upper portion of the offshore structure, where facilities, equipment, living quarters, and processing units are located. The weight of the topsides includes the weight of the modules, equipment, piping, and other structures mounted on the platform.

Ballast: In some floating platforms, ballast tanks are used to control buoyancy and stability. The weight of the ballast, which can be water or other materials, contributes to the dead load.

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Steel and Concrete Components: Various structural components, such as steel beams, columns, decks, and concrete elements, add to the overall dead load of the platform.

Foundations: The weight of the foundation elements, whether pile-supported or gravity-based, is also considered as part of the dead load. During the design phase, engineers carefully calculate and analyze the dead load to ensure that the offshore structure can safely support its own weight and any additional loads imposed on it during its operational life. The structural integrity and safety of the offshore platform heavily rely on the accurate assessment of dead load and its combination with other loads, such as live loads (temporary loads), environmental loads (waves, wind, currents), and operational loads

Live load

Temporary loads that are imposed on the structure due to its usage and operations during its operational life. Live loads are dynamic in nature and can change in magnitude and location over time, depending on the activities and equipment on the platform. Live loads are the loads imposed on the platform during its use and which may change during a mode of operation or from one mode of operations to another and should include the following:

1. The weight of drilling and production equipment;
2. The weight of living quarters, heliport, and other life support equipment;
3. The weight of liquid in storage tanks; and
4. The forces due to deck crane usage.

The live load in offshore structure includes various temporary loads, such as:

Payload: The payload refers to the weight of equipment, machinery, and materials that are temporarily placed on the platform for specific operational purposes. This can include oil and gas production equipment, drilling rigs, cranes, storage containers, and other temporary installations.

Personnel: The weight of personnel working on the platform, including operators, technicians, and other staff, is also considered as part of the live load. The number of personnel on the platform can vary during different operational phases.

Temporary Equipment: During maintenance and repair activities or special operations, additional equipment or tools may be temporarily placed on the platform, contributing to the live load.

Temporary Storage: Offshore platforms may require temporary storage of materials, supplies, or products, which add to the live load during their presence on the platform.

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Vehicles and Transport: In some cases, offshore platforms may receive visits from supply vessels or helicopters, which can temporarily impose loads when docking or landing.

The design of offshore structures must account for the live load in combination with other loads, such as dead load (permanent weight of the structure), environmental loads (waves, wind, currents), and operational loads (e.g., drilling loads for drilling platforms). Properly considering the dynamic and variable nature of live loads is crucial to ensure the structural integrity, stability, and safety of the offshore platform throughout its service life. Engineers perform detailed analysis and apply appropriate safety factors to ensure that the platform can safely support all expected live loads during its operational activities.

Impact load

To ensure the structural integrity and safety of floating offshore structures, engineers analyze and design the platform to withstand potential impact loads. This involves conducting advanced structural analysis, considering the impact scenarios, and applying appropriate safety factors to ensure that the platform can withstand unexpected loads without failure. The platform's design and construction are governed by industry standards, regulatory requirements, and best practices to address potential impact events and ensure the safety of personnel and the environment during offshore operations.

For structural component-carrying live loads which include impact, the live load must be increased to account for the impact effect

Design for serviceability limit state

The serviceability of the topside structures can be affected by excessive relative displacement or vibration in a vertical or horizontal direction.

Vibrations

All sources of vibration shall be considered in the design of the structure. As a minimum the following shall be reviewed for their effect on the structure.

- operating mechanical equipment, including that used in drilling operations;
- Vibrations from variations of fluid flow in piping systems, in particular slugging;
- Oscillations from vortex shedding on slender tubular structures;
- Global motions from the effect of environmental actions on the total platform structure;
- Vibrations due to earthquakes and accidental events.

Design limits for vibration shall be established from operational limits set by equipment suppliers and the requirements of personnel comfort and health and safety.

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It is important to be obvious that in the case of design of large cantilevers whether formed by simple beams or trusses forming an integral part of the topsides, but excluding masts or booms, they shall normally be proportioned to have a natural period of less than 1 second in the operating condition.

Deflections

The final deflected shape, **Δmax,** of any element or structure comprises three components as follows:

$$\Delta max = \Delta_1 + \Delta_2 - \Delta 0$$

Where Δ_0 is any precamber of a beam or element in the unloaded state if it exists; Δ_1 is the deflection from the permanent loads (actions) immediately after loading; and Δ_2 is the deflection from the variable loading and any time- dependent deformations from permanent loads.

The maximum values for vertical deflections based on ISO 9001. In the case of using load resistance factor design (LRFD) in the design, provides the limits to vertical deflection. Lower limits may be necessary to limit ponding of surface fluids and ensure that drainage systems function correctly.
Horizontal deflections shall generally be limited to 0.3% of the height between floors. For multifloor structures the total horizontal deflection shall not exceed 0.2% of the total height of the topside structure. Limits can be defined to limit pipe stresses so as to avoid risers or conductors over tresses, or failures. In most cases designers allow higher deflections for structure elements where serviceability is not compromised by deflection.

METHODOLOGY

Floating production storage and offloading

A floating production storage and offloading (FPSO) unit is a floating vessel used by the offshore oil and gas industry for the production and processing of hydrocarbons, and for the storage of oil. An FPSO vessel is designed to receive hydrocarbons produced by itself or from nearby platforms or subsea template, process them, and store oil until it can be offloaded onto a tanker or, less frequently, transported through a pipeline. FPSOs are preferred in frontier offshore regions as they are easy to install, and do not require a local pipeline infrastructure to export oil. FPSOs can be a conversion of an oil tanker (like the Seawise Giant) or can be a vessel built specially for the application. A vessel used only to store oil (without processing it) is referred to as a floating storage and offloading (FSO) vessel. The first of a related type, floating liquefied natural gas vessels, went into service in 2016

Several key steps and considerations

Conceptual Design: The process begins with the conceptual design phase, where the overall requirements and objectives of the floating structure are defined. This includes determining the

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purpose of the platform, the type of hydrocarbon or energy resource it will be used for, water depth, environmental conditions, and other essential parameters.

Feasibility Study: A feasibility study is conducted to evaluate the technical and economic viability of the floating structure. This involves assessing the geotechnical conditions of the site, estimating costs, analyzing risks, and identifying potential environmental impacts.

Preliminary Design: During this stage, preliminary design studies are carried out to explore different platform concepts and configurations. These may include selecting the appropriate buoyancy system, evaluating different hull shapes, and determining the mooring system based on environmental loads and water depth.

Hydrodynamic Analysis: A detailed hydrodynamic analysis is conducted to study the interaction of the floating structure with waves, currents, and wind. This analysis helps in understanding the dynamic behaviour and stability of the platform under various environmental conditions.

Structural Analysis: Structural engineers analyse the platform's structural components to ensure they can withstand the loads and forces experienced during its operational life. Finite element analysis (FEA) and other engineering tools are used to assess the integrity and safety of the structure.

Stability Analysis: Stability analysis is performed to assess the platform's stability, taking into account the buoyancy, ballast, and tendon systems. The platform must maintain stability to ensure safe operations.

Mooring Design: For floating structures that require mooring, such as FPSOs, a mooring system is designed based on the environmental conditions and platform requirements. The mooring system should be capable of securely anchoring the structure to the seabed.

Materials Selection: The choice of materials is critical for the longevity and performance of the floating structure. Corrosion-resistant materials suitable for the marine environment are commonly used.

Environmental Impact Assessment: An environmental impact assessment (EIA) is carried out to evaluate the potential effects of the floating structure on the surrounding marine ecosystem.

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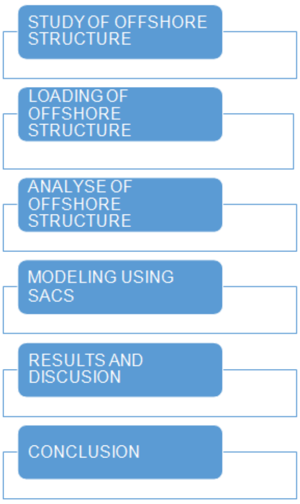
Materials Selection: The choice of materials is critical for the longevity and performance of the floating structure. Corrosion-resistant materials suitable for the marine environment are commonly used

Construction and Installation: Once the design is finalized, the construction and fabrication of the floating structure take place. Depending on the platform's size, it may be constructed in dry docks or specialized shipyards. After construction, the platform is transported to the installation site using tugboats or specialized vessels and anchored in place. Depending on the platform's size, it may be constructed in dry docks or specialized shipyards. The choice of materials is critical for the longevity and performance of the floating structure. Corrosion-resistant materials suitable for the marine environment are commonly used after construction, the platform tugboats or specialized vessels and anchored in place. Depending on the platform's size, it may be constructed in dry docks or specialized shipyards. After construction, the platform is transported to the installation site using tugboats or specialized vessels and anchored in place.

Operations and Maintenance: Once operational, the floating structure requires regular maintenance, inspections, and integrity management to ensure safe and reliable operations throughout its service life. The methodology for floating offshore structures is complex and requires a multidisciplinary approach, involving engineers, naval architects, geotechnical experts, environmentalists, and other specialists to address the unique challenges and requirements of each specific project.



Once operational, the floating structure requires regular maintenance, inspections, and integrity management to ensure safe and reliable operations throughout its service life. The methodology for floating offshore structures is complex and requires a multidisciplinary approach, involving engineers, naval architects, geotechnical experts, environmentalists, and other specialists to address the unique challenges and requirements of each specific project.

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LIFTING ANALYSIS

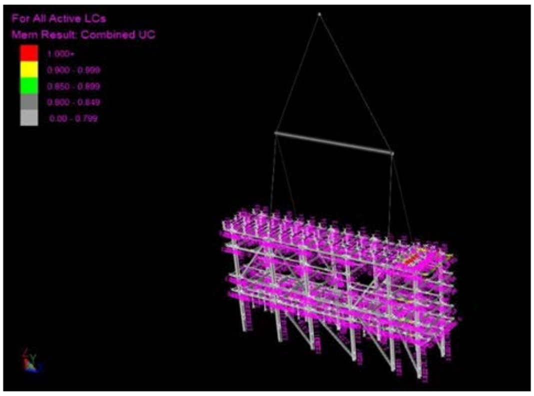
In the context of offshore structures, such as platforms or rigs, lifting analysis refers to the evaluation and assessment of the lifting operations involved in the installation, maintenance, or removal of equipment, modules, or other components on the structure. The analysis is conducted to ensure safe and efficient execution of lifting operations while considering factors such as structural integrity, load capacity, stability, and adherence to industry standards and regulations.

Load Identification: The analysis starts with identifying the loads to be lifted, including their weights, dimensions, center of gravity, and any specific handling requirements. This information helps determine the appropriate lifting equipment, such as cranes or winches, and the lifting points or attachments needed.

Structural Analysis: The structural integrity of the offshore structure is assessed to ensure it can withstand the loads imposed during lifting operations. This involves evaluating the capacity of the lifting points, the adequacy of supporting structures, and verifying that the structure's overall strength and stability are not compromised.

Lifting Equipment Selection: The appropriate lifting equipment is selected based on the characteristics of the load, such as weight, shape, and size, as well as the operating conditions. Factors such as crane capacity, reach, and dynamic effects are considered to ensure safe and efficient lifting.

Lifting Procedure: A detailed lifting procedure is developed, outlining the sequence of lifting operations, equipment configurations, load transfer points, and safety measures.The procedure takes into account factors like weather conditions, sea state, and the specific characteristics of the offshore structure.



Result and Discussions Unity check

Unity Check (UC) will be beneficial to know the strength of a member, where UC can be the ratio between actual stresses and permit stresses on a member. When the UC value is close to one, the substantial stresses almost exceed the allowable stresses, and the member is not passed.

$$Unity\ Check = \frac{actual\ performance\ value}{maximum\ allowable\ performance\ value}$$

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In our case study, the UC in the design stage is more than one in six conditions (OP 1, OP 2, OP 3, STM 1, STM 2, and STM 3), as shown in the fig below.

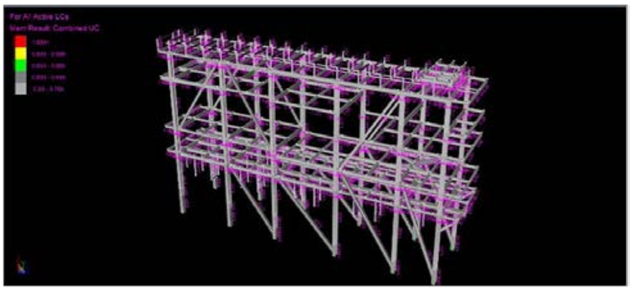

Fig 20 total Unity check

MEMBER STRESS AT MAX UNITY CHECK REPORT							
MEMBER	MAX. UNITY CHECK	LOAD CONDITION	AXIAL STRESS	BENDING STRESS		SHEAR STRESS	
				Y	Z	Y	Z
0019-0050	0.479	2024	-1.41	-128.1	1.71	-0.13	8.11
0053-0089	0.484	2024	-1.9	-130.11	-0.43	0.03	8.47
0089-0069	0.486	2020	-1.71	-130.57	-0.97	-0.07	-8.49
4005-4022	0.498	2024	-0.74	-134.81	1.26	-0.12	8.43
0175-1044	0.327	2020	0.85	82.6	-1.28	0.36	-6.03
1002-0175	0.51	2024	-0.5	-130.95	0.68	-0.17	12.81
1006-1033	0.545	2024	-0.88	-139.79	0.5	0	13.45
1033-1046	0.333	2020	1.14	84.59	-0.62	0.08	-6
1044-1058	0.102	1034	0.58	16.92	2.31	-0.35	-2.62
1046-1060	0.11	1038	0.66	18.71	-2.15	0.27	-2.77
0003-0002	0.26	2024	-2.09	66.83	2.04	1.5	2.92
0191-3017	0.511	2020	-2.79	-135.62	1.16	0.1	-8.65
2009-0185	0.539	2024	-4	-140.06	-2.79	0.34	9.08
3002-0192	0.514	2024	-4.02	-134.85	1.06	-0.09	8.6
3005-0197	0.606	2024	-4.12	-159.39	1.91	-0.19	9.87
0009-1002	0.504	2024	-17.69	106.81	1.1	0	7.68
0028-1084	0.475	2020	-17.08	-99.65	1.44	0.05	-7.23
0076-1006	0.559	2024	-18.25	119.8	1.75	0.04	8.85
003A-0308	0.079	2024	0.17	-3.58	-20.48	1.85	1.67
0066-0307	0.081	2020	0.15	-3.77	20.93	-1.99	1.86
0371-2029	0.032	1003	-1.92	-3.5	0.56	0.03	-0.83
0075-3002	0.025	3004	-0.07	-1.72	-5.35	-0.53	-0.79
0078-3017	0.024	1004	-0.04	-2.07	3.17	0.31	-0.97
0309-0386	0.057	2024	0.45	-5.58	-11.01	-0.97	-2.39
0310-0387	0.059	2020	0.46	-5.79	11.45	1	-2.4

Fig 21 Max unity check report

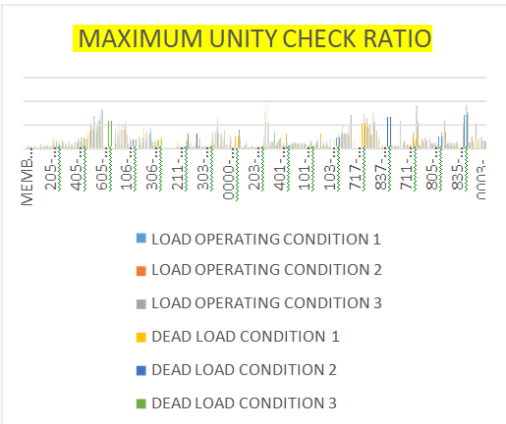

Fig 22 unity check report

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Displacement

- The maximum displacement that occurs on the structure in the X direction is in STM 2 in the Y direction is in STM 3,and in Z direction is in OP 3.
- The maximum allowable horizontal displacement of the floating structure should be limited to 1/200 height of structure above sea bed level.

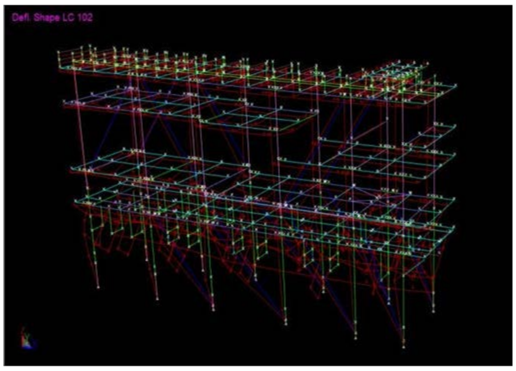

Fig 23 joint displacement

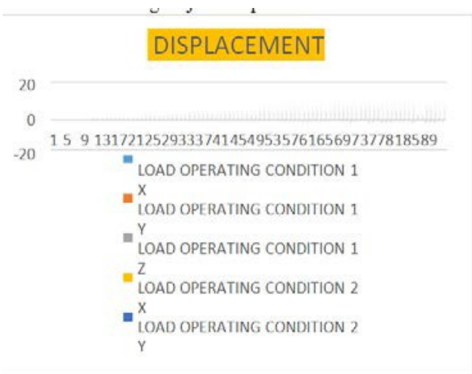

Fig 24 axial stress

Axial Tensile Stress

- The maximum Axial tensile stress that occurs on the structure in the STM 1 is 78.123 n/mm2
- The allowable axial tensile stress is 0.6 times of Fy.

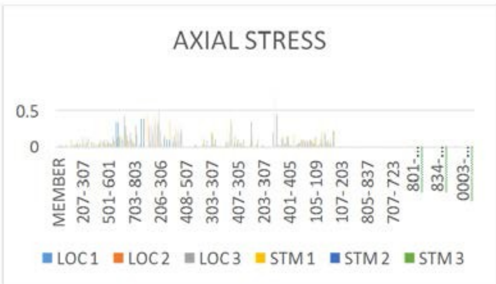

Fig 24 axial stress

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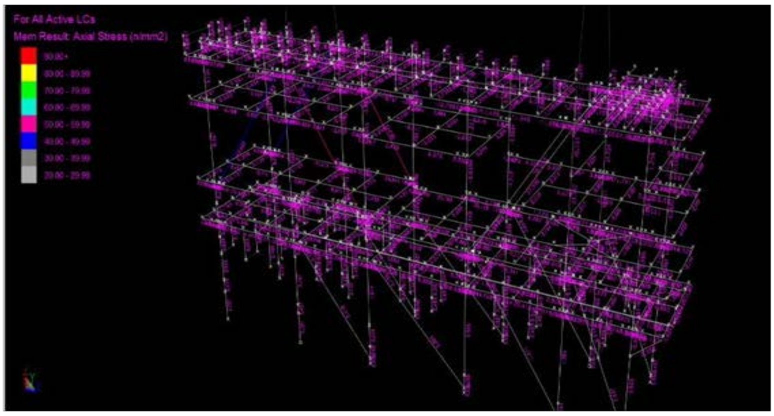

CONCLUSION

- Floating offshore structures play a crucial role in various industries, such as oil and gas exploration and production, renewable energy generation, research, and aquaculture. These innovative platforms are designed to overcome the challenges posed by deepwater environments, where traditional fixed structures are not feasible.
- Floating offshore structures, including FPSOs, floating wind turbines, Spars, Tension Leg Platforms, and more, enable the exploration and extraction of valuable resources from beneath the ocean floor and harness clean energy from offshore winds. They provide versatile solutions for transporting, storing, and processing hydrocarbons, contributing to the global energy supply.
- As floating offshore technology continues to advance, it holds the promise of enhancing production efficiencies, increasing renewable energy capacities, and improving safety and environmental performance.
- This design gives us a safe and stable floating offshore structure under the economical cost.
- The primary information on floating offshore structure that provides us with the knowledge about how the different loads could affect the structure.
- This work is conducted using a finite element programme called SACS (STRUCTURAL ANALYSIS COMPUTING SYSTEM).
- Unity check is less than 1 in all load conditions.
- The obtained results show that the critical load condition between the six load conditions i.e., operating condition 1 (OP 1), operating condition 2 (OP 2), operating condition 3 (OP 3),dead load condition 1 (STM 1), dead load condition 2 (STM 2), dead load condition 3 (STM 3).
- The operating condition 1 has a most significant effect on the structure in X direction.
- The Dead load condition 3 has a most significant effect on the structure in Y direction.
- The Dead load condition 2 has a most significant effect on the structure in Z direction

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