Analysis of environmental loads for marine structures Case study

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ABSTRACT
Offshore platform structures, whether fixed or floating, are exposed to a variety of environmental loads that affect their design and safety. The most important of these loads are winds and sea currents. Analysis of the environmental loads that affect marine structures is one of the most important aspects through which we can understand this type of facility and the impact of those loads on it, whether in terms of design or in terms of determining the materials used and their suitability to environmental conditions. Analyzing environmental loads and calculating the stresses resulting from them are among the most important analyzes that determine the extent of the platform's efficiency, safety, and stability. It is also possible to determine the extent of deformations that can occur in the platform as a result of the dynamic loads placed on it, and thus special maintenance programs can be created that help raise the performance and efficiency of the platform. And improve its work. performance. The study aims to clarify the importance of analyzing environmental loads, namely wind loads, sea currents, earthquakes, and marine platforms, how to conduct this analysis, the extent of its effectiveness, and benefiting from it through a methodology based on a combination of description, analysis, and comparison methodologies, and Bentley SACS. The results indicated the importance of conducting these analyzes that contribute to developing the performance and lifespan of the platforms by conducting the necessary treatment for the shortcomings of the platforms, whether in terms of dynamic and static balance and weather factors that affect the platforms. The results that were conducted on the case study in south of Iraq offshore platform indicated that after a height of 50 meters It is the area most affected by the dynamic force of environmental loads. The critical angle of the platform in relation to the wind was 110, and in relation to the force it was ten degrees, which resulted in a movement of the centre of gravity of the platform .

Keywords: (marine platforms, environmental loads, dynamic loads , marine structure analysis programs, Bentley SACS, factors, improving performance)

1. INTRODUCTION

Oil and gas production platforms are among the most important offshore facilities, especially for oil and gas exploration and production. The idea of extracting oil from the depths of the sea began in the late nineteenth century in the United States of America, where marine structures initially relied on wood and iron, and then the matter developed in the era of the Industrial Renaissance. Especially after the World War and the urgent need for more energy sources, the production of modern platforms began, which led to increased production and further development of the oil sector(Barltrop, N. D., & Adams, A. J. 2013).. At the beginning of the sixties of the last century, a terrible development began in the facility and marine facilities, as they began to rely on concrete materials and metals, and the platforms became more complex and sophisticated, and research increased. related to photographing these platforms, raising their efficiency, and rehabilitating them to ensure their long-term safety and stability (Bokoti, p. 2014).

This study aims to determine the type of environmental loads occurring and affecting the platforms, such as wind forces, earthquake forces, and the strength of sea currents, and to analyze those environmental loads affecting the marine platforms and to analyze the stresses resulting from these loads. The study also aims to determine the methodology through which these loads and the resulting answers can be analyzed and obtain more accurate results by relying on modern software and analysis programs such as the Bentley SACS program. Through the methodology of research, analysis, data collection, scientific and quantitative methodology, and comparative methodology, an analysis of the structure of the platform was conducted. A case study south of Iraq in the Arabian Gulf region, comparison between the results of analysis using accounting programs, verification using simulation programs and MATLAB, and mathematical verification of these results.

The problem that faced the study was related to a significant shortage in the volume of data related to the platform and other offshore platforms in Iraqi oil production companies. Also, the platform was somewhat old, which required more effort to obtain data about this platform. Also, some of the platform and its presence inside the sea were among the Among the.

2. Basic Concepts and Analytical Theories

This section introduces fundamental concepts related to marine platforms and explores key analytical theories.

2.1. Marine Structures

Marine structures are substantial facilities constructed within or adjacent to marine environments. Their primary functions encompass a wide range of activities, including oil and gas extraction, renewable energy generation, scientific research, transportation (bridges, tunnels), and cargo shipping**(Kim, W.** S., & Kim, J. 2019).

Marine structures can be categorized into two primary types:

- Fixed structures: These are stationary installations anchored to the seabed, such as oil and gas production platforms, power generation stations, fish farms, and ports(Misra, S. C. (2015)..

Mobile structures: These are structures designed for movement, including large ships, oil transport containers, and floating research stations(Barltrop, N. D., & Adams, A. J. (2013).

2.2. Marinjakets.

The marine structure consists of three main components, which are as follows:

- Legs:The legs are what hold the platform and are fixed to the bottom. They are often made of concrete and iron
- Joints: Joints are the connections by which members are connected. They are either welded connections or bonded connections.

Members: These are the members and connections through which the main parts of the structure are connected(Boccotti, P. (2014).

2.3.Environmental loads

Environmental loads, or what are called dynamic loads, are variable loads that affect the structure of marine platforms. They include wind loads, loads of surface and deep sea currents, and earthquake loads. These loads result in stresses that affect the structures of marine platforms (Demarks, P., Ciba, E., &Marcinkowski, T. 2016). .

2.3. 1. Wind loads

Ahmed Al-Riyah Wind loads are loads resulting from the horizontal force on the body of the structure and may cause it to shift from its position or cause vibrations to it, especially in towers and high platforms, which causes the parts of the structure to be affected with varying powers, which leads to the occurrence of some deformations that may lead to collapses if action is not taken. appropriate for treatment(Martín-Monje, E., &Borthwick, K. (2021).Wind affects the surfaces of platforms, as it can cause them to corrode, especially the parts exposed to the air, because the wind may sometimes carry some solid objects. The collision between them and the platform body leads to corrosion(Salgado, R. A., &Guner, S. 2021).

2.3.2. Marine current loads

Marine aircraft loads are the loads resulting from the force of marine currents, whether a pulling force or a pushing force, that work to lift the hull from the seabed and affect the resistance to the movement of the hull. These currents may lead to corrosion in the commanded parts of the hull, especially when there are currents or solid materials attached to the bases(Dhaher, C. N. 2023).

2.3.3. Earthquake loads

Rahman Earthquakes are loads resulting from ground movements, which affect structures and platforms in the sea. These earthquakes can cause what is called a tsunami, and this of course affects marine life. These loads affect the stability and balance of structures, so appropriate measures must be taken for such events.Alirezaei, M,et,al,2016).

2.3.4. Factors affecting environmental loads

In order to understand the effect of environmental loads on structures and platforms, it is necessary to understand and identify the factors that affect these loads, especially since these loads are non-fixed and variable loads, and the most important of these factors are the following:.

- Water depth: The depth of the water affects the intensity of the influence of sea currents and waves.
- Structure shape and size: The shape and size of a structure affects the amount of forces acting on it.
- Weather conditions: Weather conditions such as storms and hurricanes greatly affect the environmental loads acting on the structure.
- Characteristics of marine soil: The properties of marine soil affect the ability of a structure to resist loads.

The importance of understanding and identifying these factors is due to helping to design marine structures capable of bearing loads and with a high safety and security factor. It can also predict the possible effects resulting from these loads and take preventive measures against them. It also helps in creating periodic maintenance programs that help develop and maintain the performance of the structure.loads(Park, J. Y., Lee, D. E., & Kim, B. S. (2016).

2.4.Analysis theories

It is a set of theories that help and contribute to analyzing marine structures structurally, and through them the nature and performance of platforms can be understood.

2.4.1. Dynamic Analysis Theory

Dynamic analysis theory is a very important tool for understanding the behavior of metal structures and structures when subjected to varying loads over time. Dynamic analysis differs from static analysis in this point, as static analysis explains the behavior of metal structures and structures when subjected to constant rather than variable loads. The theory of dynamic analysis of metal structures states that the behavior of the structure at a certain moment and under the influence of a certain load is consistent with the principle of Newton's laws of motion, which stipulate that a body at rest remains at rest unless acted upon by a force that causes it to move, and a body in motion remains in motion at a constant speed unless acted upon. It has an external force. If a force acts on a body, it gives it an acceleration that is directly proportional to its force and inversely proportional to its mass.

and here the resulting force is the rate of change in kinetic torque (Borthwick, D. 2020). According to equation :

F = d p d t = d (m v)d t (1)

F = m d v d t = m a , (2)

Where :

- F is the resultant force
- m is the mass of the body
- a is the acceleration of the body.

2.4.2.Seismic Analysis Theory

Direction used in seismic analysis is important for studying the impact of earthquakes on offshore platforms, especially in areas where earthquakes are active. This point helps determine how platforms record movements and thus stop them from occurring, creating a build from the building platform. To fully understand this correctly, concepts such as the nature of earthquakes must be studied, which is known as excess energy released due to the causes of cracks in the flooring of the carpet, whether in the monthly payment or on land. These earthquakes are measured using the Richter scale.(Liu, J., & Zhang, X. (2018).

Seismic analysis carried out the dynamic construction in its response to the creators, which resulted in a reinforced production of poor construction and its workers. Spectral analysis can be chosen to be able to find solutions suitable for climatic conditions such as earthquakes and climate changes, and thus design suitable camping systems for the results of sky analyzes on safe production platforms.(Nazarov, Y. P., Poznyak, E., &Filimonov, A. V. 2015).

2.4.3. Finite Element Analysis, FEA

Finite element analysis theory is a wonderful and effective tool in analysing structures, especially since it divides the structure into small elements and analyses them in detail so that the stresses and strains at the required points can be studied, whether the loads are variable or constant, and this is what distinguishes it. In order to understand this theory of consciousness, some of the basics on which the theory of analysis by specific elements depends, where the structure is divided into small elements that may be triangles, squares, or quadrilateral parts, and each part is analysed. This method is ideal, especially for studying the work joints(Koutromanos, I. 2018). The properties of each element are also studied separately, such as bending, strain, tensile coefficient, refractive index, and physical properties, and then applying equilibrium equations at each point, and by determining stresses and strains, defects in the body of the structure can be identified and repaired. (Kurowski, P. M. (2022).

2.3.7.Stability Theory

The theory is an effective tool for identifying points that may lead to loss of stability of the structure or offshore platform under the influence of different loads. The goal of the theory is to stabilize the offshore platform or structure to be analyzed. To understand this theory, you must know its foundations, including the definition of stability, which is maintaining a constant position of a structure when subjected to random or different loads. Factors such as the materials used in constructing the structure, the nature of the loads, and design standards all affect the stability of the structure. Fig(6)shows an example of applying the theory to marine structures, explaining the difference between a stable and unstable structure based on the location of the center of gravity relative to the center of buoyancy, and how this can lead to the restoration of balance or the overturning of the structure.(Gupta, A. K. (2017)

2.4.4.Spectroscopy theory

Spectroscopy theory was used for random single effects and response to these loads. This is done using industry analysis spectroscopy, which uses a scientific tool to study the impact of random loads on marine industries. By identifying any frequency pattern or anomaly, different frequencies of submarine texts can be produced across regions with dynamic response and response, which helps in detecting inter-frequency anomalies and vibrations of random communications. Figure (16) shows an example of spectral analysis of body vibrations(Borthwick, D. 2020).

3.Method and methodology

In this part, we will explain the methodology of the study, where the combination of description and analysis methodologies and emerging methodologies was combined between the results of molecular analysis and the results of analysis using analysis and simulation models. Bentley SACS software will be used to perform this analysis .

3.1 .Applied framework for the study

The applied framework of the study explains the steps and stages of the practical study, starting with setting the goal and ending with evaluating, analyzing, and making comparisons of the results, as shown in Figure (5).

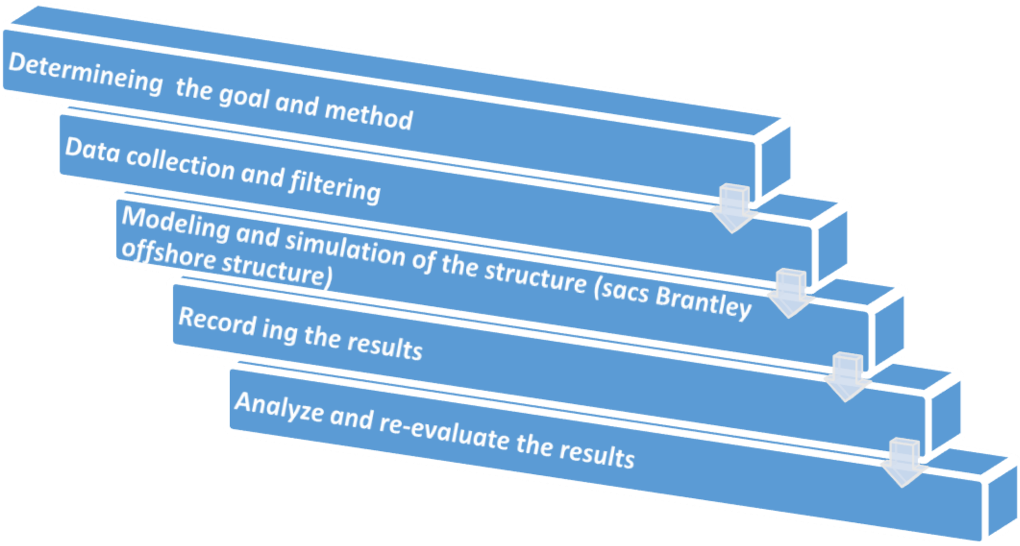

Figure 5. shows the Appling frame work(author)

3.2.Tools and materials

The study is a case study of an actual platform located south of Iraq Platform.

Table 1. Show the platform's specifications.

Description	Property
Name	Case study in southwest, Iraq platform
Location	
Owner	Basra Oil Company
The operator	SOC
Production capacity	100000 barrels/day
Start date	1976
Rehabilitationdate	1989
The platform high	40 m
The platform surface area	30000m2
The platform weighs	150000ton
Number of floors	4
The depth of well drilling	3000m
Platform type	Offshore platform
Height of towers	60m
Number of legs	8
Material of manufacture	Steel + concrete
Crew	100 p
Storage Systems |	4 tanks (2 million barrels)

Table 2. Site specifications

Description	**property**
Marine currents	0.5 to 1 knot (about 0.9 to 1.8 kilometers per hour).
Tidal currents	The area is exposed to almost daily tides
Strength of subsurface currents:	The speed of subsurface currents in the area ranges
	from 0.2 to 0.5 knots (about 0.3 to 0.9 kilometres per hour).
Wind	Northwesterly winds blow predominantly in the area
wind speed	10 to 20 knots (about 18 to 37 kilometers per hour).
Seismic activity	Far from major tectonic plate boundaries

.

Table No. 2 shows the environmental conditions of the platform site in terms of wind strength and sea currents

3.3.procedures

After setting the goal, which was to analyzecase study in Iraq platform according to the environmental loads and collect the necessary data on wind forces, sea currents, and the materials and data for making the platform, the following was done.

1 Determine the wind force affecting the platform, where the wind forces affecting the leg connections and connection members were calculated and the stresses affecting these elements were determined.

2. Determine the strength of the marine currents affecting the connections, legs, and connection members of the marine jacket, and then determine the answers affecting the elements.

3. Excluding the strength of earthquakes, as the area does not fall within any known seismic zone.

4. Define what is called Marine Growth Zone

5. Integrating the forces of wind and the force of sea currents into one force called dynamic force or environmental force and analyzing it.(Liu, J., et,al,2024).

In order to calculate the Danish force resulting from the wind force, the dynamic pressure on the platform can be calculated through the following equation: The dynamic pressure (qqq) can be calculated using the equation:

$q = 1/2 * \rho v^2 =$ Eq(3)

where:

- Q is the dynamic pressure (Pa, N/m^2).

- ρ\rhoρ is the density of air (usually about 1.225 kg/m^3 at sea level).
- v is the wind speed (m/s).

After obtaining the dynamic pressure, the force resulting from the wind can be obtained through the following equation:Power
F = q ∗ Cd ∗ A   Eq(4)
where:
F:is the force generated by the wind (Newton, N).
The wave energy per unit area can be calculated using the following equation:
E = 1/8 ∗ ρgH^2 Eq(5)
where:

- E:is wave energy per unit area (J/m^2).
- ρ\rhoρ is the density of water (about 1025 kg/m^3 for salty water).
- g is the acceleration due to gravity (9.81 m/s^2).
- H is the wave height (m).

As for calculating the force of waves affecting a specific structure, and taking into account the force resulting from the movement of the waves and the added masses, the force resulting from the waves can be calculated through the following equation:
To calculate the force of waves acting on a given structure, the Morison equation can be used, which takes into account forces arising from both wave motion and added mass:
F = 1/2 ∗ ρ^2 ∗ Cd ∗ A ∗ U + ρ ∗ Cm ∗ VdUdt = 21ρCdAU2 + ρCmVdtdU Eq(6)
where:

- F: is the total force of waves affecting the structure (N).
- P:; is the density of water.
- cd is the drag coefficient.
- A: is the area exposed to waves (m^2).
- U:is the velocity of particles in waves (m/s).
- CmC_mCm is the added mass coefficient.
- V:is the volume of the underwater structure (m^3).
- dUdt: is the acceleration of particles in waves (m/s^2).

After that, wind forces and sea current forces are combined to obtain what are called dynamic loads or environmental loads,
The total pressure resulting from the forces of wind and sea currents on the platform structure is calculated and the law states that the sum of the forces of wind and sea currents is equal to the square root of the sum of all the forces acting. It is as follows:
Σtotal = ∑_(k = 0)^(K = n)▒ 〖∑_(i = 0)^(i = n)▒σfk σfi〗 (8)
Through the law shown in the figure, where the total stress is equal to the square root of the sum of the stresses of the sea currents and the wind stresses. Through the law shown in the figure, it is clear that the resulting wind stress that occurs on the platform is equal to the square root of the product of multiplying the speed by the torque, then finding the result and finding the natural logarithm of them and multiplying it by 2, in addition to adding the constant 0.5 divided by the same value to find the wind force stress.
The highest value of stress resulting from dynamic stresses and static stresses is when the load factor is ≥1, and in the case of the study it is at a frequency of 10 Hz. The figure shows the relationship between frequencies at the frequency value of 10 Hz

4. RESULTS AND DISCUSSION

The results obtained from the Bentley SACS program will be presented. It will be discussed and analyzed. The loading procedures for the platform were carried out using theories of static analysis, dynamic analysis, theories of spectral analysis, seismic analysis, stability, finite element analysis, and conventional methods, and simulations were performed using software) and the results were comparable. Knowing the extent to which the actual results match the model results.

Table 3. shows the critical angles for wind forces and sea currents, the resultant torque acting on the legs

Environmental stress		
	ANGLE OF WAVE	TW
Member	DEGREE(ø)	KN. m
LEG1& LEG3	160	8.2
LEG2&LEG6	160	-8.2
LEG4&LEG 7	50	6.6

LEG5&LEG 8	20	-5.4

Table (3) shows the moments exerted on the legs as a result of the difference in sea currents, waves, and wind forces, and also show the angles of influence of the wave force on the legs.Of course, the legs that are subjected to the highest stresses are the legs that are subjected to the highest moments, and this is confirmed by (13), where the legs that are subjected to the highest moments are the leg 1 and leg 3 with a torque8.2 kN.m And vice versa, the legs that are subjected to the least stresses are subject to the least torques, and the least resultant torque is5.4 kn.m On legs(5,7).
where
Tw: It is the resultant angular torque or torsional torque resulting from dynamic stresses
ø:The angle in degrees of wind directions and sea currents after integration(Low, Y. M. (2016).

Environmental Loads Analysisjoints
We previously mentioned that the connections were divided into two classifications, one that bears stresses up to 400 KN, and the other type bears up to 800 KN. When studying the effect of winds and sea currents on the genets, or what is called the analysis of the dynamic loads on the genets, it has been mentioned before, but in this part we will We show the effect of the wind on the genets in terms of stresses, especially in the area that indicates the highest stresses, which is the last five meters of the platform's height. Figure 7 shows the stresses on the genets of the first type, those stresses resulting from the combination of the force of sea currents and the force of the wind.
Table No. 4

Table 4. shows the stresses resulting from wind forces and the force of dynamic stress on joints the highest stress.

Environmental stress			
	X	Y	Z
joint	KN⁄m²	KN⁄m²	KN⁄m²
SS110	-85.254	15.204	25.214
SS124	-87.221	12.1	65.241
SS131	-65.214	19.25	32.254
SS138	-58.251	16.254	60.254

Table (4) shows the values of the stresses applied to the highest-stressed joints, which are joints SS110, SS124, SS131, and SS138. As it turns out from the table, the joint with the highest stress is SS124, and the joint with the least stress is joint S131.

Table 5. shows the critical angles for wind forces and sea currents, the resultant torque acting on the joints **.**

environmental stress		
	angle of WIND	**tw**
joint	degree	KN.M
SS110	120	30.15
SS124	118	33.25
SS131	122	22.03
SS138	65	-33.023

Table (5))shows that the highest stress is at an angle of 65, where the torque reached 33 KNm. The torque was 20 kn.m the lowest stress was 20.15 kn.m an angle of 120 on joint ss131, where the torque reached 22.03 KN.m

C.Environmental Loads Analysismembers
In this part, since the wind will only affect the upper part, which is the part in which it became clear that there are four elements with high clearances, we will limit ourselves to examining these four elements and presenting their results, which are the elements SS 101, SS 102, SS 103, and 104. We will present the effect of the wind on these elements and the effect of the currents. Marine on these elements and display a diagram of the stresses to which the elements are exposed.

Table 6. shows the critical angles for wind forces and sea currents, the resultant torque acting on members

Environmental stress		
	ANGLE OF WIND	**TW**
Member	DEGREE	KN.M
SX 101	160	66.21
SX 102	160	79.79
SX103	160	54.1
SY104	0	44.2
SY105	90	32.2
SZ103	110	-34.1
SZ105	60	-32.2

The table shows that the highest stress is at an angle of 160 on remembering SX102, where the torque reached 79.79 KN.m. Whike the lowest stress is 30 kNm at an angle of 90 on remember SY105.

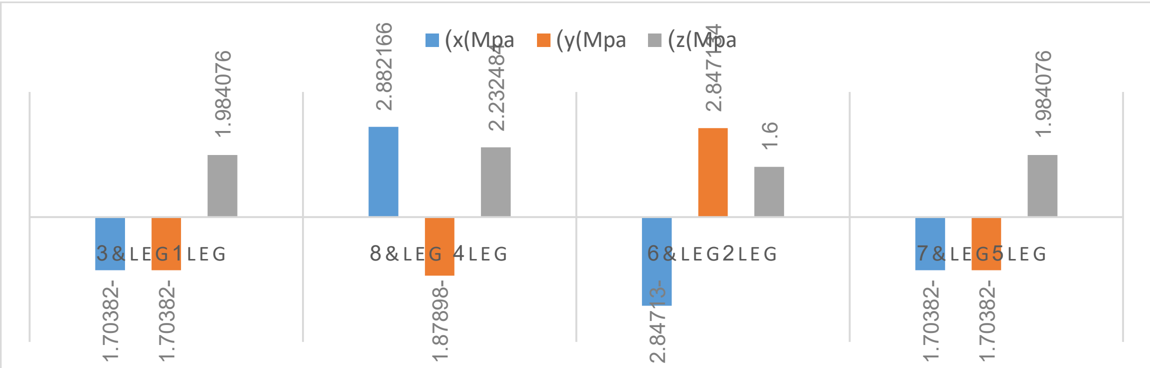

Fig 8: shows the avarage rate of stress s resulting from wind forces and the force of sea Wave currents on the legs.

Fig (8) shows the average stresses in the x, y and z directions for all the readings of the four levels. The first level is at a zero level from the surface of the water. The second level is at a level of 6 meters deep from the surface of the water. The third level is at a level of 15 meters deep from the surface. The water level is 21 meters, which is the length of the leg of the platform, according to the study.(Njoku, T. N., & Ephraim, M. E. (2019).

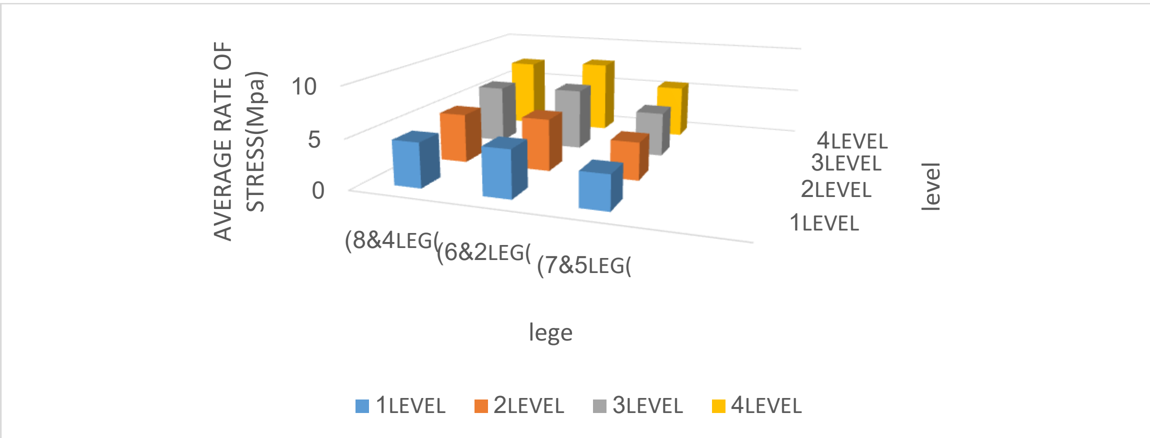

Fig 1. shows the average rate of stress s resulting from wind forces and the force of sea Wave currents on the legs at the fourth levels.

The total stress on the legs at each level separately,it is clear from the table that the average total stress on legs 4 and 8 is the highest, reaching 18 MPa, while the lowest total stress on legs (1, 3 and 7) is 9 MPa, which is approximately half the stress. Located on legs 8 and 4

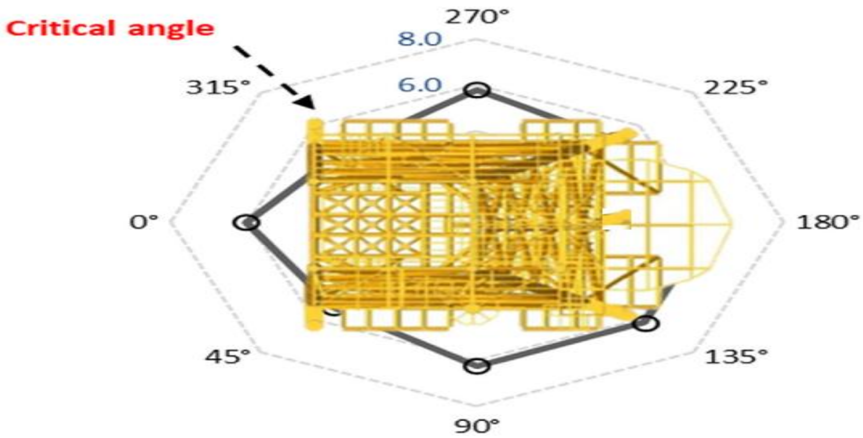

Fig 10. Critical angle of the platform according to the outputs of the Bentley SACS program

Fig (97) shows the critical angle and the angle that a wave makes with the sea floor when it reaches a shallow depth. The value of the critical angle depends on the speed of the wave, its length, and the depth of the water. This critical angle is used to determine the extent of the amount of pressure to which the platform will be exposed from the waves. As for the wind, the critical angle is the angle Which the wind creates with the surface of the earth and any structure on it. Therefore, by determining the value of this angle and its characteristics, the load caused by the wind on the platforms can be determined

Table 8. Marine Growth Zone

ITEM	From Elevation (m)	To Elevation (m)	Marine Growth Thickness (cm)
Marine Growth Profile	30	-30	10
Submerged Zone	-30	MUDLINE	5
Splash Zone	-1.5	MUDLINE	0
Atmospheric Zone	6	6	0
Marine Growth Density	1400 KG/M3	UP	0

The table displays information about scientific investigation and the researcher in a marine environment. The table identifies different zones at their elevation relative to a given level (CD), and measures the thickness of marine growth in each zone. The importance of this data is that it helps determine ways to protect the structure from marine meters, whether marine minerals, algae, or other things, and determine appropriate protection methods for it.

5. CONCLUSIONS

A set of important conclusions were reached through studying the environmental loads on the marine platform jacket, which are as follows:

• When conducting the dynamic analysis of the platforms, linear analyzes were followed because they are the best, and it became clear that there were six elements on which the dynamic stress resulting from the environmental loads was the highest possible, namely the elements SX101, SX102, SX103, SY105, and SZ103, where the stress resulting from the loads was The environmental impact on these members is significant as a result of the change in the platform's center of gravity, the angle of the wind, and the angle of the sea currents.

The gulets S110, S124, S131 and S138 are located in the splash area, which is the area most exposed to strong winds.(Tucker-Jones, A. 2014).

The effect of the force of the wind on the legs was not significant, but the effect of the force of the sea currents had the greatest effect on the legs, but it was within the permissible limits and there were no problems.(Davies, P. (2016).

. A slight corrosion was observed in the legs and submersible elements underwater as a result of what is known as marine growth. Marine growth according to the table shown in the results is 10 cm, and this causes corrosion in the amount of 13 micrometers per year.

The critical angle of the platform changed from 300 to 315 due to the change in the center of gravity, but the center of gravity changed within the permissible limits and what is allowed by the so-called tolerance basin or support base.

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