INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN: 2278 – 0211 (Online)

Stability Studies On Offshore Triceratops

Srinivasan Chandrasekaran
Associate Professor in Department of Ocean Engineering, Indian Institute of Technology Madras, India
Madhuri Seeram
PhD Scholar in Department of Ocean Engineering, IIT Madras, India

Abstract:

In the present days the oil exploration is going to deeper and ultra deep water depths. Deep and ultra deep water structures needs special care to reduce the motion responses. Triceratops (introduced by Charles et al. (2005)) is a new generation of the offshore structure with three Buoyant Leg Structures (BLS), deck, ball joints between the BLS and the deck and the foundation system either with restraining leg or with tethers. Triceratops can be installed by free floating each BLS followed with deck mating. For these purposes, the present paper discusses the hydrostatics of BLS's with two different mass distributions. The heave, roll, and pitch free oscillation studies are conducted for BLS and Triceratops experimentally and analytically. The free floating natural periods in roll and pitch degrees of freedom are found away from the wave periods which shows the ease in installation and decommission.

1.Introduction

Offshore Triceratops is new concept which suites in deep and ultra deep water depths for oil and gas exploration. This structure consist three buoyant leg structures (BLS), deck, ball joints between deck and BLS's, tethers for restoring and suction or gravity piles for foundation. The ball joints transfers only translations but not rotations about any axis. Hence Triceratops is an advantageous structure for deep and ultra deep water applications. The BLS can be with one or more number of water piercing cylindrical structures and positively buoyant and connected to sea floor with the tethers. It maintains stability even after the removal of tethers. This is advantageous on operational and survival conditions of the platform. The concept of tethered buoyant platform was introduced (Graham and Robert (1980)) and performed coupled in place analysis (Halkyard 1991) and experimental investigations on 1:89 scaled model. Several experimental and analytical investigations were performed on different shapes of BLS's (Robert et al. (1995), Shaver et al. (2001), Capanoglu et al. (2002)) and compared with analytical results. Chandrasekaran and Jain (2002) compared the response of square and triangular tension leg platforms and highlighted the advantages of triangular TLPs. The highlighted literature review scares the hydrostatics of BLS's and TLPs. Hence the present paper highlights detailed hydro-static studies on BLS's of two different structures of Triceratops. These studies are required for installation, towing of BLS's to the site and decommission of the structure to relocate in another site if required.

2.Hydrostatics Of Bls

In the present study, two different BLS's of structures called Triceratops are studied. Triceratops consist three BLS's, deck and ball joint between BLS's and deck. According to APIRP 2T (1997) code, the installation of Triceratops can be done part by part or whole structure. If the installation is planned part by part, each BLS is taken to the site by towing or by using barge and floated in the site. After the Three BLS's are floated, deck can be placed on the three BLS's by deck lifting or by deck mating processes. Then the structure is additional ballasted until it achieves the required draft and tethers will be connected. Once the tethers are connected, the additional ballast will be removed and tethers achieve the pretension. The pretension in the tethers makes the structure heave restrained. Before the installation of the structure, we require natural periods in different restoring degrees of freedom to avoid resonance with the wave periods. These studies are also required during decommissioning of the structure if the structures need to be relocated.

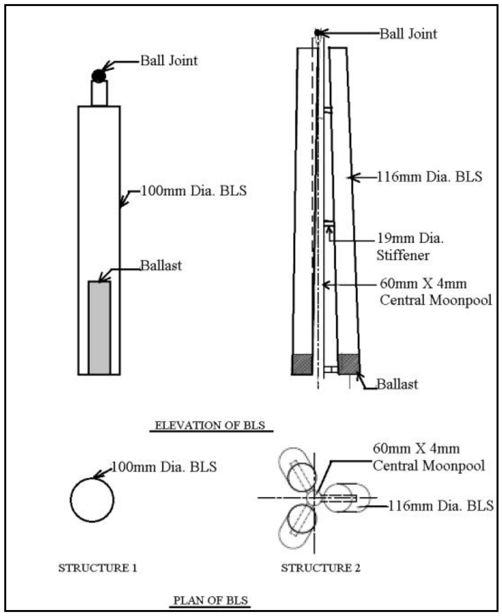

Figure 1: Plan and elevation of scaled model of BLS

The scaled models of Structure 1 (1:150) have 100mm dia. cylindrical structure as BLS where as structure 2 (1:72.41) has 4 no. of cylindrical structures as one BLS. The plan and elevation of BLS for structure 1 and structure 2 are shown in Fig. 1. The hydrostatics of each BLS's are given in Table 1 and Table 2 respectively. The buoyant leg structures are maintained positive metacentric height for the stability.

Description	Model (kg)	Prototype (ton)
Cylinder mass	1.8	6075
Ball joint and Appurtenances	0.1	337.50
Permanent Ballast	2.077	6986.25
Additional Ballast	0.81	2835
Displacement mass	4.79	16233.75
Draft (2KB)m	0.599	89.85
VCG (m)	-0.365	-54.75
Water plane area (m^2)	0.00785	176.7
Inertia (m^4)	4.71e-6	2485.69
Under water volume (m^3)	4.74e-3	15877.8
BM (m)	0.001	0.156
KM (m) = KB+BM	0.300	45.08
GM (m) =KM-KG	0.066	9.98

Table 1:Hydrostatics of 1:150 scaled model of Structure1.

Description		Model (kg)	Prototype (ton)
Structure mass		9.89	3755
Ball joint and Appurtenances		1.15	437
Ballast		22.71	8622
Displacement mass		33.71	12814
Draft (m)		0.99	71.7
VCG (m)	Calculated	-0.625	-45.25
	Experimented	-0.625	-
Water plane area (m^2)		0.0324	169.88
Inertia (m^4)		2.31e-5	635.047
Under water volume (m^3)		0.0325	12338.9
BM (m)		0.0161	0.0137
KM (m) = KB+BM		0.514	35.00
GM (m) =KM-KG		0.149	9.43

Table 2: Hydrostatics of 1:72.41 scaled model of Structure2

3.Experimental Investigations

Experimental investigations are carried out on both the BLS's. The models of the BLS's are fabricated with acrylic material. The ballast is placed at the bottom part of the cylinders to keep the vertical centre of gravity near to the keel. Complete water proof is maintained to achieve the required buoyancy. The fabricated BLS's are shown in Fig. 2. Experimental investigations are conducted at 4m flume (Structure 1) and towing tank (Structure 2) in department of ocean engineering, IIT Madras. Free oscillations studies are conducted in heave, pitch and roll degrees of freedoms. Initial position/rotation is given respective translational and rotational degrees of freedom and the free oscillations were recorded using accelerometer and inclinometers. Piezoelectric accelerometers are used for acceleration measurement and inclinometers are used for rotation measurement.

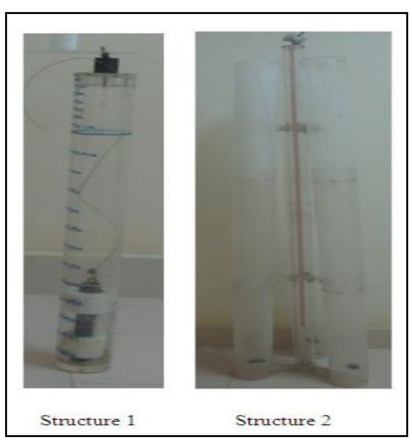

Figure 2: Fabricated Models Of BLS's

4.Analytical Studies

Analytical studies are conducted on two models of BLS's using ANSYS AQWA software. Since the BLS's are in Morison region (D/L ratio <0.2) Morison tube elements are used for modeling the cylinders. The tubes are divided as segments and formed into a rigid body. The mass, vertical center of gravity and radius of gyration in longitudinal, lateral and vertical directions are modeled. The density of flume water is also considered in the analysis. The initial positions are given in each degree of freedom and a time history analysis is performed for each case separately by solving the following equation of motion.

$$[M + M_a]\{\ddot{X}\} + [C]\{\dot{X}\} + [K]\{X\} = 0 \qquad (1)$$

5.Results And Discussions

The experimental and analytical studies are carried out on the scaled models of BLS's. The heave, pitch and roll natural periods are arrived. The comparisons of experimental and analytical results scaled to prototype are given in Table 3. Based on the experimental and analytical results the natural periods as well as damping ratios are in good comparison. The heave natural periods are also validated with the empirical relations.

DOF	Natural Periods (s)/Damping ratios (%)		
Structure 1	**Experimental**	**Analytical**	**Calculated**
Heave	19.6 (1.286)	19.59 (0.737)	19.47
Roll/Pitch	19.4 (1.01)	22.05 (1.39)	-
Structure 2	**Experimental**	**Analytical**	**Calculated**
Heave	17.2 (0.977)	17.1 (0.834)	17.73
Roll	27.0 (2.426)	29.5 (2.596)	-
Pitch	26.0 (2.613)	29.7 (2.492)	-

Table 3: Natural Periods of BLS's

6.Conclusion

Based on the above studies it is observed that the free floating roll and pitch natural periods are away from the wave periods. Heave natural periods are in wave periods zone (5 to 20s). Hence care should be taken during installation/decommission or else installation/ decommission can be planned according the sea state in the site.

- **Nomenclature**

$[C]$= Damping Matrix

D= Diameter of the BLS (m)

$[K]$= Stiffness Matrix

L= Wave Length (m)

M= Mass of the Structure

Ma= Added mass of the structure

$\{X\}$= Displacement of the structure

$\{\dot{X}\}$= Velocity of the structure

$\{\ddot{X}\}$= Acceleration of the structure

7.Reference

1. APIRP 2T, Recommended Practice for Planning, Designing, and Constructing Tension Leg Platforms, Second Edition, 1997.
2. Capanoglu. C. C, C. B. Shaver, H. Hirayama and K. Sao, Comparison of Model test results and analytical motion analyses for Buoyant Leg Structure, Proceedings of the twelfth International Offshore and Polar Engineering Conference, Kitakushu, Japan, May 26-31, pp. 46-53. 2002.
3. Chandrasekaran, S. and A. K. Jain, Dynamic behavior of square and triangular offshore tension leg platforms under regular wave loads, Ocean Engineering, 29, pp. 279-313, 2002.
4. Graham, R. Perrett and Robert M. Webb, Tethered Byouant Platform Production System, 12th Annual Offshore Technology Conference, OTC 3881, Houston, Texas, 5-8th May, pp. 261-274, 1980.
5. Halkyard., J.E., R. L. Davies and R. S. Glanville, The tension buoyant tower: A design for deep water, 23rd Annual Offshore Technology Conference, OTC 6700, Houston, Texas, May 6-9, pp. 41-55, 1991.
6. Robert W. Copple and Cuneyt C. Capanoglu, A Buoyant Leg Structure for the Development of Marginal Fields in Deep Water, Proceedings of the fifth International Offshore and Polar Engineering Conference, The Hague, The Netherlands, June 11-16, pp 163, 1995.
7. Shaver., C. B., C. C. Capanoglu and C. S. Serrahn, Buoyant Leg Structure Preliminary Design, Constructed Cost and Model Test Results, Proceedings of the 11th International Offshore and Polar Engineering Conference, Stavanger, Norway, June 17-22, pp. 432-439, 2001.