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Influence of Payloads on the Hydrodynamic Response of Semi Submersible Platform

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***Abstract**: The hydrodynamic analysis of the semi submersible platform was carried out for height. with and without mooring condition by changing the metacentric A physical model of scale 1 in 100 was tested in 1m width and 30 m long regular wave flume at CWR (Centre for Water Resource) Laboratory. The model has four rectangular columns and two rectangular pontoons along with mooring. The natural heave, pitch and roll periods of the semi-submersible have greatest impact on the downtime of platform operation.This paper focus on the influence of payloads on the hydrodynamic behavior semisubmersible platform. On the basis of present work, the configuration of Semi-submersible having four rectangular columns and two rectangular pontoons has been arrived at for the proposed desalination plant.*

***Keywords** : Floating platform, Response Amplitude Operator(RAO), Heave,payloads.*

I. INTRODUCTION

Growing concern over local water scarcity and challenges in meeting future water demand has led to heightened interest in desalination technology. As natural fresh water reserve is limited, seawater can be an important source of drinking water. Desalination plant with 10 million litres per day capacity and the plant is to be operated in severe ocean environment which induces severe motion on the platform. Hence a floating platform is required for installing the desalination plant which must have good station keeping characteristics. Floating moored structures have a significant future in offshore operations as an attractive economic alternative to fixed structures in deep waters and or in areas where there is no existing infrastructure.

Among the various components of motion of a semi submersible floating platform the acceptable heave natural period for the semi-submersible is 20 sec and the heave RAO (Response Amplitude Operator) is considered as the important criteria in the motion studies and its acceptable range is 1 to 3 .

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II. DESCRIPTION OF PROTOTYPE

A. Platform Configuration

Based on the size and weight of the plant equipments, the columns and pontoon of the semi-submersible can be rectangular shape.

Table- I: Self Weight and Pay Load for Four Column Semi-Submersible

Details of weight and load distribution	**Self weight in ton**	**Pay load in ton**
1.Deck		
Self weight	641	
Pay loads		
Pipes & bends		421
Flash chamber-4nos		270
Generators		60
Sea water pumps 8 nos		150
Quarters		25
Helipad& pilot house		30
2.columns		
columns self weight	557	
Pay loads ducts,pipes,lift		400
3.Pontoon		
Self weight	960	
Pay loads		
Condenser		600
Diesel		820
Freshwater		3200
Ballasting		1200
Cross members wt		100
Summary of payloads and the self weight		
	Self weight in ton	**Pay loads**
Deck	641	956
Column	557	400
Pontoon	960	5920
Sub total	2158	7276
To	**tal wt=(2158+7276)**	**9434**

1. B. Stability Calculation

Total draft = Column immersion + pontoon depth
= 10.79+10
= 20.79 m

Centre of buoyancy (K.B) = ((volume of water replaced by pontoon×C.G. distance from bottom)+ (volume due to column×C.G. distance))/Total volume replaced by semi-submersible.
= [(7200×5) + ((207×10.79)×(5.4+10))]/9434
= 7.46 m

B.G = K.G-K.B = 8.76-7.46
=1.33 m

BM_L = $[I_{xx}+Ah^2]/V$
= $[((9\times5.75^3/12) + (9\times5.75\times11^2)) \times4]/9434$

= 2.71 m

Similarly for BM_T = 2.34 m

$GM_L = BM_L - B.G$ = 2.71-1.33

= 1.38 m

$GM_T = BM_T - B.G$ = 1.01m (GM_T minimum)

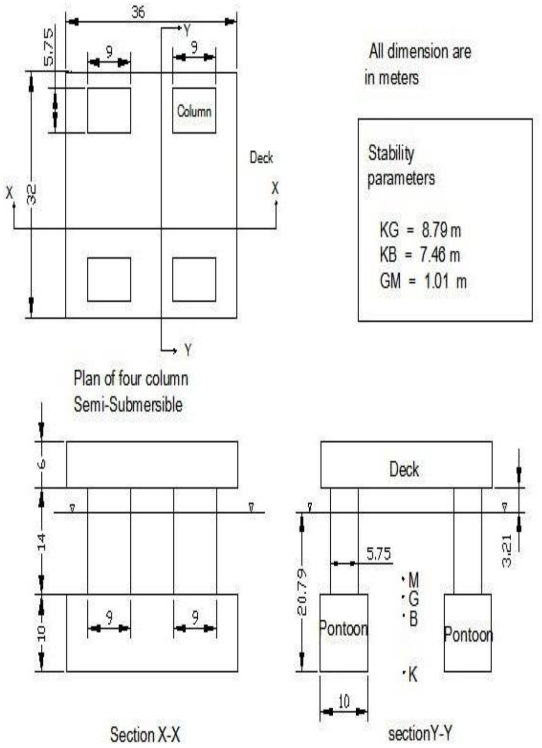

Fig 1. Plan and Section View of Four Column Semi-Submersible

III DESCRIPTION OF MODEL

The model scale chosen is 1:100. The scaled down dimensions of the model are given in Table II. The range of the wave period, experienced by the prototype would be between 10 and 23 sec and the natural period for the prototype is 20 sec. It is ensured that the model testing parameters meet these requirements.

Table- II: Scaled Down Dimension of Model

Description	Prototype(m)	Model (mm) (λ=100)
1.Pontoon		
Length	36	360
Breadth	10	100
Height	10	100
Acrylic		6
2.Column		
Length	9	90
Breadth	5.75	57.5
Height	14	140
Acrylic		4
3. Deck		
Length	36	360
Breadth	32	320
Height	6	60
Acrylic		2
4.Total weight	9434 ton	9.6136 Kg
5. Centre of Gravity	8.79 m	86.85 mm
6. Total draft	20.79 m	216.6 mm
7. Metacentric Height		
Longitudinal direction	1.38 m	17.19 mm
Transverse direction	1.01 m	13.12mm

The material chosen for the model is acrylic which has a density of 1300 kg/m^3. For the pontoon, 5 mm thick acrylic sheet, column 4 mm thick acrylic sheet and for deck 3 mm acrylic sheet are used. Mild Steel plates of 11 mm thickness in pontoon and 1 mm thick plates in deck were placed in order to match the payloads of prototype. There is hollow cylinder of outer diameter 25 mm and thickness 3 mm is placed in the pontoon according to the CG. This setup is for ballasting the pontoon. The ballasting is done by adding 12 numbers of 2 mm steel rods of 30 cm length in each of the hollow cylinders for changing the GM's. The distribution of acrylic sheets and steel plates in the model is placed in such a way so as to have the accurate location of CG. The stability calculations are carried out and the important parameters are given below.

Location of CG from base = 86.60 mm

Location of centre of buoyancy from bottom = 77.19 mm

Fig 2. Elevation of Model

IV EXPERIMENTAL INVESTIGATION

Experiments were carried out in the wave flume of following dimensions Length of the flume= 30.0 m, Width of the flume = 1.0 m ,Height of the flume = 1.0 m with water filled up to 0.6 m depth..One end of the flume has a wave generator.

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At the other end, 40 mm aggregate is put in a slope of 1:8 so that the waves don't reflect but break due to the beach effect. This holds good only water depth up to 0.6 m. The waves are generated by the to and fro motion of the sheet which is connected to a cam. The cam is connected to the motor by a belt. Turning a wheel, the tightness of the belt can be controlled and hence the rate of transfer of the motion to the cam. This helps in varying the period of oscillation and hence that of the waves. The wave flume is shown in the Fig .3. The accelerometer used is MEMS 3-axis ±2g/±6g digital output low voltage linear accelerometer evaluation board based on the LIS3LV02DL.Wave probes are used for measuring the height of the wave.

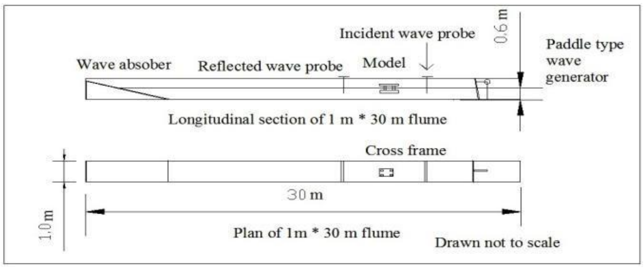

Fig. 3 Plan and Sectional Elevation of Wave Flume

A. Metacentric Height Calculation

Weight of the model = volume of water displaced × density of water= 1.5 m × 1.0 m × 0.0641m × 1000 Kg/m^3

= 9.61 Kg

$$GM = (P \times d) / (W \times \tan \varnothing)$$

where $\tan \varnothing = \Delta / L$

The following Table III indicates the detailed calculation of finding the longitudinal metacentric height.for GM_1.

Table III. Calculation of finding the Longitudinal Metacentric Height

S.No	P (Kg)	d (mm)	W (Kg)	L (mm)	∆ (mm)	Tan ø	GM_{L1}
1	0.2	260-150 =110	9.61	230	183-150 =33	0.1434	15.96
2	0.2	150-40 =110	9.61	230	150-116 =34	0.1478	15.48
3	0.2	280-150 =130	9.61	230	190-150 =40	0.1739	13.16
4	0.2	150-20 =130	9.61	230	150-109 =41	0.1782	12.84
						Total	14.36mm

The following Table IV indicates the detailed calculation of finding the transverse metacentric height for GM_1

Table IV. Calculation of finding the transverse Metacentric Height

S.No	P (Kg)	d (mm)	W (Kg)	L (mm)	∆ (mm)	Tan ø	GM_{T1} (mm)
1	0.2	260-150 =110	9.61	230	180-150 =30	0.1304	17.56
2	0.2	150-40 =110	9.61	230	150-120 =30	0.1304	17.56
3	0.2	280-150 =130	9.61	230	187-150 =37	0.1608	14.24
4	0.2	150-20 =130	9.61	230	150-114 =36	0.1562	14.65
						Total	16.02 mm

A. GM_2 (Metacentric Height with Weight Added in Pontoon)

The 24 numbers of 2 mm steel rod of 30 cm length of weight 180 grams is equally distributed in the pontoon so that the total weight is increased to 9.79 kgs and the above said experimental procedure is repeated to find the new metacentre denoted as GM_2.

Weight of the model = volume of water displaced × density of water

= 1.5m × 1.0m × 0.00652m × 1000 Kg/m^3

= 9.8 Kg

The following Table V and VI indicates the detailed calculation of finding the longitudinal and transverse metacentric height for GM_2

Table V Calculation of Finding Longitudinal Metacentric Height GM_2

S.NO	P (Kg)	d (mm)	W (Kg)	L (mm)	∆ (mm)	Tan ø	GM_{L2}(mm)
1	0.2	260-150 =110	9.8	230	180-150 =30	0.1304	17.22
2	0.2	150-40 =110	9.8	230	150-119 =31	0.1347	16.66
3	0.2	280-150 =130	9.8	230	185-150 =35	0.1521	17.44
4	0.2	150-20 =130	9.8	230	150-113 =37	0.1608	16.5
						Total	16.955mm

Table VI Calculation of Transverse Metacentric Height GM_2

S.NO	P (Kg)	d (mm)	W (Kg)	L (mm)	∆ (mm)	Tan ø	GM_{T2} (mm)
1	0.2	260-150 =110	9.8	230	177-150 =27	.1174	19.12
2	0.2	150-40 =110	9.8	230	150-117 =27	0.1174	19.12
3	0.2	280-150 =130	9.8	230	184-150 =34	0.1478	17.95
4	0.2	150-20 =130	9.8	230	150-117 =33	0.1434	18.5
						Total	18.67mm

B. Comparison of GM1 and GM2

The longitudinal metacentric height of the model with the prototype weight is 14.36 mm where as the longitudinal metacentric height of model with the added weight in the pontoon is 16.955 mm. the transverse metacentric height of the model with the prototype weight is 16.02 mm where as the transverse metacentric height of model with the added weight is 18.67 mm. This shows both the longitudinal and transverse metacentric height has been increased due to the addition of weight in the pontoon with results in increase of the stability of the structure. But the total draft is increased from 216.6 mm to 225.17 mm.

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C. Free-Oscillation Tests In Free Floating Mode

Free motion test were carried out to in order to measure the natural heave, roll and pitch periods of the model. The model was pushed down symmetrically at a certain draught and then released to perform the free oscillations. The free heave oscillations were recorded by the accelerometer. The natural heave period was determined by taking the average the average period over number of cycles. . The typical record of free oscillation test for heave, pitch and roll is shown in Fig 4, Fig 5 and Fig. 6 respectively

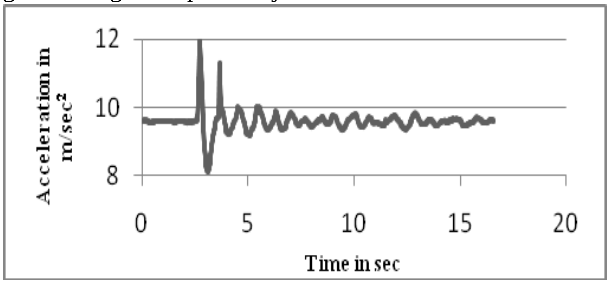


Figure 4 Free Oscillation Test for Heave

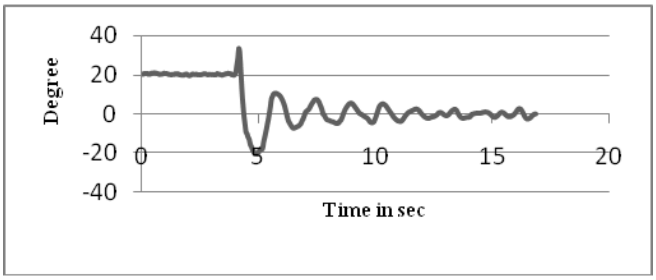


Figure 5 Free Oscillation Test for Pitch

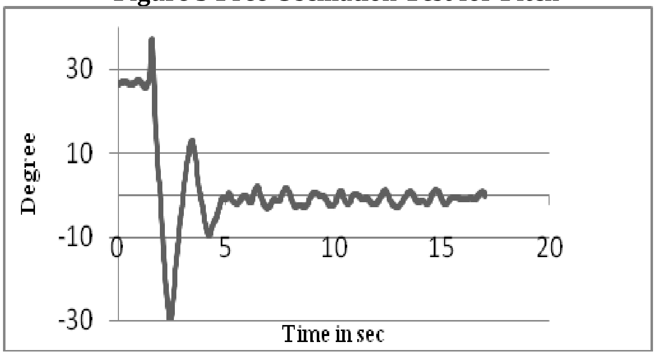


Figure 6 Free Oscillation Test for Roll

V RESULTS AND DISCUSSIONS

Motion Response Results

Experiments were conducted for 6 different frequencies in the range of 0.8 sec to 2 sec (prototype wave period between 8 sec to 20 sec). Throughout the experiments the water depth of the flume was maintained at 0.6m. The typical measured time series of wave elevation corresponding to wave period of 0.8 sec (prototype wave period 8 sec) is shown in the Fig 7.The average height is taken 0.087m

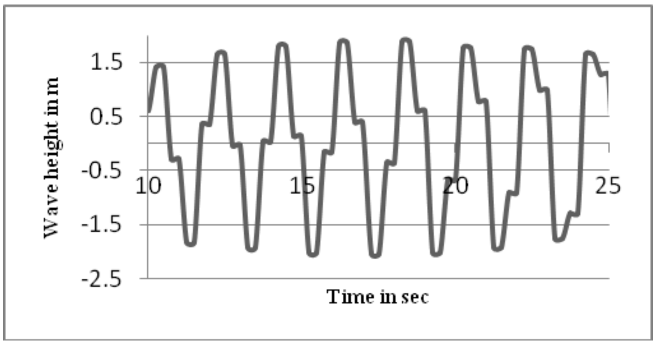


Figure 7 Wave Elevation At Wave Period 0.8 sec

The typical measured time series of Heave acceleration is shown in the Fig .8

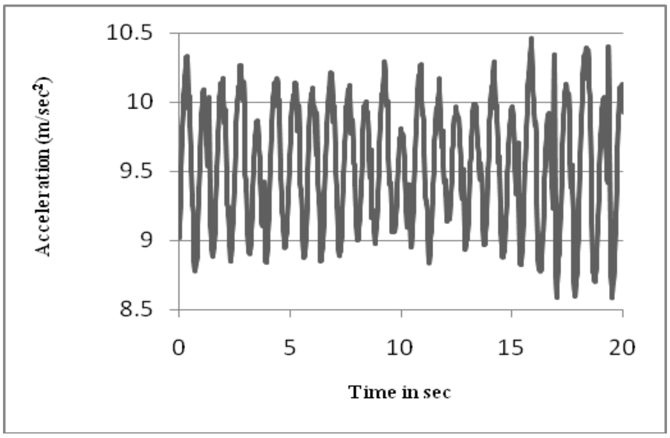


Fig 8 Heave Acceleration Time Series at Wave Period 0.8 sec

The average heave acceleration is taken as 1.2 m/sec^2 $a = A\omega^2 \cos \omega t$

For getting the maximum amplitude equate $\cos \omega t = 1$, then the formula becomes

$a = A\omega^2$

where $\omega = (2\times\pi)/T$

a = Heave acceleration in m/sec^2 A = Heave amplitude in meter

T = Respective wave period in seconds

t = Duration of number of samples in seconds A = 0.012969112/.087

Heave RAO is 0.149 m/m

The typical measured time series of pitch angular displacement corresponding to wave period of 0.8 sec (prototype wave period 8 sec) is shown in the Fig. 9

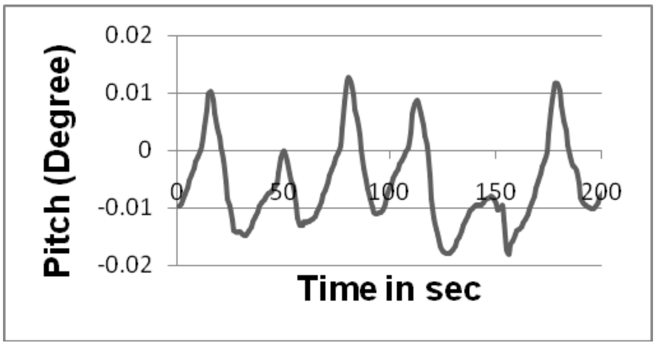
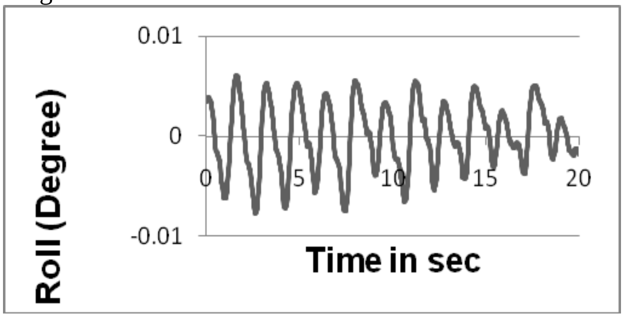


Fig.9 Pitch Time Series at Wave Period 0.8 sec

The average pitch angular displacement is taken as0.266 degree. The typical measured time series of roll corresponding to wave period of 0.8 sec is shown in the Fig.10



Figu10 Roll Time Series in Degree at Wave Period 0.8 sec

From the above graph the average roll angular displacement is taken as 0.012 degree.The typical measured time series of wave elevation corresponding to wave period of 2 sec (prototype wave period 20 sec) is shown in the Figure 11

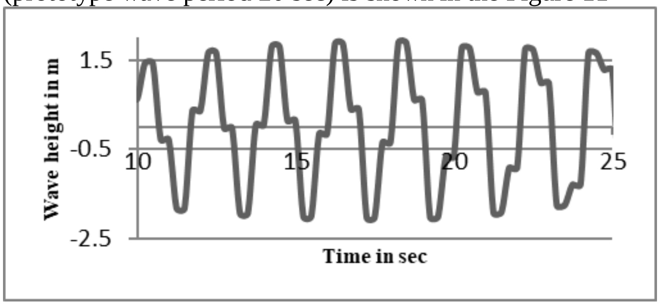


Figure 11 Wave Elevations at Wave Period 2 sec

From the above graph the average wave height is taken as 0.044m.

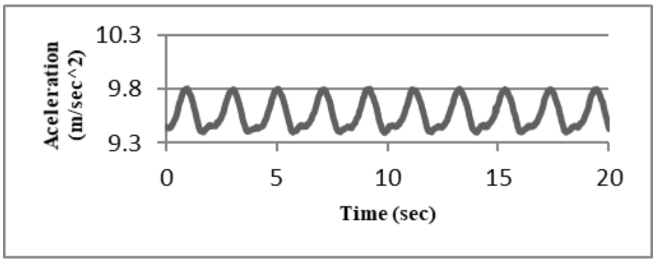


Figure 12 Heave Acceleration Time Series at Wave Period 2 sec

From the above graph the average heave acceleration is taken as 0.4 m/sec^2

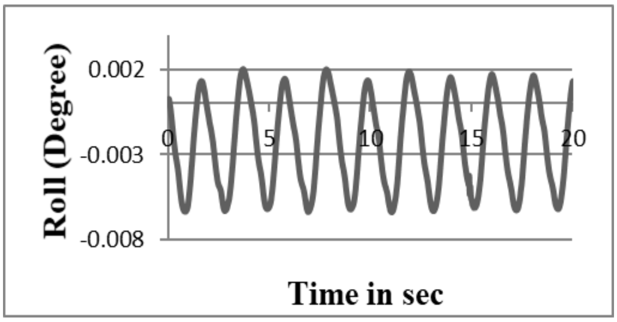


Figure 13 Roll Time Series in Degree at Wave Period 2 sec

From the above graph the average roll angular displacement is taken as 0.0075 degree

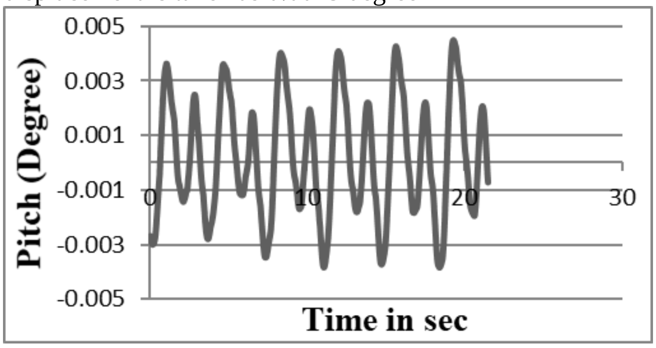


Figure 14 Pitch Time Series in Degree at Wave period 2 sec

From the above graph the average pitch angular displacement is taken as 0.64 degree

CONCLUSION

The longitudinal metacentric height of the model with the prototype weight is 14.36 mm where as the longitudinal metacentric height of model with the added weight in the pontoon is 16.955 mm. The transverse metacentric height of the model with the prototype weight is 16.02 mm where as the transverse metacentric height of model with the added weight is 18.67 mm. This shows both the longitudinal and transverse metacentric height has been increased due to the addition of weight in the pontoon with results in increase of the stability of the structure. But the total draft is increased from 216.6 mm to 225.17 mm. The natural period of roll RAO is 32 sec but we can able to generate a maximum wave period of 20 sec, still the secondary peak value matches satisfactory. The peak value of the pitch RAO is 0.41 obtained at 10.8 sec with the wave amplitude of 0.0375 m.Though the GM is improved for the addition of weight, the RAO increased. This calls for the further studies to improve RAO

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