EXPERIMENTAL STUDY ON LIQUID SLOSHING DYNAMICS WITH SINGLE POROUS VERTICAL BAFFLE IN A SWAY EXCITED SHIP

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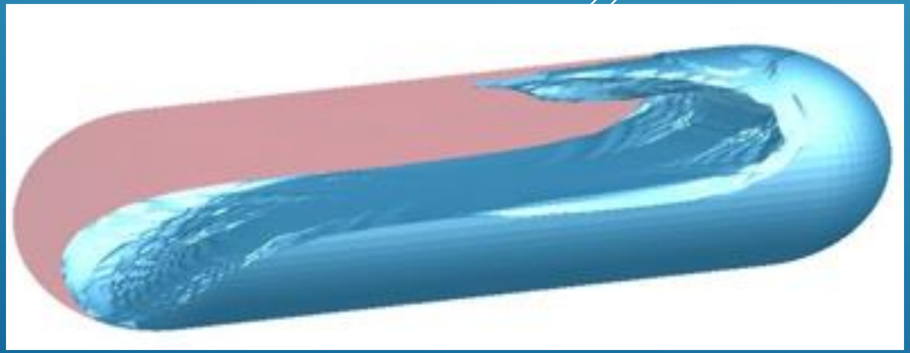
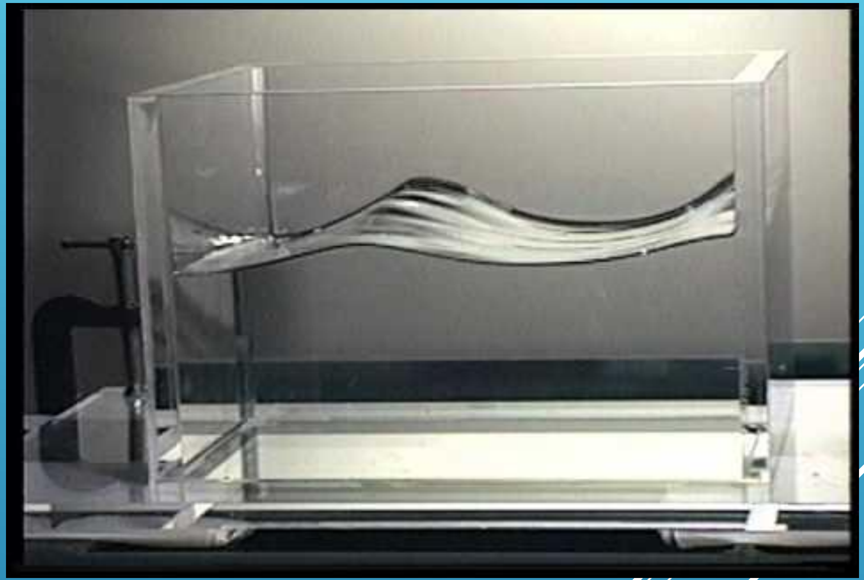
INTRODUCTION

- Storage tanks are commonly used in water distribution systems, and in industries or storing liquids
- Effect of seismic activities causing hydrodynamic forces on tanks
- Sloshing : "any movement of the free liquid surface inside other object."
- Dynamics of liquid can interact with container to alter the system dynamic significantly
- The liquid must have a free surface to constitute a slosh dynamic problem



- The dynamic behaviour of a free liquid surface depends on the excitation type and its frequency
- Sloshing Behaviour: Periodic, impulsive, sinusoidal and random, lateral, planar, non-planar, rotational, parametric, symmetric, asymmetric, pitching/yaw or combinational effects
- Analyse the sloshing dynamics
- Application of sloshing for different fill levels in a tank



Source: Feng Z C (1997) “Transition to Travelling Waves from Standing Waves in a Rectangular Container Subjected to Horizontal Excitations”

Sloshing

Experimental study

Analytical study

Numerical study

Computational Study

Cho et al. (2017): The amplification factor and sloshing force need to be simultaneously examined to find the optimal baffle porosity for the given case.

Jin et al. (2014): The total area of the perforations should not exceed 10% to effectively restrain the upward and downward sloshing motion.

Saoudi et al. (2013): Numerical results show that the presence of baffles has an important effect on the free surface displacement and on a sloshing frequency.

Wang and Xiong (2014): The introduction of baffles greatly reduced maximum impact pressure by 50% in comparison with without baffles

METHODOLOGY

LIQIUD SLOSHING BY SHAKE TABLE EXPERIMENT

- WITHOUT BAFFLES
  - 25%h | 50%h | 75%h
  - Excitation Frequencies by mathematical expression (0.4566-1.9637Hz)
  - Excitation Amplitude = 7.5mm
- WITH BAFFLES
  - 25%h | 50%h | 75%h
  - Baffle at distance L/2
  - For different porosities
  - 15% | 20% | 25%
  - Excitation Frequencies by mathematical expression (0.4566-1.9637Hz)
  - Excitation Amplitude = 7.5mm

RESULT

Validation

OBJECTIVE

To evaluate Sloshing oscillation (eeta max) for with and without baffles condition

EXPERIMENTAL SETUP

- Rectangular tank of size 1.0m (*l*) X 0.4m (*b*) X 0.65m (h) is prepared which is made up of acrylic plate of 12mm thickness.

- A level of water is maintained to match with natural frequency of the main system. A liquid tank is positioned on the shake table such that during the sway excitations, the sloshing oscillations occurs along the longitudinal axis.

- Two resistive type gauges are used to measure liquid oscillation at the ends inside the tank. The water in between the electrodes closes the circuit and during free surface oscillation, the change in resistance gives the measurement of sloshing oscillation.

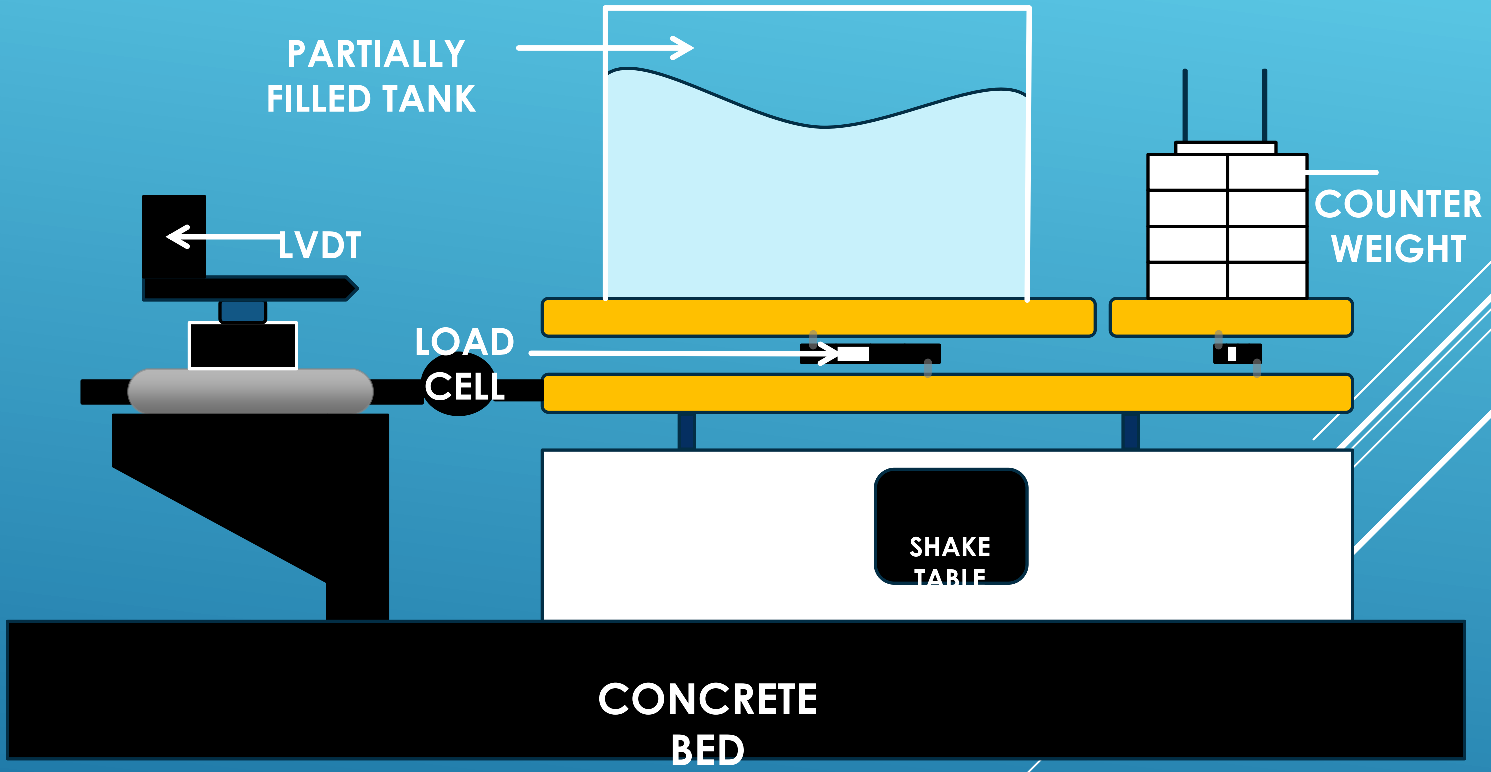


Fig. 1: Schematic diagram of the shake table

Fig. 2: Liquid sloshing tank with liquid fill condition fitting on to the shake table.

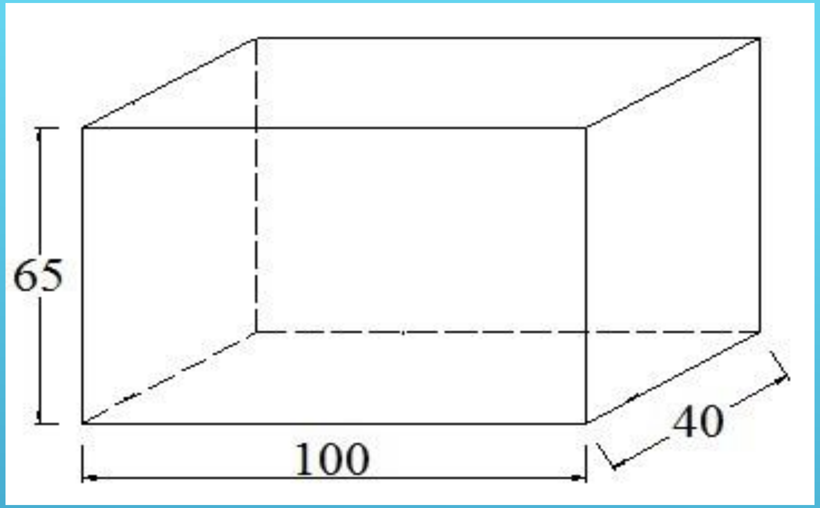


Fig. 3: All dimensions are in cm

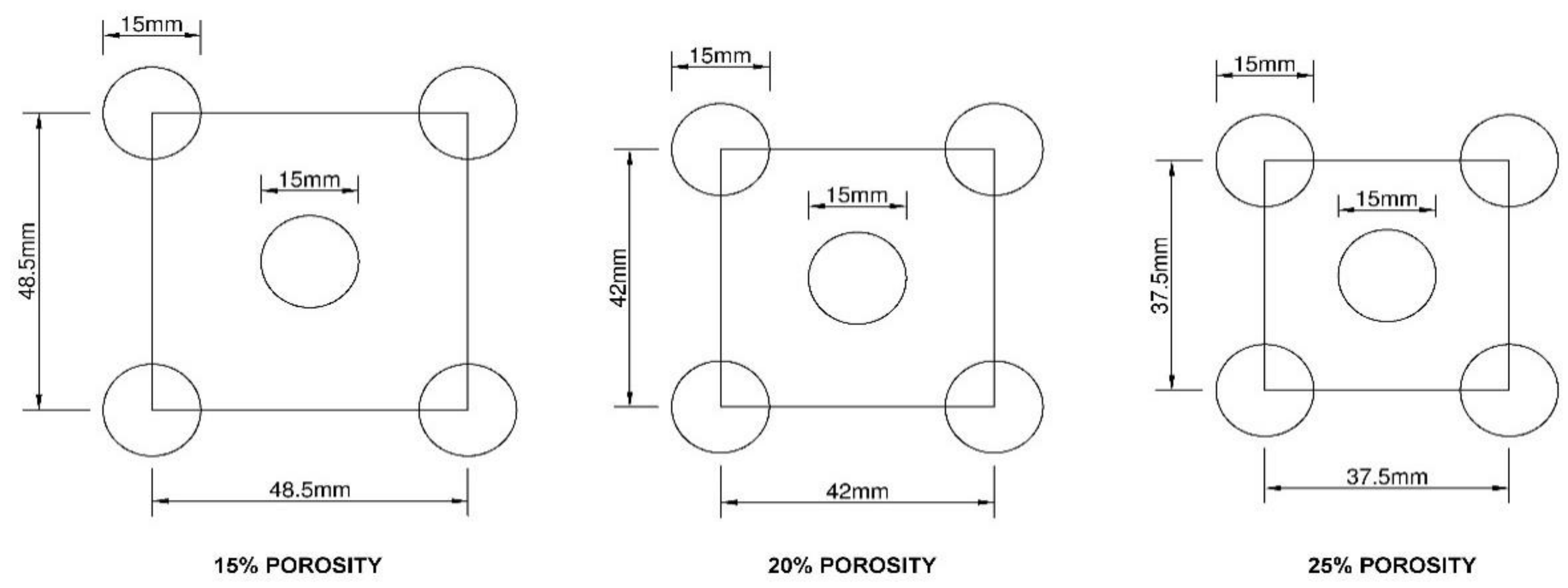


Fig. 4. Size of pores in baffles wall for different staggered position of 15%, 20% and 25% porosities

Table 1: Natural frequencies for modes in Shake Table Experiments

Mode (n)	Frequency (Hz)			Frequency ratio f / f_1			Amplitude (mm)
	h_s/l = 0.163	h_s/l = 0.325	h_s/l=0.488	h_s/l = 0.163	h_s/l = 0.325	h_s/l=0.488	
	0.4566	0.4566	0.4566	0.75359	0.588781	0.54150853	7.5
	0.4939	0.5363	0.5533	0.81515	0.691554	0.65619070	
	0.5312	0.6160	0.6499	0.87671	0.794326	0.77075426	
	0.5685	0.6957	0.7466	0.93827	0.897099	0.88543643	
1st	0.6059	0.7755	0.8432	1	1	1	
	0.7695	0.9266	0.9778	1.27001	1.194842	1.15962998	
	0.9331	1.0777	1.1122	1.54002	1.389684	1.31902277	
2nd	1.0967	1.2287	1.2468	1.81003	1.584397	1.47865275	
	1.2179	1.3281	1.3413	2.01007	1.712573	1.59072580	
	1.3391	1.4275	1.4358	2.2101	1.840748	1.70279886	
3rd	1.4604	1.5270	1.5302	2.4103	1.969052	1.81475332	
	1.5528	1.6069	1.6091	2.5628	2.072083	1.90832542	
	1.6452	1.6868	1.6880	2.7153	2.175113	2.00189753	
4th	1.7376	1.7666	1.7671	2.8678	2.278014	2.09570683	
	1.8130	1.8363	1.8366	2.99224	2.367892	2.17813092	
	1.8884	1.9060	1.9061	3.11669	2.457769	2.26055502	
5th	1.9637	1.9757	1.9757	3.24096	2.547518	2.34309772	

RESULTS AND DISCUSSION

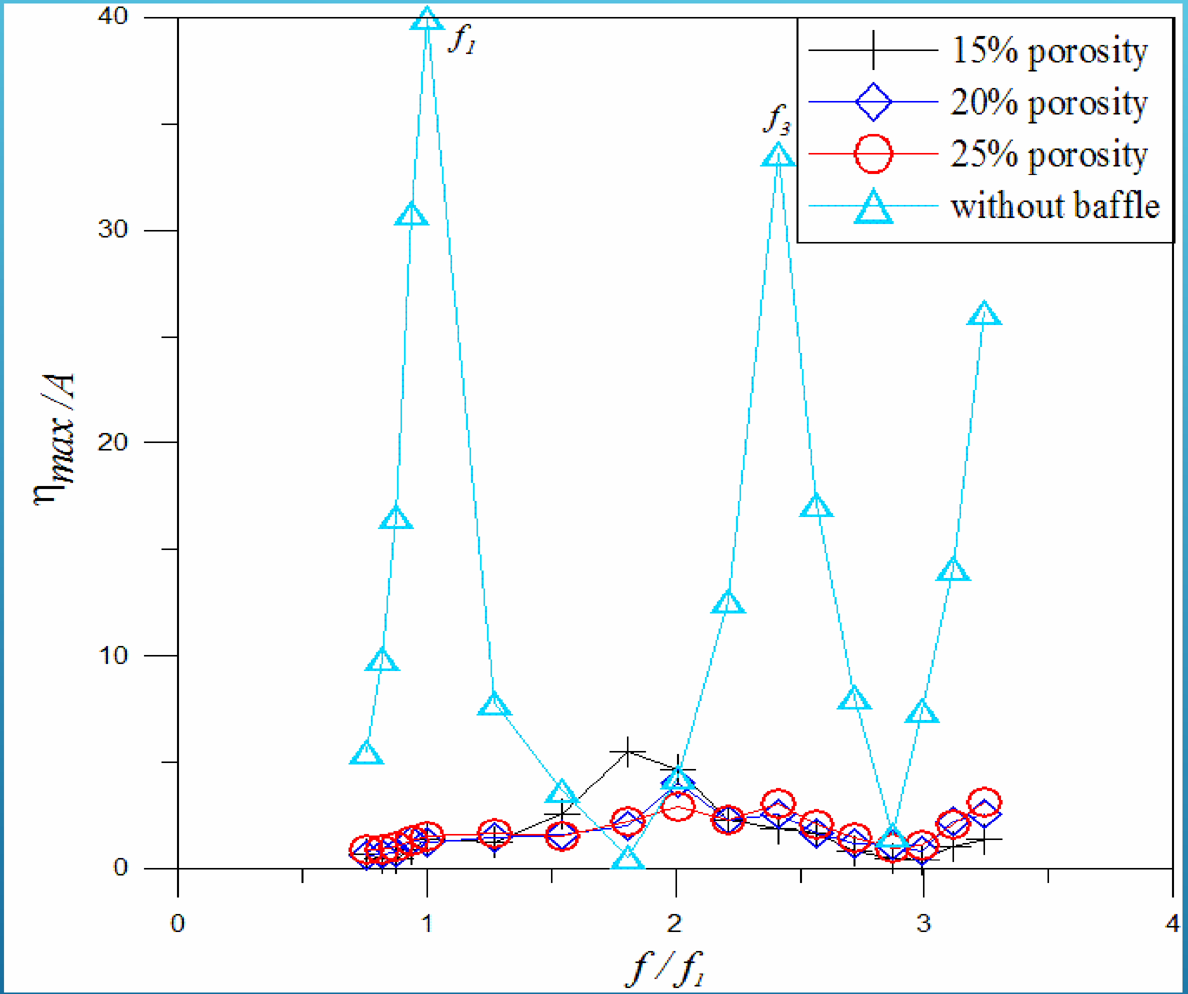


Fig. 5: Variation of η_{max} / A with and without porous baffle with various frequencies ratio for h_s/l = 0.163.

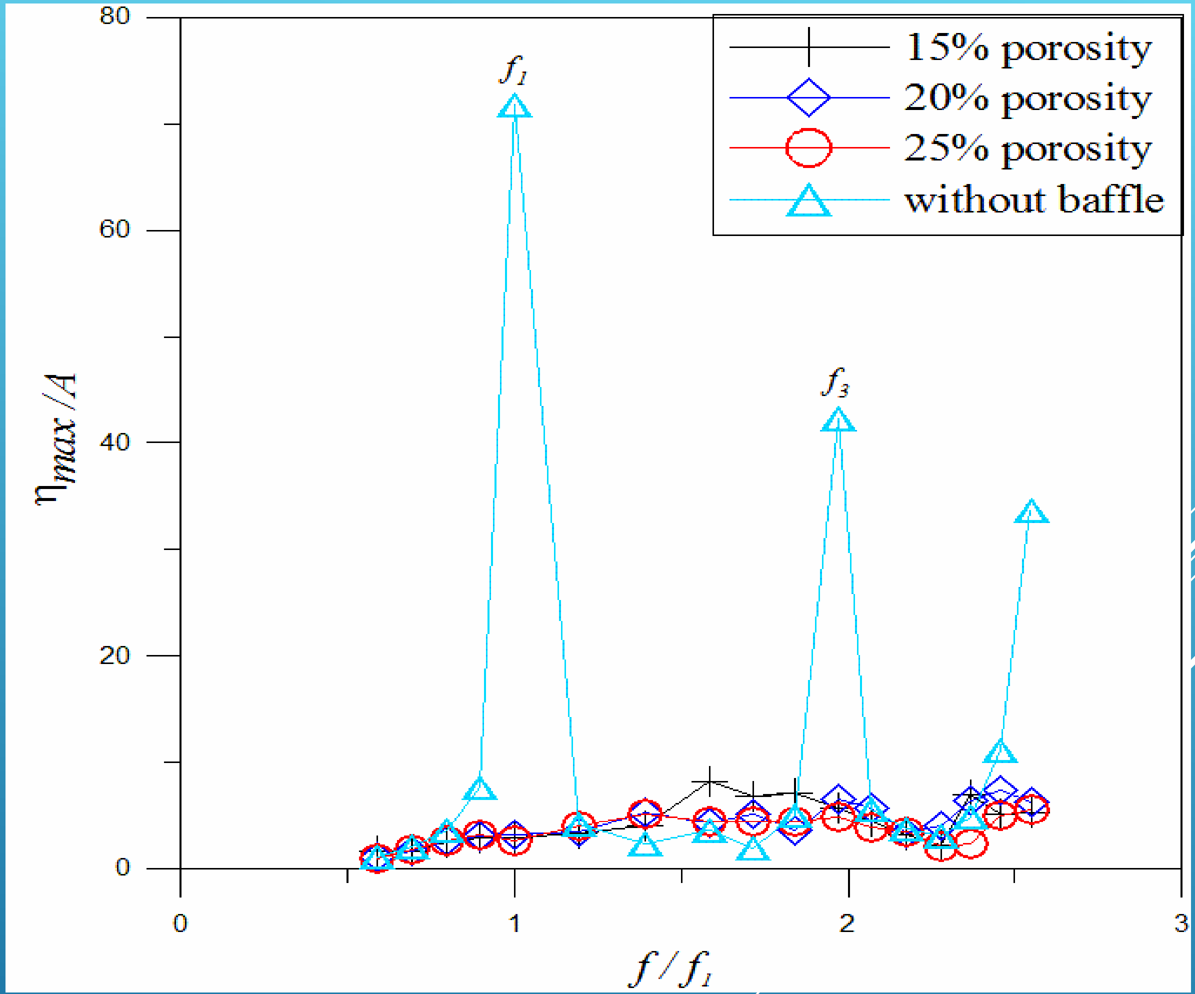


Fig. 6: Variation of η_{max} / A with and without porous baffle with various frequencies ratio for h_s/l = 0.325.

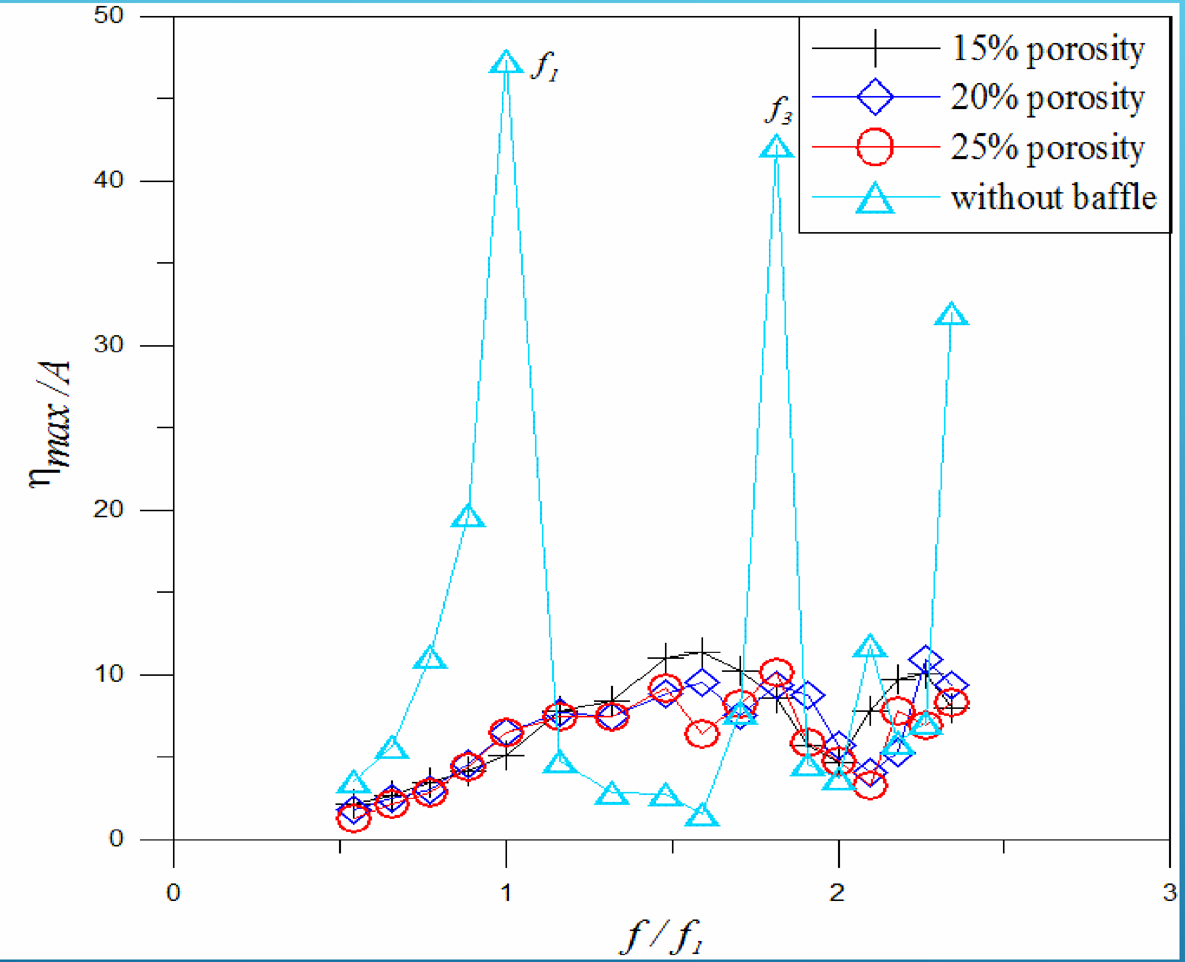


Fig. 7: Variation of η_{max} / A with and without porous baffle with various frequencies ratio for h_s/l = 0.488.

By considering without baffle case higher response are observed in the order of $f = f_1$, $f = f_3$ and $f = f_5$ i.e. at odd mode sloshing frequencies.

Maximum sloshing response is observed at $f = f_3$ for all the three porous conditions and $f = f_1$ which is for un baffled condition for all the water cases.

Maximum sloshing response elevation at $f = f_1$ is completely supressed by all porous baffle conditions. Though sloshing response is observed to be increased at $f = f_3$ and slightly decreases at $f = f_5$ due to the existence of porous baffle

CONCLUSION

It can be confirmed that the first mode of the natural frequency of the fluid in a rectangular tank is distinctly the resonant frequency, based on the results for the free surface elevations for different frequency ratios.

Increasing the excitation amplitudes and frequency increases the pressure response for both baffled and un baffled condition.

Baffles reduce natural sloshing frequencies and change sloshing mode shapes of free surface in a variety of ways. The degree of reduction and variation is enhanced with the growth of baffle lengths and heights.

It can be concluded that baffles significantly reduce the fluid motion and consequently the force response.

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