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Approximation method of the axial forces on network of connectors for modular hexagonal floating structures

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Abstract. Modular floating structures are normally made up of modules which are connected using network of connectors. These connectors are prone to heavy load due to facing the open sea wave. Previous studies have examined simple module configuration such as two rectangular form arranged linearly or three or seven hexagonal form arranged in an oblique pattern experimentally or using CFD and FE packages. Two challenges persist afterward; firstly, on applying the current findings to topology made up of a bigger number of modules and secondly on estimating the axial load values of connector at the preliminary design stage. This study developed an approximation method of axial force at the connector based on basic module configuration of hexagonal modular floating structure and axial load values determined by earlier studies. Four approximation methods vary with number of modules, arrangement and connectors facing 90^0 wave direction were proposed. Early analysis of the proposed method revealed that the axial force of the hexagonal modular connector is affected by the overall structure type and configuration such that hexagonal module-to-module connection requires higher axial load as compared to hexagonal modular cluster-to-cluster linkage due to load distribution amongst the connectors.

1. Introduction

Very large floating structure (VLFS) is applied in coastal and ocean engineering that expected rapid expansion function for the purpose of ocean space utilization. Presently, VLFS function as a floating airport, mobile offshore base, floating storage base, floating pier, floating entertainment base, etc., that gives benefit to the economy, safety and environment friendliness [17]. Therefore, the shape, size and flexibility have the potential to address special requirements in terms of design, analysis, construction, assembly and operation in achieving its various functions of VLFS. The early study dealt with the floating structure of VLFS as a single continuum structure and a variety of VLFS shape design have been proposed. Japanese Society of Steel Construction [1999] has suggested that hexagonal-shaped VLFSs be constructed to allow for easy expansion of the floating structure [7]. Tukuji et al. [2002] treated L-shaped, T-shaped, C-shaped and X-shaped VLFSs. Circular pontoon-type VLFSs are considered by Tukuji et al. (2002), Malte et al. [2003] and Watanabe et al. [2003]. In addition, Tay et el. [2012] proposed shape design of VLFS that grouping by two categories are comprised longish VLFSs with different fore/aft end shapes and comprises various polygonal VLFS plan shapes that are confined within a square boundary or a circle. However, there are disadvantages implicit in the use of single continuum structure, for instance, the huge bending moments which affected the safety of structures and the difficulty in manufacture [18]. Judging from the performance and the construction of floating structures, a multi-module of floating structure has been proposed that solved the problem being the easiness of changes of scale, structure and function and the feasibility of construction in a small-scale shipyard [11]. The multi- module of rectangular floating structure has been proposed by Fu [2007], Zhang [2015], and Eva et al [2012]. Currently, many of researcher proposes the multi–module hexagonal pontoon shape of VLFS [10,11,14,27] which allows for ease in term of expansion and mobility.

Multi–module floating structure consists of individual modules that are detached by connectors. By that, the connector becomes a key element of the multi-module of floating structure [31] has considering serious threats to the entire structure if connector failure happens. The four most common types of connector use by multi-module floating structure are fully flexible, vertical free, hinged connection and fully rigid connection [10]. Each type has its own advantages and disadvantages while it chose by implement with the VLFS function. In addition, Shixiao [2007] proposed four type model of multi-module VLFS that consider both modules and connectors may be modelled as either rigid or flexible are Rigid Module and Rigid Connector (RMRC), Rigid Module and Flexible Connector (RMFC), Flexible Module and Rigid Connector (FMRC) and Flexible Module and Flexible Connector (FMFC). Nowadays, many researchers applied flexible connector in designing their floating structure [3,23] to achieve a greater reduction in the hydroelastic response of the VLFS under wave action. Furthermore, the arrangement of multi-module floating structure also been considered in designing multi-module floating structure. Michailides et al. [2013] is studied deformable floating modules connected with flexible connectors in longitudinal and transverse directions arrangement. Kim [2007] also considers the arrangement of two floating structure unit such as tandem arranged units and side-by-side arranged units.

The study of the performance of multi-module floating structure requires the involvement of hydro elasticity in the corresponding numerical analysis that take into account the effect of both the flexibility of the structure and the presence of the connectors. The connection performs an important role in dynamic responses [31] that applied various method of numerical method calculation implemented by many researchers. Hisaaki et al. [1979] calculated the one-dimensional behavior of floating structures consisting of rigid modules with rigid or pin connectors for regular waves applied a strip method. Direct methods that solve directly the equation of motion using conceptually all nodes of the discretized system of the floating structure applied by Shixiao [2007], Kunihiro [2007], and Tay [2002]. The mode superposition methods, where the hydrodynamic analysis is separated from the eigenvalue analysis of the structure by propose the generalized modes in addition to the six rigid body modes applied by Eva et al [2012] and Michaielis [2013]. Presently, Zhang [2015] proposed a network modeling method that introduced to model the multi-module floating structures of arbitrary topological form where each module under the excitation of waves can be viewed as an oscillator and a connector is viewed as a coupling between the oscillators. While many of researcher focus in hydro elastic of multi-module floating structure, thus, there are limited researcher that study about connector internal load effect [2, 3,16, 21].

Tukuji et al. [2002] stated that the numerical computation of the hydroelastic behavior of VLFS precondition of very time consuming after finalize the estimation of elastic motion of a VLFS for the Mega- Float project in Japan, which adjusted into 5000-m length and 1500-m width within 6s of wave period. As a result, Riggs [1993] introduced approximate methods of hydroelastic analysis theories are applied to predict the dynamic response of 5- and 16-module very large floating structures in regular waves as an option to the more computationally demanding, fully three-dimensional flexible module, flexible connector model in which linear potential theory is adopted. Abd- Azm [2000] applied approximation method for the calculation hydrodynamics of floating pontoons under oblique waves through three equations of motion such as surge, heave and pitch. Xiantao et al [2017] introduced the stiffness approximation method for determining the natural frequency and the motion mode of multi-module floating structure. As concern by Linjian et al. [2017], the determination of stiffness connectors is also the key component influencing the hydrodynamic response of modules and the dynamic constraint force of connector.

2. Mathematical Proposed Method

2.1 *Arrangement of hexagonal modular floating structure*

Circular modular floating structure topology made up of one clusters of hexagonal modules have been selected and each cluster is made up of seven modules. Three stages of the approximation method that defines its mathematical framework are, firstly, identification of Endo's [1997] linear configurations on the given modular floating structure topology, secondly, the determination of connectors' network for the configurations and, thirdly, the determination of axial load on the connectors.

As for Stage 1, the possible overall configuration of a modular floating structure modules depends on the shape of its module. Common shapes are square, rectangular, hexagonal and circular. Modules will be connected using connectors, flexible or otherwise, to form the preferred cluster. Square and rectangular modules are normally connected in matrix form; 2X2, 3X3, 6X6, etc. as a cluster. Hexagonal modules can be connected linearly in a matrix form or obliquely to form a circular topology. A circular module is normally proposed as a large stand-alone but connected to other stand-alone circular using means other than the conventional connectors. Figure 1 show hexagonal modules arranged in oblique configuration by Kunihiro [2007]. Takujumi et al. [2016] propose modular hexagonal module arranged in linear and centralized configuration.

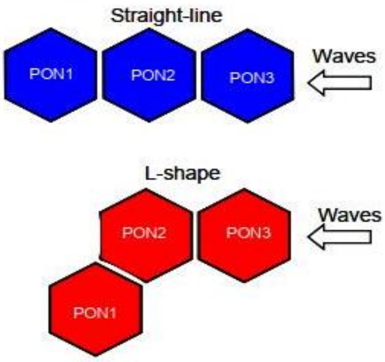

Figure 1. Hexagonal module arranged in straight line and oblique configuration by Kunihiro [2007]

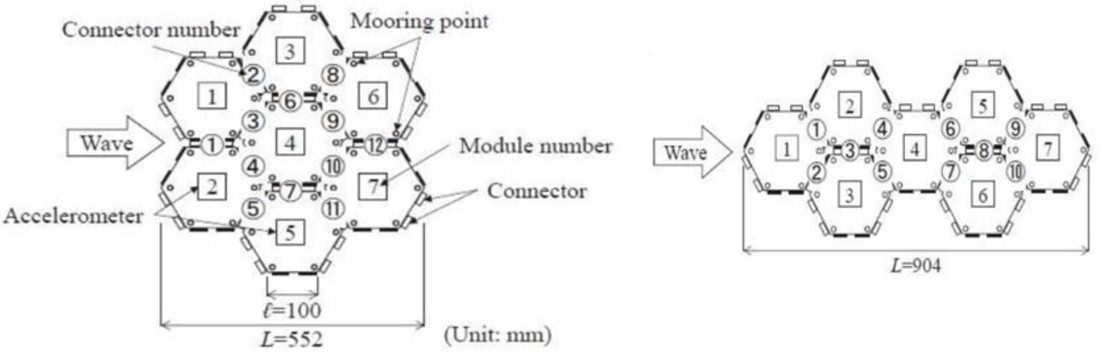

Figure 2. Hexagonal module arranged in linear and centralized configuration by Takujumi [2016]

Basic linear configuration by Endo [1997] adopted by Eva et al. [2015], which consists of two rectangular pontoon modules, are later mapped on the overall hexagonal modular floating structure configuration. Figure 3, Figure 4, Figure 5 and Figure 6 illustrate the 4 mapping strategies for a hexagonal modular floating structure cluster. The two rectangular pontoon configurations refer to Eva [2015] because later the secondary data experiment of axial load calculated by Eva adopted in this mathematical formulation.

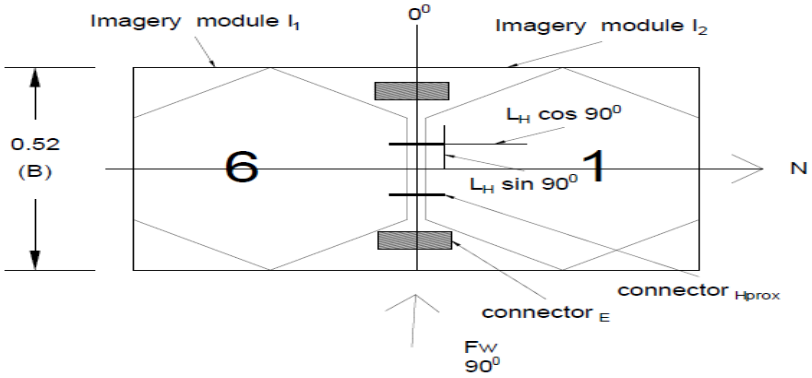

Figure 3. Endo 1 mapping two hexagonal modular with two rectangular modular by Eva et al. [2015]

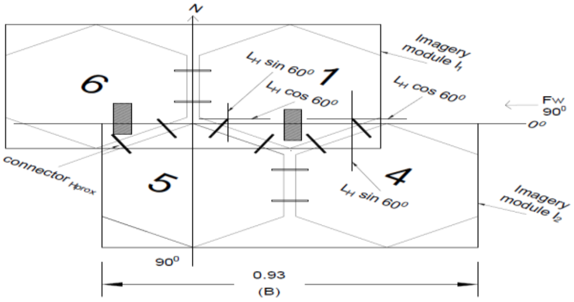

Figure 4. Endo 2 mapping four hexagonal modular with two rectangular modular by Eva et al. [2015]

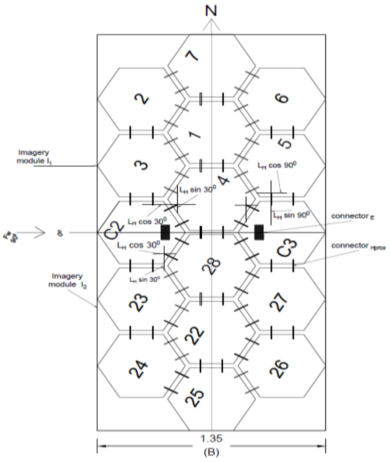

Figure 5. Endo 3 mapping two cluster hexagonal modular with two rectangular modular by Eva et al. [2015]

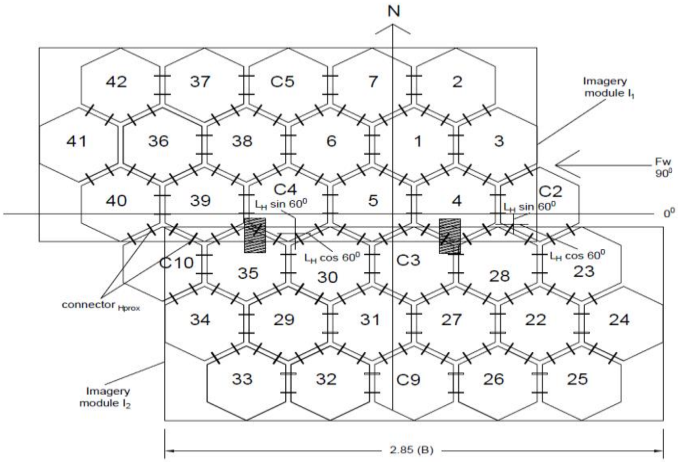

Figure 6. Endo 4 mapping four cluster hexagonal modular with two rectangular modular by Eva et al.[2015]

2.2 *The Algorithm*

The first mapping, here in after referred to as Endo1, is for two hexagonal modules, module 1 and module 6 which are in a linear configuration similar to Endo's [1997]. That also matches the configuration used by Eva's [2015] for the experimental determination of the axial load on the two connectors holding two rectangular modules with wave coming from 90° direction as shown. As such, for a similar set of environmental conditions, it is safe to assume that the load on connectors holding the hexagonal modules is approximately the same as the loads holding Eva's [2015] rectangular modules. Correction for physical difference between the two shapes is assumed handled by the value B/λ ; *B* being the breadth of the module. The value B for B/λ for the hexagonal module is the projected breadth on which the connectors are attached. λ is wavelength impacting the hexagonal modular floating structure. Plots of axial load against B/λ by Eva [2015] are for 3 wave directions (θ); 90°, 60° and 45° with respect to the axial line drawn along the length of the connector. It is to be highlighted that, theoretically, there should be no axial load on the connectors when the wave is impacting the connector perpendicularly. However, Eva [2015] detected connector loadings for that wave since the net effect of the wave on the VLFS is kiosk, 3D motion.

For $\text{Endo1}_{90}{}^{o}$, the two connectors holding the hexagonal modules should experience the same load experiences by the two Eva's [2015] connectors show in Figure 3. Hence,

$$2L_{C/E/90/\text{new } B/\lambda} = 2L_{C/H/90/(m6\text{-}m1)} \quad (1)$$

$$\text{i.e} \qquad L_{C/H/90//(m6\text{-}m1)} = L_{C/E/90//\text{new } B/\lambda} \quad (2)$$

Where $L_{C/E//90/\text{new } B/\lambda}$ is the load experiences by the two connectors holding Eva's [2015] rectangular modules, and to be read from the plot of load against B/λ experimentally determined by Eva [2015], and $L_{C/H/90//(m6\text{-}m1)}$ is the load experiences by the two connectors holding the hexagonal modules.

For $\text{Endo2}_{90}{}^{o}$ mapping (Figure 4) the loads on the network of six connectors holding the four hexagonal modules are equivalent to two connectors holding two Eva's [2015] rectangular modules each of which represent two hexagonal modules. The general expression for the axial load on connectors for $\text{Endo2}_{90}{}^{o}$ mapping is derived as follows.

The resolved component of $L_{C/H}$ in the axial (north-south) direction (south being +ve), is:F_x

$$2L_{C/H/90/(m1\text{-}m50)} \cos 60 + 2L_{C/H/90/(m1\text{-}m4)} \cos 30 + 2L_{C/H/90/(m6\text{-}m5)} \cos 30 \quad (3)$$

Likewise, the resolved components of $L_{C/H}$ in the east-west direction (east being +ve), is:

$$2\, L_{C/H/90/(m1\text{-}m5)} \sin 60 - 2L_{C/H/90/(m1\text{-}m4)} \sin 30 - 2L_{C/H/90/(m6\text{-}m5)} \sin 30 \quad (4)$$

Assuming that all connectors experience the same load, i.e

$$L_{C/H/90/(m1\text{-}m50)} = L_{C/H/90/(m1\text{-}m4)} = L_{C/H/90/(m6\text{-}m5)} = L_{C/H/90} \quad (5)$$

Hence, the resolved component of $L_{C/H}$ in the axial (north-south) direction

$$F_X = 2L_{C/H/90} \cos 60 + 4L_{C/H/90} \cos 30$$
$$= (1+2\sqrt{3})\ L_{C/H/90} \quad (6)$$

and the resolved component of $L_{C/H}$ in the east-west direction

$$F_Y = 2L_{C/H/90}\sin 60 - 4L_{C/H/90}\sin 30 \\ = (-2+\sqrt{3})\ L_{C/H/90} \qquad (7)$$

Based on the argument given above that the connectors will experience some load even though the wave is impacting perpendicular to the connectors, equation (6) should not, in any case, equate to zero. The $L_{C/H/90}^{o}$ as the axial force is the force that acts in the axis direction of connector facing to wave direction. The $L_{C/E//90/\text{new } B/\lambda}$ is the new axial force was exacted by extrapolation the secondary data of axial load from Eva [2015] using exponential trend graph equation. The axial force connector was calculated and this shall be:

$$(1+2\sqrt{3})\ L_{C/H/90} = 2\ L_{C/E//90/\text{new } B/\lambda} \qquad (8)$$

For $\mathrm{Endo3}_{90}^{o}$ the mapping is to cater for cluster-to-cluster connection; each cluster comprises of seven hexagonal modules and one additional modules as in Figure 5. Take note of the thirty-four connecting required to establish a perfect connection between cluster. Each cluster is assumed as one Eva's (2015) rectangular module and as such the load experience by the network of eighteen connectors holding the hexagonal modules is equivalent to two Eva's [2015] connectors. The general expression for the axial load on connectors for $\mathrm{Endo3}_{90}^{o}$ mapping is derived as follows.

The resolved component of $L_{C/H/90}$ in the axial (north-south) direction (south being +ve), is:F_x

$$2L_{C/H/90/(m23\text{-}mc2)}\cos 90 + 2L_{C/H/90/(mc2\text{-}m3)}\cos 90 + 2L_{C/H/90/(m28\text{-}mc2)}\cos 30 + 2_{LC/H/90/(mc2\text{-}m4)}\cos 30 \\ + 2L_{C/H/90/(m28\text{-}m4)}\cos 90 + 2L_{C/H/90/(m28\text{-}mc3)}\cos 30 + 2L_{C/H/90/(mc3\text{-}m4)}\cos 30 + 2_{LC/H/90/(m27\text{-}mc3)}\cos 90 \\ + 2L_{C/H/90/(mc3\text{-}m5)}\cos 90 \qquad (9)$$

Likewise, the resolved components of $L_{C/H/90}$ in the east-west direction (east being +ve), are:

$$2L_{C/H/90/(m23\text{-}mc2)}\sin 90 + 2\ L_{C/H/90/(mc2\text{-}m3)}\sin 90 + 2L_{C/H/90/(m28\text{-}mc2)}\sin 30 - 2L_{C/H/90/(mc2\text{-}m4)}\sin 30 + \\ 2L_{C/H/90/(m28\text{-}m4)}\sin 90 - 2L_{C/H/90/(m28\text{-}mc3)}\sin 30 + 2L_{C/H/90/(mc3\text{-}m4)}\sin 30 + 2L_{C/H/90/(m27\text{-}mc3)}\sin 90 + \\ 2L_{C/H/90/(mc3\text{-}m5)}\sin 90 \qquad (10)$$

With the same assumption that all connectors of modules experience the same load, equation 9 becomes

$$F_X = 10L_{C/H/90}\cos 90 + 8L_{C/H/90}\cos 30 \\ = 4\sqrt{3}\ L_{C/H/90} \qquad (11)$$

The $L_{C/H/90}^{o}$ for $\mathrm{Endo3}_{90}^{o}$ as the axial force is calculated and this shall equate with load value from Eva (2015) as expressed below.

$$4\sqrt{3}\ L_{C/H/90} = 2\ _{LC/E/90/\text{new } B/\lambda} \qquad (12)$$

Endo 4_{90}^{o} maps two clusters connected together and assumed as similar to one of Eva's [2015] rectangular pontoon with another two connected clusters as shown in Figure 6. Two modules have been introduced for the purpose of perfecting the circular topology and making the connection better. In such arrangement the load on the pair of Eva's [2015] connector is sustained by a network of eleven pairs of connectors holding the hexagonal modules together. The general expression for the axial load on connectors for Endo 4_{90}^{o} mapping is derived as follow.

The resolved component of $L_{C/H/\theta}$ in the axial (north-south) direction (south being +ve), is:F_x

$$2L_{C/H/90/(m23\text{-}mc2)}\cos 60 + 2L_{C/H/90/(m23\text{-}m4)}\cos 60 + 2L_{C/H/90/(m28\text{-}m4)}\cos 60 + 2L_{C/H/90/(m28\text{-}m5)}\cos 60 + \\ 2L_{C/H/90/(mc3\text{-}m5)}\cos 60 + 2L_{C/H/90/(mc3\text{-}mc4)}\cos 60 + 2L\ _{C/H/90/(m30\text{-}m4)}\cos 60 + {}_{2L\ C/H/90/(m30\text{-}m39)}\cos 60 \\ + 2L_{C/H/90/(m35\text{-}m39)}\cos 60 + 2L_{C/H/90/(m35\text{-}m40)}\cos 60 + 2L_{C/H/90/(mc10\text{-}m40)}\cos 60 \qquad (13)$$

The assumption that all connectors experience the same value of load thus allowing (13) to be simplified as

$$F_X = 22\ L_{C/H/90}\cos 60 \\ = 11\ L_{C/H/90} \qquad (14)$$

Likewise, the resolved components of $L_{C/H}$ in the east-west direction (east being +ve), are:

$$2L_{C/H/90/(m23-mc2)}\sin 60 - 2L_{C/H/90/(m23-m4)}\sin 60 + 2L_{C/H/90/(m28-m4)}\sin 60 - 2L_{C/H/90/(m28-m5)}\sin 60 + 2L_{C/H/90/(mc3-m5)}\sin 60 - 2L_{C/H/90/(mc3-mc4)}\sin 60 + 2L_{C/H/90/(m30-mc4)}\sin 60 - 2L_{C/H/90/(m20-m39)}\sin 60 + 2L_{C/H/90/(m35-m39)}\sin 60 - 2L_{C/H/90/(m35-m40)}\sin 60 + 2L_{C/H/90/(m10-m40)}\sin 60 \quad (15)$$

And the same assumption allows (15) to be simplified as

$$F_Y = 12\,L_{C/H/90}\sin 60 - 10\,L_{C/H/90}\sin 60$$
$$= \sqrt{3}\quad L_{C/H/90} \quad (16)$$

Likewise, the $L_{C/H/90}{}^{o}$ for Endo$4_{90}{}^{o}$ as the axial force is calculated and this shall equate with load value from Eva (2015) as expressed in Equation (16). Table 1 organized the final axial force expressions derived.

$$11\,L_{C/H/90} = 2\,_{LC/E/90/new\,B/\lambda} \quad (17)$$

Table 1. The final axial force expressions derived according to each circular configuration.

TOPOLOGY MAPPING	NORTH-SOUTH COMPONENT	EAST-WEST COMPONENT
Endo1$_{90}$^{o}	$L_{C/H/90}$	$L_{C/H/90}$
Endo2$_{90}$^{o}	$(1+2\sqrt{3})L_{C/H/90}$	$(-2+2\sqrt{3})L_{C/H/90}$
Endo3$_{90}$^{o}	$4\sqrt{3}L_{C/H/90}$	$10\,L_{C/H/90}$
Endo4$_{90}$^{o}	$11L_{C/H/90}$	$\sqrt{3}\,L_{C/H/90}$

3. Axial Load Connector Analysis

Normally the length of a floating structure is a concern in determining of hydroelastic of floating structure, however, in this research, the breadth of floating structure is taken into charge. This is because the breadth of floating structure is linked to the connector directly facing the wave direction. The breadth of floating increases due to the expansion of modular floating structures from one module linked with one module (Endo 1 and Endo 2) toward a linked cluster with other clusters (Endo 3 and Endo 4). Furthermore, before this modular floating only deals with linear configuration and side-by-side configuration as the function of floating airport and oil storage. Currently, the habitable modular floating structure as an artificial island demands enlarged modules linked as clusters that form a circular configuration.

The increasing number of modules linked together causes the raised number of network connectors. The network of connectors configuration in rectangular and square floating structure layout did not complex as in the hexagonal modular floating structure. Thus, the approximation method explores to development of an easy way for a designer to determine an estimation of axial force for one connector due to complicated module configuration.

The results of the present axial connector load for hexagonal modular floating structure calculated using the approximation method are shown in Figure 7. The breadth of Endo 1, Endo 2, Endo 3 and Endo 4 are 0.52m, 0.93m, 1.35m and 2.85m. From this result, the increasing breadth of the floating structure will decrease the axial force of the connector due to distributed load via many numbers of connectors. Thus, one module linked to one module as Endo 1 needs a higher axial load compared to linked cluster by cluster as Endo 4.

However, this research only takes into account the stiffness same as Eva et al [2015] paper is a concern as an extrapolation of secondary data axial force is extracted to apply in this approximation method. The approximation method load analysis influenced by stiffness has been done by other researchers.

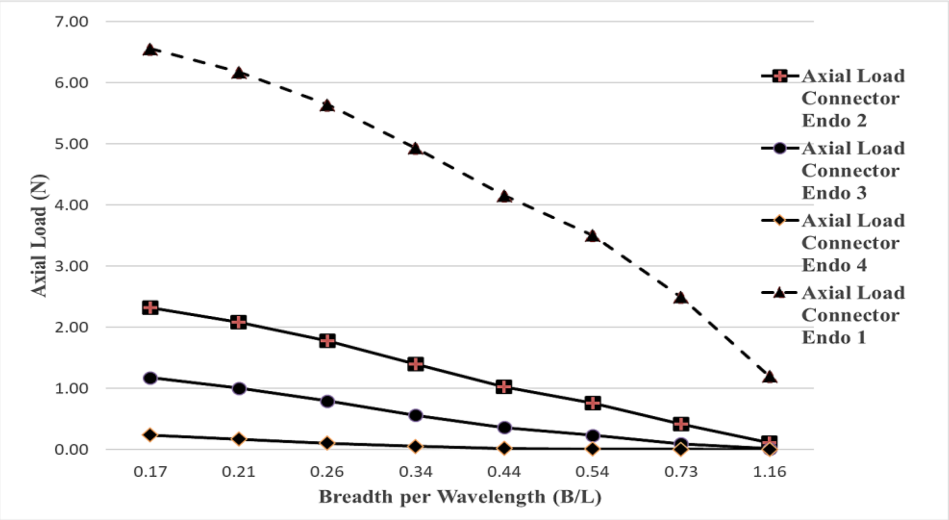

Figure 7. Axial connector force for hexagonal modular floating structure facing 90^0 wave direction

4. Discussion

4.1 *Advantages and strength of the proposed method*

The whole idea of this research is to establish a reference on an estimation of axial load for flexible connector for modular hexagonal floating structures. It has been considered an issue because the connector system is related to the relative motion between modular floating structure modules and is able to sustain forces as a result of wave motion. Furthermore, the connector system is also a key component of a modular floating structure that influences the system safety therefore, the connection load and the dynamic behavior of the system in waves are seriously concerned in the conceptual design of a modular floating structure. Additionally, current methods of load analysis involved complicated mathematical models and techniques that take time to solve then simplified methods of analysis and models are a critical need for design practice.

Limited research has been carried out on the numerical evaluation of internal forces that affect various design parameters compared to hydroelastic behavior for modular floating structures [9]. Riggs and Ertekin [1993] state that the fundamental theories method shows the most accurate analysis technique however, the performance of theory to a larger size causes a large computational problem where the solution will pressure the state-of-the-art in computer technology. The approximation model technology provides a solution that balances the computation time and accuracy [28]. The approximation method for floating structure in terms of hydroelastic behavior [1,20,29] and load analysis in mooring [6, 25, 28] have been done by another researcher. However, the approximation method in connectors for floating structures has not been explored yet. On the other hand, the approximation method for axial load connectors in the building has been done by other researcher [12, 19, 30]. Thus, the idea of an approximation method for axial load analysis for connectors in modular floating structures has been proposed for easier and faster load analysis, especially for complex connector configurations such as in Endo 3 and Endo 4.

4.2 *Limitation and constraints of the proposed method*

Mostly, many researchers consider the rectangular shape of floating structures gradually design in charge of service applications such as floating airport, bridges, and oil storage facilities. Nowadays, the hexagonal shape is the dominant idea of floating structure functional for habitable as the floating artificial island. The shape of floating structure affected the arrangement layout of the modular floating structure which are in linear, side by side, or circular configurations. Thus, a modular hexagonal produces a circular arrangement layout and applied a network connector configuration because a hexagonal has six sides to connect with other modules rather than a rectangular or square shape that has four sides.

The connector load analysis resolved is often applied in a rectangular shape and it is difficult to find secondary data load analysis for other shapes such as hexagonal. In addition, the load analysis studied that splitting the internal connector force into axial force and shear force is a challenge to find it. Meanwhile, Tay et al [2012] have studied altered inscribed rectangular and square shapes with polygons such as hexagon, octagonal and etc to determine which shape that reducing hydroelastic behavior. Hence, the approximation method adopted the secondary data of axial load analysis done by Eva [2015] mapping inscribed rectangular shapes into hexagonal. However, there is some extra space while inscribed rectangular shape into hexagonal that cannot be avoided as shown in each Endo's at Figure 3, Figure 4, Figure 5, and Figure 6.

The internal forces of connectors can be studied with numerous design parameters such as the stiffness of connectors, geometrical dimensions, module layout, and wave field characteristics. Two types of secondary data commonly found in papers by other researchers are wave frequency versus load connector and wave direction versus load. Meanwhile, the expected result of the approximation method for axial load at hexagonal modular floating structure is produced in form of the breadth per wavelength versus axial as pursued by Eva et al. [2015]. Thus, it takes time to analyze the two common secondary data to make a comparison and continues with validating the data of the approximation method that had been determined for the hexagonal modular floating structure. This is because each researcher has their own geometrical dimension of floating structure, stiffness of connector, and wave direction facing the connector when they are conducting their numerical calculation, simulation software and also the experimental.

5. Conclusion

This paper presents a new method proposed as approximation method in calculating axial load for hexagonal modular floating structure. The approximation method concerns about axial load connector of hexagonal modular floating structure has been affected by module arrangement as take into account the linear and circular cluster configuration which also increase the number of connectors applied facing 90^0 wave direction. The increasing number of modules will increase number of connectors, however, the axial load decrease as the estimation one axial load connector in Endo 4 is lower than axial force in Endo 2 and Endo 3. The connector in Endo 1 is facing the same as wave direction 90^0 presumed did not to have any axial load however because this is secondary data from the experimental their have determined the value on it. The approximation method axial load will later continue to develop the mathematical formula axial load in facing 45^0 and 60^0 wave direction. In the future, the calculation axial load of the network connector for hexagonal floating structure by approximation method will be compared with other existing calculation methods and considering the new method in view of other shape of floating structure by exploiting numerical simulations using software such as ANSYS AQWA and ANSYS STATIC.

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