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DETERMINE THE COEFFICIENT OF STATIC WIND ON BRIDGE STRUCTURE

Made Suangga, Yanti, Irpan Hidayat*

Civil Engineering Department, Bina Nusantara University, K. H. Syahdan. 9, Kemanggisan, West Jakarta 11480, Indonesia

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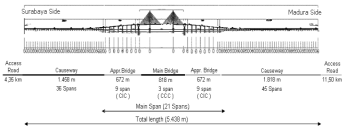
*Corresponding author
irpan@binus.edu

Graphical abstract



Abstract

A bridge structure should have a resistance to wind loads. The purpose of research is determine the coefficient of static wind load using computational calculations with FLUENT. The objects were modeled into a square 1x1 m, rectangle 2x1 m and circle diameter of 1 m with velocity of wind 10 m/s, 20 m/s and 30 m/s. The results described the value of the coefficient of drag force (C_D) for square shape larger than rectangle. The coefficient of drag force (C_D) for rectangular shape larger than circle. The value of coefficient of static wind do not depend on dimensional and wind speed. The coefficient value of wind static for Suramadu bridge which calculated by FLUENT Program and wind tunnel test have a similar chart patterns.

Keywords: Coefficient of static wind, bridge structure

1.0 INTRODUCTION

The bridge is a structure that serves as a means of connecting one place to another that separated by rivers, swamps, lakes, straits, channels, highways, railroads or other crossings. Along with the increase in human needs for transport and other facilities led to the need for the bridge has increased. Bridge quality must meet various standards that exist. One of the requirements that must be met is the resistance of the bridge in a weight-bearing.

The loading in a bridge consists of a static load and dynamic load. Static load having constant load or constant intensity which consists of dead load and live load. While the dynamic load has a load intensity that varies according to the time which consists of wind loads and seismic loads [3]. Wind load consists of static and dynamic wind loads. Determination of aerodynamic coefficients was carried out using balance method whereas aerodynamics forces are measured by strain gages based balance apparatus [1].

Static wind load has a coefficient of static wind that consists of coefficient of drag force (C_D), coefficient of lift force (C_L), and coefficient of moment (C_M). Calculation of the coefficient of static wind can be either computational or experimental wind tunnel test.

In this study, to be carried out studies effect the shape, dimensions, and the wind speed wind object against static coefficient calculated by FLUENT. Then do the comparison coefficient of static wind loads are calculated using the FLUENT computational with the results of wind tunnel tests.

2.0 LITERATURE REVIEW

Wind tunnel tests for long span bridge can be done by two methods: full model testing and sectional models testing. The steady aerodynamic forces, while the sectional dynamic testing as well as testing the full model is to get the parameters aero elastic phenomena.

FLUENT is one program CFD (Computational Fluid Dynamics). FLUENT program package consists of two programs, namely GAMBIT and FLUENT. GAMBIT

serves as a preprocessor while FLUENT serves as the main module.

3.0 METHODOLOGY

The study begins with the identification of problems that will be used as a study destination. Then followed by a study of the literature on long span bridge, wind loads, and the coefficient of static wind. Research conducted a study of the effect of the shape, dimensions, and the wind speed on the object to the coefficient of static wind with FLUENT. The objects modeled into a square 1x1 m, rectangular 2x1 m and circle diameter of 1 m with velocity of wind 10 m/s, 20 m/s and 30 m/s. The research also compared the value of the coefficient of static wind Suramadu bridge from FLUENT program with results of wind tunnel tests.

4.0 RESULTS AND DISCUSSION

4.1 Study Effect of Shape

The influence of shape to coefficient of static wind loads done by reviewing the shape of square, rectangle and circle. The wind speed on the three object are 10 m/s. The coefficient of static wind generated for square 1x1 m, as shown in Table 1.

Table 1 Coefficient of static wind square 1x1 m

α	C_D	C_L	C_M
-10	1,0904	-0,1782	-0,00197
-8	1,0703	-0,1696	-0,00084
-6	1,0419	-0,165	-0,00139
-4	1,025	-0,1305	-0,00241
-2	1,0217	-0,059	-0,00222
0	1,0214	-0,0084	-0,0008
2	1,0258	0,08493	0,00167
4	1,027	0,1287	0,00187
6	1,0416	0,1482	0,00216
8	1,057	0,172	0,00254
10	1,0854	0,1762	0,00287

From the table above, the largest coefficient of drag force (C_D) are at angle -10 and smallest are at angle 0. The largest coefficient of lift force (C_L) are at angle -10 and smallest are at angle 0. The largest coefficient of moment (C_M) are angle -10 and smallest are at angle 0. The coefficient of static wind generated for rectangle 2x1 m, as shown in Table 2.

Table 2 Coefficient of static wind rectangle 2x1 m

α	C_D	C_L	C_M
-10	0,97	-0,289	-0,00139
-8	0,968	-0,2587	-0,0028
-6	0,9671	-0,212	-0,00428
-4	0,96043	-0,1609	-0,00303
-2	0,95725	-0,124	-0,0035
0	0,9554	-0,0031	-0,00016
2	0,9574	0,09835	-0,00202
4	0,96071	0,1454	-0,00124
6	0,9672	0,16366	0,000425
8	0,968	0,1976	0,001072
10	0,971	0,234	0,002906

From the table above, the largest coefficient of drag force (C_D) are at angle -10 and smallest are at angle 0. The largest coefficient of lift force (C_L) are at angle -10 and smallest are at angle 0. The largest coefficient of moment (C_M) are angle -10 and smallest are at angle 0. The coefficient of static wind generated for circle diameter of 1 m, as shown in Table 3:

Table 3 Coefficient of static wind circle diameter of 1 m

α	C_D	C_L	C_M
-10	0,35427	-0,002051	-0,000014
-8	0,36865	0,0078636	-0,000028
-6	0,36455	0,011628	-0,000023
-4	0,3628	0,013129	-0,000025
-2	0,35211	0,015996	-0,003504
0	0,35048	0,019437	-0,003886
2	0,3392	0,02	-0,00202
4	0,337	0,021388	-0,0012398
6	0,322	0,022982	0,0004247
8	0,31458	0,02116	0,001072
10	0,31601	0,02209	0,002906

From the table above, the largest coefficient of drag force (C_D) are at angle -10 and smallest are at angle 0. The largest coefficient of lift force (C_L) are at angle -10 and smallest are at angle 0. The largest coefficient of moment (C_M) are angle -10 and smallest are at angle 0.

Based on study the influence of shape, the largest coefficient of drag force (C_D) on the angle of attack wind -10 to 10 are square 1x1 m, then rectangle 2x1 m and circle diameter of 1 m. The largest coefficient of lift force (C_L) on the angle of attack wind -10 to 2 are circle diameter of 1 m, then square 1x1 m and rectangle 2x1 m. The largest coefficient of lift force (C_L) on the angle of attack wind 2 to 10 are circle diameter of 1 m, then rectangle 2x1 m and square 1x1 m. The value of the coefficient of moment (C_M) on the angle of attack wind -10 to 10 to the object square 1x1 m, rectangle 2x1 m and circle diameter of 1 m average near 0,001 with a relatively small margin.

4.2 Study Effect of Dimension

The study of the dimensions of the value of the coefficient of static wind load done by enlarging the dimensions to 2 times and 4 times the initial dimension of the object. The wind speed used 10 m/s. Square shape used to study the effect of the dimensions of 3 pieces each measuring that 1x1 m, 2x2 m and 4x4 m. The value of coefficient of static wind generated by FLUENT to study the effect of the dimensions of a square object is shown in the following Table 4.

Table 4 Coefficient of static wind study effect of dimension of square

a	Square 1x1 m			Square 2x2 m			Square 4x4 m		
	C_D	C_L	C_M	C_D	C_L	C_M	C_D	C_L	C_M
-10	1,09	-0,18	-0,002	1,09	-0,18	-0,002	1,09	-0,18	-0,002
-8	1,07	-0,17	-0,001	1,07	-0,17	-0,001	1,07	-0,17	-0,001
-6	1,04	-0,16	-0,001	1,04	-0,16	-0,001	1,04	-0,16	-0,001
-4	1,02	-0,13	-0,002	1,02	-0,13	-0,002	1,02	-0,13	-0,002
-2	1,02	-0,06	-0,002	1,02	-0,06	-0,002	1,02	-0,06	-0,002
0	1,02	-0,01	-0,001	1,02	-0,01	-0,001	1,02	-0,01	-0,001
2	1,03	0,08	0,002	1,03	0,08	0,002	1,03	0,08	0,002
4	1,08	0,13	0,002	1,08	0,13	0,002	1,08	0,13	0,002
6	1,04	0,15	0,002	1,04	0,15	0,002	1,04	0,15	0,002
8	1,06	0,17	0,003	1,06	0,17	0,003	1,06	0,17	0,003
10	1,09	0,18	0,003	1,09	0,18	0,003	1,09	0,18	0,003

The value of coefficient of drag force (C_D) square 1x1 m same with square 2x2 m and 4x4 m. The value of coefficient of lift force (C_L) square 1x1 m same with square 2x2 m and 4x4 m. The value of coefficient of moment (C_M) square 1x1 m same with square 2x2 m and 4x4 m.

Rectangle used to study the effect of the dimensions of 3 pieces each measuring that 2x1 m, 4x2 m and 8x4 m. The value of coefficient of static wind generated by FLUENT to study the effect of the dimensions of a rectangle object is shown in the following Table 5.

Table 5 Coefficient of static wind study effect of dimension of rectangle

a	Rectangle 2x1 m			Rectangle 4x2 m			Rectangle 8x4 m		
	C_D	C_L	C_M	C_D	C_L	C_M	C_D	C_L	C_M
-10	0,97	-0,29	-0,001	0,97	-0,29	-0,001	0,97	-0,29	-0,001
-8	0,97	-0,26	-0,003	0,97	-0,26	-0,003	0,97	-0,26	-0,003
-6	0,97	-0,21	-0,004	0,97	-0,21	-0,004	0,97	-0,21	-0,004
-4	0,96	-0,16	-0,003	0,96	-0,16	-0,003	0,96	-0,16	-0,003
-2	0,96	-0,12	-0,003	0,96	-0,12	-0,003	0,96	-0,12	-0,003
0	0,95	-0,01	-0,001	0,95	-0,01	-0,001	0,95	-0,01	-0,001
2	0,96	0,01	-0,002	0,96	0,01	-0,002	0,96	0,01	-0,002
4	0,96	0,14	0,00	0,96	0,14	0,00	0,96	0,14	0,00
6	0,97	0,16	0,00	0,97	0,16	0,00	0,97	0,16	0,00
8	0,97	0,20	0,001	0,97	0,20	0,001	0,97	0,20	0,001
10	0,97	0,23	0,003	0,97	0,23	0,003	0,97	0,23	0,003

The value of coefficient of drag force (C_D) rectangle 2x1 m same with rectangle 4x2 m and 8x4 m. The value of coefficient of lift force (C_L) rectangle 2x1 m same with rectangle 4x2 m and 8x4 m. The value of coefficient of moment (C_M) rectangle 2x1 m same with rectangle 4x2 m and 8x4 m.

Circle used to study the effect of the dimensions of 3 pieces each measuring that circle diameter of 1 m, 2 m, and 4 m. The value of coefficient of static wind generated by FLUENT to study the effect of the dimensions of a circle object is shown in the following Table 6.

Table 6 Coefficient of static wind study effect of dimension of circle

a	Circle diameter 1 m			Circle diameter 2 m			Circle diameter 8x4 m		
	C_D	C_L	C_M	C_D	C_L	C_M	C_D	C_L	C_M
-10	0,35	0,00	0,000	0,35	0,00	0,000	0,35	0,00	0,000
-8	0,37	0,00	0,000	0,37	0,00	0,000	0,37	0,00	0,000
-6	0,36	0,01	0,000	0,36	0,01	0,000	0,36	0,01	0,000
-4	0,36	0,01	0,000	0,36	0,01	0,000	0,36	0,01	0,000
-2	0,35	0,02	-0,003	0,35	0,02	-0,003	0,35	0,02	-0,003
0	0,35	0,02	-0,004	0,35	0,02	-0,004	0,35	0,02	-0,004
2	0,34	0,02	-0,002	0,34	0,02	-0,002	0,34	0,02	-0,002
4	0,34	0,02	-0,001	0,34	0,02	-0,001	0,34	0,02	-0,001
6	0,32	0,02	0,000	0,32	0,02	0,000	0,32	0,02	0,000
8	0,32	0,02	0,001	0,32	0,02	0,001	0,32	0,02	0,001
10	0,32	0,02	0,003	0,32	0,02	0,003	0,32	0,02	0,003

The value of coefficient of drag force (C_D) circle diameter of 1 m same with circle diameter of 2 m and 4 m. The value of coefficient of lift force (C_L) circle diameter of 1 m same with circle diameter of 2 m and 4 m. The value of coefficient of moment (C_M) circle diameter of 1 m same with circle diameter of 2 m and 4 m.

From the study of the effect of the dimensions, square 1x1 m, 2x2 m and 4x4 m have coefficient of drag force (C_D) same. Rectangular 2x1 m, 4x2 m and 8x4 m have coefficient of lift force (C_L) same. Circle diameter of 1 m, 2 m and 4 m have coefficient of moment (C_M) same. The coefficient of static wind computed FLUENT computational program does not depend on dimensions.

4.3 Study Effect of Wind Speed

Study of the effect of wind speed on the coefficient of static wind studies carried out with a speed of 10 m/s, 20 m/s and 30 m/s (Wind Resistant Design of Bridge in Japan, 2012). The object that will be used are square 1x1 m, rectangle 2x1 m and circle diameter of 1 m.

Square 1x1 m is used to study the effect of speed measuring. The value of coefficient of static wind generated by FLUENT to study the effect of wind speed 10 m/s, 20 m/s and 30 m/s to the object shown in the following Table 7.

Table 7 Coefficient of static wind study effect of wind speed square

a	Wind speed 10 m/s			Wind speed 20 m/s			Wind speed 30 m/s		
	C_D	C_L	C_M	C_D	C_L	C_M	C_D	C_L	C_M
-10	1,09	-0,18	-0,002	1,09	-0,18	-0,002	1,09	-0,18	-0,002
-8	1,07	-0,17	-0,001	1,07	-0,17	-0,001	1,07	-0,17	-0,001
-6	1,04	-0,16	-0,001	1,04	-0,16	-0,001	1,04	-0,16	-0,001
-4	1,02	-0,13	-0,002	1,02	-0,13	-0,002	1,02	-0,13	-0,002
-2	1,02	-0,06	-0,002	1,02	-0,06	-0,002	1,02	-0,06	-0,002
0	1,02	-0,01	-0,001	1,02	-0,01	-0,001	1,02	-0,01	-0,001
2	1,03	0,08	0,002	1,03	0,08	0,002	1,03	0,08	0,002
4	1,08	0,13	0,002	1,08	0,13	0,002	1,08	0,13	0,002
6	1,04	0,15	0,002	1,04	0,15	0,002	1,04	0,15	0,002
8	1,06	0,17	0,003	1,06	0,17	0,003	1,06	0,17	0,003
10	1,09	0,18	0,003	1,09	0,18	0,003	1,09	0,18	0,003

The value of coefficient of drag force (C_D) square with wind speed 10 m/s same with wind speed 20 m/s and 30 m/s. The value of coefficient of lift force (C_L) square with wind speed 10 m/s same with wind speed 20 m/s and 30 m/s. The value of coefficient of moment (C_M) square with wind speed 10 m/s same with wind speed 20 m/s and 30 m/s.

Rectangle 2x1 m is used to study the effect of speed measuring. The value of coefficient of static wind generated by FLUENT to study the effect of wind speed 10 m/s, 20 m/s and 30 m/s to the object shown in the following Table 8.

Table 8 Coefficient of static wind study effect of wind speed rectangle

a	Wind speed 10 m/s			Wind speed 20 m/s			Wind speed 30 m/s		
	C_D	C_L	C_M	C_D	C_L	C_M	C_D	C_L	C_M
-10	0,97	-0,29	-0,001	0,97	-0,29	-0,001	0,97	-0,29	-0,001
-8	0,97	-0,26	-0,003	0,97	-0,26	-0,003	0,97	-0,26	-0,003
-6	0,97	-0,21	-0,004	0,97	-0,21	-0,004	0,97	-0,21	-0,004
-4	0,96	-0,16	-0,003	0,96	-0,16	-0,003	0,96	-0,16	-0,003
-2	0,96	-0,12	-0,003	0,96	-0,12	-0,003	0,96	-0,12	-0,003
0	0,95	-0,01	-0,001	0,95	-0,01	-0,001	0,95	-0,01	-0,001
2	0,96	0,01	-0,002	0,96	0,01	-0,002	0,96	0,01	-0,002
4	0,96	0,14	0,00	0,96	0,14	0,00	0,96	0,14	0,00
6	0,97	0,16	0,00	0,97	0,16	0,00	0,97	0,16	0,00
8	0,97	0,20	0,001	0,97	0,20	0,001	0,97	0,20	0,001
10	0,97	0,23	0,003	0,97	0,23	0,003	0,97	0,23	0,003

The value of coefficient of drag force (C_D) rectangle with wind speed 10 m/s same with wind speed 20 m/s and 30 m/s. The value of coefficient of lift force (C_L) rectangle with wind speed 10 m/s same with wind speed 20 m/s and 30 m/s. The value of coefficient of moment (C_M) rectangle with wind speed 10 m/s same with wind speed 20 m/s and 30 m/s. Circle diameter of 1 m is used to study the effect of speed measuring. The value of coefficient of static wind generated by FLUENT to study the effect of wind speed 10 m/s, 20 m/s and 30 m/s to the object shown in the following Table 9.

Table 9 Coefficient of static wind study effect of wind speed circle

a	Wind speed 10 m/s			Wind speed 20 m/s			Wind speed 30 m/s		
	C_D	C_L	C_M	C_D	C_L	C_M	C_D	C_L	C_M
-10	0,35	0,00	0,000	0,35	0,00	0,000	0,35	0,00	0,000
-8	0,37	0,00	0,000	0,37	0,00	0,000	0,37	0,00	0,000
-6	0,36	0,01	0,000	0,36	0,01	0,000	0,36	0,01	0,000
-4	0,36	0,01	0,000	0,36	0,01	0,000	0,36	0,01	0,000
-2	0,35	0,02	-0,003	0,35	0,02	-0,003	0,35	0,02	-0,003
0	0,35	0,02	-0,004	0,35	0,02	-0,004	0,35	0,02	-0,004
2	0,34	0,02	-0,002	0,34	0,02	-0,002	0,34	0,02	-0,002
4	0,34	0,02	-0,001	0,34	0,02	-0,001	0,34	0,02	-0,001
6	0,32	0,02	0,000	0,32	0,02	0,000	0,32	0,02	0,000
8	0,32	0,02	0,001	0,32	0,02	0,001	0,32	0,02	0,001
10	0,32	0,02	0,003	0,32	0,02	0,003	0,32	0,02	0,003

The value of coefficient of drag force (C_D) circle with wind speed 10 m/s same with wind speed 20 m/s and 30 m/s. The value of coefficient of lift force (C_L) circle with wind speed 10 m/s same with wind speed 20 m/s and 30 m/s. The value of coefficient of moment (C_M) circle with wind speed 10 m/s same with wind speed 20 m/s and 30 m/s.

From the study of the effect of the wind speed, square with wind speed 10 m/s, 20 m/s and 30 m/s have coefficient of drag force (C_D) same. Rectangular with wind speed 10 m/s, 20 m/s and 30 m/s have coefficient of lift force (C_L) same. Circle with wind speed 10 m/s, 20 m/s and 30 m/s have coefficient of moment (C_M) same. The coefficient of static wind computed FLUENT computational program does not depend on wind speed.

4.4 Suramadu Bridge

Suramadu bridge is the longest bridge in Indonesia at this time. This bridge crosses the Madura Strait, connecting Java Island (Surabaya) and Madura Island (in Bangkalan, exactly eastern Kamal). This bridge provides a 4 lane 2-way width of 3.5 m with 2 emergency lane width of 2.75 m. In addition it also provides special lanes for motorcyclists in each outer side of the bridge. Figure 1 shows the longitudinal bridge consists of three segments, causeway, bridge approach and the main bridge. The overall length of the bridge is 5438 m with a width of approximately 30 m.

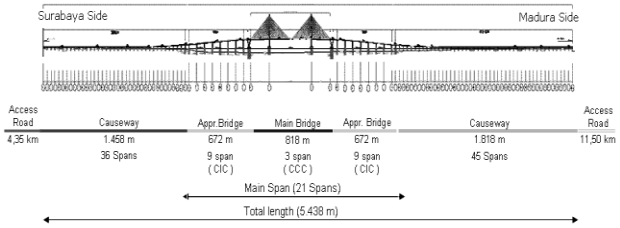


Figure 1 Longitudinal of Suramadu bridge

Figure 2 show the main bridge deck has a width of 30 m that consists of 2 main box girder. Each box girder has a height of 2.8 m and a width of 2.3 m. Details the longitudinal of bridge deck can be seen in the following picture.

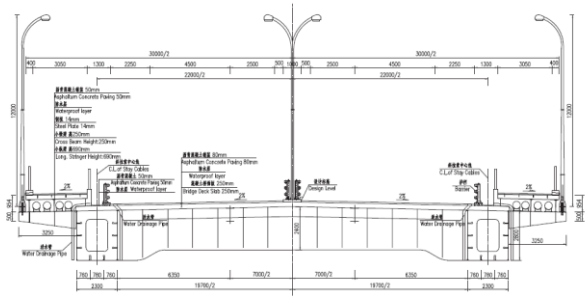


Figure 2 Bridge deck cross section

Figure 3 show the Bridge deck section actual simplified in order to facilitate the calculation of the FLUENT program.

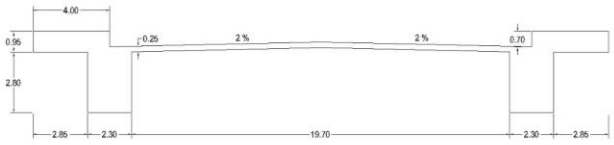


Figure 3 Simple model bridge deck cross section

GAMBIT created geometry of section, meshing and defining the type of limit. The geometry begins with inputting the coordinates of the points. The input coordinate could be shown in Table 10.

Table 10 Cross section bridge deck coordinates

No.	Coordinates (x, y, z)
1	(0, 0, 0)
2	(0, -0.95, 0)
3	(2.85, -0.95, 0)
4	(2.85, -3.75, 0)
5	(4.0, 0, 0)
6	(4.0, -0.7, 0)
7	(5.15, -0.95, 0)
8	(5.15, -3.75, 0)
9	(15.0, -0.73, 0)
10	(15.0, -0.48, 0)
11	(24.85, -0.95, 0)
12	(24.85, -3.75, 0)
13	(26.0, 0, 0)
14	(26.0, -0.7, 0)
15	(27.15, -0.95, 0)
16	(27.15, -3.75, 0)
17	(30.0, 0, 0)
18	(30.0, -0.95, 0)

After the coordinate points are made, then the points are interconnected to form a cross sectional geometry bridge deck as shown in Figure 4

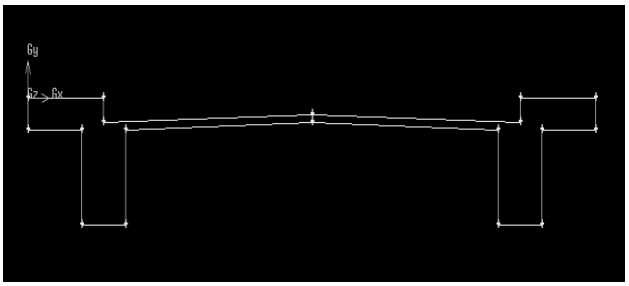


Figure 4 Sectional geometry bridge deck

After creating the geometry, the next step is to create a mesh. Mesh used in the study are maps and pave. To an area near the object mesh used is the folder while being much with the object mesh used is pave. Results mesh near objects can be seen in the Figure 5.

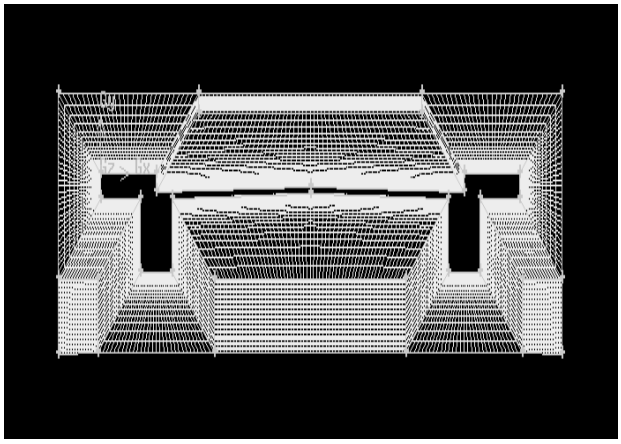


Figure 5 Mesh near object

While the results of the mesh away from the objects shown in the Figure 6 below.

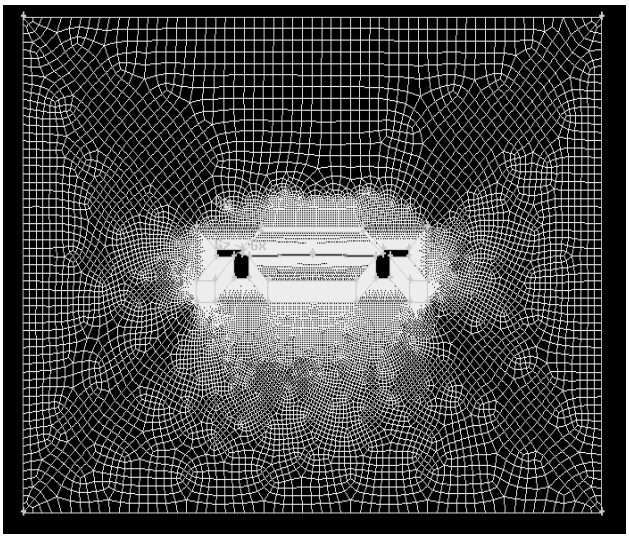


Figure 6 Mesh far from object

The boundary conditions used consist of inlet velocity (inlet, outlet, upper, lower) and the wall. Velocity inlet is used to define the flow velocity and scalar quantities other side of the entrance flow. These boundary conditions are incorporated speed specification method using component which includes the value of the fluid velocity at the entrance to each component of the coordinate axes. Wall used as a wall to the fluid flow in the channel or can be called as well as the channel wall. Wall can also be used as a barrier between the area of the fluid (liquid and gas) and solids as shown in Figure 7.

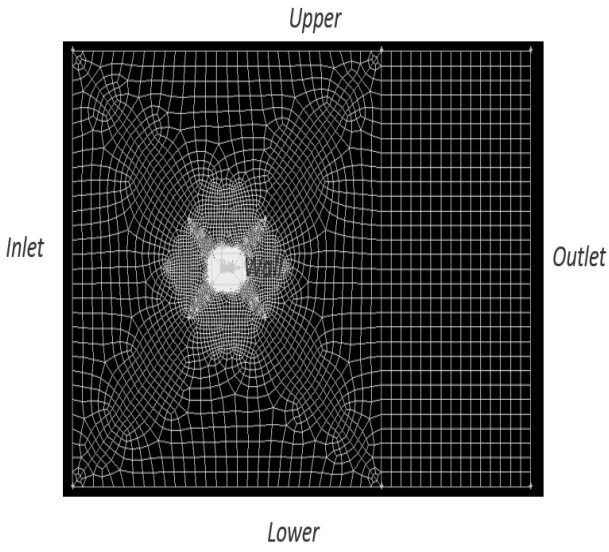


Figure 7 Boundary conditions

FLUENT is done on the determination of several parameters, namely:

- Solver Version : 2D single precision
- Formulation Solver : Pressure Based
- Model Turbulent : Laminar
- Material : Air
- Operating Conditions : 1 atm
- Boundary Conditions :
- Inlet : Velocity Inlet7 m/s
- Outlet : Velocity Inlet7 m/s
- Upper : Velocity Inlet7 m/s
- Lower : Velocity Inlet7 m/s
- Wall : Wall
- Control Solution : Simple
- Initialization : Inlet
- Iteration : 10000

The coefficient of static wind generated by computational calculations with FLUENT program as shown in Table 11 and Table 12.

Table 11 Coefficient of static wind Suramadu bridge with FLUENT

a	C_D	C_L	C_M
-10	1,068	-0,479	-0,022
-9	1,063	-0,465	-0,016
-8	1,061	-0,426	-0,019
-7	1,051	-0,426	-0,017
-6	1,045	-0,393	-0,015
-5	1,028	-0,333	-0,011
-4	1,026	-0,276	-0,011
-3	1,008	-0,237	-0,008
-2,5	0,987	-0,160	-0,007
-2	0,967	-0,161	-0,007
-1,5	0,961	-0,144	-0,005
-1	0,957	-0,098	-0,003
-0,5	0,956	-0,047	-0,017
0	0,955	0,000	0,000
0,5	0,956	0,046	0,002
1	0,957	0,098	0,034
1,5	0,961	0,113	0,005
2	0,967	0,124	0,007
2,5	0,986	0,134	0,007
3	1,008	0,145	0,008
4	1,025	0,146	0,011
5	1,036	0,158	0,012
6	1,042	0,151	0,015
7	1,048	0,153	0,016
8	1,053	0,163	0,018
9	1,054	0,167	0,019
10	1,058	0,177	0,021

The value of coefficient of drag force (C_D) Suramadu bridge with FLUENT on the angle 0 is 0,955. The value of coefficient of lift force (C_L) is 0. The value of coefficient of moment (C_M) is 0.

Suramadu wind tunnel test is done with the wind speed of 7 m/s. The coefficient of static wind generated as follows:

Table 12 Coefficient of static wind Suramadu bridge wind tunnel test

a	C_D	C_L	C_M
-10	1,986	-0,631	-0,072
-9	1,875	-0,584	-0,062
-8	1,811	-0,535	-0,05
-7	1,715	-0,483	-0,036
-6	1,637	-0,437	-0,022
-5	1,566	-0,394	-0,009
-4	1,52	-0,363	0,003
-3	1,423	-0,308	0,016
-2,5	1,385	-0,283	0,021
-2	1,362	-0,26	0,028
-1,5	1,308	-0,222	0,034
-1	1,257	-0,183	0,038
-0,5	1,251	-0,151	0,042
0	1,223	-0,11	0,042
0,5	1,21	-0,072	0,047
1	1,19	-0,034	0,049
1,5	1,191	0,000	0,05
2	1,216	0,038	0,054
2,5	1,236	0,076	0,057
3	1,253	0,101	0,058
4	1,34	0,148	0,058
5	1,47	0,218	0,057
6	1,587	0,25	0,061
7	1,738	0,314	0,063
8	1,862	0,355	0,064
9	1,951	0,373	0,063
10	1,982	0,362	0,06

The value of coefficient of drag force (C_D) Suramadu bridge from wind tunnel test on the angle 0 is 1,19. The value of coefficient of lift force (C_L) is -0,11. The value of coefficient of moment (C_M) is 0,042.

The value of coefficient of static wind Suramadu bridge from wind tunnel test [7] and computational calculated using the FLUENT program plotted into Figure 8 and Figure 9 as follows:

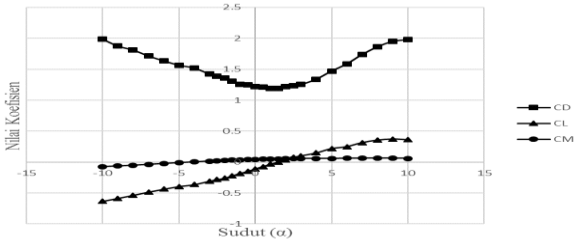


Figure 8 Coefficient of static wind Suramadu bridge from wind tunnel test

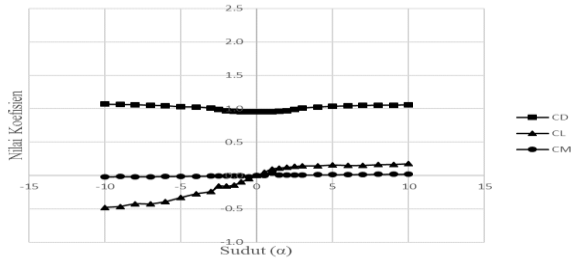


Figure 9 Coefficient of static wind Suramadu bridge with FLUENT

The coefficient of static wind Suramadu bridge calculated computational with FLUENT program has a chart pattern that is similar to the coefficient of static wind from wind tunnel test. But, the coefficient of static wind of FLUENT and wind tunnel tests are not the same. The coefficient of drag force (C_D), coefficient of lift force (C_L), coefficient of moment (C_M) were calculated using the program FLUENT is smaller than the coefficient of drag force (C_D), coefficient of lift force (C_L), coefficient of moment (C_M) from wind tunnel test. This is because the Suramadu bridge deck geometry that is modeled in FLUENT program has been simplified on the shape of the deck plan Suramadu bridge. In the wind tunnel test, the model replicated Suramadu bridge main span in accordance with the plan drawing Suramadu bridge.

5.0 CONCLUSION

This study obtained several conclusions, among others:

1. With Computational calculations with FLUENT, the largest coefficient of drag force (CD) on the angle of attack wind -10 to 10 are square 1x1 m, then rectangle 2x1 m and circle diameter of 1 m. The largest coefficient of lift force (CL) on the angle of attack wind -10 to 2 are circle diameter of 1 m, then square 1x1 m and rectangle 2x1 m. The largest coefficient of lift force (CL) on the angle of attack wind 2 to 10 are circle diameter of 1 m, then rectangle 2x1 m and square 1x1 m. The value of the coefficient of moment (CM) on the angle of attack wind -10 to 10 to the object square 1x1 m, rectangle 2x1 m and circle diameter of 1 m average near 0,001 with a relatively small margin.
2. With computational calculations with FLUENT program, the coefficient of static wind does not depend on the dimensions.
3. With computational calculations with FLUENT program, the coefficient of static wind does not depend on the wind speed.
4. Coefficient of static wind Suramadu Bridge used computational calculation with FLUENT and wind tunnel test result have similar pattern chat.

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