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Impact of Building Opening Design on Natural Ventilation Performance in Futsal Building at Surabaya

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ABSTRACT
In general, futsal buildings in urban areas have character that tends to maximize the field, a futsal building with a wide span appears that has 2,3 to 4 fields. Such conditions give rise to low wind speeds, causing problems with natural ventilation performance, especially ventilation rates and air distribution within the futsal building. This research is an experimental study using CFD simulation, with ANSYS 16.0 software. Model with 4 field with treatment ratio of inlet opening area to outlet opening ratio of 1:1, outlet opening position on the side and rear walls and openings configuration with a pattern of 1 outlet openings on each wall, having the highest ventilation rates, ie 27.97 m3/s. Model with 2 field have the highest air distribution conditions. Model 2 field with treatment ratio of inlet opening area to outlet opening area of 1/3:1, position of outlet openings on the side and rear walls and configuration of openings with a pattern of 1 outlet opening on each wall, having the highest air distribution condition, namely 86%.

KEYWORDS;- *opening design, futsal indoor, CFD simulation, natural ventilation*

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I. INTRODUCTION

Well-being conditions in humans can be realized if their health and comfort are good and in accordance with the standard, both in life, work and move places. As much as 90% of their life time is done in closed place (Jenkins, 2009). One of the activities carried out in a building or a closed room is sports, which generally have high ventilation requirements in it. The limited area of land in the city of Surabaya is one of the inhibiting factors for people to exercise, especially football (Republika, 2018). The community is looking for alternatives to channel their hobbies in sports with friends, one of them is by exercising futsal.

In general, futsal courts have smaller dimensions up to a quarter of the time a soccer field (25x15 meters). Referring to this dimension, the futsal building has the potential to form a field that is more flexible than a football stadium. This potential is used by futsal building owners to utilize the land as efficiently as possible by maximizing the number of fields. The tendency to maximize the number of fields on this land has consequences for causing a number of things, such as the basic coefficient of buildings in large buildings and the distance that coincides with surrounding buildings. Experimental research was conducted to formulate an indoor futsal building design concept, in order to have natural ventilation performance that meets the standards.

II. THEORETICAL REVIEW

Wind is one of the environmental aspects that make up a climate somewhere (Etheridge, 2012). According to the world meteorological agency climate is a series of several environmental aspects or meteorology that occur relatively routinely in a certain time, so as to form environmental characters in the range of hundreds of kilometres. In general, the climate is formed by radiation emitted by the surface of the local area (eg soil or water), so it is able to show the condition of air humidity in general the area.

In general in the context of microclimate, a terrain roughness condition can be divided into 4 namely Open Sea, Open Land, Sub Urban and Suburban (Aynsley, 1977). The greater the level of surface roughness of an area, the lower the wind speed value. According to Spirn (1986), in micro wind conditions in an area also influenced the road corridor in front of the building. The condition of the road corridor with $H/W \leq 1/3$ has a significant influence to direct the wind around the building to move in the direction of the condition of the road corridor. While the condition of the road corridor with $H/W \geq 2/3$ has a small effect in directing the wind around the building.

Natural ventilation is one of the important strategies in presenting good air quality in building. Natural ventilation with wind pressure is one of the passive cooling strategies suitable for use in the tropics where the amplitude of air temperature at night and during the day is relatively small. In warm humid tropical, comfort ventilation is required not only during the day but also at night. Some aspects of natural ventilation need to be considered in a building in the direction of air flow, the value of air flow and the supply of fresh air in the building (Defiana, 2016).

In ASHRAE 62.1-2013 standard, it has been determined that in the competition area an indoor sports building has a value of people outdoor air rate (Rp) of 10 L/s person and an area outdoor rate (Ra) value of 0.9 L/s m2 and the audience area has a value (Rp) of 3.8 L/s person and the area outdoor rate (Ra) value is 0.3 L/s m2. This value indicates that an indoor sports building is one type of building that has a high standard of fresh air supply compared to other types of buildings.

According to Allard (1998), the aspect ratio of inlet openings to the width of the outlet openings also has a significant effect on the velocity value of air flow in the building. If the wind comes in perpendicular to the building, the building envelope model with a ratio of inlet opening area to outlet opening area of 1:1 has a higher speed of up to 20% compared to the building envelope model with a ratio of inlet opening area to outlet opening area of 1/3:1/3. The difference in speed of air flow can increase to 25% when the wind comes oblique.
According to Awbi (2008), it is known that air flow in wide span buildings tends to move upwards, which is caused by the difference in pressure between openings in the lower part of the building and openings at the top of the building. Peren (2014) also stated that the building envelope model with the position of the outlet opening at the top of the building has a higher air flow velocity value compared to the building envelope model at the bottom or center of the building. These results indicate that the higher the position of the openings will increase the speed of air flow inside.

In addition to the conditions of the ventilation rates, another aspect that needs to be considered in the context of natural ventilation in buildings is the distribution of air in them. The greater the percentage of the area in the building that gets a fresh air supply, the better and able to present a healthy environment in the building. n general, areas close to the openings are areas that have good air distribution. This condition applies both to buildings with a one sided ventilation systems, cross ventilation (Peren, 2014).

One aspect of design that has an influence on the distribution of air in the building is the configuration of openings. Shetabivash (2015), stated that the building envelope model with configuration of openings which fused or extended on the walls of building had better air distribution conditions than the model of the building envelope with the configuration of openings divided into several sections on the walls of the building. In contrast, the configuration of openings divided into several parts has poor air distribution.

III. METHOD

Experimental research using ANSYS 16.0 software simulation. Environmental aspects or dependent variables in this study are ventilation rates and air distribution in buildings, while the design aspects or independent variables are building plan dimensions, ratio of inlet opening area to outlet opening area, outlet opening position and outlet opening configuration.

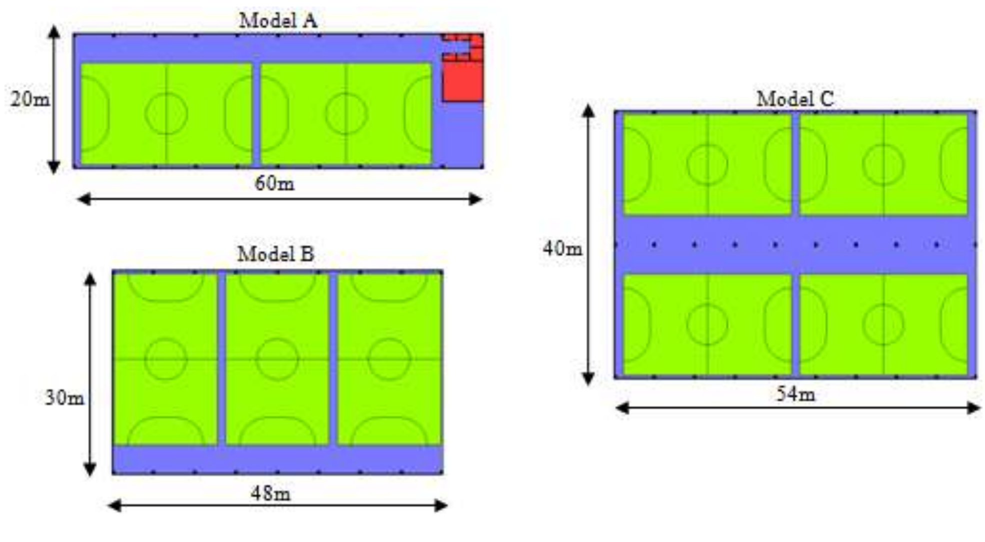

Figure 1 The Futsal Building Model Plan, A (2 Field), B (3 Field), and C (4 Field)
Population and research sample (See Figure. 1)

The futsal building population is a futsal building in the city of Surabaya. The research sample was taken from the population, by determining the limitation criteria for the sample object. This object will then be measured the speed and direction of the air flow inside. Some of the criteria for the sample object are :

a. Buildings do not use artificial ventilation systems
b. The natural ventilation system used in existing building is 1-sided natural ventilation which is assisted by chimney.
c. Has a minimum opening area of 6% of the floor area (according to air conditioning standards on SNI 03-3647-1994).
d. The building has a field with a number of 2,3 and 4 fields.
e. The building does not have a distance from the surrounding buildings, both with the side of the building and the back of the building. The considerable distance with the surrounding buildings is only on the front of the building.

Type	Inlet Area	Outlet Area	Ratio	Outlet Opening Position
A101	108 m2	36 m2	1 : 1/3	Right and left side walls
A102	108 m2	72 m2	1 : 2/3	Right and left side walls
A103	108 m2	108 m2	1 : 1	Right and left side walls
A104	36 m2	36 m2	1/3 : 1/3	Right and left side walls
A105	36 m2	72 m2	1/3 : 2/3	Right and left side walls
A106	36 m2	108 m2	1/3 : 1	Right and left side walls
B101	126 m2	42 m2	1 : 1/3	Right and left side walls
B102	126 m2	84 m2	1 : 2/3	Right and left side walls
B103	126 m2	126 m2	1 : 1	Right and left side walls
B104	42 m2	42 m2	1/3 : 1/3	Right and left side walls
B105	42 m2	84 m2	1/3 : 2/3	Right and left side walls
B106	42 m2	126 m2	1/3 : 1	Right and left side walls
C101	194.4 m2	64.8 m2	1 : 1/3	Right and left side walls
C102	194.4 m2	129.6m2	1 : 2/3	Right and left side walls
C103	194.4 m2	194.4 m2	1 : 1	Right and left side walls
C104	64.8 m2	64.8 m2	1/3 : 1/3	Right and left side walls
C105	64.8 m2	129.6m2	1/3 : 2/3	Right and left side walls
C106	64.8 m2	194.4 m2	1/3 : 1	Right and left side walls

Table 1 The Futsal Building Model Character, A (2 Field), B (3 Field), and C (4 Field)

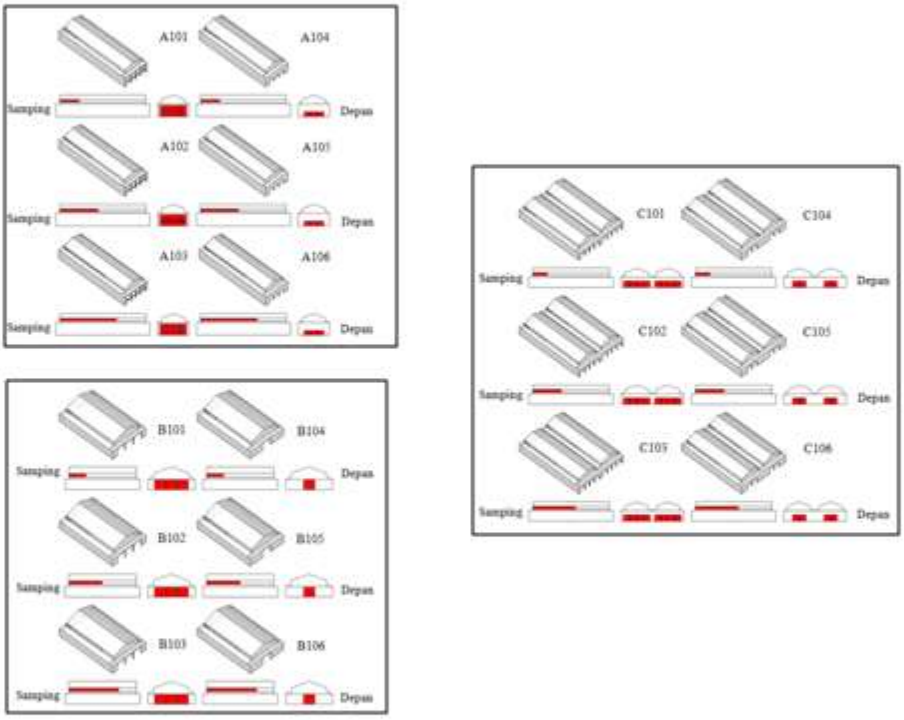

Figure 2 Experimental Treatment Model 1, A (2 Field), B (3 Field), and C (4 Field)
2. Experimental *Treatment* Model 1

The ratio of inlet opening area to outlet opening area is one of the variables observed in the study (See Table 1). The ratio of the inlet opening area to the outlet opening area used in this experiment refers to Allard (See Figure 2).

3. Experimental *Treatment* Model 2

The model in this treatment is determined to have the same ratio of inlet opening area to outlet opening area with the previous treatment, but there is a change in the position of the outlet opening (See Table 2). If in the previous treatment the position of the outlet opening is located on the side of the building, then in this treatment part of the position of the opening is on the back side of the building (See Figure 3).

4. Experimental *Treatment* Model 3

In this treatment, 3 configuration variations were carried out on each building (See Table 3). At this treatment, the ratio of inlet opening area to outlet opening area is set at 1:1 and 1/3:1. Because it tends to have a higher air flow than the others (Allard, 1998).

Type	Inlet Area	Outlet Area	Previous Outlet Position	Outlet Position Treatment
A201	108 m2	36 m2	2 side walls	2 side walls and rear wall
A202	108 m2	72 m2	2 side walls	2 side walls and rear wall
A203	108 m2	108 m2	2 side walls	2 side walls and rear wall
A204	36 m2	36 m2	2 side walls	2 side walls and rear wall
A205	36 m2	72 m2	2 side walls	2 side walls and rear wall
A206	36 m2	108 m2	2 side walls	2 side walls and rear wall
B201	126 m2	42 m2	2 side walls	Rear wall
B202	126 m2	84 m2	2 side walls	2 side walls and rear wall
B203	126 m2	126 m2	2 side walls	2 side walls and rear wall
B204	42 m2	42 m2	2 side walls	Rear wall
B205	42 m2	84 m2	2 side walls	2 side walls and rear wall
B206	42 m2	126 m2	2 side walls	2 side walls and rear wall
C201	194.4 m2	64.8 m2	2 side walls	2 side walls and rear wall
C202	194.4 m2	129.6m2	2 side walls	2 side walls and rear wall
C203	194.4 m2	194.4 m2	2 side walls	2 side walls and rear wall
C204	64.8 m2	64.8 m2	2 side walls	2 side walls and rear wall
C205	64.8 m2	129.6m2	2 side walls	2 side walls and rear wall
C206	64.8 m2	194.4 m2	2 side walls	2 side walls and rear wall

Table 2 The Futsal Building Model Character, A (2 Field), B (3 Field), and C (4 Field)

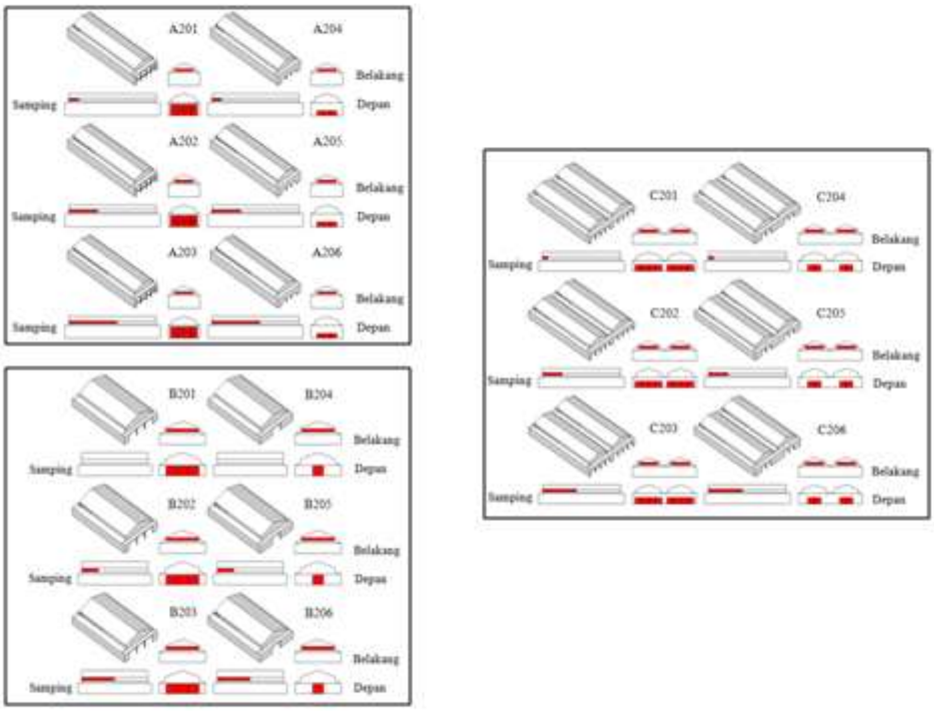

Figure 3 Experimental Treatment Model 2, A (2 Field), B (3 Field), and C (4 Field)

Type	Inlet Area	Outlet Area	Ratio	Outlet Configuration
A301	108 m2	108 m2	1 : 1	2
A302	108 m2	108 m2	1 : 1	6
A303	108 m2	108 m2	1 : 1	10
A304	36 m2	108 m2	1/3 : 1	2
A305	36 m2	108 m2	1/3 : 1	6
A306	36 m2	108 m2	1/3 : 1	10
B301	126 m2	126 m2	1 : 1	2
B302	126 m2	126 m2	1 : 1	6
B303	126 m2	126 m2	1 : 1	10
B304	42 m2	126 m2	1/3 : 1	2
B305	42 m2	126 m2	1/3 : 1	6
B306	42 m2	126 m2	1/3 : 1	10
C301	194.4 m2	194.4 m2	1 : 1	2
C302	194.4 m2	194.4 m2	1 : 1	6
C303	194.4 m2	194.4 m2	1 : 1	10
C304	64.8 m2	194.4 m2	1/3 : 1	2
C305	64.8 m2	194.4 m2	1/3 : 1	6
C306	64.8 m2	194.4 m2	1/3 : 1	10

Table 3 The Futsal Building Model Character, A (2 Field), B (3 Field), and C (4 Field)

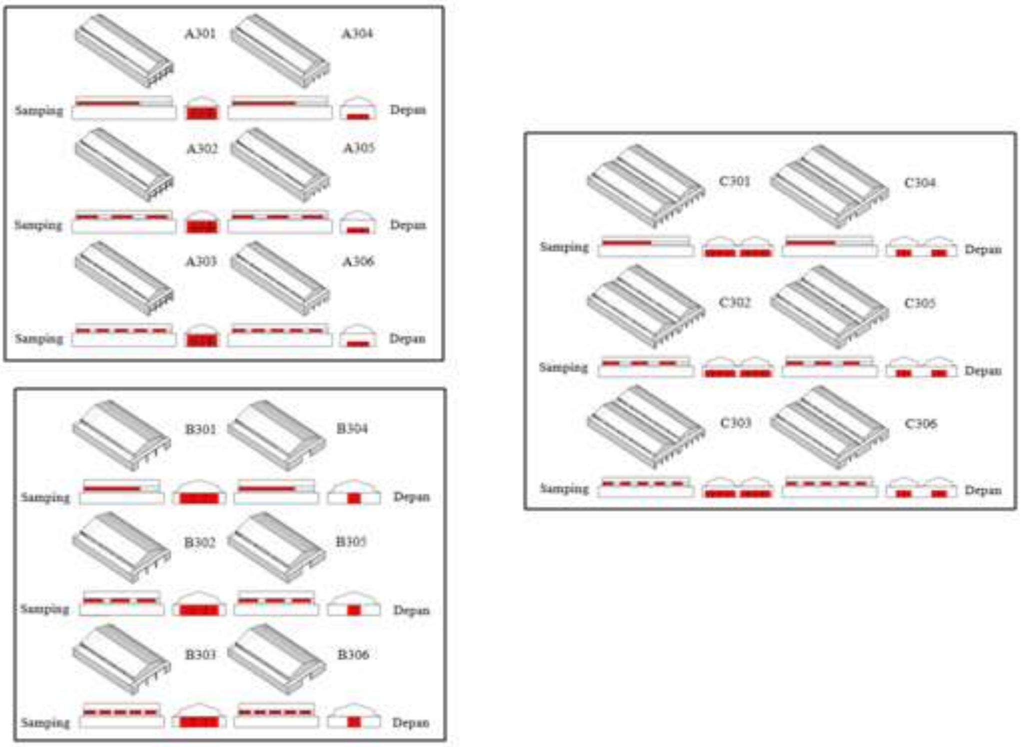

Figure 4 Experimental Treatment Model 3, A (2 Field), B (3 Field), and C (4 Field)

IV. RESULT

Experimental Treatment Model 1 Result

The simulation result in table 7 show that the highest ventilation rates are in the A103 model, which is around 12.096 m3/s. While the best air distribution is in the models A101 and A104, which is about 85% of the area which has ventilation rates above 1.086 m3/s. Unlike the 2-field model, the B103 (3 fields) and C103 (4 fields) models have the highest conditions both at the ventilation rates and the air distribution. The ventilation rates of the B103 dan C103 models are 17.043 m3/s and 24.19 m3/s respectively. While the air distribution in the B103 and C103 models is 72.5% and 75% respectively.

	Rp (L/s *person*)	Ra (L/s m2)	Plan Area (m2)	Occupancy Range	*Minimum Ventilation Rate* (L/s)	
					Min	Max
Play Area	10	0.9	750	10-20	775	875
Spectator Area	3.8	0.3	450	0-20	135	211
Total Ventilation Rates					910	1086

Table 4 Minimum Ventilation Rates at Model A (2 Fields)

	Rp (L/s *person*)	Ra (L/s m2)	Plan Area (m2)	Occupancy Range	*Minimum Ventilation Rate* (L/s)	
					Min	Max
Play Area	10	0.9	1125	10-30	11125	13125
Spectator Area	3.8	0.3	315	0-30	94.5	208.5
Total Ventilation Rates					1207	1521

Table 5 Minimum Ventilation Rates at Model B (3 Fields)

	Rp (L/s *person*)	Ra (L/s m2)	Plan Area (m2)	Occupancy Range	*Minimum Ventilation Rate* (L/s)	
					Min	Max
Play Area	10	0.9	1500	10-40	1450	1750
Spectator Area	3.8	0.3	660	0-40	198	350
Total Ventilation Rates					1648	2100

Table 6 Minimum Ventilation Rates at Model C (4 Fields)

Model	Air Flow (V)	Inlet Area (A)	*Ventilation Rate* Standard (m3/s)	Average *Ventilation Rates* (m3/s) (VxA)	Air Distribution Standard	Air Distribution Percentage
A101	0.06	108	1.086	6.426	70-80 %	85 %
A102	0.10	108	1.086	10.962	70-80 %	80 %
A103	0.11	108	1.086	12.096	70-80 %	75 %
A104	0.07	36	1.086	2.394	70-80 %	85 %
A105	0.07	36	1.086	2.646	70-80 %	75 %
A106	0.09	36	1.086	3.384	70-80%	70 %
B101	0.08	126	1.521	9.922	70-80%	59 %
B102	0.12	126	1.521	15.356	70-80%	72.5 %
B103	0.14	126	1.521	17.403	70-80%	72.5 %
B104	0.10	42	1.521	4.173	70-80%	30 %
B105	0.15	42	1.521	6.326	70-80%	33.75 %
B106	0.16	42	1.521	6.693	70-80%	30 %
C101	0.05	194.4	2.1	10.584	70-80 %	71 %
C102	0.10	194.4	2.1	18.9	70-80 %	76 %
C103	0.12	194.4	2.1	24.192	70-80 %	75 %
C104	0.06	64.8	2.1	4.032	70-80 %	52 %
C105	0.08	64.8	2.1	5.04	70-80 %	59 %
C106	0.11	64.8	2.1	7.488	70-80 %	68 %

Table 7 Ventilation Rates and Air Distribution at Model A (2 Fields), B (3 Fields), and C (4 Fields)

Experimental Treatment Model 2 Result

The simulation result in table 8 show that the average ventilation rates and the highest air distribution are in the A203 model, which is about 12.37 m3/s and 86% respectively. Furthermore, the B203 (3 Fields) and C203 (4 Fields) also have the highest condition both for ventilation rates and air distribution. The ventilation rates of the B203 and C203 models are 16.38 m3/s and 27.97 m3/s respectively. While the air distribution in the B103 and C103 models are 72% and 83% respectively.

1. Experimental Treatment Model 3 Result

The simulation result int table 9 show that the average ventilation rates and the highest air distribution are in the A301 model, which is around 10.58 m3/s and 77% respectively. Furthermore, the B301 (3 Fields) and C301 (4 Fields) also have the highest condition both for ventilation rates and air distribution. The ventilation rates of models B301 and C301 are 17.4 m3/s and 24.19 m3/s respectively. While the air distribution in the B301 and C301 models are 72.5% and 74% respectively.

Model	(V)	(A)	*Ventilation Rates* Standard (m3/s)	VxA (m3/s)	Air Distribution Standard	Air Distribution Percentage
A201	0.10	108	1.086	10.96	70-80 %	77 %
A202	0.10	108	1.086	11.34	70-80 %	86 %
A203	0.11	108	1.086	12.37	70-80 %	86 %
A204	0.06	36	1.086	2.27	70-80 %	78 %
A205	0.09	36	1.086	3.24	70-80 %	80 %
A206	0.09	36	1.086	3.37	70-80 %	80 %
B201	0.06	126	1.521	7.71	70-80 %	37.5 %
B202	0.12	126	1.521	15.27	70-80 %	72 %
B203	0.13	126	1.521	16.38	70-80 %	72 %
B204	0.09	42	1.521	3.99	70-80 %	22 %
B205	0.13	42	1.521	5.43	70-80 %	36 %
B206	0.16	42	1.521	6.69	70-80 %	34 %
C201	0.06	194.4	2.1	11.34	70-80 %	69 %
C202	0.11	194.4	2.1	21.17	70-80 %	82 %
C203	0.14	194.4	2.1	27.97	70-80 %	83 %
C204	0.02	64.8	2.1	1.51	70-80 %	9 %
C205	0.08	64.8	2.1	5.04	70-80 %	71 %
C206	0.10	64.8	2.1	6.77	70-80 %	69 %

Table 8 Ventilation Rates and Air Distribution at Model A (2 Fields), B (3 Fields), and C (4 Fields)

Model	(V)	(A)	*Ventilation Rates* Standard (m3/s)	VxA (m3/s)	Air Distribution Standard	Air Distribution Percentage
A301	0.10	108	1.086	10.58	70-80 %	77 %
A302	0.09	108	1.086	9.45	70-80 %	72 %
A303	0.09	108	1.086	10.21	70-80 %	72 %
A304	0.08	36	1.086	3.02	70-80 %	72 %
A305	0.06	36	1.086	2.25	70-80 %	68 %
A306	0.07	36	1.086	2.63	70-80 %	68 %
B301	0.14	126	1.521	17.40	70-80 %	72.5 %
B302	0.13	126	1.521	16.30	70-80 %	64 %
B303	0.13	126	1.521	16.30	70-80 %	64 %
B304	0.16	42	1.521	6.69	70-80 %	30 %
B305	0.15	42	1.521	6.32	70-80 %	28 %
B306	0.15	42	1.521	6.32	70-80 %	28 %
C301	0.12	194.4	2.1	24.19	70-80 %	74 %
C302	0.10	194.4	2.1	19.66	70-80 %	66 %
C303	0.10	194.4	2.1	19.66	70-80 %	66 %
C304	0.11	64.8	2.1	7.49	70-80 %	69 %
C305	0.07	64.8	2.1	5.00	70-80 %	52 %
C306	0.07	64.8	2.1	4.75	70-80 %	50 %

Table 9 Ventilation Rates and Air Distribution at Model A (2 Fields), B (3 Fields), and C (4 Fields)

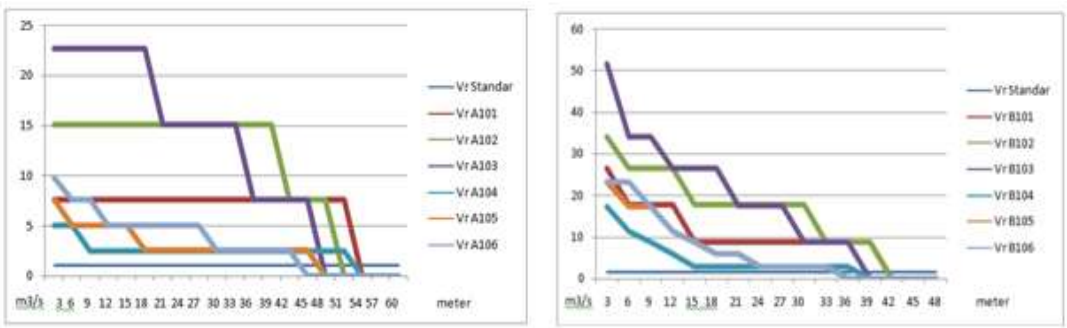

Figure 5 Experimental Treatment Model 1 Result, A (2 Fields) and B (3 Fields)

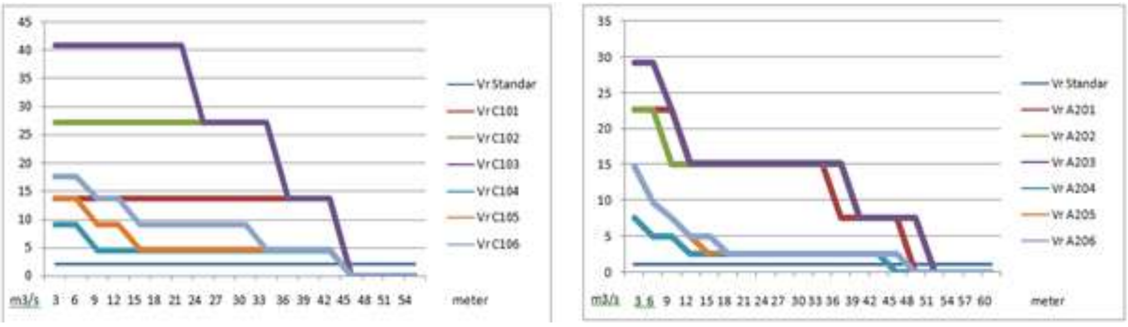

Figure 6 (Left) Experimental Treatment Model 1 Result C (4 Fields) and (Right) Experimental Treatment Model 2 Result A (2 Fields)

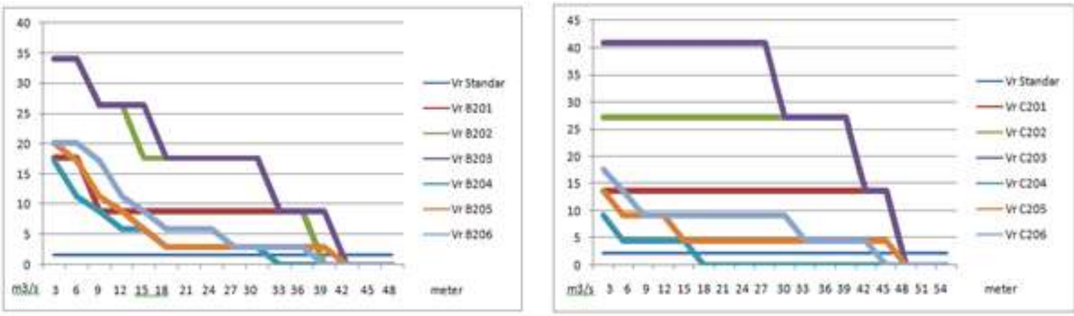

Figure 7 Experimental Treatment Model 2 Result, B (3 Fields) and C (4 Fields)

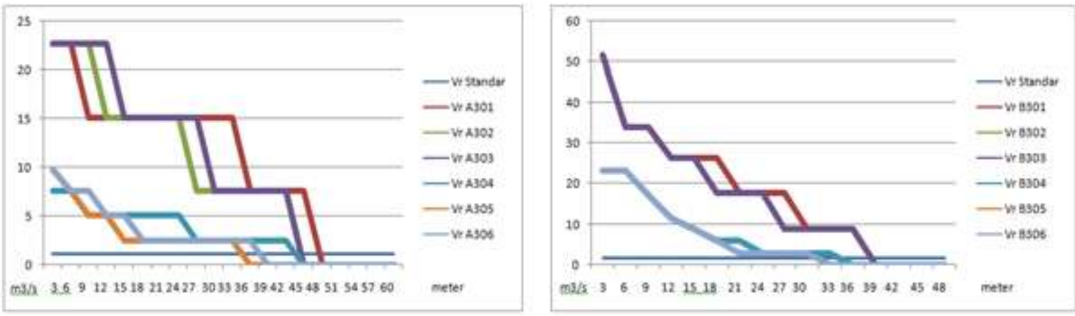

Figure 8 Experimental Treatment Model 3 Result, A (2 Fields) and B (3 Fields)

2. Comparison of the impact of treatment on 3 models of futsal buildings

a. Treatment of the ratio of inlet opening to outlet opening area has a significant influence on the condition of ventilation rates in model A (2 Fields). There is an increase in ventilation rates up to 80% between the A103 and the A104 model (See Figure 9). It is 12.096 m3/s and 2.394 m3/s respectively and in accordance with Peren (2014).

However, this treatment only has a relatively small impact on the air distribution in the building. There is only an increase about 0.11% of the air distribution between the A104 model and the A103 model. Treatment of the outlet opening position and outlet opening configuration has a relatively small impact on ventilation rates, or it is not accordance to Sheatabivash (2015). Each of them only has a difference around of 2% between the ventilation rates in the A103 and A203 models, and a difference of around 15% between the A103 and A303 models.

b. The simulation result in treatment model B (3 Fields) is relatively different from the results of treatment in model A. Treatment ratio inlet opening to outlet opening area has a significant influence on the condition of ventilation rates and air distribution in model B (3 Fields). There is an increase in ventilation rates up to 76% between the B103 and the B104 model (See Figure 10). Each of them is 17.403 m3/s and 4.173 m3/s and a 58% increase between the air distribution of the B103 and the B104 model, or in accordance with Peren (2014) and Shetabivash (215).

Another treatment, which is the outlet opening position and outlet opening configuration only has a relatively small impact on ventilation rates and air distribution (For the ventilation rates, each difference is only about 6% between B103 and B203 model, while for air distribution each difference only about 0.6% between B103 and B203 models).

c. The simulation result on treatment model C (4Fields) show similar condition to the result of treatment in model B. Treatment ratio inlet opening to outlet opening area has a significant influence on the condition of ventilation rates and air distribution in model C. There is an increase in ventilation rates up to 83% between the C103 and the C104 model (See Figure 10). Each of them is 24.192 m3/s and 4.032 m3/s and a 31% increase between the air distribution of the C103 and the C104 model, or in accordance with Peren (2014) and Shetabivash (215).

Another treatment, which is the outlet opening position and outlet opening configuration only has a relatively small impact on ventilation rates and air distribution (For the ventilation rates, each difference is only about 13% between B103 and B203 model, while for air distribution each difference only about 9% between B103 and B203 models).

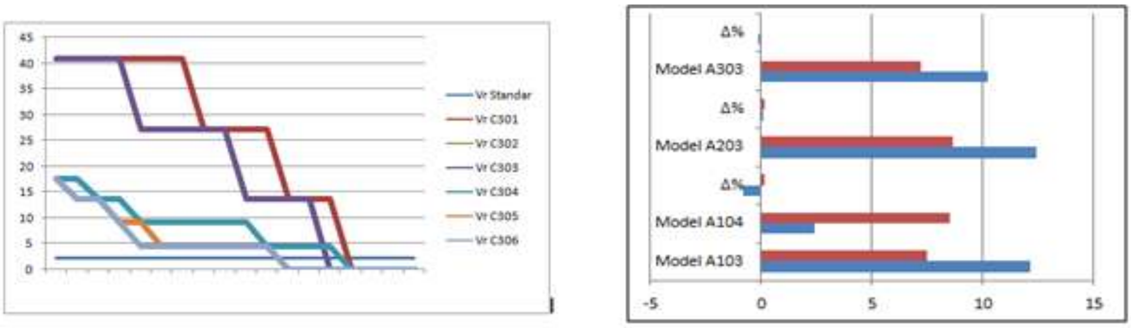

Figure 9 The Comparison of Ventilation Rates and Air Distribution Chart Model A (2 Fields)

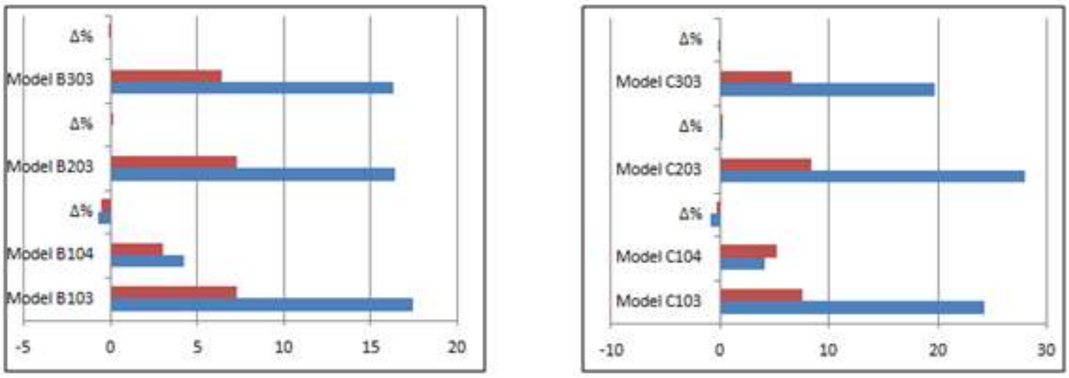

Figure 10 The Comparison of Ventilation Rates and Air Distribution Chart Model B (3 Fields) and C (4 Fields)

V. CONCLUSION

The dimensions of the building plan (due to the number of fields) have an influence on ventilation rates and air distribution in the building. Models with 4 fields have the highest ventilation rates. Model C203 (4 Fields) have the highest ventilation rates. Model C203 (4 Fields) with treatment ratio of inlet opening area to outlet opening area of 1:1 , outlet opening position on the side and rear walls and openings configuration with a pattern of 1 outlet opening in each wall, having the highest ventilation rates, 27.97 m3/s.

In the treatment of the ratio of inlet opening area to the outlet opening area, it is known that model with ratio of inlet opening area to outlet opening area of 1:1 has the highest ventilation rates and air distribution (Models A103 (2 Fields), B103 (3Fields) and C103 (4 Fields).

In the treatment of outlet opening position, it is known that model with ratio of inlet opening area to outlet opening area of 1:1 and the outlet opening position on the side and rear walls of the building has the highest ventilation rates and air distribution (Models A203 (2 Fields), B203 (3Fields) and C203 (4 Fields).

In the treatment of configuration, it is known that model with ratio of inlet opening area to outlet opening area of 1:1 and unified or elongated opening has the highest ventilation rates and air distribution (Models A301 (2 Fields), B301 (3Fields) and C301 (4 Fields).

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