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EFFECTS OF NATURAL VENTILATION ON COOLING LOADS OF A NON-RESIDENTIAL BUILDING

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ABSTRACT
Energy is a very important factor in our life in many ways and consumption of energy is essential fact for humankind to maintain their lifestyle. Nowadays, large scale buildings as office buildings, shopping centers and schools consume lots of energy and in this manner; they harm both national economies and environment. Energy efficient cooling solutions and natural ventilation is a good alternative in order to decrease energy consumption for summer periods in large scale buildings.
In this study, energy consumption of a school building's cooling system in Istanbul, Türkiye was examined. Also, natural ventilation effect on energy efficiency of the cooling system was studied.. The building consists of 12 lecture halls, 10 seminar rooms, 20 lecturer rooms, 5 man and 5 woman WCs, 3 disabled WCs, 2 club rooms, 2 shops and 1 big canteen, in 9296.34 m^2 area. It is estimated that natural ventilation is not always the feasible solution to decrease the energy consumption without appropriate control methods.
Keywords: energy consumption, natural ventilation, energyplus

1. INTRODUCTION
Climate change is one of the major problems of the world lately [1]. The most important reason of this change is global warming, which is the result of increasing greenhouse gases emission. Increasing trend of greenhouse gases is an energy consumption connected with fossil fuels. On the other hand, energy is very important in our lifes on all hands [1] and energy consumption is essential for people. The uphill task is decreasing energy consumption with continuing economic growth. Thus, energy efficient solutions and strict rules must be performed.
Nowadays, buildings like offices, shopping centers, schools, etc. consume great amount of energy in order to maintain comfort and affect both environment and national economies negatively. Alternative energy methods and energy efficient solutions are essential to prevent this amount of energy consumption. Özbalta, T.G. estimated that buildings have about 30% to 50% energy saving potential with these methods and solutions [2]. The increased efficiencies of heating and hot water systems, air conditioning, ventilation, lightening installations, depend on the technological developments, are the reason of major energy saving potentials in buildings. Increasing energy efficiency in buildings is not only decreased end use energy demand, but also decreased large amount of CO_2 emission, thus it helps to prevent global warming effect on the world. One way of increasing efficiency in buildings is natural ventilation. Making ventilation via natural ways provides economical and environmental benefits, 94.4% end use energy consumption in buildings is spent by HVAC systems within the life cycle period of building [3]. So, natural ventilation (NV) is very popular alternative against HVAC systems, lately. But in some climates air conditioning with natural ventilation is not enough to provide human comfort [4]. In these cases, supplemental mechanical systems have to be used and these type of air conditioning systems are called hybrid systems. Lomas, K.J. et. al. said that “Hybrid buildings can reduce energy consumption whilst offering the potential to combat tough climatic and site conditions and the prospect of meeting stringent internal environmental conditions” [5].

Hybrid Ventilation strategy is used in different types of non-residential big scale buildings like offices, museums, schools etc. For example, The IONICA Office Building Cambridge, UK, designers used hybrid systems [6]. Zones on the north side were conditioned by mechanical systems and zones on the south side were conditioned by NV. Designers used six wind chatchers on the roof to maximize the wind driven natural ventilation and also at the top of the atrium solar energy enhanced the stack effect for natural ventilation in summer. So, selected cooling options presented flexible solutions to provide comfortable indoor environment with low working expenses [6]. In different study, Lomas, K.J. et. al. showed some general examination about the efficiency of NV in buildings and debated that how advanced natural ventilated buildings incorporated stacks combined passive and mechanical ventilation in Harm A Webber Library, for Judson College, Illinois, near Chicago [5]. In other study, Ji, Y. et. al. presented a low energy building design in Hangzhou, south China [1]. The passive ventilation system of building was investigated using computational fluid dynamics. Also, they calculated the thermal performance of building design for a year using dynamic thermal simulation with local hourly standard weather data. Modeling results showed that hybrid ventilation systems are appropriate for low energy building design even in sub-tropical climates.
In this study, energy consumption of a school building‘s cooling system in Ayazağa Istanbul Türkiye was examined. Also, natural ventilation effect on energy efficiency of the cooling system was studied and Energy-plus energy simulation program was used for all analysis. Simulation results showed that using temperature-controlled NV decreases annual cooling energy consumption (ACEC) while increasing building's peak electricity for cooling demand (PECD) for this school building.

2. BUILDING DESCRIPTION AND CLIMATE

Ayazağa Central Classrooms Building consists of 12 lecture halls, 10 seminar rooms, 20 lecturer rooms, 5 man and 5 woman WCs, 3 disabled WCs, 2 club rooms, 2 shops and 1 big canteen, in 9296.34 m^2 area. Energy-plus geometry of building can be seen in Figure 1. Building has east-west orientation. Total exterior percent glazing of building is 30.3% and nearly all glazing surfaces are on south, east and west sides. North side has small amount of glazing areas. All glazing areas except north perimeter and ground floor have shadings. These shading equipments can be seen in Figure 1a. In analysis, default construction materials of Energy-plus were used. Name of constructions can be seen in Table 1.

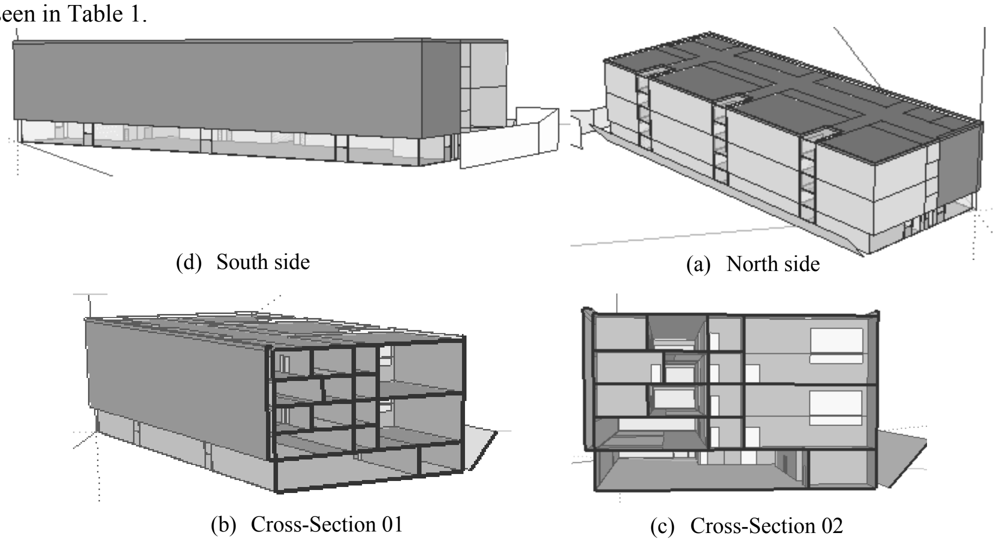

Figure 1. Energy-plus geometry of Ayazağa Central Classrooms Building

Istanbul's (N 40° 58', E 28° 49') ASHRAE climate zone is 3C and ASHRAE uses warm-marine to describe its climate. Detailed properties of Istanbul's climate can be found from technical literature. Building has 51 zones and some of these zones like fire exit and toilettes weren't conditioned, so net conditioned area is 8633.82 m^2 and total number of conditioned zones is 34.

Table 1. Building Construction Parameters

Construction Name	Outside Layer	Layer 02	Layer 03	Layer 04	Layer 05
Exterior Floor	I02 50mm insulation board	M15 200mm heavyweight concrete	-	-	-
Interior Floor	F16 Acoustic tile	F05 Ceiling air space resistance	M11 100mm lightweight concrete	-	-
Exterior Wall	M01 100mm brick	M15 200mm heavyweight concrete	I02 50mm insulation board	F04 Wall air space resistance	G01a 19mm gypsum board
Interior Wall	G01a 19mm gypsum board	F04 Wall air space resistance	G01a 19mm gypsum board	-	-
Exterior Roof	M11 100mm lightweight concrete	F05 Ceiling air space resistance	F16 Acoustic tile	-	-
Interior Ceiling	M11 100mm lightweight concrete	F05 Ceiling air space resistance	F16 Acoustic tile	-	-
Exterior Window	Clear 3mm	Air 13mm	Clear 3mm	-	-
Interior Window	Clear 3mm	-	-	-	-
Exterior Door	F08 Metal surface	I01 25mm insulation board	-	-	-
Interior Door	G05 25mm wood	-	-	-	-

Whole building is conditioned by VAV system. This system's cooling demand is provided by a chiller and a chilled water loop while its heating demand is provided by a boiler and a hot water loop. Building is occupied during weekdays between 8:00 am to 6:00 pm. Building internal gains are consisted of people, lights and electric equipments. People and lights density of building are 0.05382 person/ m^2 and 10.7639 W/ m^2 respectively and electric equipment power, only in office zones, is 700 W. Thermostat settings for offices and classrooms can be seen in Table 2.

Table 2. Thermostat settings for conditioned spaces

Zone Type	Heating 06:00-18:00	Heating 18:00-06:00	Cooling 06:00-18:00	Cooling 18:00-06:00
Classrooms& Off.	21,1	16	23,9	30
Corridors	17	12,8	28	35

3. SIMULATION AND RESULTS

Since the aim of this study is to see the effect of natural ventilation on energy consumption, in simulations, design values of VAV system were auto sized by the program instead of existing HVAC system properties.

In first simulation, analysis was done with full HVAC system and total amount of cooling energy at cooling period, that building was used annually, was calculated in kWh. Also, peak cooling energy consumption time and peak cooling load was obtained. In second simulation, windows and doors were used as free openings for NV at east, south and west sides. At the north side, 3 windows with 47.25 m^2 area on the top of wall were used as free openings to take advantage of stack effect. These openings were controlled with availability management system in Energy-plus to ventilate building naturally. Thus, hybrid ventilation system was obtained and simulated. In control strategy, management system observed the temperature of control zone and if the temperature difference between indoor and outdoor is bigger that 3°C, it opens required windows and doors. Results are given in Table 3.

Table 3. Results of simulations

Simulation	ACEC [kWh]	PECD [W]	Peak Time
First simulation	345308.38	64247.72	29-AUG-10:00
Second simulation	76690.57	86838.89	29-AUG-10:00

As can be seen from the Table 3, ACEC for building decreases significantly with NV use and this is an expected result. However building PECD increases 35% which means that larger chiller system is needed. Figure 2a shows the increase of chiller's electric demand from facility, at 29 August 10:00 a.m. Figure 2b shows the conditioned zones' sensible cooling rate. In this figure, the effect of the increasing peak cooling load via NV on sensible cooling rate can be seen. In figures, solid and dashed lines show hybrid and VAV system respectively.

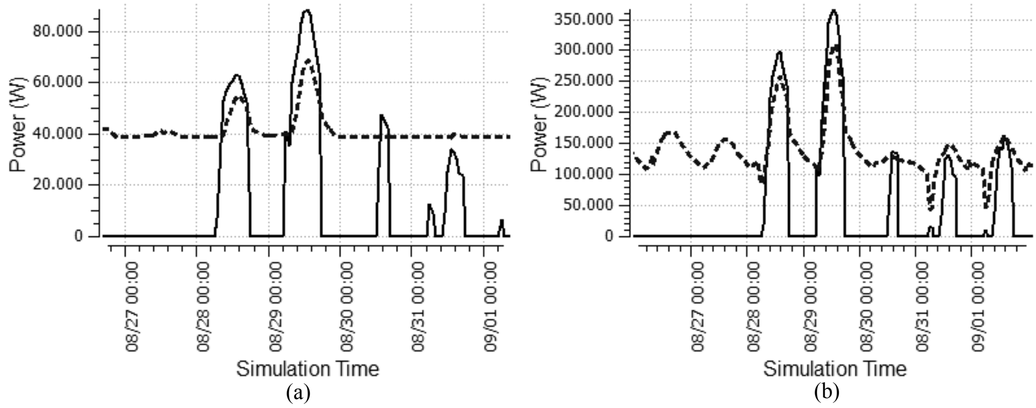

Figure 2. (a) Chiller electric demand, (b) Conditioned zone sensible cooling rate

The possible reason of this result is humidity ratio of the outdoor air. Management system only observed the temperature of control zone and without considering the humidity of outdoor air (OA). Thus, because of the temperature difference, relatively cold and humid air infiltrated to the building earlier time in morning. This OA decreases the indoor air (IO) temperature a little but it increases the humidity ratio of IO. As a result, peak load of chiller increases. The other negative effect of NV in this simulation is increasing the uncomfortable time, based on Simple ASHRAE 55-2004.

4. CONCLUSION

In this study, one school building HVAC system was investigated with and without NV. Results were showed that NV is an energy efficient method and it can be used to decrease the energy consumption of buildings. It is seen that using NV decreases ACEC 78% while increasing building's PECD 35% for this school building. As a conclusion, hybrid ventilation systems are not always the feasible solution to minimize the energy consumption without scheduled appropriately. Thus, designers have to be very careful to manage the control mechanism of hybrid system to obtain the optimum solution.

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