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Design of Exhaust System for Industrial Shed

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***Abstract*: Heating, discomfort, and lack of proper fresh air are the common problems faced by industrial buildings and firms. In regards to this it needs ventilation, the purpose of ventilation in a building is to provide fresh air and remove unwanted heat and stale air. This paper is oriented on the design of the exhaust system at normal temperature and pressure to provide ventilation and create a laminar flow of air for an industrial shed that is compact and around 10000 sq. feet in area with a capacity of 45 persons, includes with the design of the layout of the compartments of the industry. The design of the exhaust system is carried out on the method by the calculation of the total heat generated from machines, electric appliances, and the body of workers. The design is done according to the standard norms. Airflow in industrial buildings can significantly improve environmental conditions, increase worker comfort, prolong the storage life of goods & stock. This study helps in improving ventilation and airflow in the industry.**

***Keywords*: Design of ventilation, Exhaust system, Natural ventilation, Turbo air ventilator.**

1. Introduction

An exhaust system is a system in which inside hot air forcefully pushes outside by reducing the inside air pressure below the outdoor air pressure. It is a part of ventilation, ventilation moves outdoor clean air into a building or room. The primary function of the ventilation system is to prevent acute discomfort, heat-induced illness, and possible injury of those working in or generally occupying a designated hot industrial environment and to provide healthy air for breathing.

In this research, an exhaust system to design, and ventilation to develop in the industrial shed. The area of 10000 square feet of the industrial shed has been given which is compact, in which the design and to arrange all the different work sections in the layout of the industrial shed as per the ventilation, to select the type of ventilation system and the exhaust system for removing hot air, to provide ventilation air in laminar flow are the main purposes.

There are approximately 45 workers and employees. The whole design research is focused on removing the heat at normal temperature and pressure from the body of workers and employees, machines, and the electricity-consuming appliances. There are few types of ventilation systems that are generally known, natural ventilation, mechanical ventilation, hybrid ventilation systems, dilution exhaust ventilation, local exhaust ventilation, heating ventilation, and air conditioning, displacement ventilation.

2. Review of the Literature

Siti Halipah Ibrahim et. al. discussed that Malaysia is located in the equatorial region and that's why they experience high temperature with high relative humidity. The poor passive design could lead to overheating. In addition, the occupants in modern low-cost housing suffer overheating due to poor ventilation and roof design problems. The outside fresh environment could not enter into the house Due to the minimum number of openings on the roof of the surface, that's why the inner temperature of the house is more than the ambient temperature concluded that the openings on the roof surface played an important role in reducing the temperature inside the house. The optimum roof helped to reduce the indoor air temperature by up to 10°C compared to the normal roof [1]. M. W. Muhieldeen et. al. studied and discussed that the current warehouse without proper air ventilation is hazardous for health and a high amount of humidity and temperature are inside the warehouse. To overcome the above problem he discussed two types of ventilation techniques 1) Installation of the wind-driven turbine, 2) Crosswind ventilation. In the installation of the wind-driven turbine, they suggest installing the wind-driven turbine ventilators on top of the rooftop of the warehouse, the wind-driven turbine ventilators are made to work in two modes. The first mode requires wind blows towards the turbine on the rooftop where the spinning of the turbine creates more negative pressure from the warehouse indoor chamber to the outdoor air via Bernoulli's principle. Next, the turbine can draw air out from the warehouse without any wind via stack ventilation. In crosswind ventilation they explain about an increased number of openings of the warehouse's front and rear walls can easily provide good ventilation & it will affect better air circulation and human comfort. The objective of the research was aimed to improve human comfort with less amount of cost [2].

Taekhee Lee et. al. performed 6 experiments, they aimed to evaluate airborne particulates and volatile organic compounds (VOCs) from surgical smoke when a local exhaust ventilation (LEV) system is in place. Surgical smoke was generated from

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human tissue in an unoccupied operating room using an electro-cautery surgical device for 15 min with 3 different test settings: (1) without LEV control; (2) control with a wall irrigation suction unit with an in-line ultra-low penetration air filter; and (3) control with a smoke evacuation system. Flow rate of LEVs was approximately 35 L/min and suction was maintained within 5 cm of electro-cautery interaction site.it is obtained that utilization of the LEVs for surgical smoke control can significantly reduce but not completely eliminate air-borne particles and VOCs. LEV systems should be used to increase protection of operating room workers from surgical smoke exposure, and more effective LEV devices may need to be evaluated. Utilization of the local exhaust ventilation for surgical smoke control can significantly reduce but not eliminate airborne particles and volatile organic compounds [3].

William J. Kosik et. al. studied and discussed about the hybrid ventilation. Buildings with hybrid ventilation systems use both mechanical ventilation and natural ventilation strategies. There are two main types of hybrid ventilation systems. 1) Changeover (or complimentary)- changeover systems, as the name implies, have spaces that are either totally in mechanical air conditioning or totally in natural ventilation mode. 2) Concurrent (or zoned), again as the name implies these systems are designed to have the concurrent operation of both the mechanical and natural ventilation system. Again this paper suggests some design strategies and guidance while selecting the ventilation system for the building and it shows the importance and benefits of hybrid ventilation over the mechanical ventilation system [4].

Dan William C. Martinez et. al. their research provides a new design and automation concept for tertiary buildings in mixed-mode ventilation systems with combined functions of mechanical air conditioning and natural ventilation. It aims to make use of simple automation design and set-up to significantly reduce energy consumption while keeping optimum occupants' comfort. The paper also provides a prototype architectural design of the building to handle the automation control to maximize the cooling potential from the integrated natural ventilation. However, the most important impact of the automation system is the decreased energy consumption which response to the present trust of the government and the community on energy efficiency and conservation [5].

Md. Fazle Rabbi et. al. conducted a study on the heating and ventilation problem of conventional buildings and shows that about 50 to 60 % of the building power is wasted in heating and ventilation. So their research and study aimed to design and develop a solar passive cooling system, solar passive cooling techniques are not so much well-established as compared to solar passive heating techniques due to the dependency on the judicious use of night ventilation, shading, evaporator cooling. The solar passive model consists of a solar ventilator or a chimney. This solar air heater or chimney is placed on the roof which acts as an exhaust fan by sucking hot air from the room and ventilating it out during the daytime. They had successfully designed the solar chimney or solar passive cooling system and conducted a successful experiment on the 5 feet long, 4 feet wide and 3 feet high room in which they had resulted that, the passive room maintained the temperature at about 4˚C to 5˚C below the ambient condition and at about 2˚C to 3˚C below the reference room temperature, which can be considered as comfortable. And concluded that a solar passive cooling system is effective [6].

Steven J. Emmerich et. al. Conventional heating, ventilation, and air conditioning HVAC systems in commercial buildings meet both outdoor air ventilation & space conditioning requirements using air distribution approaches that provide a mixture of outdoor air & recirculated air to achieve good air mining within the occupied spaces. This includes a review of the scientific literature from sources including the American Society of Heating, Refrigerating and air condition engineers, Air infiltration Centre and published case study information. Limitations: - 1) Separate duct work for parallel paths can increase the first cost. 2) Separate diffuses for outdoor air & recirculated air may not provide adequate mixing. 3) Displacement Ventilation System needs to have large air output. The Conclusion of this is to evaluate the potential benefits & limitations of these advanced ventilation systems, specifically displacement ventilation & dedicated outdoor air systems, in commercial buildings [7].

Nor Halim Hasan et. al. conducted a study in Malaysia on design the local exhaust system in spray booths. The study of a local exhaust ventilation system for spray booths helps to measure the level of concentration of air contaminants, to evaluate the significant effect of health outcomes on the level concentration of air contaminants. Air contaminants pose a serious health risk. Large amounts of dust or fumes are generated. Emission sources are near the worker's braking zone. This paper concludes that the main object of a local exhaust system is to remove contaminant as it is generated at a source. The study will be focusing on small-medium industries such as car repair or paint shops & compare them to big-scale manufacturing [8].

Mansi Joshi et.al. carried out a study on the turbo ventilator in the natural ventilation, for which they have conducted the surveys and their researches on Torrent Research Center Ahmedabad, Sangath: An Architect's Studio, Ahmedabad, and live case study on Industry for Turbo Ventilator. In this survey, they have found the use of locally available natural materials, RC-framed structure with brick in-filled walls, and vermiculite, a natural mineral, which is used in insulation of roof and cavity walls. Their study aims to calculate and provide the number of turbo ventilator for natural ventilation in the context of Indore, M.P. In which they had selected the 22 inches diameter turbo ventilator and calculated it by using the air change rate of 12 times per hour for the volume of 100000 cubic feet, and resulted in the number of turbo ventilators according to the season and the temperature change. And concluded that according to the temperature, wind velocity, and humidity the performance characteristics of turbo ventilators may vary. This research paper helps and gives a different perspective of calculation and selection of the ventilation system and the selection of exhaust system and played an important role in our project. It shows the advantages of the turbo ventilator over other exhaust fans [9].

From the above, all research papers give the importance of ventilation and differentiate each type of ventilation system according to their purposes and explain the different types of design and research methods that can be applied in the study. As in this research paper, our objective is to design a ventilation system in which the removal of hot air from the industrial shed and airflow rate in laminar flow for ventilation is important. In which the design of the shed and selection of the ventilation system is important. And for this purpose, we have chosen natural ventilation with a stack ventilation effect.

Natural ventilation: Natural ventilation is the flow of air between the outside and inside of the building. Natural ventilation originates from two natural forces: pressure differences created by the wind. around the building and wind-driven ventilation; and temperature differences 'stack effect' ventilation.

Natural ventilation system with the technique of stack ventilation system is whey more efficient and economic which is best suited in all purposes for the ventilation of the industrial shed in which our main focus is on the removal of heat and provision of the oxygen and the natural ventilation system with stack ventilation suited perfectly.

3. Methodology

A. Design method of the industrial shed layout

In the design of the layout, we first analyzed the industry work, its capacity, the number of workers, their shift, and according to their shifts of work we estimated the maximum number of workers in the industry, this industry is small scale industry or a firm in which there are approximately 13 different types of sections for different types of works from each and according to that we have to arrange the different section in a specific manner by employing the ventilation to each compartment so we applied rules of ventilation according to the Maharashtra Factory Rule 1963, and by taking some help of Auto-cad software we successfully arranged all the different compartments and could show the diagram.

B. Design method of the exhaust system for the industrial shed

a) First we have to select the type of ventilation that we have to provide which is already been selected as natural ventilation with stack ventilation specification, first of all, we have to calculate the total air required per person in cubic meter per second, heat generated from the body of the workers and the machines, and the flow rate of air required to remove and provide oxygen, for this calculation we have taken data given in the ACGIH 1998 manual of industrial ventilation, and the data given from some online platforms and also the formulas given in it. And according to it, we have selected the type of ventilation and the exhaust system for the removal of hot and contaminated air. b) Accordingly, we have to analyze the data calculated of the rate removal of hot air, also we have to analyze the data collected related to the exhaust fan and select the best efficient and economic exhaust fan for the industrial shed ventilation, and to find the number of exhaust fans and their proper positions.

4. Design

The existing industrial shed is 10000 sq. feet with a staff cabin of approximately 1500 sq. feet. In the working area of 85% of the shed, the volume of staff cabin is given as 25*60*12 ft^3, the volume of the shed is calculated as 492000 ft^3 or 13932 m^3. By considering the normal temperature and pressure, pressure (P) is considered as 1 ATM or 101325 pa, temperature (T) is 20^0C or 293K the density of air (ρ) is 0.075 LBM/ft^3 or 1.2041 kg/m^3, here we are neglecting the humidity content in the air and only considering dry air so, the dynamic viscosity (μ) $1.8*10^{-5}$ NS/m^2. The 30% area of the industrial shed is occupied of instruments men and machines both and 70% area is free. There should be 5 compartments like a) Raw material storage, b) Job preparation, c) Machine work, d) Quality assurance and inspection, e) packing and dispatch. Each compartment will have 5 people and 5 people are for normal work, the work schedule is given as, i) 7 am to 3 pm - 30 persons are available, ii) 3 pm to 10 pm - 30 persons are available, iii) 10 pm to 7 am - 15 persons. It is found that at a time maximum of 45 persons or workers available at the industry.

Steps of design;

- Design of industrial shed,
- Selection of type of ventilation and design of inlets,
- Total heat calculation,
- Total air flow rate calculator needed for ventilation,
- Calculation of velocity and dynamic pressure,
- Selection of exhaust fan and calculation of no. of exhaust fan needed and their positions.

Table 1
Dimensions of all compartments and rooms

Sr. No.	Compartments or Rooms	Length in ft	Breadth in ft	Height in ft	Area occupied in Ft^2	Area occupied in m^2
1	Staff cabin	60	25	12	1500	139.35
2	Work module storage area	25	15	4	375	34.84
3	Machine room	140	15	-	2100	195
4	Raw material storage	30	20	20	600	55.74
5	Packing and dispatch	32	30	20	960	89.19
6	Tooling area	25	20	20	500	46.45
7	Restroom	15	15	12	225	20.9
8	Washroom	10	10	16	100	9.29
9	Product gallery	15	5	12	75	6.97
10	Maintenance room	55	25	20	1375	127.74
11	Quality inspection trolley	3	3	3	9	0.84
12	Stacker	10	4	10	40	3.72

A. Design of industrial shed

The Staff cabin, Maintenance room, and Tooling area are exactly situated at the center of the industrial shed. The Machine room is divided into two equal divisions for better heat dissipation and ventilation, there are a total of 24 machines shown in the industry and 12-12 machines are provided in both the divisions. The restroom and washroom both are situated at the opposite corners on the left and right sides. There are a total of six gates for in and out and for air inlets and two gates are more for loading and unloading of goods which are larger than that of the other six gates which are approximately 20 by 20 feet in dimensions.

The whole industrial shed is designed by the application of the rules given in the Maharashtra Factory Rule 1963. The permissible illumination in the factory i) for passageways is 50 LUX, ii) For workshop and assembling is 500 LUX [12]. The LED bulbs of 13 watts of 1100 lumen for passageways and 45 watts of 5800 lumen for workshops and assembly [20] [21]. And it is calculated that the 12 bulbs of 13 watts and 94 bulbs of 45 watts are required to illuminate all the industrial shed.

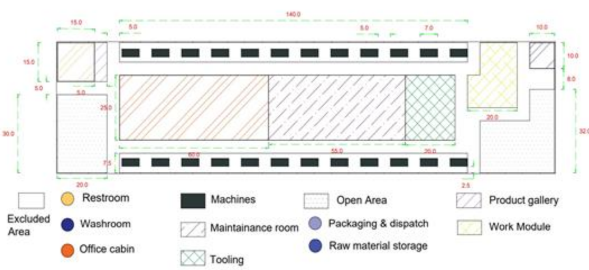

Fig. 1. 2D Industrial Shed Layout

B. Design of inlets and selection of the type of ventilation

According to the Maharashtra Factory rule 1963, section 22-A ventilation and temperature, In every factory, the number of ventilation openings in the workroom below the caves shall be provided of an aggregate area of not less than 15 percent of the floor area and so located as to afford a continued supply of fresh air [12].

So we have taken an extra opening for the ventilation and exclude the floor area of the washroom, restroom, and office cabin because these areas need separate ventilation systems and can be excluded from the industrial shed.

The total floor area obtained by excluding the above rooms, cabins, and objects we have found that we have to give the ventilation for a total of 6564 sq. feet. 15% of the 6564 sq. feet equals 984.6 sq. feet.

And our total openings are of area 1100 sq. feet, which is greater than the required. So, the openings are sufficient.

C. Total heat calculation

For total heat calculation we have considered here the three main bodies i) The heat released from worker's body, ii) Heat released from machine body, and iii) Heat released by electric appliances.

i) The heat released from worker's body at 20^0C and an average weight of 70kg.

The heat generated in KJ/min and BTU/hr: i) For machine operator the heat release = 5.1 K cal/min = 21.3384 KJ/min [Here 1 KJ/min=56.907 BTU/hr= 1214.3 BTU/hr]. b) For workers in walking and working= 8.5 K cal/min= 35.564 KJ/min = 2023.84 BTU/hr. And for employee in sitting position = 4.8 K cal/min= 20.0832 KJ/min=1142.876 BTU/hr [10].

The total energy in BTU/hr:

Heat from 15 employees =15*1142.876=17143.14 BTU/hr

Heat from 24 machines workers = 24*1214.3 = 29143.3 BTU/hr

Heat from 6 workers = 6*2023.84 BTU/hr = 12143.04 BTU/hr

Total heat release from 45 workers = 17143.14 + 29143.3 + 12143.04 = 58429.48 BTU/hr

ii) Heat released from machine body: We are considering the lathe machines for heat calculation

Input energy = 2755 W. The overall efficiency of the lathe machine with motor is = 0.812*0.85= 0.69= 69%. Therefore, losses in the energy = (1 – 0.69)*100= 30.98%.

All values in the calculation for lathe machines are assumed. Consider theoretically that the vibration and the sound losses are 5%

So the remained loss will be heat loss= 30.98 – 5= 25.98%

Therefore, overall heat loss is approximately 26% with the body temperature of the lathe machine as 35^0c.

Heat loss = 0.26*energy input = 0.26*2755= 716.3 W

And for 24 lathe machine it is approximately = 716.3*24= 17191.2W= 17.192 KW……..[22] [23] [24] [25] [26]

And in BTU/hr it is 1W= 3.41 BTU/hr

17192.2W= 58633 BTU/hr

Therefore, overall heat generation = 58622 BTU/hr, and the body temperature is approximately 35^0C.

iii) We have already calculated the number of bulbs required, Here we have considered that the average efficiency of the LED bulbs is approximately 33% [20].

So, 12 bulbs of 13W [21]. Therefore the energy input is 13W and the $\dot{\eta}$= 33%, $\dot{\eta}$= output/input and loss = (1 - $\dot{\eta}$)*input = (1 – 0.33)*input, therefore heat loss or energy loss= 0.67*13= 8.71 W/bulb.

For 12 bulbs heat loss= 12*8.71= 104.52W.

The temperature of the LED bulb is approximately varying from 60^0C to 100^0C or (140^0C to 212^0C) [19]

So we are considering the average of 60 & 100= 80^0C = 176^0F

94 bulbs, 45w, Heat loss or energy loss= (1 - $\dot{\eta}$)*input energy= (1 – 0.33)*45= 30.15 W

For 94 bulbs it is =94*30.15= 2834.1W, temperature of bulb = T = 80^0C = 176^0F [19]

Total heat loss = heat loss from 12 bulbs of 13W + heat loss from 94 bulbs of 45 W = 104.52 + 2834.1= 2938.62W.

D. Total calculation of rate of air flow required for ventilation

i) Rate of airflow for the removal of heat from the workers

Here we are considering the sensible heat instead of latent heat from the ACGIH 1998 manual to calculate the rate of airflow

Hs = Qs*ρ*Cp*ΔT(60 min/hr) [10]

Where, Hs = sensible heat gain, BTU/hr, Qs = volumetric flow rate sensible heat, CFM, ρ = Density of the air, LBM/ft^3, Cp = specific heat of the air, BTU/LBM –F, ΔT = change in temperature F

For air Cp = 0.24BTU/lbm-F and ρ = 0.075 lbm/ft^3, consequently, the equation becomes,

Hs = 1.08*Qs* ΔT or Qs = Hs/(1.08*ΔT)

Here for 45 persons Hs = 58429.48 BTU/hr, Qs = 58429.48/(1.08*ΔT) = 17687.01 CFM

ΔT = T2-T1 = 98.6-68 = 30.6^{0}F, Here T1 = 68^{0}F = 20^{0}C, T2 = 37^{0}C = 98.6^{0}F

Qs = 1768.018 CFM = 3003.88 m^3/h.

ii) Rate of air flow for removal heat from 24 machines

Qs= Hs/(1.08*ΔT), [10]

ΔT= T2 – T1= 27^{0}f, T2= 35^{0}c = 95 F, T1 = 20^{0}c = 68^{0}F,

For 24 lathe machine calculated as Hs = 58622 BTU/Hr

Qs = Hs/(1.08*ΔT) = 58622/(1.08*270) = 2010.36 CFM

Qs = 3415.6221 m^3/h ~ 3416 m^3/h

iii) Rate of airflow for removal of heat from LED bulbs or electric appliances

Hs= 2938.62W, here 1W= 3.41 BTU/hr

Therefore, Hs = 2938.62 * 3.41 = 10021.69 ~ 10020.7 BTU/h, T2 = 176^{0}F, T1 = 20^{0}C = 68^{0}F

Qs = Hs/(1.08*ΔT) = 10020.7/(1.08*(176 – 68))= 10020.7/(1.08*108)= 85.92 CFM

Qs = 85.92 CFM = 145.98 m^3/h

Rate of airflow required to remove the heat from all bulbs = 145.98 m^3/h

iii) Here oxygen in the air is approximately 21% and we are considering the extreme oxygen required condition for breathing the air. [18]

Here 60 breaths/min [15] [16] is the worker's maximum for an average worker and the air capacity of the lung is from 4 to 12 liters [17] so we are considering 8 liters.

Air required per minute = 60 breaths/min * 8litre/breath
= 480 litre/min maximum

Air required for 45 persons = 480*45 = 21600 litre/min = 1296 m^3/h.

The total rate of airflow is equals to 7862 m^3/h.

E. Calculation of velocity and dynamic pressure

The velocity pressure or dynamic pressure is developed by the air velocity.

q = dynamic pressure in pascals.

ρ = fluid mass density

V= flow speed in m/s

q = (ρ* v^2)/2 [10]

= 1.0241*0.0214^2 = 2.7597*10^{-4} Pa

Which is negligible than that of the atmospheric pressure. So it can be neglected. [11]

The total air inlet = total air out

So the air required or minimum air required is equal to the 7862 m^3/h

Area for inlet = 1100 ft^2 = 102.2 m^2

Therefore, Q = A*V

V = Q/A….(Where A is an area for inlet air, V is the velocity of air) = 7862/102.2 = 76.93 m/h = 76.93/3600 = 0.0214 m/s

Which is very very less than that of the velocity permissible.

Under section 22-A of Maharashtra factory rule, 1963 velocity of inlet air for natural ventilation should be less than 0.5m/s [15].

So, 0.0214 < 0.5 m/s, the openings are enough.

F. Selection of exhaust fan and calculation of the number of exhaust fans required

We have analyzed different types of exhaust fans but we have found that the wind-driven turbo ventilators are best suited for the natural ventilation and the stack effect.

Turbo ventilators: A ventilator, usually mounted on the roof of a building, deck of a ship, etc., having at its head a globular, vanned rotor that is rotated by the wind, conveying air through a duct to and from a chamber below. The ventilator is the combination of both natural and forced ventilation systems. It functions as a natural ventilator when there is a difference in thermal or wind pressure between the inside and outside of the building which forces the air to move through the opening of the ventilator. And one more reason for the selection of turbo ventilators is the stack ventilation. The turbo ventilator is best suited for stack ventilation and perfectly suitable for natural ventilation. After analyzing some research papers, we have concluded that the 600 mm diameter turbo ventilator exhausts at the same airspeed air at a good rate than the other are less diameter turbo ventilators like 300 mm, 500 mm & 400 mm diameter turbo ventilators. Greater the diameter larger will be the flow rate [13] [14].

Calculation: Here we have already chosen the ventilators for the industrial shed which is 600mm in diameter with an exhaust capacity. So we are considering the data given by wind speed of 2m/s, at 2m/s exhaust capacity is 1494 m^3/h………[27]

Therefore, number of turbo ventilators = total rate of airflow/exhaust capacity = 7862/1494= 5.26 ~ 6.

Therefore, the number of turbo ventilators required is 6.

It means that the minimum number of 600 mm diameter turbo ventilators required is 6.

Due to the stack effect, hot air will rise which is shown below in the diagram, and because of the suction pressure developed by the rotations of wind-driven turbo ventilators the hot air will be sucked by the turbo ventilators and forced out from the industrial shed and the negative pressure will develop. Then cold air below at the ground level will enter into the industrial shed and ventilation will be provided.

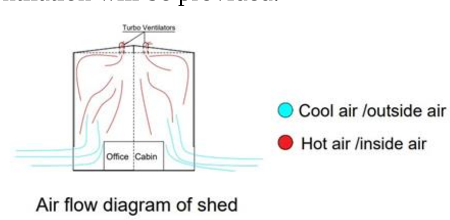

Fig. 2. Air flow diagram of industrial shed

G. Positions of turbo ventilators on the roof

The turbo ventilators are set at the top of the roof and divided into two sections 3-3 and situated on both halves shown below.

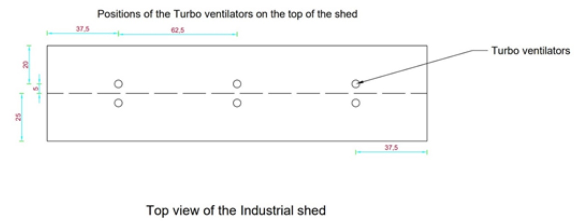

Fig. 3. Positions of the turbo ventilators on roof of shed

5. Result

1) The total flow rate required to remove all heat is 6566 m^3/h.
2) The total airflow Q = 7862 m^3/h including the air required for breathing.
3) Dynamic pressure developed by the airflow rate is approximately 2.76 * 10^{-4} Pa.
4) Here we had selected the turbo ventilators as an exhaust fan which is better than that of any other exhaust fan. These turbo ventilators are 600mm or 24 inches' diameter in size and are 6 in numbers to be fitted on the industrial shed for proper ventilation.

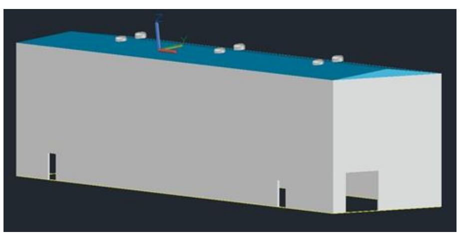

Fig. 3. 3D Final diagram

6. Guidelines

It is concluded that the natural ventilation system with the stack ventilation is suitable and can be applied in the industry. And we had selected the turbo ventilation for the exhaust which ran on the natural wind and for the inlets we had provided the door openings in the design, the dynamic pressure generated was found to be negligible, the aim and the objective of this project had been done successfully. And the only 6 no. of turbo ventilators are enough to remove all heat and provide the oxygen to the industry in an industrial shed.

References

[1] Siti Halipah Ibrahim, Qairuniza Roslan Rohaida Affandi , Abdul Wafi Razali, Yon Syafni Samat, Mohd Nasrun Mohd Nawi, "Study On The Optimum Roof Type With 30° Roof Angle To Enhance Natural Ventilation And Air Circulation Of A Passive Design" International Journal of Technology (2018) 8: 1692-1701, December 2018.
[2] M. W. Muhieldeen, Danson Loi, Vishnuvarthan A/L Paramanandam, Wong Mun Fai, Barrathan Arthimoorthy, Yeo Chuan Wei, Kanesskumar, Latchumanan, Gabriel Koh, "Combined Ventilation Methods in a Large Scale Warehouse Building to Reduce Indoor Air Temperature", American Journal of Energy and Power Engineering 2015; 2(5): 74-78.
[3] Taekhee Lee, Jhy-Charm Soo, Ryan F. LeBoeuf, Dru Burns, Diane Schwegler Berry, Michael Kashon, Jay Bowers & Martin Harper "Surgical smoke control with local exhaust ventilation: Experimental study", Journal of Occupational and Environmental Hygiene, vol. 15, no. 4, 341-350, 2018.
[4] William J. Kosik, P.E. "Design Strategies for Hybrid Ventilation", Ashrae Journal; ProQuest Central; 43, 10; Oct. 2001.
[5] Dan William C. Martinez, and Alvin Y. Chua, "New Design and Automation Concept of an Energy-Efficient, Tertiary Building for Mixed-Mode Ventilation System", in International Journal of Automation and Smart Technology · December 2017.
[6] Md. Fazle Rabbi, Mrittunjoy Sarker, Mohammad Mashud, "Alternative Room Cooling System", American Journal of Engineering Research (AJER), Volume 4, Issue 6, pp. 215-218, 2015.
[7] Steven J. Emmerich, Tim McDowell, "Initial Evaluation of Displacement Ventilation and Dedicated Outdoor Air Systems for U.S. Commercial Buildings", NISTIR 7244, prepared for: U.S. Environmental Protection Agency Washington, DC, July 2005.
[8] Nor Halim Hasan, M.R. Said, A.M. Leman, "Design of Local Exhaust Ventilation for Spray Booths: Proposed Study", ARPN Journal of Science and Technology, Vol. 2, No. 6, July 2012.
[9] Mansi Joshi, Suhas Choudhari, Aradhana Maheshwari, "Turbo Air Ventilator Used in Natural Ventilation", International Journal of Research in Engineering, Science and Management Volume 1, Issue 10, October 2018.
[10] American Conference of Governmental Industrial Hygienists (ACGIH) "Industrial Ventilation, Manual of Recommended Practice. 23rd Edition", 1998.
[11] Bureau of Indian Standards "Indian Standard Code of Practice for Natural Ventilation of Residential Buildings", First Revision, Second Reprint May 1996.
[12] Maharashtra Factory Rule 1963.
[13] Ganesh K. Jadhav, P. M. Ghanegaonkar, Sharad Garg, "Analysis of Turbo Ventilator Using CFD," International Journal of Innovative Technology and Research, vol. 3, no. 6, October - November 2015, 2515 – 2518.
[14] Dovydas Rimdžius, Juozas Bielskus, Vytautas Martinaitis, Violeta Motuzienė, and Giedrė Streckienė, "Experimental Evaluation of Turbine Ventilators Performance under Different Test Conditions", E3S Web of Conferences 64, 0 (2018), ICPRE 2018.
[15] Lynne Eldridge, MD, "What Is a Normal Respiratory Rate?"
[16] https://www.verywellhealth.com/what-is-a-normal-respiratory-rate-2248932
[17] Wikipedia, the free encyclopedia, "Respiratory rate"
[18] https://en.wikipedia.org/wiki/Respiratory_rate
[19] Wikipedia, the free encyclopedia, "Lung volumes", https://en.wikipedia.org/wiki/Lung_volumes
[20] Asking lot, "What is the maximum liters of oxygen?", https://askinglot.com/what-is-the-maximum-liters-of-oxygen
[21] Razorlux lighting, "Light bulb heat temperature chart",
[22] https://www.razorlux.com/light-bulb-heat-temperature-chart.html
[23] Viribright, "Comparing LED vs CFL vs Incandescent Light Bulbs", https://www.viribright.com/lumen-output-comparing-led-vs-cfl-vs-incandescent-wattage/
[24] David Hakimi, "How to Determine How Many Lumens You'll Need to Properly Light Your Space"
[25] https://www.alconlighting.com/blog/residential-led-lighting/how-do-i-determine-how-many-led-lumens-i-need-for-a-space/
[26] Green Riverside, "Energy Efficient Motors", https://www.energydepot.com/RPUcom/library/MISC003.asp
[27] Electrical technology, "Single-phase and three-phase motors",
[28] https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.electricaltechnology.org%2F2012%2F04%2Fmotor-hp-input-voltages-full-load.html&psig=AOvVaw02FU-YHyY-VVWrcnurjOM9&ust=1620201983736000&source=images&cd=vfe&ved=2ahUKEwjxr_TuyK_wAhVgzzgGHf5-BGQQjRx6BAgAEAc
[29] CareerRide, "Numerical - Power required for machining, given efficiency of lathe machine - Manufacturing Processes - 2", https://www.careerride.com/mchoice/numerical-power-required-for-machining-given-efficiency-of-lathe-machine-manufacturin-3827.aspx
[30] Divyesh Vegad, studied electric engineering, "How much power consumes a 5HP 3phase motor in 1 hour?", https://www.quora.com/How-much-power-consumes-a-5hp-3-phase-motor-in-1-hour/answer/Divyesh-Vegad?ch=10&share=eb74672e&srid=uvHoc3
[31] William Adkins, "How to Calculate Cost of Electricity for Electric Motor 3 Phase",
[32] https://sciencing.com/how-6179452-calculate-electric-motor-3-phase.html
[33] A. M. Mohammed Usman & Brother, "Turbine Ventilator", http://www.asbava.com/turbine-ventilator.htm.