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Design and Calculation of Tunnel Ventilation for Cairo Metro Line 3 (A Case Study)

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Keywords
Tunnel ventilation; Cairo Metro Line 3; Ventilation rate; Static head pressure; ABC rigid duct tubing

Abstract

One of the problems of tunnels is lacking enough fresh air for passengers inside the subway. Also, because of the friction of the train with the railways inside the tunnel, high heat is generated. So, the design and calculation of an efficient ventilation system are critical for the tunnels. There are several methods used to determine the most effective tunnel ventilation systems while reducing fan energy costs, including their operating performance. The main task of an optimal tunnel ventilation system is to determine the quantity, location, and function of fans to distribute the required fresh air flow at the lowest possible cost. The main parameters for selecting a suitable fan that meet the optimal design of the tunnel ventilation system are the ventilation rate (Q) and the static head pressure (H). Both Q and H of Cairo Metro Line 3 were studied and calculated under different conditions of ventilation design from the obtained data. The amount of the ventilation rate by the fan was taken 80 m^3/s which is the actual air flow rate taken from data of the National authority of Cairo Metro No.3. In addition, a comparison is made between various methods to determine the most effective tunnel ventilation system. The static head pressure (H) was calculated. According to the American Brattice Cloth (ABC) rigid duct method, the static head equals to 1171.5P_a, which is the most economical value that is giving the lower power consumption and rate of ventilation.

Nomenclature

P_{air}	power (k_{watt})	P_1&P_2	Absolut pressure at two points (P_a)
Q	Ventilation rate (ft^3/min)	K_c	Compression friction factor ($Kg^2/s^2.m^4$)
H	Static head pressure (in. WG)	D_{fan}	Diameter of fan (m)
K	Friction factor (Kg/m^3)	R	Mine resistance ($N.S^2/m^8$)
P	Perimeter of air way (m)	n_s	Specific speed (r.p.m)
L	Length of tunnel (m)	n	Speed of fan (r.p.m)
An	Area of duct (m^2)	P_m	Motor power (h_p)
η	Fan efficiency (%)	Q_s	Specific volume (ft^3/min)
$η_s$	Efficiency of performance blade-setting (%)	r.p.m	Revolution per minute
ABC	American Brattice Cloth	D	The optimum fan diameter (m)

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1. Introduction

Road tunnels and subways are mainly built to eliminate surface traffic, reduce noise and pollution, and expand the transportation network. These tunnels facilitate communication in agglomerations and on steep terrain. In general, a ventilation system is installed in each tunnel to pump out air volumes in a suitable way[1]. Tunnel ventilation is a crucial component of road and subway designs[2, 3]. Mechanical ventilation and natural ventilation are the two main types of tunnel ventilation[4, 5]. Modern tunnels frequently employ a variety of ventilation systems, mostly because of their unique features, layouts, and traffic patterns[6, 7].The most widely used ventilation systems are longitudinal and transverse. Transverse ventilation systems are ideal for long tunnels and the design of tunnel ventilation systems can be conducted using numerical models[8].

Recent studies suggest that longitudinal ventilation is the optimum option as stated by Betta., et al [9, 10] for tunnels shorter than 3 km in length. The curvature of the tunnel has a significant impact on air flow when the jet fans are farther from the ceiling. The ideal longitudinal distance between two jet fans ranges from 90 to 120 m .The width between the jet fans is 2.4m and the distance is 1.77 m between the ceiling and the diameter of the fans as stated by Jacques and Wauters [11] and Wang et al. [12]. The angle of inclination of jet fans in ordinary tunnels ranges from 7-8˚ as stated by Witt et al.[13]. Chen et al.[14] found that the best angle of inclination for jet fans in crowded tunnels of 2-4˚and 6˚for free tunnels .As for straight tunnels, the longitudinal distance of jet fans ranges from 60 to100 m and the distance between the ceiling of the tunnel and the fan is 0.3 m, it is located 100 m from the entrance of the tunnel [12, 14]. Air velocities are appropriately distributed according to the choice of location and system of fans in the tunnel as stated by Król et al .[15].

The design and calculation of tunnel ventilation systems is essential in the case of a temporary or permanent tunnel ventilation system. Ventilation systems use dedicated ducts to supply and extract fresh air into the tunnel. According to the previous, this research covers a research gap that was highlighted in this paper. which is that many researchers ignore obtaining the most economical alternative to obtaining (Q, m^3/s and H, Pa) actual duty for the final selection of the fan, determining its characteristics and location to pump ventilation rate into the tunnel with a specific ventilation system. So, the case study would be in the tunnel of Cairo Metro number 3 with a length of 1075 m, which extends from ATTABA station to BAB EL SHAARIA.

The Objectives of the work are to study the design and the calculation of the optimal ventilation system in the tunnel of Cairo Metro number 3, the following aims are:

- Calculation and design of ventilation rate of tunnel of tunnel of Cairo Metro number 3 according to ventilation rate of 80 m^3/s which is taken from the data of the National Authority for tunnels.
- Determination of the different types of ducts through which the ventilation rate passes by pumping ventilation fans under different conditions.
- Determination of air quantity, location of fans and regulators to distribute the required fresh air flow at the lowest possible cost.
- Selection the most economical design for less energy consumption and high fan efficiency.

2. Literature review

Many studies have been conducted on the tunnel ventilation systems of follows:

Kamal et al. [16] used PLAXIS and a 2D finite element commercial software, in the tunnel of Cairo Metro No. 4 for the design and calculation of the air flow. Jacques and Wauters [11] and Wang et al. [12]developed a model for the development of air flow and the effect of jet fans for longitudinal and curved tunnels using computational fluid dynamics(CFD). Additionally, Xue et al.[17]found that the greater the angle of inclination of the blade of the jet fans, the better the air flow became inside the tunnel. Therefore, the conditions of the rocks surrounding the tunnel must be known because they have an effect on the air velocity, as stated by Deng et al.[18].

Krasyuk et al. [19] studied the effect of longitudinal ventilation inside subway to calculate the ventilation rate. The results showed the best value for the air flow rate pumped from the fan is 117.7 m^3/s which leads to higher fan efficiency and lower energy consumption as stated by Yu et al.[20]. Eldakdoky [21]designed a case study that takes into account the generation of heat resulting from the friction of the train with the railways inside the tunnel. This study resulted in the possibility of obtaining a good ventilation design by controlling the ventilation rate using mathematical models and simulations. It was used as a case study Eldakdoky to calculate the static head pressure and ventilation rate in the design of the permanent ventilation of the tunnel by studying the factors affecting the shape of the tunnel as stated by Liu et al.[22].

Söderberg and Liu et al. [22, 23] used a mesh method to design the calculation of static head pressure and ventilation rate through the model K-omega SST model. As a result, a simulation is made of the air velocities entering the ventilation tunnel when the maximum speed of the train is not less than 120 km/hr. The simulated resulted in the availability of air quantities in an appropriate manner for the tunnel at this speed as stated by Liu et al.[23].

3. Methodology

3.1 Model description

The tunnel investigated in the current study is the tunnel of Cairo Metro number 3, which runs from ATTABA station to BAB EL SHAARIA. It is a two-directional tunnel, 1075 m in length as shown in Fig.1. The maximum width and the height of the tunnel cross section are 9.8 m and 6.3 m respectively, as can see from the cross-section of the tunnel in Fig.2. The ventilation design will be limited in this tunnel with a ventilation rate of 80 m^3/sec as shown in a side section of the entire tunnel for two stations (ATTABA station to BAB EL SHAARIA),1075 m in length as indicated in Fig.3. In addition, the ventilation rate system inside the tunnel can be designed and calculated under the following tunnel conditions: dry bulb temperature 38˚C-45˚C, relative humidity of 24.5% and specific volume of 0.90 m^3/kg.

Fig .1. A telegraph photo of the tunnel used in this case study.

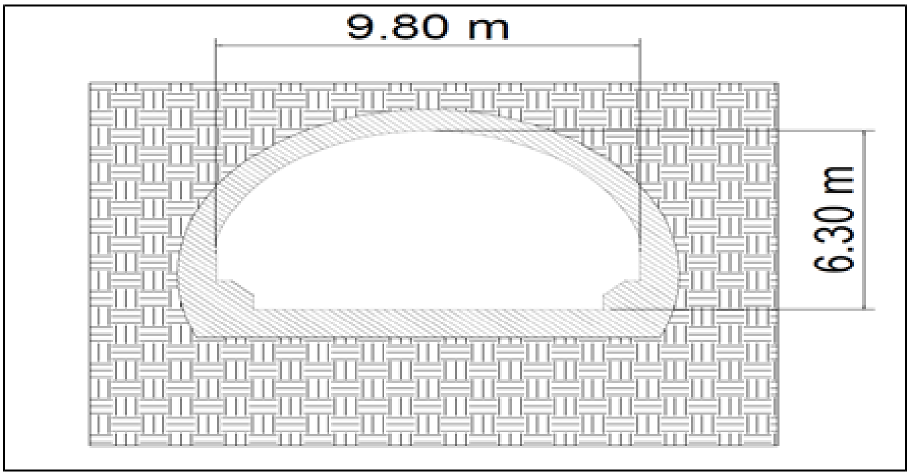

Fig.2. Cross-section of tunnel

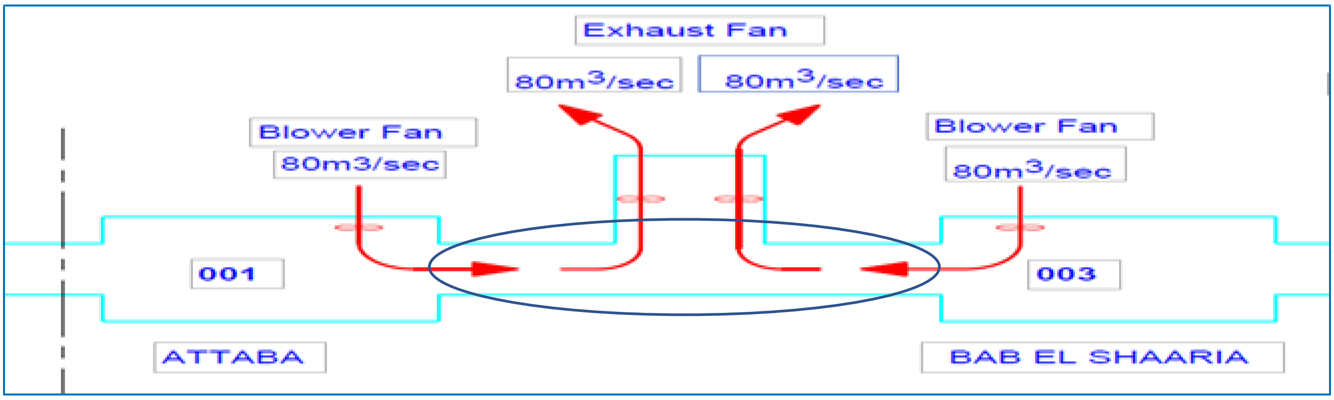

Fig.3. A side section of the tunnel of Cairo metro number 3

3.2 Estimation of the economic value of static head pressure.

The static head pressure, H, is determined in six different ways, as described below.

3.2.1 Using friction pressure chart (Jeffery)

The chart provides an easy method for ascertaining the pressure required to pass a given ventilation rate through a given size of tubing based on the coefficient of friction [24]. Since power is the pace at which work is done, it is necessary to have enough power to compensate for energy losses in airstreams while using fans. this power can be calculated from Equation(1) as stated by Hartman et al.[25]. Also, the total static head pressure, H, can be calculated from $\frac{0.2}{100} \text{x} \left(\frac{\text{length of the tunnel}}{0.3048}\right)$ [26].Table1 gives the values of static head pressure, H, and power P_{air} calculated from the chart (Jeffery) at a ventilation rate of 80 m^3/s.

$$P_{air} = \frac{QXH}{1000} \quad (1)$$

Table 1: The required duty from friction pressure chart.

Duct type and mode	**Q, m^3/s**	**H, P_a**	**P_{air}=Power, k_{watt}**
Blowing through canvas tubing.	80	1757.63	140.61
Exhausting through wire reinforced canvas tubing X2.4.	80	4218.41	337.47
Blowing or exhausting through metal, fiberglass, or rigid plastic tubing X0.75.	80	1318.22	105.45

3.2.2 Using Atkinson`s formula for vent pipe

Hartman et al.[24] and Dang et al.[27]said that the ducting's material, diameter, and level are dependent on the friction factor, so the friction factors can be used with several types of ventilation ducts. According to the Atkinson formula, friction loss is a function of the square of the velocity, so static head pressure can be calculated from Equation (2) as stated by MC Person [25, 28]. Considering the different values of K to calculate the duct used in each case, as in the Table 2.

Table 2: Quoted friction factors for flexible duct [25, 27].

Friction factor, kg/m³	
Pipe or tubing	Average, used
Steel, wood, fiberglass(rigid)	0.0037
Jute, canvas, plastic(flexible)	0.0046
Spiral-type canvas	0.0051

Table 3 gives the values of static head pressure Hand power P_{air} calculated from Atkinson's formula at a ventilation rate of 80 m^3/s.

$$H = \frac{KPL}{A^3} Q^2 \tag{2}$$

Table 3: The required duty from Atkinson's formula.

Duct type and mode	**Q, m^3/s**	**H, P_a**	**P_{air}=Power, k_{watt}**
Steel, wood, fiberglass (rigid), K= 0 .0037	80	1914.80	153.18
jute, canvas, plastic(flexible), K= 0.0046	80	2380.69	190.45
Spiral-type canvas, K= 0.0051	80	2639.46	211.15

3.2.3 Using head –loss formula for compressed air flow

According to Equation (3) recommended to use the head-loss formula for compressed airflow in high pressure ventilation systems rather than the Atkinson equations, which were designed for air as an incompressible fluid as stated in[24]. Tao et al.[28] said that blowers and exhaust are the two types of ventilation employed in tunnel ventilation. In blower types, the face of the airway is directly exposed to fresh air. As a result, fresh air enters the tunnel, and pollutants quickly move to behind the tunnel as in Fig. 4 (a). Fresh air is delivered to the face through the main tunnel while the contaminated face air is taken out through a duct in the exhaust technique of ventilation as in Fig. 4 (b). These techniques are studied by Tao et al.[28] and Malloch et al.[29]. Also, the values of static head pressure, H, and power P_{air} are calculated from the compressed air formula at a ventilation rate of 80 m^3/s as in Table 4.

$$P_1^2 - P_2^2 = \frac{k_c\, l}{D^5} Q^2 \tag{3}$$

(a) (b)

Fig.4. Shows the entry of fresh air into the tunnel and the exhaust suction: (a) Blower fan, (b) Exhauster fan.

Table 4: The required duty from compressed air formula.

Duct type and mode	Q, m^3/s	H, P_a	P_{air}=Power, k_{watt}
Blowing Rigid	80	1732.60	138.60
Blowing Flexible	80	2018.55	113.86
Exhausting	80	1762.73	141.01

3.2.4 Use of ABC mine vent

The total theoretical length of static head pressure, H, can be calculated from the actual tubing length plus coupling loss equivalent plus exit loss equivalent as stated American Brattice Cloth (ABC)[30]. According to American Brattice Cloth (ABC) [30], actual tubing length equals the physical length of your total typing; coupling loss equivalent 6 feet (1.83m); length of tubing section used 100 ft. (30.48m); and exit loss 100 ft. were used (30.48).

3.2.5 Use of ABC mine duct

Also, in ABC mine duct, the total theoretical length of static head pressure, H, can be calculated from the actual tubing length plus coupling loss plus bend loss as stated in American Brattice Cloth (ABC)[30]. Actual tubing length equal the physical length of your total typing; coupling loss 8 feet (2.44m); length of tubing section used 100 ft. (30.48m); and bend loss approximately 35 ft. (10.67m), as stated American Brattice Cloth (ABC) [30].

3.2.6 Use of ABC rigid duct tubing

It is possible to calculate the static head pressure, H, for a particular diameter of rigid duct tubing and the air volume by using the tubing resistance nomograph in order to select the appropriate size of rigid duct. So,one can easily use the nomograph to determine the static head pressure in order to know the different diameters of the ducts while knowing the amount of ventilation rate Q, to be pumped into the tunnels as stated by American Brattice Cloth (ABC) [30]. It is considered one of the best ways to determine the value of each of Q and H the most economical alternative, least expensive, and high efficiency. Table 5 gives the values of static head pressure,H, and power P_{air} resulting from different types of ducts at a ventilation rate of 80 m^3/s.

Table 5: The required air pressure of mine vent, mine duct, and rigid duct.

Duct type and mode	Q, m^3/s	H, P_a	P_{air}=Power, k_{watt}
Mine vent (lay flat) blower tubing	80	2100.96	168.07
Mine duct (blowing and exhausting)	80	13423.50	1073.88
Rigid duct (blowing and exhausting)	80	1171.5	93.72

3.2.7 Determination of the required duty for economical alternative

Table 6 gives the summary of the calculation of the static head pressure and ventilation rate for six different methods to determine the required duty for economical alternative. From this table it is noticed that the ABC rigid duct tubing method is suitable for selecting the primary and final fans based on a static head pressure of 1171.5 P_a and a power of 93.72 k_{watt} at a ventilation rate of 80 m^3/s, which is the most economical value that gives the lower power consumption.

Table 6: The required duty for different systems of tunnel ventilation

System	Required duty	
	H, P_a	**P_{air}=Power, k_{watt}**
1.Using friction pressure chart (Jeffery) Blowing through canvas tubing. Exhausting through wire reinforced canvas tubing X2.4. Blowing or exhausting through metal, fiberglass, or rigid plastic tubingX0.75.	1757.63 4218.41 1318.22	140.61 337.47 105.45
2.Using Atkinson`s formula for vent pipe Steel, wood, fiberglass (rigid). Jute, canvas, plastic(flexible). Spiral-type canvas.	1914.80 2380.69 2639.46	153.18 190.45 211.15
3.Using head –loss formula for compressed air flow Blowing Rigid. Blowing flexible. Exhausting Rigid.	1732.60 2018.55 1762.73	138.60 113.86 141.01
4. Use of ABC mine vent ABC mine vent (lay flat) blower tubing.	2100.96	168.07
5.Use of ABC mine duct ABC mine duct (Blowing and exhausting).	13423.50	1073.88
6.Use of ABC rigid duct tubing ABC rigid duct (Blowing and exhausting).	1171.5	93.72

Fig. 5. Illustrates power P_{air} according to static head pressure, H, to determination is the most economical value that gives the lower power consumption.

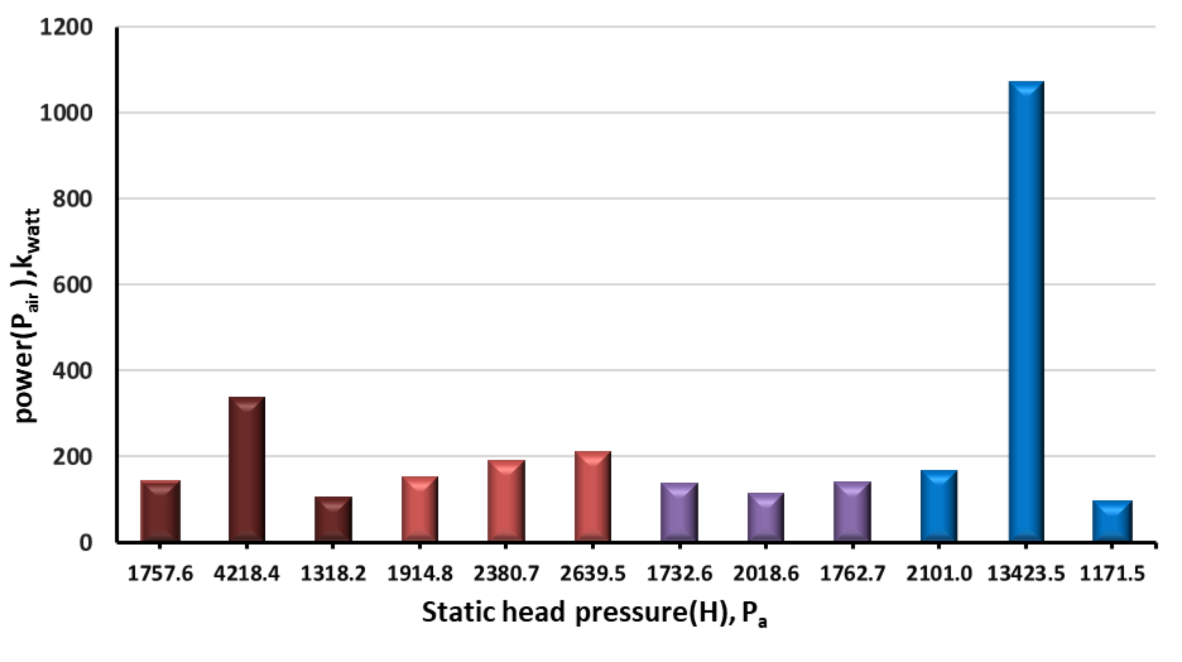

Fig. 5. Various alternatives for power and static head pressure at ventilation rate of 80 m^3/s.

The lower value of 1171.5 P_a determined the required duty for the economical alternative. On its basis, the static head pressure, H, for the final selection of fans is determined according to the ventilation rate taken from the tunnel of Cairo Metro number 3 at 80 m^3/s. This value can increase or decrease according to the length of the tunnel and the value of the ventilation rate as shown in Fig. 5.

3.3 Fan selection

Selection of fans is studied in several researches according to Bleier [31]and Hartman et al.[24]. Bleier [31]found that there are an infinite number of fans available that have specific characteristics and locations for required operation in tunnels. They are prepared specifically by some manufacturers to make it easier to select the best fans for specific settings. Therefore, there are several methods used for fan selection, including primary and final fan selection.

3.3.1 Preliminary fan selection

The primary selection of fans is determined by the area of duct and fan diameter resulting from Equations (4) and (5) as stated by Hartman et al.[24] and Bleier [31]. As stated in [25], there are four ways for the primary selection of fans, namely data table woods, special selection Jeffrey, selection chart ADM, and equivalent orifice. So, the primary selection of fans is determined by special selection Jeffrey and gives speed 880 r.p.m, diameter 96in and type of special selection ^HU.

$$A = \frac{1.2\,Q}{\sqrt{H}} \tag{4}$$

$$D_{fan} = \sqrt{\frac{A}{0.44}} \tag{5}$$

3.3.2 Final fan selection

According to data obtained from the National Authority for tunnels in Egypt. It is possible to construct a fan performance table for a given type of speed, diameter of fan, efficiency of performance blade-setting, and air velocity from Equations (6), (7), and (8) [24]. Table 7 gives the ventilation rate Q, static head pressure H, motor power P_m and fan efficiency %. This Table is used to determine the characteristics curve for the fan as in Fig .6. To find the most efficient fan to meet the ventilation requirements and determine how changing conditions speed and pitch will affect fan performance.

$$Q = \frac{Q_s n D^3}{n_s} \tag{6}$$

$$H = \left(\frac{nD}{n_s}\right)^2 \tag{7}$$

$$P_m = \frac{QH}{6346\eta_s}\ X\,100 \tag{8}$$

Table 7: Fan performance table

Q, m^3/s	**H, P_a**	**P_m, h_p**	η_s, **%**
47.74 (105414.06 ft^3/min)	1758.42 (7.05in.WG)	١٩٥,٣٧ (145.74 k_{watt})	60
68.47 (145081.83 ft^3/min)	1580.75 (6.34in.WG)	١٩٥,٩٩ (146.21 k_{watt})	74
82.44 (174692.12 ft^3/min)	1288.97 (5.17in.WG)	١٨٠,٢٥ (135.02 k_{watt})	79
91.78 (194486.27 ft^3/min)	1022.61 (4.10in.WG)	١٦٣,١٣ (121.69 k_{watt})	77.1
99.26 (210335.07 ft^3/min)	745.27 (2.99in.WG)	١٤١,٨٢ (105.80 k_{watt})	69.9

3.4 Fan characteristics curve

Characteristics curve is used to obtain the final fan selection in the tunnel of Cairo Metro number 3. And get an actual duty, according to data obtained from the National Authority for tunnels in egypt, is shown in Fig.6. Table 8 gives the values of static head pressure, H, and ventilation rate, Q, resulting from Equation (9) as stated in[24, 25].

$$R = H/Q^2 \quad (9)$$

Table 8: Construct my characteristic curve.

Q, m^3/s	H, Pa
47.19 (100000 ft^3/min)	407.57 (1.63in-WG)
56.63 (120000 ft^3/min)	586.90 (2.35in-WG)
66.07 (140000 ft^3/min)	798.82 (3.20in-WG)
75.51 (160000 ft^3/min)	1043.36 (4.18in-WG)
84.95 (180000 ft^3/min)	1320.52 (5.54in-WG)
94.38 (200000 ft^3/min)	1630.29 (6.54in-WG)
103.82 (220000 ft^3/min)	1972.63 (7.91in-WG)

Fig. 6. Illustrates ventilation rate according to static head pressure and efficiency to final fan selection by a graph that shows the actual duty which determines the characteristics of the fan and is represented by the amount of ventilation rate, static head pressure and fan efficiency.

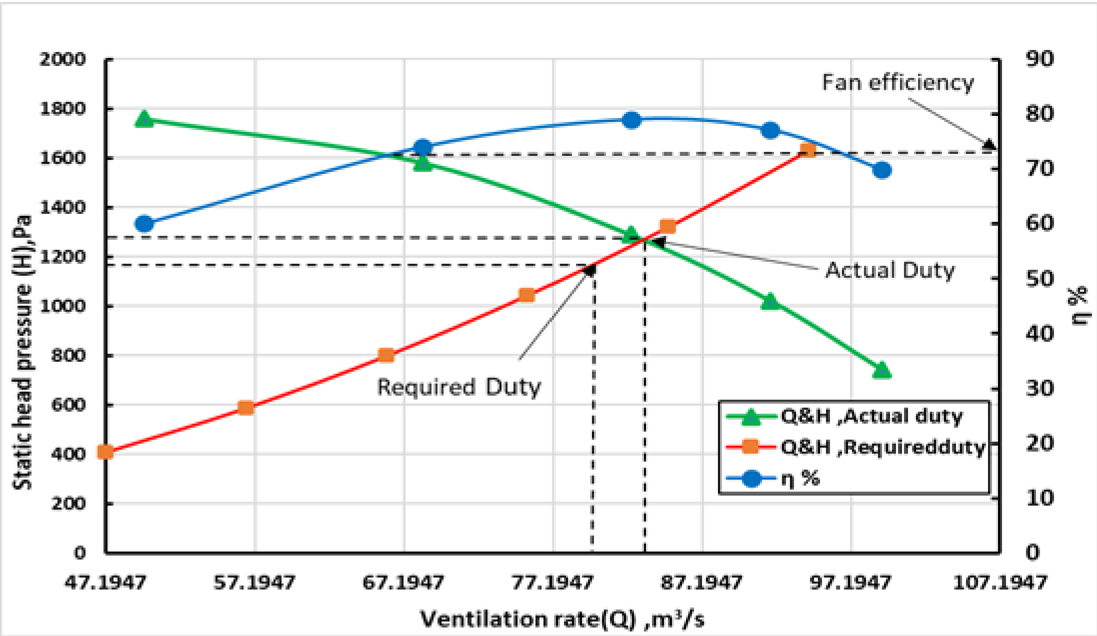

Fig. 6. Characteristics curve for fan.

From Fig. (6), it is found that the actual duty value is 84 m^3/s and the static head pressure is 1270 P_a. Therefore, the values of speed, pressure, efficiency, and motor power are obtained. Therefore, the maximum ventilation rate is set at 80 m^3/s and the static head pressure 1171.5 P_a the maximum required duty value. Table 9 gives the final fan selection for the results obtained from Fig. 6 based on the design and calculation of the appropriate ventilation system in the tunnel of Cairo Metro number 3.

Table 9: Final fan selection.

Type	Jeffrey 8HU
The optimum fan diameter	٩٦ inch
Speed	880 r.p.m
Ventilation rate	80 m^3/s
Fan head	1171.5 P_a
Fan efficiency	73%
P_m	146.05k_{watt}

Fig. 7. shows the process of conveying fresh air from outside by a blower fan through ducts in the tunnel of Cairo Metro number 3 at a ventilation rate Q and static head pressure H, obtained from the final selection of propeller characteristics from Table 9. While the contaminated face air is taken out through the exhaust fan. Also, Table10 describes the ventilation system in Cairo Metro Line3's tunnel.

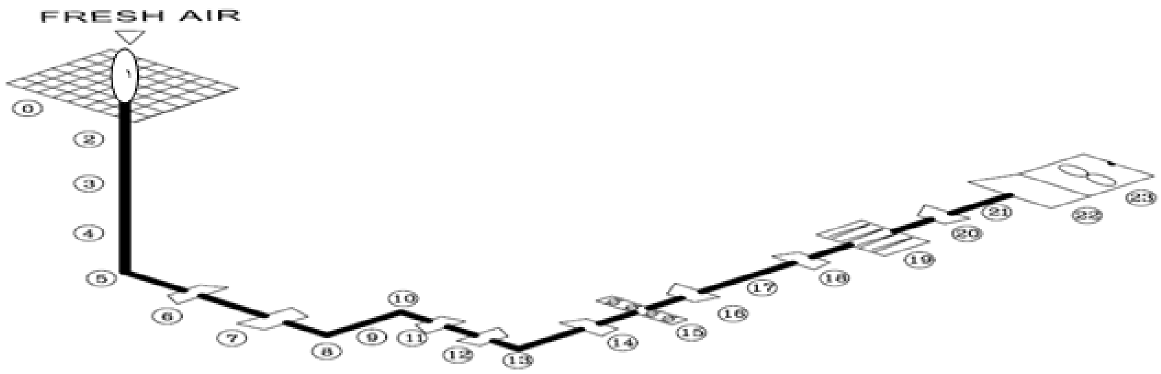

Fig. 7. A schematic diagram of Cairo Metro Line 3 tunnel ventilation [32].

Table 10: Description of tunnel ventilation for schematic diagram.

Legend			
NO	Description		
0	Grating	12	Abrupt contraction
1	External fresh air inlets	13	Elbow 90˚
2	Straight duct rectangular	14	Abrupt contraction
3	Straight duct rectangular	15	Opposed air foil blades
4	Straight duct rectangular	16	Abrupt transition
5	Elbow 90˚	17	Straight duct rectangular
6	Abrupt expansion	18	Abrupt contraction
7	Abrupt contraction	19	Sound attenuator
8	Elbow 90˚	20	Abrupt transition
9	Straight duct rectangular	21	Straight duct rectangular
10	Elbow 90˚	22	Circular bell mouth inlet
11	Abrupt expansion	23	Exhaust fan

4. Results and discussion

Tunnel ventilation is essential, whether it is a curved or longitudinal tunnel. Curved tunnels are more problematic than longitudinal tunnels, so they need continuous ventilation, and the problem of unavailability of ventilation as a result of high heat generation in the tunnel, especially in metro stations, has a detrimental effect on passengers.Therefore, through our study of the tunnel of Cairo Metro number 3, the design and ventilation were calculated on the ventilation rate of 80 m^3/s, resulting from the data of the tunnel of Cairo Metro number 3. There are several methods used to determine static head pressure, H, namely nomograph (Jeffery), atkinson formula, head loss formula for compressed air, ABC mine vent ,ABC mine duct and ABC rigid duct tubing.

But, H, it was selected from the ABC rigid duct method, it is is the most economical one that is giving the lower power consumption static head pressure (1171.5 P_a and air power 93.72 k_{watt}) as in Table 6. The graph shows the most economical consumption with a suitable power and static head pressure (1171.5 P_a and 93.72 k_{watt}) as in Fig. 5. There are two ways for selection fans, which are a primary and final fan selection. From a primary special selection chart(8HU)with a diameter of 96-inch and a speed of 880 r.p.m it selected the most suitable fan.

Fig. 6 shows the characteristics curve of the actual duty for the fan, the final selection of its diameter of 96 in ,speed of 880 r.p.m, ventilation rate 80 m^3/s, fan head 1171.5 P_a, fan efficiency 73% and motor power, P_m 146.05 k_{watt} Also, the actual duty was obtained and the value became from the graph equal to 84 m^3/s and 1270 P_a .Therefore, the tunnel ventilation for the tunnel of Cairo Metro number 3 was designed and calculated for the final selection of the appropriate fan characteristics for pumping into the tunnel on a regular basis and we selected the most suitable fan as shown in the Table 9. Fig.7 shows the entry of fresh air from the surface through the ducts into the tunnel using a blower fan. It also shows the process of air passage in the tunnel through the characteristics of the fan obtained from calculating the static head pressure, H, and ventilation rate ,Q, as shown in Table10.

5. Conclusions and recommendations

The calculation method was used from the data of the National Authority for Tunnels, from which the ventilation rate, Q, and static head pressure, H, were obtained. The above calculation methods will be used for future study to improve tunnel ventilation.

From the above study, it can be found that:

- The ABC rigid duct method is the best design for tunnel ventilation, as it provides lower power consumption and higher efficiency than nomograph (Jeffery), atkinson formula, head loss formula for compressed air, ABC mine vent, and ABC mine duct.
- The power in each case was calculated from the data obtained from the tunnel of Cairo Metro Line No. 3 tunnel, and the ventilation rate in all cases was 80 m^3/s, resulting in a constant head pressure of 1171.5 P_a, indicating that there is sufficient power to compensate for the energy loss in the air flows. The power P_{air} is appropriate for this static head pressure, and the length of the tunnel under consideration can cause the power to change depending on the size and shape of the tunnel.
- From the results obtained from the graph of (Q, m^3/s & H, P_a &η%) for actual duty which equals 84 m^3/s and 1270 P_a as in Fig.6.The most suitable characteristics for fan speed, pressure, head fan, efficiency and diameter are as shown in Table 9. Therefore, the amount of ventilation rate in the tunnel can be improved by controlling the fan speed,the number of fan blades, and selecting more than one fan by changing the dimensions of the tunnel.
- It is possible to study the effect of tunnel dimensions by changing the ventilation rate and study this change in the shape of the tunnel and compare one of the above-mentioned methods and

select the most economical ,high efficiency method. Fans can then be used to expose fresh air into the tunnel.

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تصميم وحساب نظام تهوية الأنفاق لمترو القاهرة الثالث (دراسة حالة)

الملخص العربى

يمثل نقص الهواء داخل الأنفاق أحدي المشكلات تواجة مستخدمي الأنفاق. فأن الأحتكاك الناتج من حركة القطارات يؤدي الي ارتفاع درجة الحرارة المتولدة. ولذا فقد تم أجراءهذة الدراسة لعمل تصميم وحساب نظام تهوية. وتتمثل المهمة الرئيسية لنظام تهوية الأنفاق الأمثل في تحديد كمية وموقع ووظيفة المراوح لتوزيع تدفق الهواء النقي المطلوب بأقل تكلفة ممكنة. ومن المهمات الرئيسية لاختيار مروحة مناسبة تلبي التصميم الأمثل لنظام تهوية النفق هي معدل التهوية (Q) والضغط الساكن (H) . كما تم دراسة وحساب كل من Q و H لمترو القاهرة خط ٣ تحت ظروف مختلفة لتصميم التهوية من البيانات التي تم الحصول عليها من الهيئة القومية للأنفاق. أتضح أن الضغط الساكن بلغ ١١٧١,٥ باسكال، باستخدام طريقة أنابيب الهواء المثبتة الأمريكية (American Brattice Cloth (ABC، وهي تلك القيمة الأكثر اقتصادا لترشيد استهلاك الطاقة ومعدل التهوية.

الكلمات الدالة

تهوية الأنفاق، مترو القاهرة خط ٣، معدل التهوية، الضغط الساكن، أنابيب الهواء المثبتة.