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Tips on Application of Natural Ventilation in Prevalent Buildings in Iran

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ABSTRACT: Methods of using natural ventilation in the architecture of the buildings have been studied. Architectural elements such as: the atrium, the ceiling light aperture, the courtyard, the staircase, dome roof, duct of the installations, and vertical channels of the building such as channel of the elevator are widely used in Iranian buildings. Feasibility of using these elements for natural ventilation has been studied taking into account the relevant standards. Significant results of the study are the sizes of the openings suitable for each case of ventilation. For the ventilation based on vertical paths such as the installation duct or the atrium, the ratio of the path area to the opening to it should be 0.78 times of the hydraulic diameter of the path. The area of the opening of the room to outdoor should 1.5 times of the opening of the room to the path. For ventilation using the light ceiling aperture the area of the opening to outdoor is independent of building area and should be 1 m^2. In ventilation using duct and staircase the should be an opening on the doom roof with area equal to the area of the duct.

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1. Introduction

Natural ventilation has been widely used in traditional ancient buildings in Iran in cities such as Yazd, Isfahan, and Kerman. Architectural elements such as Baadgir (wind catcher) and domed roofs are the well-known elements employed for natural ventilation. While in the modern buildings natural ventilation has been neglected and mechanical ventilation is used instead. In Iranian National Building Regulations Nos.14 & 19 [1,2] the required air for ventilation has been given. The authors have studied international building regulations on natural ventilation [3]. In reference [4] application of natural ventilation for buildings and design strategies & modeling methods have been reported.

In the present study ventilation performance of several architectural elements in prevalent buildings in Iran has been studied.

2. Methodology

The Loop Design Method (LDM) has been used for ventilation rate estimations in the present study. In the LDM the pressure drop is obtained as a function of air flow rate and geometrical specifications. The LDM has been explained in details in reference [4]. Equations of "Cross Ventilation", "Skylight Ventilation", "Mechanical Duct", "Vertical Channel", and "Combined Duct and Staircase" have been used for estimations of natural ventilation rates under several conditions.

Eqs. (1) to (4) shows an example of combining the ventilation duct and staircase. The wind pressure and static pressure are balanced with the pressure drop across the opening and air flow paths. Fig. 1 shows the schematic of a combined system.

$$\Delta p_w + \Delta p_s = \Delta p_{inl-2} + \Delta p_{st} + \Delta p_{inl-3} + \Delta p_{inl-4} + \Delta p_d + \Delta p_{ex} \tag{1}$$

$$\Delta p_w + \Delta p_s = \frac{\rho_o Q_{st}^2}{2C_d A_{inl-2}^2} + \frac{8fL_s \rho_o Q_{st}^2}{\pi^2 D_{h-st}^5} + \frac{\rho_o Q^2}{2C_d A_{inl-3}^2} + \frac{\rho_i Q^2}{2C_d A_{inl-4}^2} + \frac{8fL\rho_i Q_d^2}{\pi^2 D_{h-d}^5} + \frac{\rho_i Q_d^2}{2C_d A_{ex}{}^2} \tag{2}$$

$$\Delta p_s = (\rho_o - \rho_i) g \Delta z \tag{3}$$

$$\Delta p_w = (c_{p-inl2} - c_{p-ex}) \left(\frac{\rho U_{ref}^2}{2} \right) \tag{4}$$

3. Results

The main contributions of the present study are summarized as follows:

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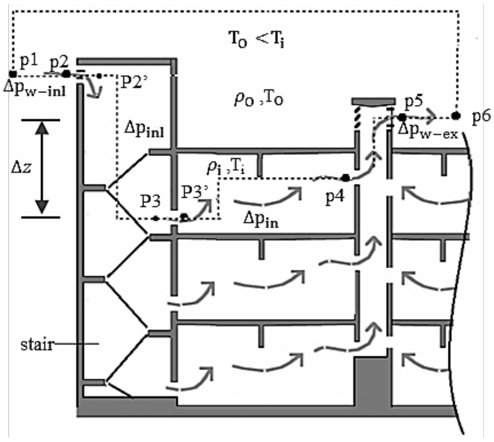

Fig. 1. Pressure drop in the combined system by duct and staircase

• The dome roof with a skylight is the best method for natural ventilation. This method is very suitable for one floor building or upper floor of a multi-floors building. According Fig. 2, the ventilation rate may be increased by 50% in windy climate. The inlets should be toward the incoming wind and the exhaust should be backward to the wind direction.

• The Mechanical Duct is a suitable device for ventilation of the floors which cannot be ventilated by skylights. A duct with square intersection of 0.6×0.6 m may induce ventilation rate about 0.3 $m^3.s^{-1}$.

• A combination of a duct with a staircase is shown in Fig. 1 may induce ventilation rate about 0.2 $m^3.s^{-1}$.

• Performance of an atrium depends on the size of the openings connected to it. At the best condition it may reach a flow rate of 3 $m^3.s^{-1}$. The effect of opening size on the flow rate of an atrium is shown in Fig. 3. It can be seen that for large hydraulic diameter of an atrium, the opening size affects the ventilation rate while this effect can be ignored for small hydraulic diameter of an atrium.

Table 1. Effect of natural ventilation induced by 5 K temperature difference on thermal load.

System	Ventilation Rate ($m^3.s^{-1}$)	Load (W)
Skylight	0.7	4300
Mechanical Duct	0.3	1800
Duct + Staircase	0.2	1200
Atrium	3	18000

• Effect of the natural ventilation rate on thermal loads (cooling or heating) depends on the ventilation rate induced by each system. The thermal loads due to the natural ventilation systems for temperature difference of 5 K are given in Table 1. It can be seen that the most effective element for natural ventilation is an atrium.

4. Conclusions

• Pass through ventilation is recommended in narrow buildings with small pressure drop in the direction of flow. The sizes of the openings at the inlet and outlet in this ventilation should be equal.

• Roof ventilation significantly dependent on architecture. The proposed area for the exit opening of a skylight in a house of 3 m height is 1 m^2 and independent of its base area. The skylight has its best performance in this exit opening area and the increase in area will not affect the ventilation rate.

• In ventilation with ducts and vertical passages, the area of the passage from the room to that pass shall be equal to the hydraulic diameter of that passage. In other words, the ratio of the cross-sectional of the passage to that passage should be about 0.78 hydraulic diameter of that passage. The area of the other openings, such as the room intake vent should be about 1.5 times the area of the opening of the room the duct.

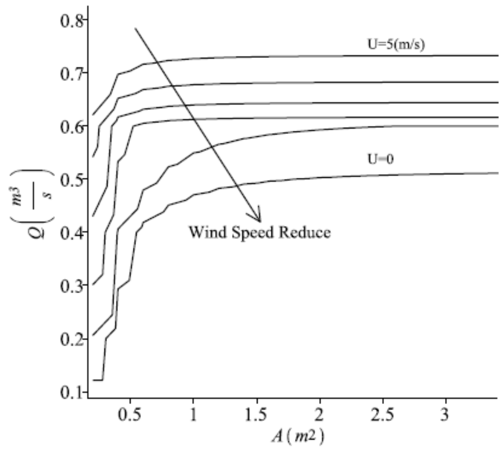

Fig. 2. The flow rate of patio vs. exhaust area for the different wind speeds in ceiling light (patio)

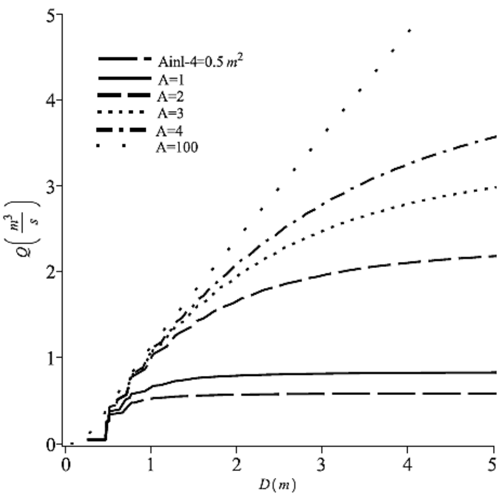

Fig. 3. The flow rate vs. the diameter of atrium for different inlet size to atrium

• In the staircase and duct ventilation system where the opening of the skylight at the dome roof acts as a wind catcher, the area of the opening of the dome roof should be about the duct cross sectional area. The opening area to living space should be 1.5 times of the duct area, and the opening on the ducts should have an area equal to the numerical value of the duct's hydraulic diameter. For example, in standard dimensions of duct (square with 0.6 m side), the opening the dome roof is about 0.4 m^2 and the opening on the duct is 0.6 m^2, and the opening of staircase and residential area 1 m^2.

• For an atrium, the proper dimensions of the openings are similar to those of vertical ducts.

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