AIR PRESSURE - A POTENTIAL FORCE FOR NIGHT COOLING OF ATRIUM BUILDINGS

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ABSTRACT

In order to save energy for building cooling during hot days in regions with cool nights, air circulation throughout the interior of the building has been envisaged as a means to lower the temperature of the building structural mass. In this way, energy required for cooling the building interior is reduced, due to lowered temperature of the wall, ceiling and other structural elements mass, and a greater storage of heat resulting from various heat gains the following day when air-conditioning is on. This paper deals with the distribution of pressure in a multi-level atrium building, which is becoming a frequent architectural feature in central urban regions , especially in business, commerce and other public areas.

By the application of the basic principle of pressure distribution in the complex conditions of a multi-level atrium building, it becomes possible to consider the effects of configuration of the central air space – atrium, i.e., its height and opening position, on pressure distribution and natural ventilation potential..Investigations in the field have also indicated the possibility of applying alternative sources of energy in building ventilation and cooling as a contribution to the design of an energy efficient and sustainable architectural unit, as well as to building engineering in general.

KEY WORDS

Atrium building, pressure distribution, stack effect, natural ventilation, cooling

INTRODUCTION

Apart from the possibility of using renewable energy sources, a building structure can also save energy. By itself, a building, which is in function in an environment, without using its own potential, is energetically under-utilized and incompatible with the environment.

The obvious need to condense urban structures within the central downtown area, as well as the increasing necessity for cooling during hot seasons, indisputably require increased percent of energy spent for building ventilation and cooling. The already existing temperature difference between the indoor and the outdoor air in the course of building utilization has a direct effect on pressure distribution and the potential of natural ventilation and cooling in the building during summer nights.

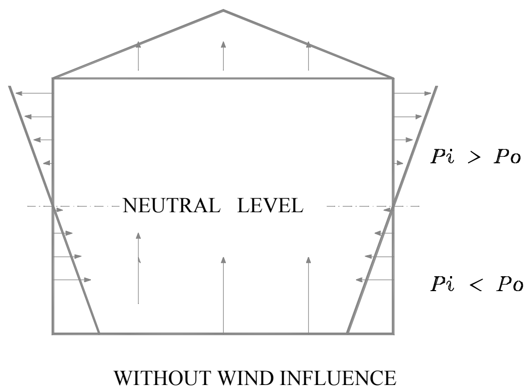
The form of a multi-level atrium building is adjusted to the natural process of air exhaust. Consequently, design of structural elements not only from the architectural but also from the energy efficiency point of view, should be part of the process of building the structure from the beginning (the initial idea) to the end (its completion).

DEVELOPMENT OF PRESSURE DISTRIBUTION

Pressure distribution in a building results from the difference in the indoor and outdoor air density due to difference in temperature and wind action as a consequence of solar radiation, as well as air-conditioning and mechanical ventilation operation. It tends towards balance, therefore the higher-pressure air flows towards the lower pressure space. In this way the quantity of air is balanced, i.e., total mass of incoming air becomes equal to the mass of outgoing air.

PRESSURE DISTRIBUTION IN A SINGLE SPACE

Inside a heated room there are areas of increased pressure – the "over-pressure" in the upper zone, with a tendency of air to leave the room in the direction of the zone of lower outside pressure, while in the lower zone an area of "under-pressure" is formed, with a tendency of infiltration of higher pressure air from the outside. The warmer air being of lower density, and the colder air being of higher density, there is a natural vertical airflow. (chimney effect). On the other hand, during summer days, when the temperature of indoor air is frequently lower than that of the outdoor air, there is quite a contrary process of pressure distribution and air circulation.



Marks: Arrows show magnitude and direction of pressure difference

Fig. 1 Pressure difference for typical heated space

The level where there is no difference between the inside and outside space, i.e., there is no tendency of air flow through external walls, is called the neutral pressure level – NPL (Figure 1.).

Difference in pressure resulting from the chimney effect depending on the height (h) is:

$$Ps = (\rho_o - \rho_i)\ g\ ((h - h_{npl}) = \rho_i g\ (h - h_{npl})\ (t_i - T_o)/T_o$$

Where
Ps= pressure difference resulting from chimney effect, Pa
ρ= air density, kg/m2 (for indoor conditions around 1.2)
g = gravity constant, 9,81 m/s2
h = observed height, m
npl = neutral pressure level, m
T = average absolute temperature, K

Pressure distribution, i.e., neutral pressure level position, NPL, provided there is no wind action, openings for air flow are identical, and there is no resistance to vertical air flow, depends on the façade perforation, i.e., the size and the vertical distribution of openings

Pressure distribution in a multi-level building
Accurate pressure distribution definition, i.e. neutral pressure level position, becomes more complicated when the internal space is divided by horizontal, non-hermetic partitions (resistance to vertical internal air circulation is formed) and with the introduction of vertical air spaces such as staircase areas, closed atria, elevator manholes and other installations and chimney ducts. This situation leads to the formation of a dominant vertical air circulation direction affecting the pressure distribution along levels

Pressure distribution in an atrium building

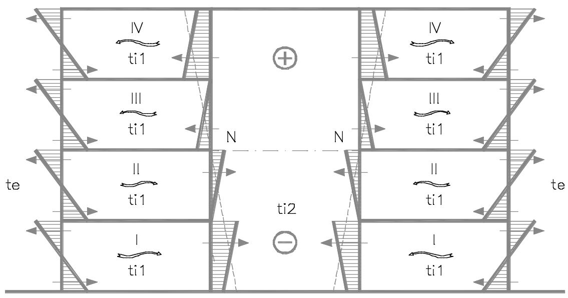
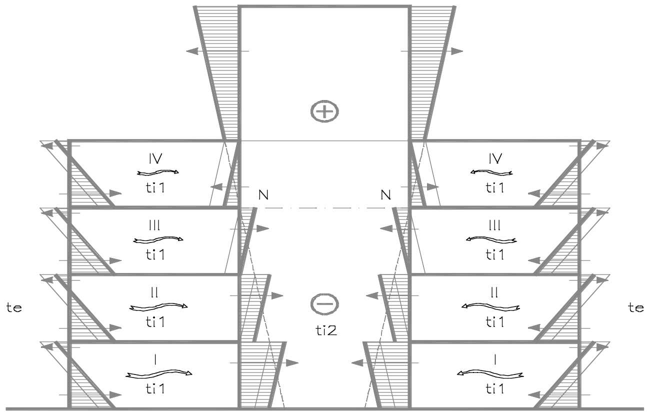


Fig. 2a – Pressure distribution in atrium building without openings

ti1>ti2>te
Hn−n=H/2

Figure 2a presents a section of a multi-level atrium building with the effects of temperature (chimney effect) on pressure distribution in winter season when additional heating is necessary, and during summer nights when cooling is required. The inclination of the line of pressure difference is uneven due to varying temperature differences between individual spaces, provided there is a constant proportional relation between them. In the initial case NPL is situated in the middle of the atrium space with even distribution of positive and negative pressure. During winter and summer nights (night cooling), i.e. when the indoor temperature is higher than the outdoor temperature, air flows from lower levels to the upper levels through the atrium space with the intensity perpendicular to the distance from NPL. (Figure 2b).



Slika 2b - Raspodela pritisaka u atrijumskoj zgradi sa otvorom na vrhu

ti1>ti2>te
Hn−n>H/2

In case an opening is made in the lower atrium part or in the underground duct, NPL lowers increasing the portion of increased pressure vertically. Pressure difference lines move towards the middle of the atrium, the air exhaust from lower levels being reduced, its infiltration into the higher levels increased (Figure 2c).

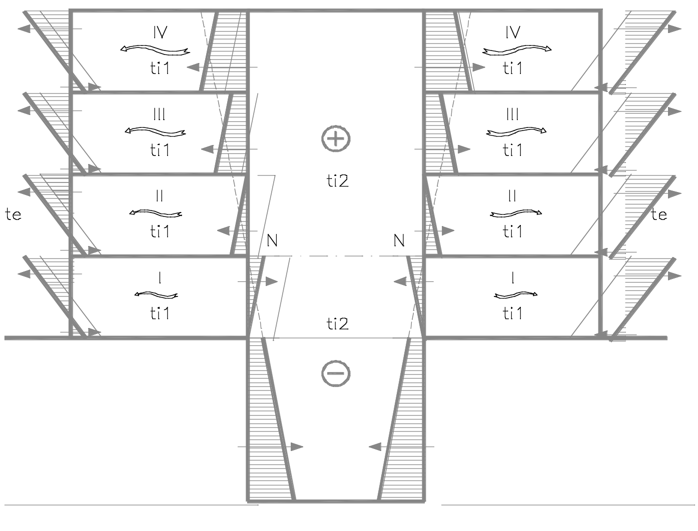


Fig. 2c- Pressure distribution with an opening on the top

ti1>ti2>te
Hn−n<H/2

In case two openings are made, both in the upper and in the lower parts of the atrium, or it is vertically elongated symmetrically in both directions, NPL will remain in the middle and the pressure distribution will be balanced identically with the initial case. Due to free circulation of air in the atrium, it can be assumed that the temperature in this area will gradually drop and become even with the outdoor temperature, thus further line inclination of the increasing pressure difference due to the increased temperature difference. (Fig 2d)

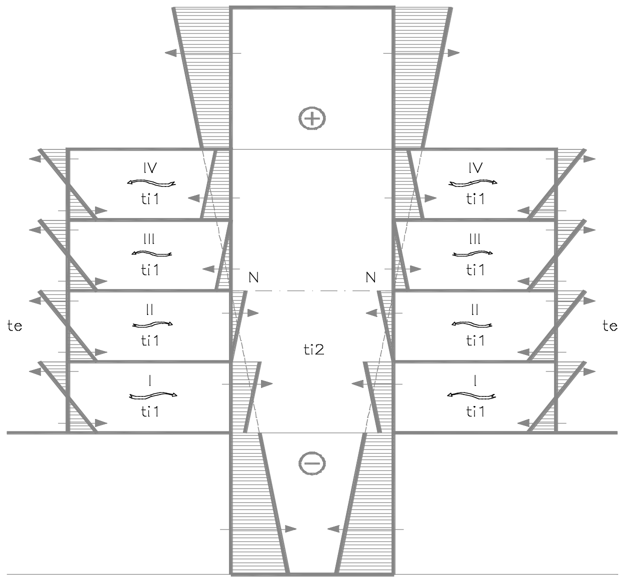


Fig. 2d – Pressure distribution in atrium building with top and bottom openings

ti1>ti2>te
Hn−n=H/2

CONCLUSION

On the basis of investigations of pressure distribution effects on the passive night cooling potential, it can be concluded that there is a direct interdependence between the building structure in an environment and the In case two openings are made, both in the upper and in the lower parts of the atrium, or it is vertically elongated symmetrically in both directions factors affecting temperature of both indoor and outdoor spaces.

Solar energy used for heating the air as an alternative and recycled source, as well as the energy for its additional heating in cold season, can also be used to remove the used air, i.e., for natural ventilation and passive cooling during summer nights.

Atrium as a central air space in a multi-level building is not only an architectural and structural feature, but also energy potential to control the effects of pressure distribution on the structure. Its vertical variation, i.e., opening of the apertures, has a direct influence on the pressure distribution in the whole building, and thus on the conditions of its ventilation. difference lines move towards the middle of the atrium, the air exhaust from lower levels being reduced, its infiltration into the higher levels increased

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