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THERMAL PERFORMANCE OF VERTICAL SHAFTS IN BUILDINGS: AN OVERVIEW OF EFFICIENT DESIGN PARAMETERS

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Abstract:

There are indications that buildings that include vertical shafts can affect the performance of buildings. Many Publications in major peer-reviewed journals from different fields (energy and buildings) were found using various keywords (Air shaft, light well, vertical shaft, thermal performance, etc.). The review of previous studies was on the role of natural ventilation in vertical shaft buildings in different climates, efficient design parameters, and their application to improve thermal performance and decrease energy consumption. These parameters include various vertical shaft configurations and components such as vertical shaft geometry, opening characteristics, roof properties, and materials. The height, length, and width of vertical shafts significantly impact indoor thermal conditions and energy consumption. The second effective design parameter was the openings, which strongly influence air velocity, air pattern, airflow, air temperature, and ventilation rate.

Keywords:

Air Shaft, Light Well, Vertical Shaft, Thermal Performance

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Introduction

Vertical shafts in buildings are one of the elements of sustainable design used to improve thermal performance and reduce energy consumption in buildings. The vertical shafts have a variety of benefits. According to (Dai et al., 2006; Freewan et al., 2014; Guangming & Ding, 2005; Li et al., 2015; Nada & Said, 2018; A. Yang et al., 2014), they are providing daylight and natural ventilation to the interior spaces that do not have a direct opening to the external environment. Although vertical shafts often have the same function, there are different names such as air shaft (Ghazit et al., 2017), light well (Li et al., 2015), light shaft (Padilla-marcos et al., 2018), ventilation shaft (A. S. Yang et al., 2014), and meenware (Mohammed et al., 2020). Historically, vertical shafts have been used in ancient civilizations, such as: using light well in the citadel of Qaitbay in Egyptian civilization (figure 1). In addition, the impluvium and compluvium shafts in Romans civilization ((Bagnall & Frier, 2006). In New York City, the vertical shafts have been used in Jewish immigrant apartment buildings for increasing the number of rooms to accommodate the largest number of people (Biddle et al., 2003). In Saudi Arabia, some of the building owners were using Meenware for other functions, such as a service core for the central spaces in deep plan buildings to install plumping lines and outdoor units of air conditions (Mohammed et al., 2020). Many studies discussed the effect of vertical shafts design on natural ventilation, while there is a small number of studies that have examined improving the thermal performance. For that, this study reviews previous literature to identify the design parameters that improve the thermal performance of the vertical shafts and their adjacent spaces.

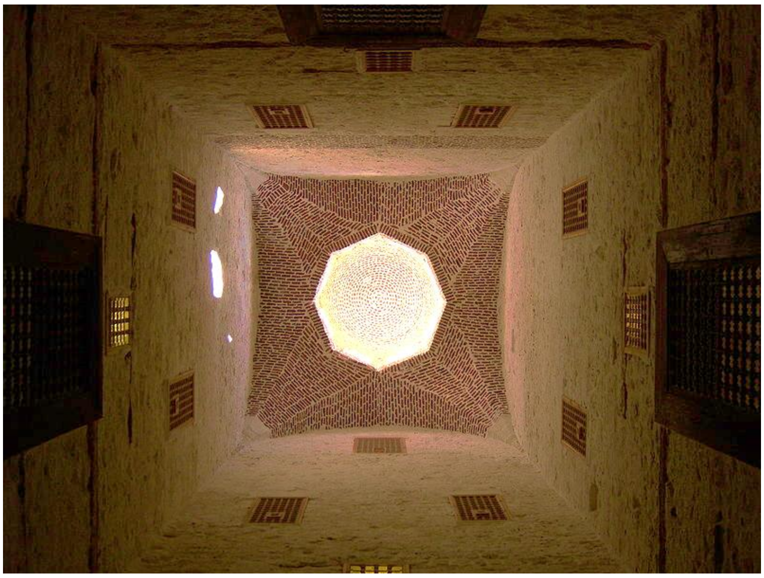

Figure 1 Light well ceiling in Qaitbay Citadel in Alexandria

Methodology

Many Publications from 1990 in major peer-reviewed journals from different fields (energy and buildings) were found using a variety of keywords (Air shaft, light well, ventilation shaft, and vertical shaft). The review of previous studies was on the role of natural ventilation in vertical shaft buildings in different climates, efficient design parameters, and their application to the improvement of thermal performance and decrease of energy consumption in buildings. The automatic search was performed via different online databases such as Thomson Reuters, Scopus, and Google Scholar.

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Result and Discussion

The design parameters can affect vertical shaft performance with daylight, natural ventilation, and thermal performance. In this study, the scope of the design parameters that affecting the thermal performance only. This section illustrates how vertical shafts and adjoining spaces' thermal conditions are improved by implementing efficient design parameters. Different methods such as experimental, analytical, mathematical, and numerical modelling have been used to assess vertical shaft thermal performance (see table1).

Opening Characteristics

Many factors of opining can affect the thermal performance of vertical shafts, namely: size, location, and the number of openings. The most influential factor is the size of the opening. Generally, when the size of the opening increase, the air temperature reduces significantly. The second factor is the location of the opening or the height of opining from the ground level. According to (Hussain & Oosthuizen, 2012), when they increased the opening height from 0m to 1.2m, the temperature decreased by 2.5 C. The opening also has impact on air change. According to (Miguel et al., 2019), the airflow through the opening increases ten times when the flap is placed in the roof opening. In addition, (Gaber et al., 2015) found that the connection to the outdoor environment using double-level void in cross-flow configuration was the most effective configuration to increase air velocity and reduce air temperature. Another study (Prajongsan & Sharples, 2012) suggested using the ventilation shaft in a room with one window to make a cross ventilation pattern in the room with a new window in the ventilation shaft. The result showed that the air velocities were greatly enhanced, and the percentage of comfort hours during the summer increased from 38% to 56%.

Geometry

The geometry of the vertical shaft includes many factors, such as the vertical shaft size, height, and form. The longer the light shaft in the wind direction was, the better the air change efficiency. It was confirmed that light shafts up to 12 m high and with height/length (H/L) rates lower than 3 were those achieving the best efficiency (Padilla-marcos et al., 2018). According to (Ahadi et al., 2018), the ventilation rate increased by simulated different lengths, widths, and heights of the vertical shaft. Results show that the square light-well with 4×4m minimum dimensions and the rectangular light well with 3×4 m dimensions can provide an adequate ventilation rate.

Roof and Floor Properties

According to (Nada & Said, 2017), the vertical shaft opened from the top and bottom has good air circulation, which reduces the air temperature inside vertical shafts, leading to reduced energy consumption. Regarding the roofs of vertical shafts, some studies showed the impact of the roof design on air temperature and air velocity. According to (Miguel et al., 2019), the airflow through the opening increases ten times when the cases had a triangle-shaped flap with the base on the top and the opposite vertex in the middle of the top border of the light shaft.

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Table 1: Summary Of Thermal Performance Of Vertical Shafts Under Review.

Element	Design Parameter	Impact	Method	Reference
Thermal Performance	Opening size Location Number	Air flow rate Temperature Energy demand	Simulation model	(Wang, 2012)
	Size Height Form	Air flow rate Energy load	CFD Simulation Model	(Zhai et al., 2011)
	Ceiling Form, Height	flow rates temperature distribution	Site measurement CFD Simulation model	(Wang & Abdullah, 2011)
	Material Thermal Mass	Airflow rates temperature distribution	Experimental	(Chan et al., 2010)
	Opening (Roof)	Air change	CFD	(Miguel et al., 2019)
	Opening (Wall)	Airflow Air velocity Air temperature	CFD	(Gaber et al., 2015)
	Opening (Wall)	Thermal comfort energy consumption	CFD	(Prajongsan & Sharples, 2012)
	Hight Length Width	Ventilation rate	CFD	(Ahadi et al., 2018)

Conclusion

This study showed an overview of the previous academic researches on the vertical shafts in different names around the world on influential vertical shafts design parameters. The article explains how these parameters can be employed and improved to provide a better thermal condition for vertical shafts and adjoining spaces. This study started with a brief overview of the evolution of vertical shafts through history, vertical shafts design approaches, and their problems, while giving insight into the importance of natural ventilation in the vertical shaft and its potential capability to replace current mechanical ventilation systems with high-energy consumption. This study emphasized the significance of vertical shaft components and configurations, as design parameters and their application to improve indoor thermal conditions and ventilation regime. The capability of each parameter was summarized with its efficiency, requirements and limitations. Studies on the efficient vertical shaft design parameters and their

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thermal effects can provide a strong standing point for further researches required to develop empirical guidelines for future vertical shaft designs.

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References
Ahadi, A. alah, Saghafi, M. R., & Tahbaz, M. (2018). The optimization of light-wells with integrating daylight and stack natural ventilation systems in deep-plan residential buildings: A case study of Tehran. *Journal of Building Engineering*, *18*(December 2017), 220–244. https://doi.org/10.1016/j.jobe.2018.03.016

Bagnall, R. S., & Frier, B. W. (2006). *The demography of roman Egypt* (Vol. 23). Cambridge University Press.

Biddle, G., American, S., & Museum, A. (2003). *Tenement Life*.

Chan, H.-Y., Riffat, S. B., & Zhu, J. (2010). Review of passive solar heating and cooling technologies. *Renewable and Sustainable Energy Reviews*, *14*(2), 781–789.

Dai, Z., Li, H., & Ren, Z. (2006). *Ideation Analyse for Architecture Creation: Adaptitude & Multi-attribute*.

Freewan, A. A. Y., Gharaibeh, A. A., & Jamhawi, M. M. (2014). Improving daylight performance of light wells in residential buildings: Nourishing compact sustainable urban form. *Sustainable Cities and Society*, *13*, 32–40. https://doi.org/10.1016/j.scs.2014.04.001

Gaber, T., Remaz, D., Alkaff, S., & Kotani, H. (2015). CFD modeling for natural ventilation in a lightwell connected to outdoor through horizontal voids. *Energy & Buildings*, *86*, 502–513. https://doi.org/10.1016/j.enbuild.2014.10.030

Ghazit, A., Wei, Z. Z., Jianpeng, Y., Baoan, P., Wei, Z. Z., Yang, A.-S., Wen, C.-Y., Juan, Y.-H., Su, Y.-M., Wu, J.-H., Caciolo, M., Stabat, P., Marchio, D., Ã, Y. S., Han, H., Riffat, S. B., Patel, N., Hwang, T., Go, B., … Said, M. A. (2017). Performance and energy consumptions of split type air conditioning units for different arrangements of outdoor units in confined building shafts. *Building and Environment*, *38*(1), 285–303. https://doi.org/10.1016/j.solener.2017.07.005

Guangming, L. L. H. Y. Q., & Ding, W. (2005). Exploration of Commercialization of Cashew Industry in South and Southwest Yunnan [J]. *Journal of South China University of Tropical Agriculture, 3*.

Hussain, S., & Oosthuizen, P. H. (2012). Numerical investigations of buoyancy-driven natural ventilation in a simple atrium building and its effect on the thermal comfort conditions. *Applied Thermal Engineering*, *40*, 358–372.

Li, J., Song, Y., Lv, S., & Wang, Q. (2015). Impact evaluation of the indoor environmental performance of animate spaces in buildings. *Building and Environment*, *94*(P1), 353–370. https://doi.org/10.1016/j.buildenv.2015.08.007

Miguel, Á. P., Meiss, A., & Gil-valverde, R. (2019). *Alternative solution proposal to improve the air change in light shafts based on flaps*.

Mohammed, A., Majid, R. A., Alsolami, B., & Kurban, A. (2020). Residents‘ perception of meenware design in residential buildings in saudi arabia. *International Journal of Scientific and Technology Research*, *9*(4), 2151–2157. https://www.ijstr.org/final-print/apr2020/Residents-Perception-Of-Meenware-Design-In-Residential-Buildings-In-Saudi-Arabia.pdf

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Nada, S. A., & Said, M. A. (2017). Performance and energy consumptions of split type air conditioning units for different arrangements of outdoor units in confined building shafts. *Applied Thermal Engineering*, *123*, 874–890. https://doi.org/10.1016/j.applthermaleng.2017.05.104

Nada, S. A., & Said, M. A. (2018). Solutions of thermal performance problems of installing AC outdoor units in buildings light wells using mechanical ventilations. *Applied Thermal Engineering*, *131*, 295–310. https://doi.org/10.1016/j.applthermaleng.2017.12.016

Padilla-marcos, M. Á., Meiss, A., & Feijó-muñoz, J. (2018). *A new application model of building ventilation with light shafts : a proposal based on case study assessment *. 19*(10), 796–810.

Prajongsan, P., & Sharples, S. (2012). Enhancing natural ventilation, thermal comfort and energy savings in high-rise residential buildings in Bangkok through the use of ventilation shafts. *Building and Environment*, *50*, 104–113. https://doi.org/10.1016/j.buildenv.2011.10.020

Wang, F. (2012). Design and low energy ventilation solutions for atria in the tropics. *Sustainable Cities and Society*, *2*(1), 8–28.

Wang, F., & Abdullah, A. H. (2011). Investigating thermal conditions in a tropic atrium employing CFD and DTM techniques. *International Journal of Low-Carbon Technologies*, *6*(3), 171–186.

Yang, A. S., Wen, C. Y., Juan, Y. H., Su, Y. M., & Wu, J. H. (2014). Using the central ventilation shaft design within public buildings for natural aeration enhancement. *Applied Thermal Engineering*, *70*(1), 219–230. https://doi.org/10.1016/j.applthermaleng.2014.05.017

Yang, A., Wen, C., Juan, Y., Su, Y., & Wu, J. (2014). AC Using the Central Ventilation Shaft Design within Public Buildings for. *Applied Thermal Engineering*. https://doi.org/10.1016/j.applthermaleng.2014.05.017

Zhai, X. Q., Song, Z. P., & Wang, R. Z. (2011). A review for the applications of solar chimneys in buildings. *Renewable and Sustainable Energy Reviews*, *15*(8), 3757–3767.