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Introduction to the Conference Proceedings
1-3 February 2018, University of Catania, Catania, Italy

One of the main challenges of the twenty-first century is to increase the sustainability level of our cities. This requirement is mostly associated to environmental issues, and a great effort has been made in the past years to build a low-carbon society. However, a town, to be considered sustainable, must, above all, be safe, particularly against natural hazards, which in Europe are mostly related to climate changes (e.g., hurricanes, floods, storms, and landslides) and seismic events (earthquakes). Unfortunately, sustainability is still not a prerogative of most European cities, especially those placed in seismic countries such as Italy, where at least 50% of the residential stock is earthquake-prone, while over 80% of the same stock is highly energy-consuming and carbon dioxide-emitting, thus contributing to trigger hazards related to climate changes. In this context, renovation actions, which combine both energy and seismic issues, are strongly needed. This assumption has to be promoted for the following main reasons: energy renovation alone will be worthless if an earthquake destroys the building; to prevent life losses and damages; to avoid several costs otherwise duplicated (costs for building-site setup and scaffolds, claddings, plasters and other finishings, etc.). Nevertheless, several barriers considerably limit the real possibility to extensively undertake combined retrofit actions, especially for multi-owner housing and high-rise buildings. These barriers are of different kinds: (i) technical (e.g., unfeasibility and/or ineffectiveness of conventional retrofit solutions, and need of regulatory simplification); (ii) financial (e.g., high renovation costs, “split-incentive”/“landlord–tenant dilemma”, and insufficient incentives and subsidies); (iii) organizational (e.g., temporary alternate accommodation for occupants, consensus to the retrofit expenditure by condominium ownerships, and excessive time to obtain building permits); and (iv) cultural/social (insufficient information and skills, and lack of adequate policy measures to promote renovation actions).

The Seismic and Energy Renovation for Sustainable Cities - SER4SC 2018 Conference, held in Catania, 1st to 3rd February, aims to overcome these barriers and to bridge the gap between sustainability and safety, with a link that may conserve both human and environmental resources.

This edition contains 56 papers arranged by theme into 6 thematic sessions. Each submission received reviews from at least two different Scientific Committee members and we would like to express our thanks to all the reviewers that provided detailed comments and feedback on all the submitted papers.

The selected papers were organized into sessions for the oral presentation, according to the key topics of the conference.

1st Session

Urban vulnerability and sustainable cities
Sustainability and safety of cities. Description of the vulnerability and/or energy performance scenario of any region or town. Tools and methods for assessing the urban vulnerability to natural hazards and for determining the scale of intervention to adequately reduce this vulnerability. Cost evaluation for the improvement of the urban resilience to natural hazards. Scenarios of possible financial incentives.

Resolution of organizational and practical problems
Strategies to overcome different organizational and practical problems, which considerably limit the real possibility to undertake retrofit actions, especially for multi-owner housing and high-rise buildings: consensus to the retrofit expenditure by condominium ownerships, excessive duration of renovation works and temporary alternate accommodation for occupants, split-incentive/landlord-
tenant dilemma, excessive time for getting construction permits, need of regulatory simplification, etc.

Economic and financial policies to promote renovation measures
Economic and financial tools, measures and policies to promote renovation activities.

Strategies for promoting the social sensitivity to prevention actions
Development of new policies to promote the awareness of the disastrous consequences of inadequate or insufficient prevention actions. Strategies to disseminate, among interested stakeholders, technical skills and competences on retrofitting measures, as well as to highlight the economic convenience of undertaking combined seismic and energy renovations. Training activities.

2nd Session
Construction techniques of historic and recent buildings
Description of construction techniques adopted for historic buildings (i.e. built before 1950) and recent buildings (i.e. built from the 1950s to the 1980s). Relationships between construction techniques and seismic or energy performance of buildings.

3rd Session
Seismic and energy regeneration strategies at district and urban scale
Urban regeneration strategies for the reduction of seismic vulnerability and/or energy dependence. Integrated land use and transport planning to reduce energy consumption due to private means of transportation.

4th Session
Design, monitoring and management tools
Novel tools for design, monitoring and management of existing buildings (e.g. BIM, parametric design, form finding, sensor grids, building management systems, etc.), with particular reference to renovation and post-renovation activities.

Retrofit optimization through prefabricated systems
Development of prefabricated systems to accelerate seismic and/or energy renovation activities, in order to reduce costs and inconvenience to the occupants.

5th Session
Technical solutions, materials and methods for seismic and energy renovation
Technical solutions, materials and methods for the seismic and/or energy renovation of historic and/or recent buildings.

6th Session
Decision support tools for the selection of the optimal retrofitting scenario
Development of user-friendly decision support tools to select the best seismic and/or energy renovation scenario, in terms of effectiveness, efficiency, costs, available incentives and subsidies, safety, inconvenience to the occupants, etc.10. Resolution of organizational and practical problems.

Diagnostic techniques and numerical models to assess seismic vulnerability and energy performance
Development of novel diagnostic techniques and numerical models to determine the seismic vulnerability and/or the energy performance of historic and/or recent buildings.
Despite the different disciplines and viewpoints represented at the conference, all participants agreed that the challenge of combining energy renovation actions and seismic upgrades are urgent and represents today a prevention action that is becoming more and more necessary to increase the sustainability level of our towns. Seismic and energy renovation of buildings will allow reaching very relevant benefits, at environmental, social and economic levels.

Consequently, wide engagement actions, at both local and European level, are fundamental to raise awareness of the social, environmental and cultural relevance of prevention actions, and to achieve consensus and behavioural change towards decisional strategies for both energy efficiency and seismic safety.

Prevention is essentially a matter of mindset and culture. Since European countries have a great tradition and culture, the basic premises for developing a prevention attitude are all there.

In this context, schools, universities and research institutes play a crucial role, stimulating institutions and political forces to strongly promote the upgrade of the building stock.

This virtuous circle is possible, as well shown by the movement for the restoration of historic cities that has originated in Europe and afterwards has reached brilliant results of urban rebirth, which are clearly evident in Italy as well as in many other countries.

This conference has engaged expertise and experiences of scientists, scholars, professionals and decision-makers from different countries, in order to find new effective, affordable and holistic solutions, which may positively contribute to enhance the sustainability level of our towns. In other words, this conference has aimed to become a hub, where people can discuss and start developing new robust renovation strategies for sustainable cities.

Acknowledgements:

We would like to thank our sponsors for their invaluable help for the success of the conference. We especially thank the Department of Civil Engineering and Architecture of the University of Catania (DICAR), the Order of the Engineer of Catania, the Foundation of the Engineer of Catania, the National Association of Building Constructors of Catania (ANCE Catania) for their attention to the issue of sustainable urban renovation, and their action of spreading the culture of risk mitigation.

Giuseppe Margani
Vincenzo Sapienza
Gianluca Rodonò
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Construction techniques of historic and recent buildings
Role of Sky-gardens in Improving Energy Performance of Tall Buildings

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Abstract

Natural ventilation has been used as a passive strategy for many decades but only now its importance in tall buildings for addressing the issues of high energy usage and reducing carbon footprints is emerging. Sky-gardens can play an important role in successful implementation of natural ventilation through amplification of natural wind speeds. This study presents a state-of-the-art review on optimization of tall buildings energy performance through incorporation of sky-gardens. Pros and cons of use of natural ventilation for multi-story buildings are highlighted. Details of involved technical difficulties and barriers in the construction and operation process of sky-gardens are also given. Relevant case studies of existing tall buildings around the world using this strategy are analysed to critically evaluate its effect. The results of this study will be useful for incorporation of sky-gardens and improving energy performance in similar buildings. In the end recommendations for future research needed with respect to sky-gardens in tall buildings are also provided.

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Keywords: Construction Techniques; Tall Buildings; Energy Performance; Sky-Garden; Natural Ventilation

1. Introduction

“The higher we live from the ground level, the more disconnected we feel from the natural world and even from each other within a community” [1]. Built environment is known to be the major cause of carbon footprint and local and global climate change. Buildings are responsible for 30-40% energy consumption in the world, while 40%-45% of energy consumption and 36% of CO2 emissions in the Europe [2] [3]. On the other hand, building and construction sector provides employment up to 5%-10% at a national level and so it the reason for 5%-15% of a country's GDP [2]. This has become the main reason for the fast urbanization of cities, which together with other reasons such as increasing land prices in city centres, green land preservation movements, global competition, emerging technologies etc. has led to increased construction of both the height and number of n of tall buildings. According to the database of US Department of Energy that covers tall buildings constructed after 1980s in 16 different US cities; the energy use by HVAC system consumes 33% of total building operational energy [4]. As our need to make taller buildings increase so does the issue to making building sector more energy efficient.

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1.1. Historical evolution of ventilation systems and energy consumption in tall buildings

P. Oldfield categorized the tall buildings into five generations according to their energy consumption trend. According to him first generation buildings are the tall buildings built from 1885 to 1916. Energy consumption in the buildings of this category were predominantly due the heating spaces and vertical transport. In these buildings the energy saving strategies were thermal mass and compact and bulky shape so that the winter heating can be reduced. buildings of this generation were naturally ventilated through light openings. their renovation resulted into a fully airconditioned system [4] [5].

Second generation buildings are the tall buildings built from 1916 to 1951. In these buildings the energy saving strategies were thermal mass and thermal mass within the envelope, however winter heat loss in these buildings was more due to their slender shapes (Small volume vs large surface area). On the other hand, this slender shape was useful for day light penetration in these structures. Like first generation the buildings of this generation were also naturally ventilated through light openings and later renovated as a fully airconditioned system [4] [5].

Third generation buildings are the tall buildings built from 1951 to 1973. The main feature of these buildings was the use of heavy curtain walls. These buildings consisted of 50%- 75% glazed surface giving rise to the U-values of the surface and hence the extreme heat loss, while in the past two generations this range was 20%-40%. Tall building of this generation was totally dependent on mechanical air conditioning and artificial lighting hence giving rise to the higher amount of energy consumption [4] [5].

Fourth generation buildings are the tall buildings built from 1973 to the present day. Key features of these buildings are incorporation of double glazing and increased technological details in curtain walls, compact shape and mechanical air conditioning. This is the reason that even in the presence of a great glazed surface area, the U-value remains less. Like third generation these buildings were also totally mechanically ventilated [4] [5].

Fifth generation buildings are the tall buildings built from 1997 to the present day. In these buildings the energy saving strategies were onsite energy generation, use of natural ventilation, double or triple glazed high-performance curtain walls, solar transmittance through transparent façade and slender shapes of the buildings. Fifth generation is more environmental sensitive [4] [5].

1.2. Natural ventilation in tall buildings

As the building size increases air flow patterns become more complex due to interaction with different indoor and outdoor environmental factors, so to achieve the desired thermal comfort and indoor air quality standards the ventilation design of multi-storey building is often moved from natural ventilation towards HVAC systems. HVAC systems are not only high consumer of energy but require careful design, installation, operation and maintenance [6]. Benefits of natural ventilation in high-rise and low-rise buildings are equally effective, still there are only few buildings in which ventilation system is based on 100% natural ventilation. Usually in the fifth generation of tall buildings, hybrid system is being used in order to keep avoiding the risks which can be caused by pure naturally ventilated buildings. However, in that case the major benefits of natural ventilation cannot be achieved. The physical mechanism of natural ventilation is same in low-rise buildings and high-rise buildings. The driving force is pressure difference between the inlet and outlet of the airflow. This pressure difference can be caused by wind or buoyancy [7].

D.W Ethridge divided the natural ventilation strategies in tall buildings into two categories:

i) isolated spaces
ii) connected space.

In both strategies of natural ventilation, the flow pattern always remains the same (i.e. fresh air enters occupied space). In first case (i.e. isolated space natural ventilation) the spaces to be ventilated are considered isolated in terms of airflow. Theoretically, building is considered to be divided in different zones and each zone has an independent system for natural ventilation. While zonal design of natural ventilation is very difficult to achieve such system due to the necessity of vertical shafts and lifts etc. In the later case (i.e. connected space natural ventilation) the whole building acts as a unit. This is more practical approach in case of tall buildings utilizing stack effect. However, there arise another problem as in case of connected system as the internal opening sizes should be large in number and size (vice versa to the isolated system) and it leaves the natural ventilation design results less predictable [7].

2. Introducing sky-gardens in segmentation in tall buildings

There are many concerns regarding the issue of high pressure due to wind and stack in tall buildings above the canopy layer, still there are no limitation for height of the building to the use of natural ventilation. However, the total height of the building can be divided into several parts which are isolated from one another by a space [8] called segmentation. This case is less complicated than a connected tall building i.e. without segmentation but is still challenging than a low-rise building due to wind direction that give rise to aerodynamic effect around the outlet on each segment. These open spaces can be designed as “sky-garden” or “sky court” [7].

2.1. Concept of sky courts and sky-garden in tall buildings

As described before, the fifth generation of tall buildings is more sensitive regarding environmental issues and hence demands the transformation of architectural design strategies from active to passive systems. In this regard natural ventilation and daylight has got its importance since these two natural resources can significantly reduce the energy consumption in tall buildings. Today academics and professionals are focusing more in adopting passive design strategies in order to improve indoor air quality, reduce the energy consumption and carbon footprint. In past generations of tall buildings open spaces have been used in the form of atrium and arcades to have daylight and natural ventilation, however there have always been the risk of potential heat gain due the direct exposure to solar radiations. Incorporation of greenery in such spaces can reduce these risks by reducing the UHI effect and heat absorption in building fabric. Furthermore, the green surfaces help in cooling the environment between 3.6-11.3 degrees centigrade, while wall surfaces can be cooled by 12 degrees centigrade [9]. This is the reason that in today’s architecture of Tall buildings sky-gardens have taken significant importance. According to Pomeroy (2009) sky-garden can be defined as an open or enclosed green space that can be incorporated at any level in tall buildings in order to provide adequate light and ventilation as well as recreational space to the inhabitants of the adjacent floors. In literature sky-garden is often termed as sky courts or rooftop gardens. sky-gardens and usually tends to vertically balance “open space to built-up ratio”. Trees in these sky-gardens and sky courts acts as shading devices as well as wind breakers and that’s why help in reducing the load on structural frame. They also play the role of a buffer zone for urban noise, improve air quality by cleaning it i.e. reduces pollutants, dust particles and carbon dioxide in the air. Other ecological benefits of incorporation of sky-gardens in tall buildings include reduction of rainwater discharge and incidence of flash floods during extreme rainy weather [10]. Furthermore, roof top greenery helps in reducing local temperature from 0.6°C to 1.3°C, relative humidity, solar gain and cooling loads. It has also been proved from analysis that sky-gardens improve
the permeability of building to wind and helps in increasing the wind speed in order to support natural ventilation process of buildings. However, there is very great research gap regarding this aspect [11]. Jie et al. (2004) simulated the air field around the high-rise buildings having sky-garden. They analyzed the influence of air flow direction, distance between buildings, building height and sky-garden volume on natural ventilation of buildings. According to them the building sky-garden in upstream buildings helps in enforcing the natural ventilation of downstream buildings [12]. However, this work has been published in Chinese language only that makes a barrier for the other researcher to get data. Wood et. Al (2013) described the efficiency of natural ventilation accelerated by sky-garden in high rise buildings by analyzing various case studies [13]. Table 1 shows different tall buildings with sky-gardens utilizing different ventilation techniques (such as intake of air, air extraction, a combination of both or to induces ventilation in inward facing spaces.

Table 1 Example of tall buildings using natural ventilation and sky-gardens

<table>
<thead>
<tr>
<th>Building name, Place, Year</th>
<th>Use of Sky-garden</th>
<th>Aspect of natural ventilation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commerzbank Frankfurt, Germany, 1997</td>
<td>Central atrium coupled with radial arrangement of offices</td>
<td>Induced ventilation in inward facing spaces</td>
</tr>
<tr>
<td>Manitoba Hydro Place, Winnipeg, Canada, 2008</td>
<td>South facing winter gardens (2-storey and 6-storey stacked sky-gardens)</td>
<td>Air intake</td>
</tr>
<tr>
<td>Post Tower, Bonn, Germany, 2002</td>
<td>North facing Atria</td>
<td>Exhaust</td>
</tr>
<tr>
<td>30 St Marry Axe, London, 2004</td>
<td>Series of four stacked sky-gardens on the top of each other</td>
<td>Combination of air intake and air exhaust (depending on the atria located on leeward or windward direction)</td>
</tr>
<tr>
<td>Torre Cube, Guadalajara, Mexico, 2005</td>
<td>2-storey and 6-storey stepped, spiraling sky-gardens</td>
<td>Exhaust</td>
</tr>
<tr>
<td></td>
<td>Stepped 4-storey sky-garden</td>
<td>Air intake</td>
</tr>
</tbody>
</table>

2.2. Impact of sky courts and sky-garden on energy performance of tall buildings

According to Tian et al. (2011) in most recent tall building projects; incorporation of horizontal green spaces is usually being done at three levels [14]:

- **rooftop Level**: Which is different from green roof in terms of accessibility, exposure to the sun and wind. While rooftop garden and sky bridges are not directly connected to the building envelope so not providing same thermal benefits as a green roof or green wall.
- **macro-scale Level**: Sky-gardens provide the more benefits at macro scale i.e. reduction in urban heat island effect, mitigation of air pollutants and storm water management etc. If these systems are incorporated in the building at a larger scale, they can reduce the energy consumption by cooling the ambient air and reducing the use of mechanical air-conditioning for cooling.
- **intermediate Level**: Another type of horizontal green space at intermediate level is podium garden that brings the same benefits for reduction of energy consumption as green roof. However, lack of awareness social and economic factors, less budget and incentive both from government and private
sectors and technical risks and issues lead to the less propagation of incorporation sky-gardens in the tall building systems [14].

2.3. Technical difficulties and barriers in the construction and operation process of sky-gardens

The irrigation systems of sky-gardens put a limitation on its incorporation into the tall buildings, that is the reason it is more popular in tropical and subtropical climatic zones where frequency of rain showers helps this system to go on naturally. Furthermore, vegetation needs a specific condition of climate round the year for growth that is another limitation of this system. That’s why the cities like California and Florida are feasible places for the sky-gardens and farming in sky-gardens [15]. The incorporation of sky courts in tall buildings is constrained in terms of future adaptability due to the tall building’s footprint and the authorities that regulate the functions and use of this space which makes this place private or semi-public while having the characteristic of public place [16]. Other difficulties include the high cost and maintenance e.g. In normal practices consultants plan sky-gardens and sky courts for building aesthetics and performance purposes however they do not provide proper maintenance plan for this system. Ultimately the responsibility is taken by the developers or inhabitants. Urban rooftop farming, on the other hand itself is a big issue since it leads to labour cost together with the other challenges i.e. Insufficient knowledge of landscape, Corps are usually for the occupants and are insufficient for neighbourhood leading towards the reliance on the industrial farms, growth of some bacteria can cause spreading disease to urban consumer due to the quicker distribution, water proofing and drainage need special care and maintenance plan, farms can be over reaped in the absence of special care. A successful operation process of sky-gardens needs a careful consideration of urban context, building type, social context of residence and physical environment around the building otherwise the provision can be a failure at any stage of operation [11]. The location of a roof garden or sky garden is very important in terms of accessibility [19]. Since the sky garden is located in such a way that it is accessible to the users of same floor or immediate floors, so they are more easily acceptable by the developers and occupants. On the other hand, rooftop gardens are more prone to the intense winds which together with the inappropriate techniques of planting becomes the major factor for failure of such element in building. There are some other social and economic factors which makes the shortage of sky-garden in urban districts i.e. ignorance of occupants towards the benefits of urban greenery and developers choose to have maximum economic benefits and choose to not pay for sky gardens once it is sold [20].

3. Incorporation of sky-gardens in existing tall buildings (Renovation Approach)

Lack of green spaces in urban cities should be compensated by the incorporation of greenery and plantation into the existing tall buildings [20]

Though number of detailed studies illustrate the benefits associated with horizontal and vertical vegetation systems there is limited literature available regarding the use of sky-gardens as retrofitting technique [22]. Some studies have explored retrofit through vegetation such as those by Nadia et. al (2013) [23] and Mazzali et al. (2013) [24] for walls as well as study Perini et al. (2013) [22] on design process in greenery retrofit of naturally ventilated building. Study by Mithraratne et al (2014) explored the long-term costs associated with renovating existing buildings through construction of greenery systems. Their isolated study concluded that in the amount of maintenance cost needed far exceeded the possible environmental benefits [25]. Future studies are hence needed to evaluate the actual energy and cost savings associated with sky-gardens in tall buildings.
Two types of retrofits are possible on roofs of tall buildings: extensive and intensive green roofs. However, each retrofitted green roof system comes with its own set of pros and cons. Extensive green roofs are light in weight, economical, natural and does not need expertise in planting techniques. This system can be adjusted in any kind of structure. These qualities make this system more suitable to be incorporated into the old tall buildings in congested areas. However, it has also got some limitations as it doesn’t have biodiversity and provides limited recreational value. This kind of sky-gardens are featured with flower beds and turfs [20] [21]. Intensive green roofs (also termed as podium roofs) have deep soil, a good irrigation system. This system is more favorable for incorporation in buildings during construction. This system has high maintenance and management cost [20] [21].

4. Case studies

For this research detail case studies are done on two tall buildings that are described below and the specifications are shown in Table 2:

4.1. Liberty Tower of Meiji University, Japan

The Liberty Tower of Meiji University is located in temperate climate. The concept of this building is “life cycle energy saving” and the shape of the building was defined to accelerate the phenomenon of natural ventilation together with the other strategies to reduce energy consumption. It has wind floor which together with the central core brings air from the floors below and exhaust outside causing stack effect. The wind floor has the opening on four side and it is located on the eighth floor while building in total consists of 23 floors. Its CO$_2$ emissions per usable area is 40% less compared to average emissions of educational tall building of Japan. Use of water recycling system makes it more ecological. Windows control the natural ventilation automatically. Automatic outdoor air intake control system based on CO$_2$ sensor increase its significance [18]. Overall the driving forces are wind and stack for the air intake and air exhaust. The classes are arranged along the perimeter of the building having windows with automatically controlled opening at the bottom for air intake. The exhaust of used air is done in natural as well as mechanical mode [7].

4.2. Commerzbank, Germany

According to the location of building it lies in temperate climate which make it more feasible to use the natural ventilation and sky-gardens. It is located in densely built-up financial district of the city. The building has triangular plan and atrium in the centre which is running the full height of the building while divided into four segments. Around this central atrium sky-gardens and offices are arranged in spiralling configuration. The sky-gardens are arranged around the atrium in a way that there is always a windward garden and a leeward garden for each segment of atrium to manage the intake and exhaust of air [7]. Characterized by 3000 motorized office windows, 100 atrium garden windows and huge area devoted for atrium airflow, this building uses natural ventilation for enhancing cooling strategy and reducing energy consumption by reducing the cooling load. Its main design strategies are double skin façade and stepping sky-garden connected with the central atrium. The atrium space can be seen from each office space and provides fresh air and natural ventilation to these spaces. Natural ventilation can be used throughout the year in the building while mechanical ventilation is used to moderate the local climate of atrium. The fresh air enters through the large windows located the top of each atrium exterior. The windows intake the air directly from the external climate, that passes through the atrium
and get supplied to the office spaces. These window open and close 10-20 times a day, depending on the weather condition [17].

4.3. Comparison of Case Study Buildings

Even though the climatic conditions are feasible for natural ventilation for both the buildings but Commerzbank can utilize natural ventilation as cooling strategy for longer time in the year and can save significant amount of energy without the incorporation of many technologies that has been used in Liberty Tower of Meiji University building. There is significant difference of height in two buildings still the taller building is using natural ventilation in more efficient way, that lead us to conclude that there is not much problem in using this passive strategy, due to height of the building. However, in the design of Commerzbank a careful consideration was given towards segmentation of height of building and incorporation of sky-garden. Sky-gardens are not only helping to create better airflow paths but also provide good indoor air quality [8] [13].

Table 2 Data of case studies [7].

<table>
<thead>
<tr>
<th>Building Name</th>
<th>Liberty Tower of Meiji University</th>
<th>Commerzbank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Location</td>
<td>Tokyo</td>
<td>Frankfurt</td>
</tr>
<tr>
<td>Completion year</td>
<td>1998</td>
<td>1997</td>
</tr>
<tr>
<td>Climate</td>
<td>Temperate</td>
<td>Temperate</td>
</tr>
<tr>
<td>Building Type</td>
<td>Educational</td>
<td>office</td>
</tr>
<tr>
<td>Building Height (ft, m)</td>
<td>119m</td>
<td>295m</td>
</tr>
<tr>
<td>No. of Floors</td>
<td>23</td>
<td>56</td>
</tr>
<tr>
<td>Building Architect/Project Team</td>
<td>Nikken Sekkei</td>
<td>Norman Foster</td>
</tr>
<tr>
<td>Ventilation systems</td>
<td>Mixed-mode: Contemporary</td>
<td>Mixed-mode: Contemporary</td>
</tr>
<tr>
<td>Natural Ventilation strategy</td>
<td>Cross &amp; Stack</td>
<td>Changeover</td>
</tr>
<tr>
<td>Vegetation</td>
<td>N/A</td>
<td>Sky-garden</td>
</tr>
<tr>
<td>Design Strategies</td>
<td>Ventilation &quot;wind core&quot; (central</td>
<td>Double skin façade, stepping sky-garden</td>
</tr>
<tr>
<td></td>
<td>escalator void), &quot;Wind Floor&quot;</td>
<td>connected with the central atrium,</td>
</tr>
<tr>
<td></td>
<td>over central void, innovative</td>
<td></td>
</tr>
<tr>
<td></td>
<td>window openings in lecture rooms</td>
<td></td>
</tr>
<tr>
<td>Energy Consumption</td>
<td>166Wh/m2</td>
<td>117kWh/m2</td>
</tr>
<tr>
<td>Approximate %age of the year natural ventilation can be utilized</td>
<td>29%</td>
<td>80%</td>
</tr>
<tr>
<td>Percentage of Annual Energy saving for heating and cooling</td>
<td>55% compared to a fully air-conditioned Office building in Japan</td>
<td>63% compared to a fully air-conditioned German Office building</td>
</tr>
</tbody>
</table>

5. Conclusion and future recommendations

Tall buildings are the result of fast urbanization of cities and the pressure of overpopulation. High-rise structures result in huge carbon footprint and increase in the local and global temperatures. To avoid
this situation there is great need to move towards passive strategies and make the buildings energy efficient. Among different passive strategies, use of natural ventilation stands prominent as it brings significant reduction in energy consumption of tall buildings. Segmentation and incorporation of sky-gardens brings a lot environmental benefits together with the acceleration of the process of natural ventilation and improvement in the energy performance of tall buildings. There are great initiatives taken towards the development of policies and incentives by the government of many countries i.e. Joint Practice Note (JPN), issued by the Hong Kong SAR Government in February 2001 [11]. However, importance of sky-gardens in tall buildings is still not acknowledged by the developers because of high investment cost required. Limited literature is available on the renovation of tall buildings for sky-gardens that acts as barrier on its wide application.

There is a great need to emphasise on the importance of this passive strategy and greening system and make more policies towards the maintenance plan of communal sky-gardens. In order to compensate the insufficiency of greenery in dense urban cities, detailed plans, specific legislations and appropriate planting techniques should be developed. The existing sky-gardens should be improved by developing biodiversity and new sky-garden should be incorporated in the existing building. More research involving detailed simulations and measurements is needed to assess the advantages and controlling factors to obtain sky-gardens best suited for different categories of tall buildings.

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References


Role of Sky-gardens in Improving Energy Performance of Tall Buildings


