Creeping Insulation - Hong Kong Green Wall

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***Abstract*—**Hong Kong is a densely populated city suffering badly from the urban heat island effect. Green wall offers a means of ameliorating the situation but there are doubts over its suitability in Hong Kong's unique environment. In this paper, we look at the potential for green walls in Hong Kong first by summarizing some of the Chinese green walling systems and associated vegetation in use, then by an introduction to three existing green walls in Hong Kong, and finally through a small experiment aimed at identifying the likely main effects of green walled housing.

The results indicate that green walling in Hong Kong is likely to provide enhanced internal house environment in terms of warm weather temperature reduction, stabilization and damping, with direct energy savings in air-conditioning and indirect district benefits of reduced heat island effect and carbon emissions. The green walling insulation properties also suggest the possibility of warmer homes in winter and/or energy savings in mechanical heating provision.

***Keywords*—**Case studies, experiment, green wall, Hong Kong.

I. Introduction

INCREASINGLY today, people are becoming more aware of the quality of their living environment. Hong Kong is a densely populated city, with tall and packed buildings and an extant air pollution problem because of its highly functional transportation system and proximity to China's heavy industries. Because of its urban heat island effect, the number of very hot days (maximum air temperature greater than 33°C) and very hot nights (minimum air temperature greater than 28°C) has increased dramatically. Being in a subtropical location, the ambient air temperature for much of the year is uncomfortably warm and humid. To counteract this hotter environment, the vast majority of the buildings are cooled by air conditioning. Of course this generates an energy by-product in additional to the huge amount of energy consumed every day for other purposes. This converts to heat which, in combination with the dense urban area, results in Hong Kong having not only an air pollution problem but also a heat island problem. One of the ways ameliorate this vicious circle is to reduce the amount of heat entering into buildings.

The introduction of vegetation onto the external surfaces of buildings can help in this. Theoretically, plant life on façades traps air as a layer of heat insulation. Transpiration of plants also cools down buildings. The amount of water evaporated because of transpiration increases proportionally to the size of the greened area involved, which means that more clouds form in the sky above the city to block sunlight and hence, in theory at least, contributing to cooling the urban area.

Some people in Hong Kong already do this by growing plants on rooftops to create green roofs. Green walls have an even bigger potential as they have a much larger surface area than roofs. The vegetation on green walls should help to reduce temperature fluctuations, carbon dioxide concentration and harmful substances in the air, etc. Is it possible that green walls can eventually be widely used in Hong Kong's buildings and became an alternative façade of the future?

Countries such as Japan, China and Spain are already using the green wall concept in buildings. For example, in Barcelona, there is a building covered in vegetation. Also in Barcelona is even a building with plants on inner atrium walls. In Hong Kong, however, this is not popular or well known. In addition, green wall experiences in foreign countries are not necessarily transferrable to Hong Kong, since climate, existing spaces, height of buildings and people's attitudes may be different. Just one recent official experiment relating to the efficiency of green walls has been carried out by the government to date. This paper aims to provide further evidence on the feasibility of green walls in Hong Kong.

Since Hong Kong is also a developed city with many existing tall buildings, attention is focused on the feasibility of green walling existing buildings. Existing buildings, however, have several problems of their own. The provision of vegetation needs extra support in addition to the walls making approvals harder to obtain than with existing buildings, as new buildings can be changed while still in the design stage to cope with this by adding the support into the design and therefore. In addition, objections to green walls are more likely with existing buildings as new build green walls become one of the inherent features of the building, so people understand and accept this prior to buying or renting making. Maintenance work also has to be planned afterwards instead of from the beginning as can be done with new build work. Therefore the efficiency of green walls provided in existing buildings is much less and with greater problems than for new buildings.

Therefore, there are many concerns concerning the possible application of green walling to Hong Kong's existing buildings. People may have different opinions and concerns about the system, and the possible choices of systems that can be used may be limited. The objective of this paper, therefore, is to help establish the extent to which green walling can help in protecting Hong Kong's unique environment (high rise buildings, polluted air, hot and humid climate) and culture, and creating a better future living environment for its residents by identifying the most appropriate form of green walling for Hong Kong's existing residential buildings and extent of its

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heat insulation effect, the key technical problems and factors to be faced in its adoption, and the opinions and concerns of potential occupants on the extent to which green walling would affect their normal activities.

In this paper, we first look at what is known about green walling and the popular systems in use in China and Hong Kong. This is followed by some case studies of some of Hong Kong's existing green walls to identify the practical possibilities in the city. Finally, as one of the benefits of green wall that is the easiest for people to feel is the cooling of indoor temperature, an experiment is described to find out the extent to which green walling really cools down temperature. Together, these considerations help in identifying the important factors that affect the prospects of green walling in Hong Kong and potential for contributing to Hong Kong's environmental improvement.

II. GREEN WALL SYSTEMS

A green wall is a wall, either freestanding or part of a building that is partially or completely covered with vegetation and, in some cases, soil or an inorganic growing medium. They are also referred to as living walls, biowalls, vertical gardens or more scientifically VCWV (vertical vegetated complex walls). The concept of the green wall dates back to 600 BC with the Hanging Gardens of Babylon. The modern green wall is considered to have been invented by Stanley Hart White at the University of Illinois Urbana-Champaign in 1931-38. Research in the topic is relatively new and being of significant interest only recently. The majority of this has been outside China and is well known. This literature review will therefore concentrate on the lesser-known work of Chinese scholars, which differs in some of its detailed and more technical treatment due to a combination of special cultural and climatic circumstances.

The Chinese term for green walling is "Vertical Greening", although we use the western term "Green Wall" in the discussion that follows. Although sometimes defined as "the vertical faces of buildings greened by planting climbers", Fukuzumi's method [1] of using non-climber plants to plant on walls, such as grasses, indicates a preferred definition of green wall to be simply the greening of vertical faces of building structures [2]. In developing his method, Fukuzumi suggests building frames with many partitions inside, in a similar appearance to wire mash. Each partition is filled with flexible and waterproof fill (such as polyester, nylon or similar materials) that allows the passage of air. Soil and plants are then put into the fill and the green wall made by hanging the frames on walls. The beauty of this is that there is no need for any repairs or maintenance as the frames can be easily detached from the walls. The choice of vegetation is also greatly extended beyond from simply vines and the flexibility of this system allows seasonal decoration changes to be made.

An alternative green wall system that shares some of the advantages of Fukuzumi's system is by Huang Yue-yi and Huang Ceng-xin and has already been granted a patent in China. This comprises a combination of triangular flowerpots that can be joined together and mounted on walls. The number of flowerpots used depends of the size of the walls. It potential for use in Hong Kong however seems to be limited as the flowerpots all open upward. During Hong Kong's normal summer rainy season, therefore, it is to be expected that the flowerpot arrangement will collect quantities of rainwater, creating a heavy extra loading on the building structure. Other minor problems include the possibility of strong winds blow the soil or even the plants out of the pots, since the roots are bounded and unable to grow very deep. The flowerpots' shape is also conducive to catching any airborne rubbish.

The modular system provides another means of green walling. This involves a panel with a growing medium fill inside. On the panel, there are the holes that provide access to many permanent planting cells. Again, the possible choices of plants are not limited to just climbers. Plants can be incorporated in replaceable planting cells before the panels are installed to allow them to grow to the sizes needed. This is a more practicable system as the plants are contained in replaceable cells and can therefore be easily rearranged and replaced. The cell covers are tight and prevent any wind from blowing away the plants and soil. This system can also incorporate with an automatic irrigation system, which makes maintenance work much easier.

III. GREEN WALLING IN HONG KONG

A. Regulations

People cannot just install some racks on their external wall and grow plants to make green wall. This is breaking the Hong Kong law of Unauthorized Building Works. According to the leaflet *Remove Unauthorized Building Works – It's an illegal affair*, published by the Buildings Department, UBWs comprise any additions or alterations to buildings that are not approved by the Building Authority. Vegetation itself is not a UBW, but the racks or other supporting structures are UBWs if not approved. Therefore, for existing buildings, special contractors need to be employed to make sure the green wall installation is people safe building safe. Approval from the government is also necessary for any extra build work.

B. Systems

Green walls in Hong Kong commonly involve the modular system. This has its own self-weight, with the combined weight of the panels, soils, plants and water providing a significant extra loading for buildings. This limits the choice of green wall systems available. Although there are ways of reducing the weight of green walls, such as using a light growing medium, there is still an increase in associated costs.

However, while special systems are good for use in low-rise buildings and structures, the maintenance needs of Hong Kong's high-rise buildings and extra weight imposed to the main structure present major problems. In particular, the prevalence of strong winds in Hong Kong will induce a considerable effect on the green wall system and plants. For the Hong Kong situation, the traditional approach is most likely to be the cheapest and the easiest to employ, i.e. greening by planting climbers and vines. This is because many climbers just climb up or down walls without the need for frames or additional supports. This not only imposes a minimum load on the structure, but also reduces other potential problems, such as unauthorized building work or possibility of being contaminated with rubbish to create air pollution or hygiene problems. It is also easier to examine experimentally. The research therefore aims to investigate the green wall system covered by climbers.

C. Choice of Vegetation

In accepting this restriction to the sole use of vines, the next issue concerns the type of vines available. For buildings less than 30m high, traditional green walling can be used by planting climbers and allowing them climb up or down the walls. However, not all vines are able to attach themselves to the wall unaided and many need racks to wrap around. The possible choices are therefore quite limited. Chen Qing and Cai Yong-li [3] list the most commonly used vines and climbers for green walls in China, divided into three categories by greening purposes. If the greening purpose is mainly to reduce indoor temperature, then vines such as Boston Ivy (*Parthenocissus tricuspidata*) and Ivy (*Hedera nepalensis* var. *sinensis*) are recommended as they grow densely and with relatively large leaves. On the other hand, should the greening be for decoration purposes, vines such as Wisteria (*Wisteria sinensis*) are considered as a better choice.

The obvious choice of vegetation in Hong Kong is a species currently found in Hong Kong as green walling aims to provide a good living environment and importing new species usually creates problems for the local eco-system. The local species also can suffer seriously. An example, of how newcomers can jeopardize the local environment is *Pueraria lobata*. The four plants mentioned above, however, can all be found in Hong Kong, making them all valid choices. There is a lack of experimental results on the efficiency of these different types of vine green walls and therefore we have to rely on information concerning the vines themselves. In doing this, it is clear that the various vegetations not only help to reduce the concentration of carbon dioxide, but also absorb substances that are harmful to human beings. Mao Shi-zhong, Zhao Tai-jiu and Liang Hui-ling [4] for example have examined the properties of twenty-seven different cultivated plants that are commonly found inside buildings to see how they can help reduce pollutants in the air. Ivy was also one of the experimental targets of their study. This showed that Ivy not only absorbs carbon dioxide as most of the plants do, but also Formaldehyde, Xylene and Benzene - an indication of some overlooked possible advantages of green wall.

For the Hong Kong situation, a green wall experiment was conducted by the Housing Authority with the help of The Chinese University of Hong Kong. This showed that, after adopting green walls, façade surface temperatures reduced by 16℃, with indoor temperatures decreasing by 1.5℃. Also reported were concerns voiced by the Vice Chairperson of the Housing Authority, Ms Fung, who said that the people living there think that the vines and supporting frames may become “stepping stones” for thieves and create security problems and that some people simply just dislike vines and climbers. As a result, green walls in Hong Kong are now mainly restricted to public facilities such as footbridges and shopping malls. The extent to which these concerns are felt by the residents and how they may be overcome is an issue yet to be resolved. Also, with such a limited trial, it remains to be seen what other potential problems may occur.

The next section reports on some cases in Hong Kong where green walling has been used. This is followed later by a small experiment aimed at shedding more light on the properties of green walling in Hong Kong.

IV. Cases

In this section, the potential of green wall for existing residential buildings is examined for feasibility in Hong Kong. There may be problems that have yet to be determined. As an initial enquiry, a preliminary interview was conducted with of Jaime, a manager of Strongly International Limited, and who has much of experience with green wall construction projects in Hong Kong. He has faced many real cases and therefore his point of view is very useful in determining what care is needed and concerns that exist in green wall adoption.

Jaime provided details of many projects that he has completed. These projects show that there are many different ways to applying green wall technology, from being just on a facade to decoration panels, advertisement, partition walls and noise barriers. The following three cases illustrate how these have been installed by Jaime in Hong Kong to date.

A. Vision City, Tsuen Wan

Vision City is a private development project in Tsuen Wan, and with a large 29m high green wall behind which is a car park. Two green wall systems are used. One is a wall-mounted system, with the other being a self-stand system. The green wall is formed by many different plants, which are used to form patterns. A fully automatic irrigation system is installed, as it is difficult to be watered manually due to its height. This is a value-added project according to the contractor.

B. Tsueng Kwan O Road Noise Barrier

For this project, the upper part of the noise barrier uses a traditional design, with the lower part only being a green wall. This lower part is required to provide two functions - a noise reduction to less than 25dB and noise absorption of less than 8dB. As discussed above, the green wall can achieve both these two requirements. In addition, this is the first project that the Highways Department of Hong Kong used a green wall in the form of absorption panels in a noise barrier system.

C. HSBC Green Card Advertisement

Green walls can also be installed in indoor areas. In this case, it forms an advertisement in a MTR station. The whole advertisement comprises a self-standing system. Different species of plants are contained in modular panels to form a pattern. As the wall is in modular panels, it is easy to be removed and replaced. The demonstration period lasted for one month and the MTR management would not allow any plant irrigation due to safety concerns. The contractor therefore used materials that would not shrink and also store plenty of water. This design was successful and the plants on the advertisement survived until the wall's removal.

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D.Concerns and Key Factors of Green Wall Applications

Five concerns emerge from these case study projects:

1) **Water consumed for irrigation**. Plants need water to survive and therefore irrigation is necessary. Many plants are needed to cover a whole building with vegetation, making water consumption very large. However, water is a resource not to be wasted.
2) **Attraction of pest and insects**. Plants need water and soil to grow. However, moisture, shelter and food create an environment conducive for pests and insects, which can be a problem for both the plants and human residents alike. To prevent this happening without recourse to pesticides involves improving in the design of the pots and using the right growing medium. The drainage system in green wall is also an important aspect in this.
3) **Allergy of pedestrians**. Plants may be an allergen for some people, with many being susceptible to the presence of pollen. This can affect residents and the passing public alike. Although there are some plants that do not have flowers and therefore do not produce pollen, the full extent of this problem is not fully understood to enable decisive action to be identified.
4) **Extra maintenance needed**. Green walls need more maintenance than conventional walls. Irrigation requirements can be met by installing automatic irrigation systems. However, regular maintenance is also needed to remove and replace dead plants, remove weeds, kill pests and insects, repair of panels (for modular systems), change plants patterns, etc. Much of this is not easy to carry out as existing Hong Kong residential buildings are often tall, so that workers very likely have to work at height.
5) **Cost**. The four points above all involve extra costs. In the absence of any contributions from the government or other external organizations, these have to be borne by the property owner and/or the tenants. This has been shown in several previous studies to be a major barrier to the adoption of green buildings in general and not likely to be any different for green walling.

Some of these concerns can be easily solved by amending building designs to include green walls for new buildings. However, there are more problems associated with existing buildings.

V.Experimental Work

This experimental study focuses on the heat insulation properties of green walls. Hong Kong is located in a semi tropical region with a warm and humid climate. The summer is quite hot, with the hottest temperature of over 36°C. According to the records of the Hong Kong Observatory, there is an average of 13.1 days per year (1971–2000) with a minimum temperature above 28°C. For a good proportion of the years, many people switch on their air conditioners. Therefore, if green walls can reduce heat transfer into buildings, they should also help to reduce the number of days that need air conditioning.

There are three specific a priori expectations:

1. Phase Difference in Temperature Changes

It is expected that the green wall could provide extra heat insulation for the green wall house compared with the control house (without green wall). If the heat insulation effect is significant, the temperature change of the green wall house should change but react later than the control house. If this happens, it should be reflected in the graphs in the form f phase differences in the curves.

2. Relative Humidity Difference

Vegetation needs water to survive and watering affects the relative humidity of the surrounding area. Relative indoor humidity should also be affected.

3. Cooler Green Wall house

As discussed above, a green wall can cool down buildings. This should be reflected in the experiment. The model green wall house should therefore be cooler than the control house.

An experiment was done to estimate the efficiency of green walls as heat insulators. The experiment involved the study of two types of climbers - the Boston Ivy and Ivy - as follows.

F. Field Study and Experiment Models

Two model houses were constructed on the rooftop of the Hong Kong Polytechnic University (E. core). The two houses were exposed to sunshine and close to the real situation faced by most residential buildings in Hong Kong. Thermocouples were placed inside the model houses to record temperature changes. The temperature in the two models was monitored over a one-month period.

To build the two model houses (Fig. 1), it was easier to prefabricate the roofs inside the laboratory than make them in-situ. The size of the roofs was set to be 600 x 600 x 30mm. Wire meshes were used to prevent the roofs breaking. At first, a cement sand mix was used to provide a spacer 30mm thick. Then the spacers were put into formwork to help fixing the wire meshes. The spacers were also used to control the thickness of the roofs. The concrete mix was 1:2:2, with fine aggregates being used as the roofs were thin.

Each of the model houses was positioned on one 18mm thick wooden board. Lightweight blocks (600 x 200 x 75mm) were used to build up the walls. Two layers of blocks were laid before laying the roof. The gaps between the blocks and the roof were filled by mortar.

Thermocouples were connected to the board. The board used in the experiment could hold at most 16 thermocouples. However, in order to record the actual temperature, a known reference temperature was needed. The reference was placed inside a computer cast. Before the start of the experiment, calibration was necessary. The recorded and real temperatures were input into Excel to establish their relationship and then typed into Labview. The program would automatically convert the data.

Every model house contained two thermocouples. These were pushed through a gap in a plastic tube between the bricks. One was just exposed to the air to measure the dry bulb temperature inside the house. Another was moistened by wet cotton wool to measure wet bulb temperature. In order to keep the cotton wool wet, a bottle of water was prepared and the cotton wool was half bathed. The same set up was also used outside to measure the ambient dry and wet bulb temperatures. This provided three sets of measurements in total.

Ivy was used in this experiment. Seven pots were placed on the roof to allow the vines to cover the walls. Plastic hooks were hooked together to prevent the vines from being blown away by the wind.

The two houses were placed far away from each other to prevent their shading each other. The yellow box in the middle contained a computer used to record the data. A plastic box was used to prevent the computer getting wet.

Fig. 1 Ivy green wall

Fig. 2 shows the positioning of the model houses, with their separation being from each other far enough to prevent their shading each other. The yellow plastic box in the middle contains the computer used to record data.

Fig. 2 Experimental set up

According to a Bansal [5], shading provided by leaves is good for cooling. About 5–20% of solar radiation on the leaves is used for photosynthesis, 5-20% for reflection and 20–40% for evaporation. The remaining 15–45% passes through as light and heat. Therefore, for the model covered with vegetation, this cooling effect should be manifested in lower indoor temperatures. If the heat insulation is significant, temperature change of the green wall house should change but react a little later than the control house and be shown on the graphs as curves with phase differences. In addition, watering should affect the relative humidity in the surrounding area and therefore also affect the relative indoor humidity.

G.Results

The temperature of the model house with green wall was always lower than the control on seventh and eighth of March. This shows that the insulation properties of the green wall prevented both heat entering into the green wall house and cooler air escaping.

TABLE I
TEMPERATURE CHANGES IN MARCH

	Temperature (ºC)		
	Ambient Dry Bulb	Control Dry Bulb	GW Dry Bulb
Date	Max	Min	Max
07/03	23.07	18.49	22.59
08/03	19.19	16.97	18.62
10/03	14.15	11.05	15.00
11/03	14.71	11.72	15.64
13/03	20.41	15.86	22.48
14/03	21.55	17.11	24.32
26/03	22.84	17.59	30.57
27/03	24.21	19.26	28.69
28/03	27.10	19.32	32.44
30/03	**22.68**	**19.92**	**25.50**

On 10th March, the temperature of the green wall house was always higher than the control one. The temperature on that day was low. On 11th, 13th and 14th of March, sometimes the temperature of the green wall house was higher than the control house, and sometimes lower. However, the lowest temperature of the green wall house was never less than the lowest temperature of the control house. Likewise, the highest temperature of the green wall house was never higher than the highest temperature of the control house, indicating the internal temperature to be more stable in the green wall house.

As the vegetation acts as an extra heat insulation layer, it also helps the indoor temperature changes in a more gentle way. As can be seen from Fig. 1, the temperature change of the green wall model house is usually smoother than that of the control house. A good example of this occurred on the 7th March, from 03:30 to 14:30, when the temperature of the control house gradually decreased with many small variations, while the temperature of the green wall house dropped slowly and smoothly.

Although there are errors and possible ways of improving the accuracy of this experiment, the potential of green wall is clearly demonstrated. Green wall is not only beautiful, but can also improve the living environment. People should find their house more comfortable when using green wall, as it can keep the house cool in summer and warm in winter. As shown in the experimental data of 13th and 14th March, the highest temperature is reduced by approximately 2^{o}C.

H. Limitations

- In this experiment, Ivy was used as the vegetation covering the green wall model house. Although seven pots were brought, it was still far from enough to cover the model house entirely. Many parts of the walls were still exposed to direct sunshine. The temperature difference between the two houses is estimated to be a further 2^{o}C-3^{o}C more if the model house is fully covered with vegetation.
- Full-scale models could not be made due to the limited resources available for the research. As a result, the models were too small to fully reflect the real situation. In addition, with such small models, the area of the roof occupied a larger proportion of the total surface area than with real residential buildings, so that the heat intake from the model's roof had a disproportionally larger effect than normal.
- Pots are placed on top of the roof to let the Ivy climb down on the walls to provide shading, therefore taking up some space and providing covers for the roof. As the models were small, the percentage of the area covered by pots was also larger than normal and the soil and water inside the pots contributed more than normal towards the roof's heat insulation properties.
- Water played an important role in cooling down the model. When the weather was hot, the plants needed more water and the opposite when it was cold. The amount of water provided was therefore different from day to day. This means that the cooling effect due to evaporation was also different in different days.
- Due to time limitations and the associated need for ease of construction, the models were built of concrete blocks instead of the normal concrete construction of residential building facades in Hong Kong. However, the blocks contained many voids, and therefore had heat insulation properties that were different from normal concrete.
- Wet bulb temperatures were recorded to measure the relative humidity changes inside the model houses. The small size of the model houses, however, made it difficult to provide openings to simulate windows and doors and so the results of the relative humidity changes in the two houses were not meaningful.
- Since the model houses contained no openings, no air exchange or sun lighting to indoor areas was possible. The combined effect of openings and green walling is as yet unknown. Sunlight entering into an indoor area can increase the temperature irrespective of the presence of a green wall. The existence of openings decreases the percentage of green wall cover and lowers its heat insulation effects. Air exchange also tends to balance indoor and outdoor temperatures. As a result, the effects of having green walls are likely to be higher in the model than in reality.
- Although the experiment lasted for a month, the data for 2/3 of the days involved contained errors. For example, some recordings during a day were abnormally high by up to a few thousand degrees. In the end, only 10 days' data were thought to be sufficiently accurate to reflect the true situation.

VI. Conclusion

Hong Kong is a densely populated city, with tall and packed buildings and an extant air pollution problem with an ambient air temperature that is uncomfortably warm and humid for much of the year. To counteract this hotter environment, the vast majority of the buildings are cooled by air conditioning, which is not only high energy consuming but actually adds to the problem in contributing to the city's heat island effect. Green walling offers a means of ameliorating the situation and in this paper we have looked at its potential for use in Hong Kong first by summarizing some of the Chinese green walling systems and associated vegetation in use, then by a introduction to three existing green walls in Hong Kong, and finally through a small experiment aimed at identifying the likely main effects of green walled housing.

The result of these considerations lead to the conclusion that green walled housing in Hong Kong is likely to be beneficial in providing enhanced internal house environment in terms of warm weather temperature reduction, stabilization and damping, with direct energy savings in air-conditioning and indirect district benefits of reduced heat island effect and carbon emissions. The green walling insulation properties also suggest the possibility of warmer homes in winter and/or energy savings in mechanical heating provision.

Not mentioned in this paper, however, are the possible effects of introducing vegetation on the physical condition of the walling. Creepers and climbers, by their very nature, retain moisture that is passed on to the surfaces on which they come into contact. In the UK, for example, old ivy covered buildings are notorious for their damp external walls. One solution to this is to damp proof the wall as part of the greening process, which may be a difficult task when attempting to green an existing building. Further research is needed to resolve this problem.

References

[1] Y. Fukuzumi, *U.S. Patent No. 5,579,603*. Washington, DC: U.S. Patent and Trademark Office, 1996.

[2] J.C. He, T.P. Zhang, Y.L. Li and D.G. Ye, "City vertical greening in china and new vertical greening techniques," *Urban Environment & Urban Ecology* 16(6), 2003, pp: 289–291.

[3] Q. Chen and Y.L. Cai, "Selection and disposition of vines in urban vertical greening," *Urban Environment and Urban Ecology*. 19(5), 2006, pp: 26–29.

[4] S.Z. Mao, T.J. Zhou and H.L. Liang, "Indoor anti-pollution plant selection and daily management," *Journal of Guangxi Academy of Sciences*, 24(3), 2008, pp: 217-219.

[5] N.K. Bansal, G. Hauser and G. Minke, *Passive Building Design,* Elsevier Science, New York, 1994.