

城市立体绿化的创新探索

Innovation and Exploration of Urban Three-Dimensional Greening

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摘要: 立体绿化是城市绿地系统的重要组成部分,既增加了寸土寸金城市中的生态绿量,提高了绿视率,又提升了城市街区空间里的美学与社会学价值,起到了改善城市生态环境质量、实现城市绿化增量、美化空间效果的作用。当前世界各地一些城市在发展立体绿化时进行了政策的导向与扶持、安全性与养护的技术攻关、形式的艺术创新等实践,但立体绿化在生长条件、植物配置、容器选择、施工养护等方面都需要克服许多不利的因素,需要对建筑空间进行研读并科学分析光照、温度、风力、水分等非生物因子,合理选择适合高空安全固定的容器与健康生长的植物种类。在分析与借鉴世界各地立体绿化成功经验基础上,在上海中心城区恒基旭辉天地、天安千树等项目中进行了立体绿化技术攻关与艺术创新的研究与实践,在容器、植物配置、安全等方面取得了阶段性成果,对上海及其他城市立体绿化技术支撑和形式创新具有指导意义与参考价值。

关键词: 风景园林; 立体绿化; 植物; 创新; 设计; 实践

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Abstract: As an important part of urban green space system, three-dimensional greening increases the quantity of ecological green in city by improving the green vision rate as well as the aesthetic and sociological value in the urban block space. In addition, it is helpful to improve the quality of urban ecological environment, to increase the amount of urban greening and to beautify the spatial effect. At present, some cities around the world have made efforts in policy guidance and support, and some practices such as technical research on safety and maintenance, artistic innovation of forms in the development of three-dimensional greening. However, some unfavorable factors need to be overcome, such as growth conditions, plant arrangement, container selection, construction and maintenance. It requires research on construction space and scientific analysis of the influence of non-biological factors such as light, temperature, wind power, and moisture which are suitable for high-altitude places. This paper resorted to the experience of successful cases of three-dimensional greening around the world, and carried out research and practice on technical breakthrough and artistic innovation in three-dimensional greening projects of The ROOF (Xuhui Tiandi of Hengji) and 1000 Trees (Tian'an Qianshu) in the central urban areas of Shanghai. As a result, it has gained progressive achievements in container, plant arrangement and safety, which are valuable to guide three-dimensional greening in Shanghai and other cities in technical support and form innovation.

Keywords: landscape architecture; three-dimensional greening; plant; innovation; design; practice

1 项目背景

1.1 国内外立体绿化由来

城市立体绿化的鼻祖可追溯到公元前6世纪的古巴比伦国王尼布甲尼撒二世,他为王后修建的“空中花园”是已知人类历史上最早的立体绿化。中国立体绿化的历史也源远流长,据《古今图书集成》记载,距今2400年的春秋晚期,南京古城墙上曾栽种过绿色植物,这可能是我国历史上有记载的最早的城市立体绿化。

世界发达国家对立体绿化非常重视,如德国在2002年颁布《屋顶绿化指导原则》,145个城

市把屋顶绿化等纳入城市发展规划内容,70个城市提供财政补贴,207个城市有减免排水费的激励措施,现德国屋顶绿化已有1亿多平方米,占可绿化屋顶的50%以上,取得了可持续发展的绿色效果;新加坡政府在有限的国土面积上不仅开发建设了许多公园和绿地,还在政策上对立体绿化进行扶持,由政府承担50%的费用,规划时严格要求沿街围墙、沿口预留种植槽等植物的规定,有力推动了立体绿化的发展;日本东京在1991年颁发了《城市绿化法律和都市建筑物绿化计划指南》,在《自然保护法》中规定住宅与商

业建筑20%以上屋顶必须绿化,目前东京的屋顶绿化已占14%以上。世界发达国家的绿色新政推动了以发展绿色低碳经济为核心的新经济革命,立体绿化已在生态系统承载范围内改变着生产与消费方式、城市文化、市民精神。

在上海市立体绿化专项规划(2016版)中,明确定义立体绿化是指以建(构)为载体,以植物材料为主体营建的各种绿化形式的总称,包括屋顶、垂直、沿口与棚架绿化等^[1]。为鼓励立体绿化的发展,在上海市绿化委员会办公室2015版《立体绿化文件汇编》中确立了绿化折算比例^[2]。



图1 皮克林酒店立体绿化仰视图

Fig. 1 Bottom view of three-dimensional greening of Pickering Hotel



图2 大阪难波公园立体绿化

Fig. 2 Three-dimensional greening of Osaka Namba Park

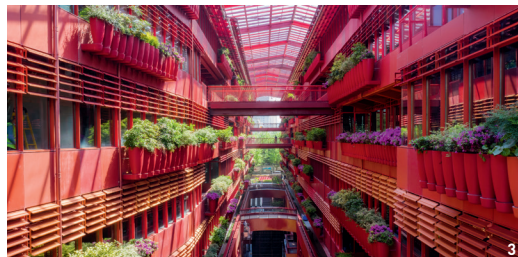


图3 内街沿口绿化实景图

Fig. 3 The actual view of the greening along the inner street



图4 内外街沿口绿化实景图

Fig. 4 The actual view of greening along the inner and outer streets

近年来,国内外立体绿化不仅仅体现在法规的制定、政策的扶持与生态绿色的增量上,还进行了针对存在问题的技术攻关,如植物在空中长期存活率低、艺术性缺失,以及安全和维护等亟须解决的痛点问题。再者,形式单一也是立体绿化发展的瓶颈,如何在创新中推动立体绿化向前发展成为一个新的课题,要在科学的基础上进行艺术与形式的创新,让立体绿化的发展空间变得更加广阔。

1.2 国际上立体绿化创新案例

新加坡的立体绿化不仅绿量大、形式多、布局新、风险小,而且科技含量高、生态与美学效果显著。以新加坡皮克林酒店^[3](图1)沿口立体绿化为例,项目示范了如何在城市核心区用立体绿化来解决城市环境对绿化需求的问题,设计时考虑了周边街区的人流需求,在建筑沿口每隔3层设置一个混凝土岩层种植槽与养护道,在种植槽中种植不同的植物。随着植物的不断生长,建筑逐渐被垂直与横向绿植所包围,而梯田状的连续岩层板被用来衔接酒店各功能板块空间,用绿色形成独特的空中花园,以安全与创新的方式模仿梯田状的连续混凝土板种植槽种植各种植物。在符合新加坡国家立体绿化政策前提下,创造了连立体绿化在内的15 000m²的绿化面积,相当于基地7 500m²的2倍,等同于酒店前芳林公园面积,成为世界上高楼林立城市中立体

绿化创新的成功典范^[4]。

日本大阪难波公园的立体绿化(图2),根据建筑构成的商业梯级峡谷形态,在商业各层的露台、沿口层层设置种植池与种植槽,种植植物形成美妙的平面及峡谷立体花园,让游客在行走时可以从不同的角度体验到不一样的花园式自然空间氛围。2006年意大利米兰设计师斯坦法诺·博艾里把730株乔木、5 000株灌木、11 000株草本植物种植到了近112与80m高的2栋高层住宅建筑物空中的露台上,以科学的给排水系统、种植土层、安全的支撑与养护系统、不同的植物共同形成了空中的垂直森林,不仅起到了除尘、降噪等生态功能,还美化了城市。如种植的植物随着季节变化而产生不同的景色:春天,这些植物将成为一道充满渐变绿意及开花的风景;夏天,枝叶的浓荫给住户带来清凉;秋天,不同类型的植物形成五彩斑斓的美景;冬天,植物会变成另一种状态。这个垂直森林的目的是最终建立起人与自然的和谐共生关系,2014年建成后每年吸收CO₂30t,每天放出O₂52kg。

各国不同立体绿化项目旨在净化寸土寸金城市中的空气质量,吸收CO₂和灰尘颗粒,并制造O₂供人吸收。用立体绿化创造的不仅仅是人类和植物的联系,还会吸引一些昆虫、鸟类等动物的到来,促成一个生物多样性的城市生命共同体,是自然与建筑和谐共生的新模式。

1.3 城市立体绿化的重要性

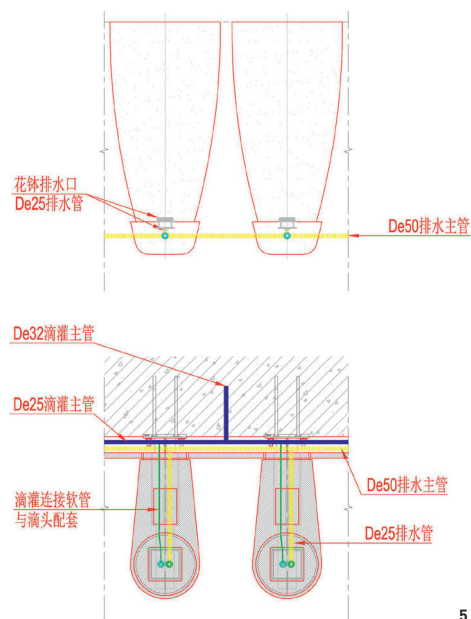
大城市从规划上留给绿地建设的面积是有限的,而立体绿化能有效利用城市平面以外的有限空间,让绿色由平面走向空间,提高城市的绿化覆盖率与绿视率。在功能上能吸尘,降噪;能保温隔热,节约能源;能滞留雨水、缓解城市下水排水压力等;能起到改善城市生态环境、提高居民生活质量与城市街区视觉美感等多方面的作用。因此,整体上是城市绿地生态系统的重要组成部分,是城市中的自然。自然中的城市的绿色增量,对于寸土寸金的大城市发展立体绿化的重要性是不言而喻的,这也是各国对立体绿化进行政策导向与扶持的原因。

2 项目案例及实践

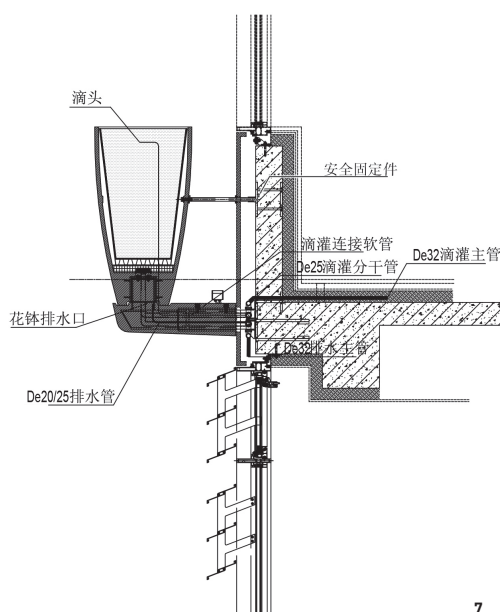
基于对立体绿化重要性的认识及国际上创新立体绿化项目的数据参考,在上海中心城区进行了立体绿化形式创新探索与技术难点攻关。

2.1 恒基旭辉天地

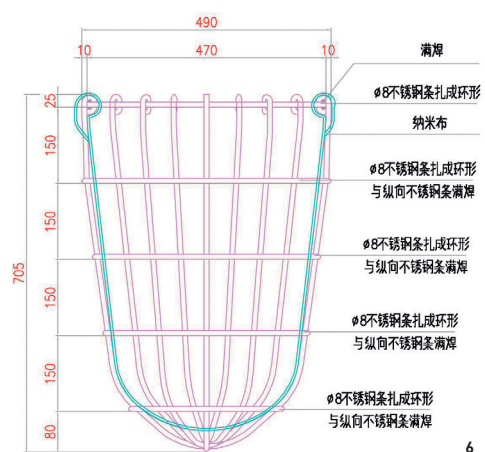
项目位于上海市黄浦区的新天地板块,建筑基地占地面积8 000m²,建筑40 000多平方米,遵循上海市城市绿地与立体绿化实施细则条例(2015.9)^[2],充分考虑政府对项目绿地率的比例要求,在提高城市空间绿视率的同时实现城市生态、生活美学、历史人文等社会功能的复合。其中,地面绿地有一层,加底下中庭种植面积为



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7



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图5 花钵外体

Fig. 5 Outer body of flower pot

图6 花钵内胆(单位: mm)

Fig. 6 Flower pot liner

图7 花钵固定

Fig. 7 Fixing of flower pot

1 700多平方米, 另外的绿地面积根据上海对立体绿化的面积折算要求, 采取种植1 000多平方米的立体绿化来满足绿地率要求。基于国际上成功的城市立体绿化经验与上海城市中心高楼林立的现状^[5], 在创新意识驱动与缓解城市绿量缺失的前提下, 在4栋建筑的14个外立面窗口外沿布置了大小不等的2 500个创新设计的艺术花钵(图3、4), 连绵种植着各色植物, 意图在寸土寸金的中心城区既解决政府规定的绿地比例要求, 同时成为立体绿化创新探索的实践典范。

2.1.1.1 基于生态、人文、美学的方案创意

1)花钵创意: 老上海法式建筑, 其建筑外立面多为砂岩米色, 而屋顶多为丹霞红色, 本项目建筑师设计的建筑外墙砂岩色与内墙丹霞红色灵感源于街区的历史与人文。另外在建筑上会沿窗口外悬挂花钵并种花草来体现法式的浪漫生活。根据植物生长与艺术创新的思考, 花钵的形式(深盆)、色彩、结构、与空中的艺术排列组合都是独创的。

2)花钵的艺术排列组合: 根据建筑构成的类似峡谷空间, 花钵的排列创意根据自然峡谷植物生长的空间沟槽与绘画美学原理进行排版, 实现因街区绿化形式变化而来的视觉聚焦、艺术享受与街区激活。

3)空中长效混合花园: 根据自然峡谷中植物生长方式与商业街区空间美学的需求, 基于植物的生态习性要求, 以常绿园艺植物为基调加入其

他不同的变色与开花植物, 形成长效、稳定、色彩变化的容器园艺组合。

将这些自然、生活、文化元素转译到当下立体绿化中, 成为街区里一种新颖的、有生态功能、有文化内涵、有绘画美学的立体绿化新形式, 这些源于生活与艺术的灵感构成了恒基旭辉天地立体绿化的创新空间形式、艺术构成与植物生命季相的本底。

2.1.2 基于方案的具体设计与技术难点

1)花钵与固定。

本次立体绿化承载植物的容器是特别设计的花钵, 根据植物生长对土壤的要求, 摒弃以往高空常规的浅盆做法, 创新点在于花钵高度加高, 使容纳植物生长扎根的土壤更深, 同时把花钵由外体(图5)与内胆(图6)组合而成, 利于更换与温度传导的隔断。花钵外体规格有6种, 直径分别为570、510、440、410、360、310mm。花钵钢构底托与上部不锈钢拉杆结合, 使两者的结合体与窗沿口墙体稳固连接(图7)。外体采用强化混凝土(HUPC)与板材料制成, 花钵的颜色与整体墙面颜色保持一致。花钵内胆选用不锈钢条网与纳米布结合。

2)种植介质。

种植介质要求结构疏松、通透性好, 保水、保肥能力强。

3)植物种类选择的前提条件。

考虑到植物对光照、风力、温度等自然因素

有一定的要求^[5], 通过对光照、风向、温度的分析, 提出了基于气候学、生态学、园艺学的植物选择策略。

(1)场地光照。

东南、南立面上部及内街南立面上部、西立面光照强, 适宜选择喜阳植物。外街下部、内街北立面和南立面下部、北立面光照弱, 选择耐阴植物。北侧和东北侧光照强, 选择阳性植物。

(2)风力。

东立面为十字路口, 风速较大, 要选择根系发达、小叶、革质或半革质灌木。西立面静风区较多, 可选择耐半阴、较大叶植物。

(3)温度。

植物对温度有一定要求, 在最适温度下, 植物能迅速而正常地生长发育; 在最低和最高等不利情况下, 植物将停止生长发育或受到伤害, 但仍可维持生命; 如果温度再继续下降或上升, 植物将受损甚至死亡。

(4)植物种类选择。

基于以上种植容器位置、所处街区的气候分析, 在空中的植物生境条件是比较差的, 非生物因子如光照、温度、风力、水分等影响特别明显。在花钵植物种类选择上, 抗风、抗蒸腾、抗高温、抗低温及须根发达植物为上佳选择, 通过2019—2020年的实验工厂与预栽培种植筛选出叶小、革质、抗性强的灌木与多年生植物, 如杜鹃、络石、小叶扶芳藤、火棘、南天竹、金叶

大花六道木、花叶香桃木等几十种植物，这些植物叶片的蒸腾作用相对较小、生长慢，能够减少风、光、温等不利环境对空中植物的影响。到了蒸腾作用旺盛的夏季，叶片厚厚的革质层有利于抵御阻挡一部分的水分被蒸发，有效避免了夏季高温叶片卷边等现象^[6]。

2.1.3 植物的创新配置

植物配置遵循从生态学、园艺学、绘画美学原则出发的创新长效混合园艺配置，以植物四季变化来与建筑、空间、人一起成为生命、生长、生活的共同体，空中绿色统一聚焦与融合了从不同角度来的视线，创新实现从个体到组合到群体的生长稳定的可持续园艺种植模式。内街园艺配置强调丹霞红背景里的绿色渐变，浅绿、嫩绿、鹅黄到墨绿的韵律组合，以常绿植物为基调在四季变化中调和内街空间，吸收各波段的光，春天开花的杜鹃等植物和冬天开花的茶梅等植物穿插于绿色群落中；外街米黄沙色背景里强调绿色中各种开花植物的组合，用绿色与各种开花植物、变色植物来美化与激活街区，如开花的安库杜鹃、八仙花、紫娇花，变色的红枫、小丑火棘等组合形成空中联系中又有变化的风景绿带。基于绘画的美学原理，在建筑外立面植物色彩分布上的色系为上浅下深，用不同植物组合凸显植物的四季变化^[9]。

春季色彩韵律变化：不同的绿色作为组合，金色-花叶-翠绿-深绿，从上至下由浅色逐渐过渡至深色(图8、9)。

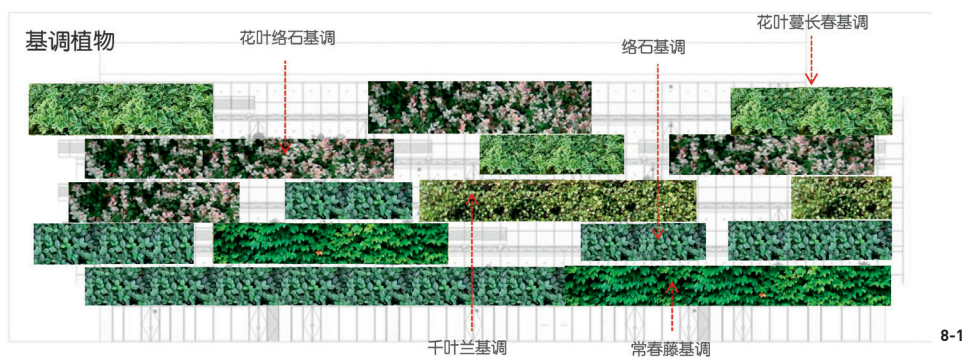
夏季色彩韵律变化：选用叶色为蓝灰、银灰及开蓝色、淡紫色花的植物，用冷色调从视觉上给炎热的季节降温。

秋冬季色彩韵律变化：选用秋冬植物叶、茎的红色或秋冬植物的变色以及果实、花色的暖色调能与建筑在色彩上更为融合，增加亲近感。

不同规格花钵通过有规律的艺术排列组合与窗沿口墙体固定，花钵里种植不同的植物并控制其生长高度，形成自然与美学的植物韵律变化(图10)。

2.1.4 滴灌系统与吊篮维护系统

1)滴灌系统是维持植物生长的必备条件，采取集中供给、分层安装给排水管到花钵，每盆设置2个滴箭，根据不同楼层、不同植物组合为花钵设置自动与人工控制结合的水分与肥料滴灌系统^[7]。



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图8 春季植物配置

Fig. 8 Plant configuration in spring

图9 春季色叶及开花植物

Fig. 9 Colored leaves and flowering plants in spring

2)空中吊篮维护系统：在建筑缺失养护通道的前提下，以横向移动轨道与吊篮系统解决维护通道缺失的难题，实现了安全、有效、及时的精细养护。

2.1.5 阶段性成果

1)立体绿化实景。

通过以上基于街区、人文、生态、美学与社会学思考与安全前提下的创意设计与实践，由2 500个大小不同的花钵组成的空中艺术花园(图11、12)让绿化从平面走向了空中，走向了重构、链接、新生的空中花园。可达性公共空中花园可以唤醒人们的感官与感知，体味现代都市的生活意趣与艺术氛围；以生态习性、现代设计和科学手法打造出沉浸式空中花园，实现以绿色催生城市的文明格调与精神内涵^[7]。

2)容器、植物、养护等的技术攻关。

创新与技术支撑密不可分，容器的创新与色彩设计、植物的选择与园艺配置、滴灌的分层与分时控制、养护吊篮的运用支撑了恒基旭辉天地立体绿化项目的形式创新与实际效果，克服了空中植物生长的不利因素。

2.2 天安干树立体绿化

天安干树位于上海普陀区苏州河畔，根据政府规划保护建筑予以保留，新建建筑为2座山形的综合性商业、办公高层楼，遵循上海市城市绿地与立体绿化实施细则条例(2015.9)^[2]，充分考虑政府对项目绿地率的比例要求，设计方案采取结合基地建筑形态、滨水区域、人文历史沿革，整合滨水公园与一、二楼平台及栏杆、空中树坛等复合立体绿化的关系。用立体绿化来补充绿地率指标(图13)，形成上海苏州河畔的天安干树多样化城市立体绿化格局，以栏杆垂直绿化、台地屋顶绿化(图14)、空中树坛(图15)的实践来实现城市立体绿化形式的创新。

2.2.1 立体绿化的特色

1)二楼平台屋顶绿化：遵循上海《屋顶绿化技术规格》(DB31/T 493—2010)，设计主要用长效混合花境来营造，形成园艺配置的干花与空中干树的呼应关系，而且会带来平台的活力，又能欣赏苏州河水流动的美景。

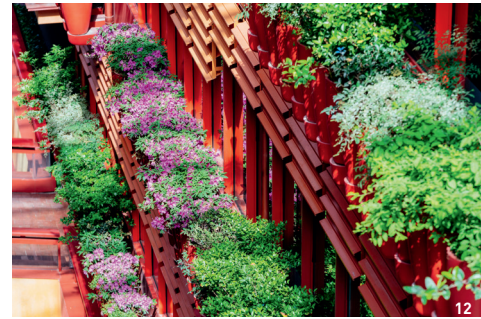
2)栏杆垂直绿化：充分利用栏杆进行垂直绿化，种植了百米长的紫藤花带与月季花带，从而



图10 植物配置效果
Fig. 10 Plant configuration effect
图11 仰视效果
Fig. 11 Bottom view effect
图12 局部实景
Fig. 12 Part of the actual view



图13 绿地率指标
Fig. 13 Greening rate index
图14 二楼屋顶绿化
Fig. 14 Roof greening on the second floor
图15 空中树坛
Fig. 15 The tree pot in the sky



形成另外一种美丽的立体花园。

3)通过混凝土立柱的支撑与固定,在空中形成种植树坛,形成有特色的空中森林立体绿化新形式。

2.2.2 设计与施工的难点——不同高空树柱植物的选择与安全

- 1)考虑荷载、雨、风及雪等因素。
- 2)在负荷允许区选择种植矮灌木、地被植物,6层以上严格控制空中生命树坛内树高不超过4m。

3)遵循植物适应性的原则,选择适合的植物。

4)选耐修剪、粗放式管理及生长缓慢的植物。

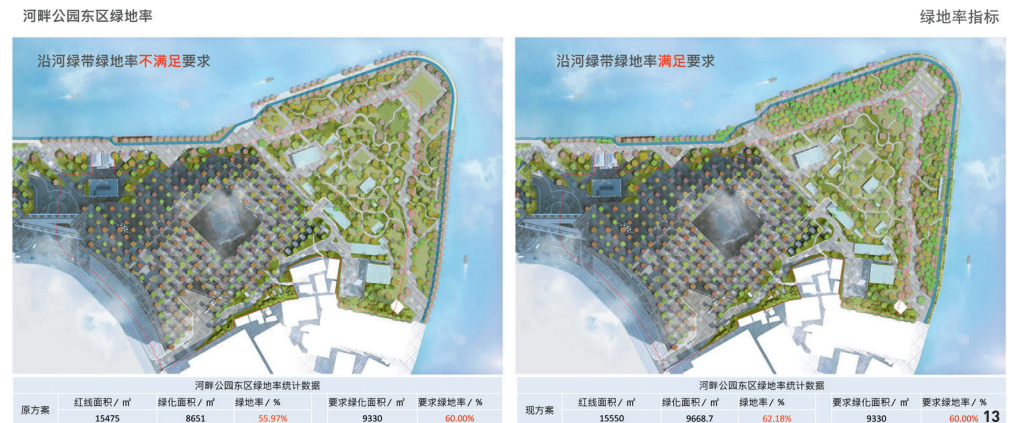
5)选择能够高抗风、抗旱与抗高低温的植物。采用多年生植物以减少维护需要。

6)避免选择果实植物以减少因为果实坠落而引起的危险。

2.2.3 空中树坛的植物配置(图16)

在保证安全稳定的基础上选择多样化树种,保证色彩搭配美学。建筑生命树柱的阴面,选择耐阴树种;边角树柱选择耐阴、抗风、耐倒伏的植物。

阴面常绿树占比比阳面更大,为保证色彩丰富度选常绿色叶树,如红叶石楠、红花檵木等。阳面选择喜阳树种,如垂丝海棠、紫薇等开花品种。边角树柱因为风口影响,需选用抗风、耐倒伏树种。为保证四季皆有绿,阳面常绿树种的占比不低于50%,高空建筑生命树柱关系到景观阴暗面及风口气候问题,在树种选择时,从安全、习性和美学等多方面考虑。落叶树的色彩丰富,且花、叶随季节变化不断,在景观上增添了更



多的趣味与亮点^[8]。保证植物园艺美学配置分布的同时,落叶树周围结合常绿树种,保证每个区域景观面在冬季不会出现偏枯现象。生命柱中垂藤植物布置于外侧、角点处软化边角。柱盆内灌木控制常绿、落叶互相搭配,保证四季皆有绿色。

2.2.4 空中树坛乔木的安全与固定

- 1)种植时土球顶低于树坛水平面25mm,有利于土球的固定。
- 2)乔木土球在土层中固定。
- 3)乔木主干四方用钢拉索固定。
- 4)树坛设置防倒栏杆。
- 5)定期检查生长状况,及时修剪遮挡风枝与病枯枝。
- 6)保持排水良好,防止水分过多引起

土壤软化与松动(图17)。

2.2.5 阶段性成果

通过施工完几年来的观察,天安干树的立体绿化目前已相当稳定并在健康生长,因为安全措施得当,空中的生命树坛与树坛中乔木保持着良好的状况(图18)。

3 问题和建议

3.1 植物受冻

2020年12月上海极端气温达到-10℃,恒基旭辉天地与天安干树的部分植物受冻明显,如

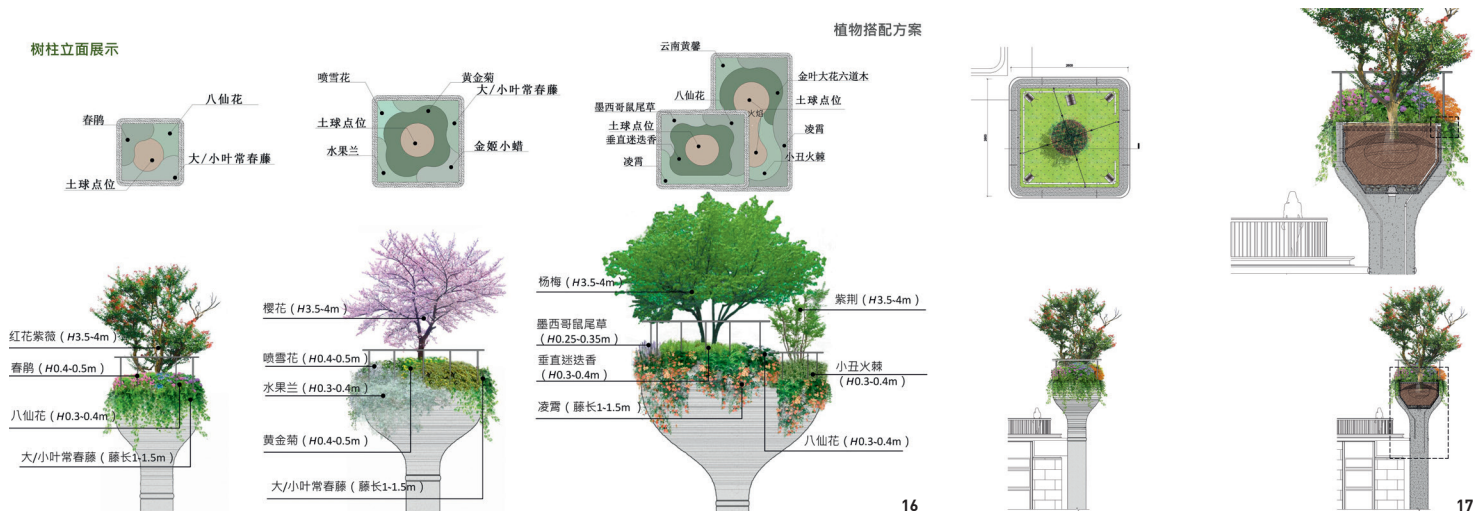


图16 空中树坛的植物园艺配置

Fig. 16 The plant gardening configuration of the tree pot in the sky

图17 空中树柱及大树的拉索固定

Fig. 17 Sky tree pillar and cable fixing of the tree

图18 天安干树鸟瞰效果

Fig. 18 The aerial view of Thousand Trees in Tian'an

千层金全部冻死，肾蕨、干叶兰、黄金菊受冻明显，影响景观效果。建议各城市根据气候特点选择耐高温又能耐低温的植物种类，并采取相应的预防措施^[10]。

3.2 滴灌材质

恒基旭辉天地滴灌使用的是PVC管，虽然硬度好，但受冲击时易脆裂；天安干树用的铜管具有韧性好、强度高、使用寿命长的优点。建议以铜管为长久考虑选择。

3.3 养护不便

2个项目因为没有考虑养护通道，只能依靠空中吊篮与高梯进行检查与养护，建议高空立体绿化以发达国家为例建立横向养护通道或横轨吊篮，便于养护。

4 结论

通过恒基旭辉天地和天安干树立体绿化形式的创新设计与实践，用不同习性的植物混合种植于花钵、空中树坛中，形成连续有韵律的、生长于空中的植物园艺式布置，既增加了寸土寸金中心城区街区中的生态绿量，提高了绿视率，又用绿色激活和提升了可达性街区里的美学、历史、人文等社会学价值，实现了用立体绿化形式来补充绿地率不足的问题，同时用立体绿化唤醒街区的活力，重构、连接、新生出一种新街景花园文化。在对花钵、空中树坛的创新形式、色彩、结构及植物生长支撑体系中的实验、预栽培及立体

绿化实施中取得的经验与成果，将有利于上海及其他大城市立体绿化形式的创新发展^[11]，有利于植物选择、容器等的个性化、专业化、产业化发展，也将对城市立体绿化形式创新具有指导意义和参考价值。

注：文中图片均由作者拍摄或绘制。

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Innovation and Exploration of Urban Three-Dimensional Greening

YU Jinlong

1 Project Background

1.1 The origin of three-dimensional greening at home and abroad

As a developed country, Germany promulgated *Guiding Principles for Roofs Greening* in 2002, so 145 cities began to include green roofs in their urban development plans, 70 cities provide financial subsidies, and 207 cities set up some incentives to reduce or exempt drainage fees. In Singapore, the government has not only constructed many parks and green spaces, but also supported three-dimensional greening from policy. The government bears 50% of the cost, which strongly promotes the development of three-dimensional greening. Tokyo, Japan also issued *Urban Greening Law and Urban Building Greening Planning Guide* in 1991, and *Nature Conservation Law* stipulates that roofs of residential and commercial buildings must have more than 20% greening.

In *The Special Plan for Three-Dimensional Greening* (2016 Edition) issued by Shanghai, it is clearly defined that three-dimensional greening refers to the general name of various greening forms constructed with buildings (structures) as the carrier and plants as the main body, including roofs, verticals, edges and shed greening. In order to encourage the development of three-dimensional greening, Shanghai Municipal Green Commission Office established the greening conversion ratio in the *Compilation of Three-Dimensional Greening Documents* (2015 Edition).

1.2 International cases of three-dimensional greening innovation

Singapore's three-dimensional greening not only has a large amount of green biomass, various forms, new layout and low risk, but also has high scientific and technological content and remarkable ecological and aesthetic effects. Taking the three-dimensional greening along the entrance of Pickering Hotel in Singapore as an example, the pedestrian flow demand of the surrounding blocks is also considered in the design. Therefore, concrete rock planting grooves and maintenance road are set every three floors along the entrance of the building, and the plants in the grooves are different. On the premise

of conforming to Singapore's *National Three-Dimensional Greening Policy*, a greening area of 15,000m² including three-dimensional one has been constructed, which is far more than twice the base area of 7,500m², so it has become a successful innovated example in those high-rise cities.

Three-dimensional greening projects vary from country to country, but they all aim to purify urban air quality. More carbon dioxide and dust particles can be adsorbed by plants, and meanwhile, more oxygen is produced. Thus, a biodiversity urban community is created.

1.3 The importance of urban three-dimensional greening

The area reserved for green space construction in big cities is limited, but three-dimensional greening can actually break through this limitation, because the space outside the two-dimensional plane is used to increase the green space and green looking ratio. From a functional perspective, dust collection and noise reduction are realized; it also helps a lot in thermal insulation, energy saving, retention of rainwater, alleviating the pressure of urban sewage and drainage, etc.

2 Project Case and Practice

Based on the recognition of the importance of three-dimensional greening, the relative innovative exploration and study on technical difficulties have been developed in Shanghai central city.

2.1 Henderson CIFI the roof

The project was carried out on Xintiandi in Huangpu District, Shanghai. It follows *Shanghai Municipal Green Space and Three-Dimensional Greening Implementation Rules* (2015.9). The government's requirements for the proportion of green space in the project are fully considered, which are achieved with an increased green looking ratio, realization of social functions such as urban ecology, life aesthetics, history and humanities. Under the premise of driving the sense of innovation and alleviating the lack of urban greenery, 2500 artistic flower pots of various sizes, planted with different flowers, are

arranged on the outer edges of the 14 facade windows of the 4 buildings.

2.1.1 Scheme innovation based on ecology, humanities and aesthetics

1) Creative choice of flower pots: in the old Shanghai French architecture, flower pots are hung outside the windows with flowers and plants, which shows the romance of French life. Considered with plant growth and artistic innovation, the form (deep pot), color, structure, arrangement and combination in the sky of the flower pots are all original.

2) Artistic arrangement and combination of flower pots: the arrangement of flower pots originates from the idea that plants grow in natural canyon and the principle of painting aesthetics.

3) Long-lasting mixed garden in the sky: based on evergreen gardening plants, other matched colors and flowering plants are added to form a long-lasting, stable, and color-changing gardening combination.

2.1.2 Specific design and technical difficulties based on the scheme

1) Flower pots and fixing.

According to the requirements of plants, the height of the flower pots is increased, so the plants can take root deeper in the soil. The flower pot is composed of an outer body and an inner container, which makes replacement easier and helps the partition of temperature conduction.

2) Planting medium.

The planting medium should have loose structure, good permeability and be good at water and fertilizer conservation.

3) The precondition of plant species selection.

Considering that plants have certain requirements for natural factors such as light, wind and temperature, through the analysis of light, wind direction and temperature, a plant selection strategy based on climatology, ecology and horticulture is proposed.

(1) Site lighting.

(2) Wind.

(3) Temperature.

(4) Plant species selection.

Based on the above analysis of the location of the planting container and the climate of the neighborhood, the impact of non-biological factors, such as light, temperature, wind, and moisture, is particularly obvious. So plants that are resistant to wind, transpiration, high or low temperature, and with well-developed fibrous roots are the most suitable choice.

2.1.3 Innovative configuration of plants

This should be based on the principles of ecology, horticulture, and painting aesthetics. The innovative and long-lasting mixed gardening configuration should be combined with the changes of plants in four seasons to integrate with architecture, space, and people, thus becoming a community of life, growth, and life.

The changes of color rhythm in spring/summer/autumn and winter

2.1.4 Drip irrigation system and hanging basket conservation system

1) Drip irrigation system is essential for plant growth.

2) Hanging basket conservation system: when the plants in the building lack conservation, the horizontally moving track and hanging basket are used, which can realize safe, effective and timely fine conservation.

2.1.5 Phased achievements

1) Three-dimensional greening actual view.

The aerial art garden composed of 2,500 flower pots of different sizes allows greening to break through the two-dimensional plane. This realizes the urban style and spiritual connotation with the theme of greening.

2) Technical research on containers, plants, conservation, etc.

The innovation and color design of the container, the selection of plants and the gardening configuration, the layering and time-sharing control of drip irrigation, and the use of hanging baskets support the formal innovation and practical effects of the Henderson Project.

2.2 Three-dimensional greening of thousand trees in Tian'an

This project is located on the bank of Suzhou River in Putuo District, Shanghai. The design combines the architectural form of the base, waterfront area and cultural and historical evolution, and integrates the waterfront park with the first and second floor terraces and railings, tree pots in the sky and other composite three-dimensional greening. The practice of roof

greening and tree pots has increased the rate of green space and realized the innovation of urban three-dimensional greening.

2.2.1 Features of three-dimensional greening

1) Greening of the second-floor terrace: the design mainly uses long-lasting mixed flowers, which makes thousands of flowers in gardening and thousands of trees in the sky the best match.

2) Vertical greening of railings: fully greening the railings, and 100-meter-long wisteria and rose flower belts are planted.

3) Through the support and fixation of concrete columns, the tree pots are put in the sky, forming a distinctive three-dimensional greening of the aerial forest.

2.2.2 Difficulties in design and construction—The selection of trees and plants in the sky and construction safety

1) Factors such as load, rain, wind and snow should be taken into consideration.

2) Low shrubs and ground cover plants shall be planted in the load allowable area, and the tree height in the air tree pots above the 6th floor shall not exceed 4 meters.

3) Follow the principle of plant adaptability and select suitable plants.

4) Choose plants that are resistant to pruning, easy to manage, and grow slowly.

5) Choose plants resistant to high wind and drought, and high and low temperature. The maintenance needs of perennial plants are low.

6) Avoid choosing fruit plants to prevent the danger caused by falling fruits.

2.2.3 The plant configuration of the tree pots in the sky

Diversified tree species selection on the basis of ensuring safety and stability.

2.2.4 Safety and fixation of trees in the sky

1) The top layer of soil should be 25mm lower than the level of the tree pot, which is good for fixation of the soil. 2) The tree should be fixed in the soil. 3) The four sides of the trunk of the tree are fixed with steel cables. 4) The tree pot is equipped with anti-falling railings. 5) Regularly check the growth status of the trees, and timely trim off the windshield branches and diseased or dead branches. 6) Maintain good drainage to prevent softening and loosening of the soil caused by excessive moisture.

2.2.5 Phased achievements

From several years of observation after

construction, the three-dimensional greening of Thousand Trees in Tian'an is in a stable stage, the trees grow healthily. Thanks to appropriate safety measures, both the tree pots in the sky and the trees are still in good condition.

3 Questions and Suggestions

3.1 Prevent plants from freezing

It is recommended to choose high temperature and/or low temperature resistant plant species according to the climate of each city, and take corresponding preventive measures.

3.2 Drip irrigation material

It is recommended to consider copper pipes.

3.3 Inconvenience of conservation

For both projects, since the conservation channel was not considered at the very beginning, it is recommended to learn more from developed countries in terms of high-altitude three-dimensional greening, and establish a horizontal conservation channel or hanging baskets with horizontal rails.

4 Conclusion

Through the innovative design and practice of the above two three-dimensional greening projects, different types of plants are mixed and planted in flower and tree pots to form a continuous and unique plant gardening style that grows in the sky, which not only increases the amount of ecological green biomass and green view ratio, but also enhances the aesthetic and sociological value in urban block space. In addition, the problem of insufficient green space rate has also been solved. At the same time it wakes the vitality of the block, a new streetscape garden culture is naturally reconstructed, connected, and regenerated.

(Editor / MA Lin)

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Yu Jinlong, male, born in 1963, Shaoxing, Zhejiang Province, Chief Designer and Senior Engineer of Shanghai Beidouxing Landscape Design Engineering Co., Ltd., research area: landscape design, garden craftsmanship, garden culture (Shanghai 200050)