Modular living wall:
Collaborative, regional design on an urban campus in Texas

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ABSTRACT
This paper discusses the design and installation of an extensive west facing living wall on the University of Texas at Austin campus. The pilot project illustrates the importance of bringing multiple expertise together to address challenges in urban design. In its hot and subtropical climate, this custom, prefabricated system holds 99 hexagonal cells that are alive with diverse regional plant species, and varied wildlife habitats. The design of the honeycomb system allows for an appropriate level of installation and fabrication efficiency, alongside its aesthetic provision. Every cell in the wall holds flora and fauna specificity with a geometric logic for self-shading the substrate volume. The appropriateness of the vegetation indicates that there are suites of native plant species, tolerant of higher temperatures and limited water availability, especially critical in the specific climate of this application. The project ultimately manifests a new approach to architectural design with a living wall system to integrate fauna with flora and utilizes nature’s intelligent honeycomb patterning throughout its fabricated domain.

Key words: living wall, habitat, collaboration, modularity
INTRODUCTION

With challenges of increased urbanization, the opportunity to use living architecture in as many aspects of the built environment becomes an imperative to create more livable, green spaces. In an attempt to address these challenges, façade greenery is suggestive of an alternative landscape approach to a wall design—one that is in service to ecological improvement. Although these lately abundant living walls are often focused on aesthetics, if aggregated across a city, they hold pervasive potential to leave a lasting, “human induced” improvement to the planet.

In the United States some of the fastest growing cities are located in Texas and include Austin, which saw an approximately 32% increase in population growth from 2010 to January of 2018 (Austin Texas.gov 2018). Now, a relatively young city faces the challenge of becoming denser to meet the need of the population. All these bare surfaces in our dense cities offer a way to increase our ecological currency and enhance our urban experiences.

Generally, there are three main types of exterior green wall systems. These include green walls where vegetation is supported on a trellis structure (‘green façade’), rooted in growing media attached to the wall itself (‘living wall’) or grown on retaining structures engineered to stabilize a slope (‘living retaining wall’). In North America, green façade systems make up approximately 95% of all green walls (Blaine and Peck 2015). Benefits of these systems are both physical and biological: from slowing down storm water, cooling buildings and the adjacent microclimate, and removing pollutants from the air and water to providing habitat biodiversity (Francis and Lorimer 2011). Green walls can be both beautiful and functional and are a space conscious way of bringing nature into our dense urban centers.

Despite their current proliferation, there are significant challenges that face the use of living architecture. More temperate climate living walls can rely on soil-less water systems, however, the design of extensive green walls, in a hot, subtropical climate like Austin can pose some challenges with extensive heat gain. High temperatures coupled with extreme climatic conditions, especially in southern cities in the United States can be a major limitation to plant health and the durability of wall materials. Installation and maintenance of living walls can be incredibly difficult requiring long hours using specialized equipment. Plant suitability for such systems can pose extreme financial burden for longevity. Finally, varying conditions around the city require options for custom configurations and not a one-size-fits-all approach.

Although the majority of living wall system designs have modularity to some degree, the design specifics of this pilot research project were used to solve some of the aforementioned challenges. The extruded hexagonal geometry of the cell eases the extraction or replacement during installation and maintenance. Second, this modular system allows custom configurations to meet the specific needs of each wall type and condition found in a building or city. The system upholds an appropriate soil volume and suitable plant species. Such alternatives have only begun to install systems in desert cities such as Dubai, where water usage is inherently excessive.
Ultimately, these systems should handle the heat and extreme conditions while providing habitat to urban wildlife by using specific native plant species, custom substrate and by designing to reduce the impact of extreme temperatures.

**DESIGN CONSIDERATIONS**

**Climate**

In contrast to green roof technology (Blaine and Peck 2017), green wall installation has been focused in slightly warmer ecoregions (Griffith, et. al 2010) primarily in California, New York, and Florida and had been dominated by green façade with modular, rigid panels. The capacity for vegetated wall and roof structures to provide critical ecosystem services in warm, subtropical cities, such as Austin, is necessary to take into account (Asher et al. 2016). Among many other ecosystem services, these systems have the opportunity to help reduce the urban heat island effect and cool building interiors in addition to providing urban habitat.

![Figure 1](image_url)

*Figure 1* This illustration shows the different EPA Level III ecoregions in Texas referenced for regional, native vegetation for the living wall (Griffith et al. 2004).
The project, located in Austin, Texas (30°11’N. 97°52’W, elevation 247 m, average annual precipitation 34.25 inches) on the west façade of the architecture school is just blocks away from the State Capitol and is within a dense urban campus condition. According to U.S. Climate Data (www.usclimatedata.com/) the sub humid, subtropical Austin climate experiences a bimodal rainfall pattern that often peaks in spring (May—June) and fall (September—October). In the summer months, the average high temperatures range between 87°F in May and 97°F in August. Additionally, nighttime temperatures tend to remain high in the summer months (>75°F) especially in the urban core. Central Texas also is prone to sporadic rainfall patterns and temperatures especially during periods of drought, where temperatures range even higher, precipitation levels fall, and the time between precipitation events increases. Warmer climates, such as Austin’s pose a number of problems for living wall designs due to high ambient air and soil temperatures, varied rainfall patterns and high evapotranspiration rates. With this in mind, the design considered four critical aspects -

1. Adequate soil volume to ensure plant root health and to reduce desiccation,
2. Reduced air volume between vegetation cells to decrease heat profile,
3. Proper substrate that has a low heat capacity, and
4. Appropriate vegetation that is adapted to local conditions.

Region

Ecoregions, Environmental Protection Agency (EPA) Level III and IV, denote areas of general similarity in species composition and in the type, quality and quantity of environmental resources. These geographically distinct areas possess similar geology, soil types, climate, evolutionary history and biological relationships between species. (Griffith et al. 2004) They are designed to serve as a spatial framework for the research, assessment, management and monitoring of ecosystems and ecosystem components.

The living wall consists of vegetation from three main Level III ecoregions, the Texas Blackland Prairies, Edwards Plateau and Chihuahuan Desert (Figure 1). Due to the context of the project and hotter urban conditions some of the vegetation was selected from areas in ecoregions west of Austin. In addition, vegetation was selected that have been observed in: limestone cliff conditions of the Balcones Canyonlands such as Beargrass and Little bluestem; granitic rock plants such as American five-minute grass and Yellow stonecrop as observed in the Llano Uplift ecoregion; and climbing species such as Cross vine and Virginia creeper. The plant species selected from these ecoregions required less water resources and showed generalist qualities of growth form and soil depth requirements. Other vegetation requirements, height and spread of species, and flower color was considered when laying out the plants in the living wall creating a pleasing and subtle pattern with ten selected plant types (Figure 2).
Figure 2 This diagram shows the original planting layout of the living wall. Some of these locations may have changed due to vegetation mortality and/or presence of volunteer species.

Campus

In May 2016, the collaborative team installed the living wall pilot project along the west façade of Goldsmith Hall, the primary building for the University of Texas at Austin’s School of Architecture (UTSOA). Five years in the making, the project tests the limits of what is possible with living walls in central Texas through ongoing research, data collection and analysis.

The primary goals of the project include observing and testing living wall technology at the University for evaluating future use, providing a living laboratory for educational opportunity, and contributing to the ongoing research on living wall systems around the world. The 10’ x 20’ x 18” (609.6 cm length x 365.76 cm height x 30.48 cm deep) living wall is comprised of 93 plant, 4 habitat and 2 light cells, with a total of 99 individual units (71 of which are a standard size). The honeycomb arrangement allows the greatest number of neighboring cells on a vertical surface while allowing enough space for the vegetation to flourish and grow. Each standard cell holds approximately 4 liters, 0.14 cubic feet of substrate, about the same size as a standard 1 gallon pot; comparatively much greater than most off-the-shelf products. The approximate weight of each cell with substrate and plant is 16 pounds. To reduce weight, yet optimize soil volume and reduce temperatures, the extruded 15 inches deep cells are self-supported with gravity and self-shading from the overlap behind the wall frame (Figure 3). Held in close proximity (approximately 3 inches) behind the wall frame, this arrangement reduces the air volume between cells.
Figure 3 The cross-section on the left illustrates a standard living wall cell. The image on the right shows the cells horizontally and illustrates how they nest together to optimized space and reduce air volume around each cell.

Architectural Form + Materials
The wall contains 71 uniform prefabricated hexagonal cells formed from marine grade thermoplastic, or Acrylonitrile butadiene styrene (ABS). The cells were CNC milled from flat, nominal 4’x8’ sheets. With an integrated ergonomic handle, the design intends for ease of handling and reinserting vegetation cell. The cellular system facilitates plant propagation in the nursery prior to installation into the wall. The size and geometry of the containers provide greater soil volume for each plant and habitat species. The 60° angle allows for gravity support upon installation, which results in a self-shading state in the intensity of the west facing solar condition.

Due to its location, the living wall sits in front of an existing safety standpipe, a device used as an emergency water source when necessary. By local fire code, a 36” opening respected the necessary clearance around this device. This then forced 28 non-uniform cells to adhere to the standpipe in their irregular geometry (Figure 4). These “odd cell” stocking material comes from 100% consumer waste plastic felt, or Eco-fi® Classicfelt™. This product has proven to be durable for two years with minor failure in some. These uniquely shaped cells were 3D modelled and then sewn from the exported flat patterns. Their three-dimensional shape formed from a standard
domestic sewing machine and epoxy glued into the ABS plastic frame faces.

Figure 4 Different materials used on the wall and the irregular cells found around the safety standpipe.

Habitat
An especially unique feature of the living wall at Goldsmith Hall is the design of 4 unique wildlife habitat cells. In addition to the Texas native plants, that act as urban wildlife habitat themselves, the habitat cells were specifically designed for different species and uses. Each habitat cell conforms to the standard living wall cell size and includes: a songbird nest cell, a bee nest cell, a provision cell and a reptile bask/hunt cell (Figure 5). The songbird nest cell design was based on urban birds observed on the campus property; the target species was the Carolina wren. The bee nest cell design is based on urban bee sampling performed by the Jha Lab with the target species as above ground nesting bees such as mason bees and leafcutter bees. The provision cell focuses on providing materials to some species, while providing nesting space for others. The target species include songbirds such as wrens and chickadees, invertebrates such as spiders, ladybugs, wasps, moths, butterflies, and lacewings, and fox squirrels. Lastly the reptile bask/hunt cell design was based on urban reptiles observed on the campus property. The target species are nocturnal reptiles such as the house gecko and diurnal reptile species such as green anoles.
Figure 5 These three-dimensional mock-ups test the different habitat cells, ultimately resulting in the final designs shown in the images on the right.

Substrate
The substrate used on the Living Wall is a patent pending mix, SkySystem™ developed at the Wildflower Center from over a decade of research. The media is designed specifically for planting on structure, such as green roofs, walls and elevated planters, and for semi-arid, and sub-tropical climates. The soil media helps regulate soil temperatures, protecting the plant rhizosphere from the excessive heat. The micro-particulates and compost in the media retains water to ensure verdant growth with minimal irrigation post establishment. In addition, the mixture is composed of 100% recycled material sourced regionally, when possible.

Water
Irrigation for the living wall was designed and installed in collaboration with campus Facilities Services - the Landscape Services Irrigation & Water Conservation Department. The team considered the use of storm water for irrigation, but limited grant funds and the location of the
pilot wall restricted the use of such systems. Irrigation water is obtained from the main portable source for campus, however the team focused on designing the wall as water efficient as possible. First, each vegetation cell has its own drip emitter to deliver water directly to the plant without any overspray. Secondly, early experiments with irrigation run times got the exact amount of water needed to moisten the media in the cell to field capacity. Thus, there is no runoff from the cells, unless during a large rain event. Third, the living wall is irrigated in the early morning hours to reduce evaporation and finally, regionally native plant material is utilized that can handle hot temperatures and does not need excess irrigation.

Installation
At the beginning of May 2016, a volunteer Wildflower Center planting day filled each of the cells; fitted with a rectangle of filter fabric over the drainage holes and a layer of pea gravel with a final layer of washed river gravel.

For the campus installation event, the vegetation units were transported to Goldsmith Hall and the metal wall frame was populated with the corresponding plant cells. Student volunteers and faculty participated in the installation (Figure 6). Facilities Services - Landscape Services Irrigation & Water Conservation oversaw the installation of the irrigation system. Once the frame and cell system was completely installed, the irrigation tubing emitters tested positive.

Figure 6 The image to the left shows the cells after being planted, resting horizontally on the ground at the nursery. The image on the right shows student volunteers installing the living wall cells into the metal trellis frame.
Maintenance
The vegetation cells are maintained quarterly throughout the year, during the winter, spring, summer and fall. We have performed a total of 6 maintenance visits since the living wall installation. All maintenance activities are documented and reported to help determine the health of the plant material, maintenance requirements for each species, and any volunteer species that have populated the wall. During a maintenance visit, each vegetation cell is inspected and data is collected on observations and what actions are performed. These items include:

1. Documentation of presence/absence of flowering vegetation,
2. Documentation of presence/absence of seed production,
3. Documentation of vegetation mortality,
4. Indication of whether dead plant material was removed from parent plant,
5. Indication of whether weeds were removed from the cell, and
6. Documentation on what types of weeds/volunteer species are present.

On average it takes two people (one person to perform the activities and the other to record) about 1 ½ - 2 hours to perform a maintenance visit. In the winter, the most vegetative biomass is collected from the living wall. The grass species used require de-thatching so as not to become decadent and slowly decline (Figure 7).
LESSONS LEARNED

Architecturally, the frame system and plant cells are thriving. The weight of the structure, material efficiency and expenditure, and fabrication processes, however, need a granular optimization. Forming plastic cells was toxic and inefficient. Material cells are much cheaper and easier to produce but perhaps do not have the same life span or thermal protectiveness. A future installation would consider the use of black rather than white plastic for visual effect and thermal optimization.

The distribution of irrigation to each vegetation cell is another aspect of the project that could be modified. The pilot has demonstrated that specific plants can survive in the system without water, thus allowing it to be scalable without such watering redundancy. Likewise, the quantity of irrigation line needed for each cell created a complicated and difficult to maintain system. The horizontal configuration of the cells, for nursery planting purposes, did not drain well. Thus,

Figure 7 The above images show the living wall before and after maintenance activities were performed in the winter of 2016.
some of the species that require dry conditions rotted out during the time in the nursery after large rain events. Adapting the substrate to the drainage system of the horizontal geometry of the cells is still up for further research.

### Table 1 Living wall plant species survival

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>07.26.16</th>
<th>11.15.17</th>
<th>Survival Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aristida purpurea*</td>
<td>Purple Three-awn</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bignonia capreolata</td>
<td>Crossvine</td>
<td>1</td>
<td>1</td>
<td>100%</td>
</tr>
<tr>
<td>Bouteloua curtipendula</td>
<td>Sideoats Grama</td>
<td>15</td>
<td>14</td>
<td>93%</td>
</tr>
<tr>
<td>Carex cherokeensis</td>
<td>Cherokee Sedge</td>
<td>2</td>
<td>1</td>
<td>50%</td>
</tr>
<tr>
<td>Chasmanthium latifolium</td>
<td>Inland Sea Oats</td>
<td>4</td>
<td>2</td>
<td>50%</td>
</tr>
<tr>
<td>Hesperaloe parviflora</td>
<td>Red Yucca</td>
<td>10</td>
<td>10</td>
<td>100%</td>
</tr>
<tr>
<td>Manfreda maculosa</td>
<td>False Aloe</td>
<td>8</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Nassella tenuissima</td>
<td>Mexican Feathergrass</td>
<td>7</td>
<td>6</td>
<td>86%</td>
</tr>
<tr>
<td>Nolina sp.</td>
<td>Nolina</td>
<td>23</td>
<td>21</td>
<td>91%</td>
</tr>
<tr>
<td>Parthenocissus quinquefolia</td>
<td>Virginia Creeper</td>
<td>3</td>
<td>3</td>
<td>100%</td>
</tr>
<tr>
<td>Schizachyrium scoparium</td>
<td>Little Bluestem</td>
<td>14</td>
<td>12</td>
<td>86%</td>
</tr>
<tr>
<td>Tripogon spicatus</td>
<td>American Fiveminute Grass</td>
<td>5</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Bouteloua curtipendula</td>
<td>Sideoats Grama</td>
<td>15</td>
<td>14</td>
<td>93%</td>
</tr>
<tr>
<td><strong>PLANT TOTAL</strong></td>
<td></td>
<td>107</td>
<td>99</td>
<td>75%</td>
</tr>
</tbody>
</table>

*Note: data taken during a time period from July 26, 2016 to November 15, 2017. *Purple Three-awn rotted in the living wall cells before they were installed into the wall due to large rain events in spring 2016.

### CONCLUSION

The living wall at Goldsmith Hall aims to address challenges these systems face for mass adoption by the industry and cities around the world, while providing a pilot to learn from in an academic setting. The modularity and architectural form of the cells proved successful in terms of installation and maintenance. The custom design of the extruded cell optimizes soil volume while allowing the volumes to overlap and self-shade. Native, regional vegetation and appropriate substrate allowed for the vegetation on the wall to propagate and attract biodiversity as hoped. The architecture discipline is now charged to be geological in scope, climatically motivated, and furthermore driven by a collaborative mainframe to share space with ecology.
ACKNOWLEDGEMENTS
This project would have been impossible without the support of the University of Texas Green Fund Grant, a competitive grant program funded by tuition fees to support sustainability-related projects and initiatives proposed by university students, faculty or staff. We would also like to thank Professor Frederick Steiner for his encouragement throughout this project. In addition, thanks to all the brilliant research assistance and interns that moved this project forward.

LITERATURE CITED


