Negotiating the ground plane: calibrating the geometry of climate-adaptive urban surfaces

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ABSTRACT: *The paper outlines the strategy initiating students to the complex relationships between technology and society in the research studio context. By leveraging accessible open-source databases, digital modeling, and fabrication techniques, the studio systematically addresses the complex, social-cultural, ecological, and economic (infrastructural) relations through the performance of surface geometry of the ground plane with regard to water in three distinct scales.*

KEYWORDS: Water Management, Surface Geometry, Infrastructure, Urban Landscape, Precast Paving Units.

INTRODUCTION

Today, society's reliance on smooth, impermeable street surfaces stifles innovation in the modern transportation infrastructure. At an increasingly accelerated pace, technological innovations have thrust us into the epoch of the Anthropocene[1]. Ironically, the "innovative infrastructures" from the past struggle to adapt to the persistent pressure of climate change, creating elevated risks for chronic flooding[2]. The resistance to adaptation and change is referred to as the socio-technical dilemma of urban obduracy[3]. It suggests why we had overlooked some advantages of the alternative paving systems before they were rapidly phased out in the first quarter of the 20th century (Figure 1).

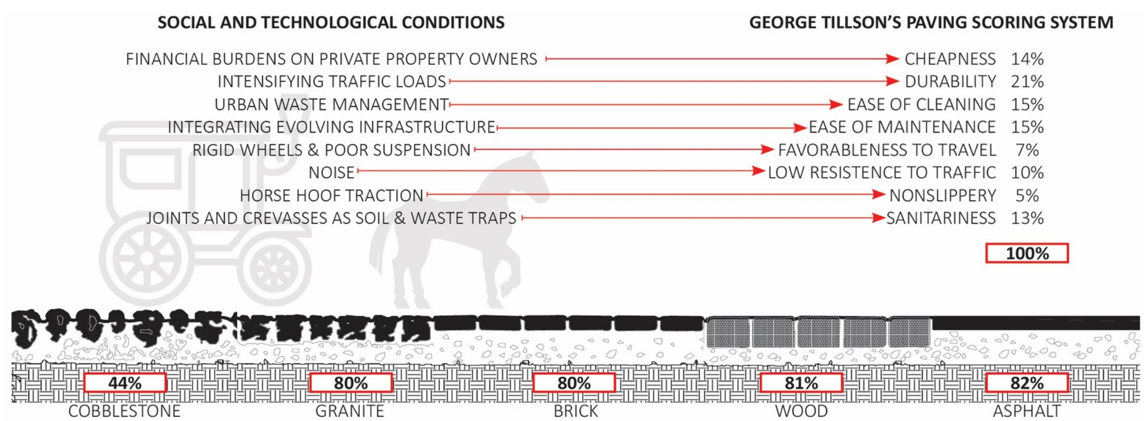

Figure 1: Tillson's Paving Scoring System4. Source: (Authors 2021)

New Orleans occupies the Mississippi Delta, the complex ecological system formed by the soil deposits interacting with the river and the gulf. In this soft, fluid ground, finding stability is a constant challenge5. With a thoughtful application, modular precast concrete paving systems can reestablish a symbiotic relationship between the built environment and landscape as both infrastructure and public amenity. By leveraging the digital design and fabrication techniques, the ground surface geometry can be reconsidered to be performatively and aesthetically aligned; to detain, retain or permeate water, mitigate flooding, and aesthetically embrace the reflectivity of the water surface. It will contribute to the context's overall spatial quality, encouraging the ground plane's productive occupation.

The paper outlines the strategy initiating students to the complex relationships between technology and society in the research studio context. By leveraging accessible open-source databases, digital modeling, and fabrication techniques, the studio systematically addresses the complex, social-cultural, ecological, and economic (infrastructural) relations through the performance of surface geometry of the ground plane with regard to water in three distinct scales: component, street, and urban scale.

APPROACH

At the component and street scale, we aim to slow down the storm runoff by momentarily storing it where it falls. A discontinuous, textured, permeable surface enhances pedestrian mobility by increasing accessible surface during and immediately after the rain, channels and detains water to promote plants and tree growth, filter pollutants, and spatially amplify the experience by optically reflecting the surrounding landscape. On an urban scale, we aim to detain overflow from the drainage system during peak storm intensity to maintain the demand at capacity (Figure 2).

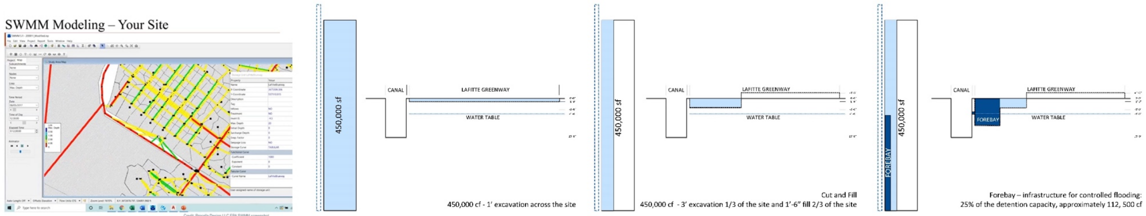

Figure 2: SWMM model analysis6 and implications of the storm drainage overflow retention. Source: (Authors 2021)

The studio prioritizes the design process informed by visualized quantifiable parameters through simulations and prototyping to find "the equilibrium" beyond individual beliefs and aesthetic preferences. The design methodology and resulting solutions are internationally relevant, as the water-related issues are no longer unique to our region[7].

The hypothesis is: Through advanced computational design and fabrication techniques, the surface geometry of the streets and paving units can be performatively and aesthetically aligned; to detain, retain or permeate water, mitigate flooding, and aesthetically embrace the reflective quality of water, contributing to the atmospheric quality of the context and encouraging the productive occupation of the ground plane.

Roads and streets are the earliest, most effective technological utilities related to sustained urban settlements. However, similar to other technological applications developed to overcome the constraints of our physiological adaptation, the benefit is counteracted by adverse impacts on various social-ecological systems.

A good example is smooth, impervious concrete and asphalt surfaces applied to local residential streets. In the era of the Anthropocene, it can be considered a technical overcorrection, accelerating stormwater collection and discharge, overwhelming drainage systems, and causing chronic flooding. The application of smoothness across multiple street typologies is ripe for re-examination. A discontinuous, textured, porous surface can "slow" the water movement by storing it momentarily where it falls. Appropriately channeled and detained water will promote plants and tree growth that provide shade, filter pollutants, and spatially amplify the experience, dynamically capturing the surrounding urban landscape through its reflective surfaces.

To provoke students to reconsider the prevailing smooth, impervious asphalt, and concrete street surfaces, we developed two exercises and a representational technique to engage surface geometry performance at street and component scales.

1. COMPONENT SCALE

1.1 The eccentric tiling units

At the component scale, we've explored modular precast systems' surface geometry and fabrication methods that shape and form the street surface to function as infrastructure and amenity.

> eccentric |ikˈsentrik|
> adjective
> 1. (of a person or their behavior) unconventional and slightly strange: my favorite aunt is very eccentric.
> 2. technical (of a thing) not placed centrally or not having its axis or other part placed centrally.8

Typical masonry units such as bricks, CMUs, and precast paving blocks conform. They are designed to fit in a stable, axial/symmetrical manner, forming predictable, continuous surface planes. The logic of stacking is easily recognizable as repeating patterns. The two-and-a-half-week exercise introduces a biased "eccentric" surface to the default 12" x24" x4" rectangular unit through subtraction. Initial geometric constraints are to alter no more than three sides of the original module. By introducing eccentricity to the geometry of the units, dis/continuous surfaces emerge when tiled on a level horizontal plane. Students systematically investigate the distinct aggregation patterns or absence thereof by paying attention to the dis/continuous extension of surfaces from one unit to another. They speculate the potential function of surface dis/continuity relative to water and sediments, leveraging digital modeling and 3D printing for rapid prototyping and testing (Figure 3).

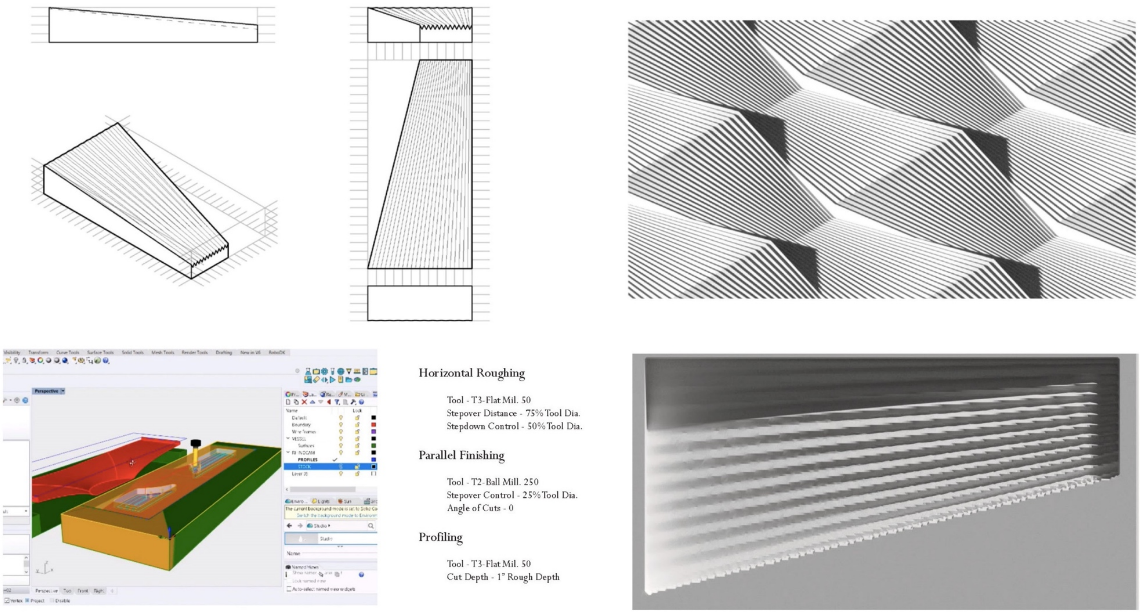

Figure 3: Student work examples of Eccentric Tiling Units exercise. Source: (Authors 2019, 2022)

The two key concepts and skills instilled in students are:

1. The complex surface geometry of the site and the components are abstracted, digitally constructed, and controlled as a series of linear ridges, valleys, and planes, not as contour lines of compound curvilinear surfaces.
2. Slope and water flow analysis tools[9] are utilized on the abstracted surface geometry to visualize and confirm the performance of the geometry or to identify issues and test improvements.

Students learn how to translate the folded geometry and the constraints of a physical "sheet" material as a guide to rationalize and control the complex surface geometry in Rhino (Figure 3). This simple notion becomes the basis for surface representation and analysis in the street and urban scale exploration (Figure 4).

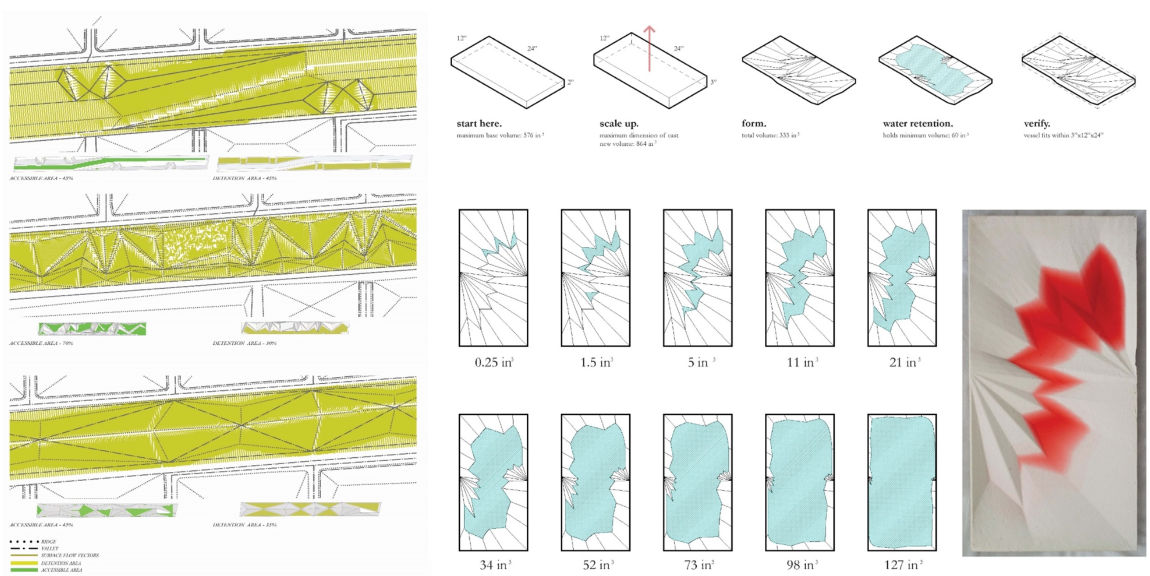

Figure 4: Student work examples of the performance analysis of complex surface geometry at urban and component scales. Source: (Authors 2019, 2021)

Virtual CNC-Milling simulation via Rhino-cam is also introduced to speculate the effect of "tooling" as an additional factor to construct and control surface geometry, jumpstarting the skill development for the subsequent physical prototyping. The exercises utilize accessible advanced computational design and fabrication techniques to bring attention to the function of complex surface geometry. The potential of dis/continuous aggregated surfaces is investigated through iterative prototyping, testing, and observation while introducing the basic skills necessary for subsequent exploration.

2. STREET SCALE

2.1 The striating the smooth

At the street scale, we've explored the design of street surface geometry in a specific New Orleans location. The Striating the Smooth exercise builds on the Eccentric Tiling Units. The three-week exercise asks students to improve the urban streetscape with enhanced street surfaces by strategically deploying precast paving systems based on eccentric unit prototypes. For developments over 5000 sq. ft., New Orleans mandates owners to detain at least the first 1-1/4" of rainfall on-site. However, public streets are not subject to this code. We leverage the "hypothetical" water detention mandate on public roadways to reconsider the potential of the streetscape.

Using the public database, students identify underprivileged streets in the city to speculate improvements. The topographical surface of New Orleans is composed of three primary characteristics: the backslope, the bowl, and the lowlands. Students select an approximately two-square-mile area in each topographical condition based on their interests. Then, with the i-Tree Landscape web application,10 the locations are analyzed with a few basic data parameters, starting with an equally weighted scenario of low tree stocking area and high population density. The resulting prioritization maps guide the selection of nine-city blocks with a particular local street within a 1/4 mile of an existing bus stop. Students then examine the surfaces of the selected blocks and their geometry concerning mobility, ecology, and atmosphere mediated by water.

The students are asked to develop two paver variations concerning pedestrian accessibility: accessible and inaccessible. Inaccessible surface type is less suited to be walked on; It is intended to gently delineate pathways (vehicular from pedestrian, for example) or as edge conditions and provide the opportunity to creatively articulate the transition from one type to another. Along with the surface analysis (slope, water flow direction, and retention volume) and reflective surface rendering methods, CNC formwork milling/tooling and Hydrocal casting techniques are all introduced in the workshop format. The intention is to foster iterative physical prototyping and testing of the paving system on a larger scale. The project encourages students to reconsider local residential streets, a fixed, utilitarian infrastructure with high-impact design opportunities, by leveraging the necessary urban water management requirements (Figure 5).

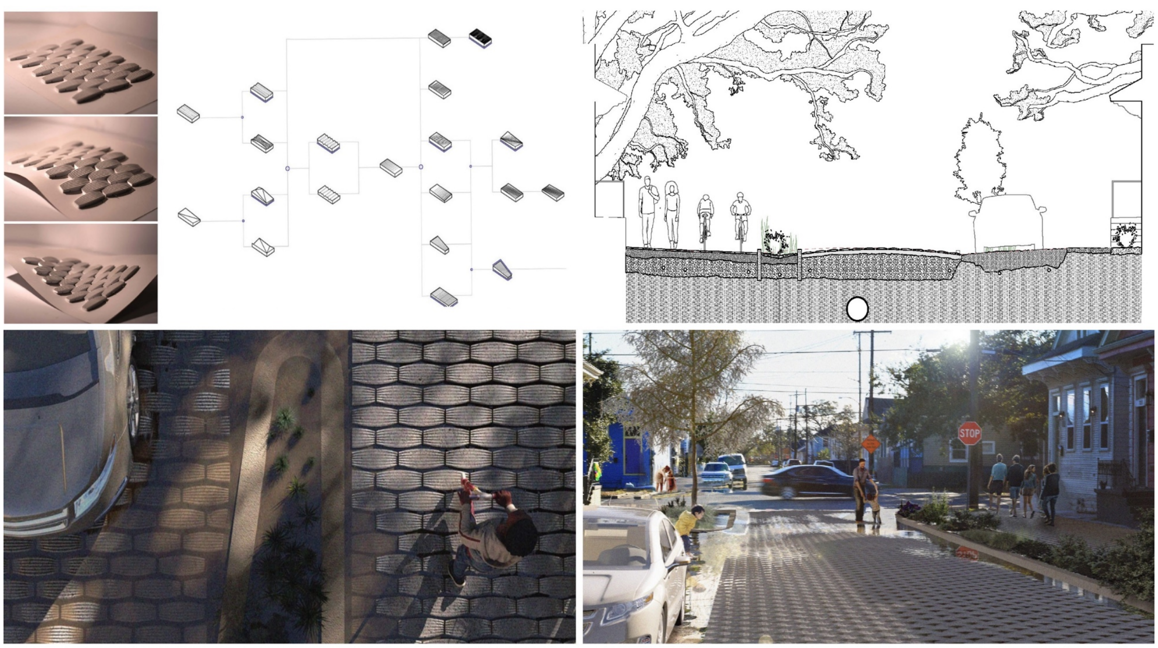

Figure 5: Student work examples of the street scale surface geometry and component application. Source: (Authors 2022)

2.2 The reflective surface representation

The reflective surface representation technique introduces water as a dynamic, reflective surface and a quantifiable interactive substance over the aggregated pavers. Students learn to control the qualitative rubric of reflective/translucent substances in a digitally simulated environment. Students also learn to quantify how much water the system's surface geometry can detain and speculate the transformation of the amount over time. The change in water level will affect the amount of reflective surface and the perceived quality (Figure 6).

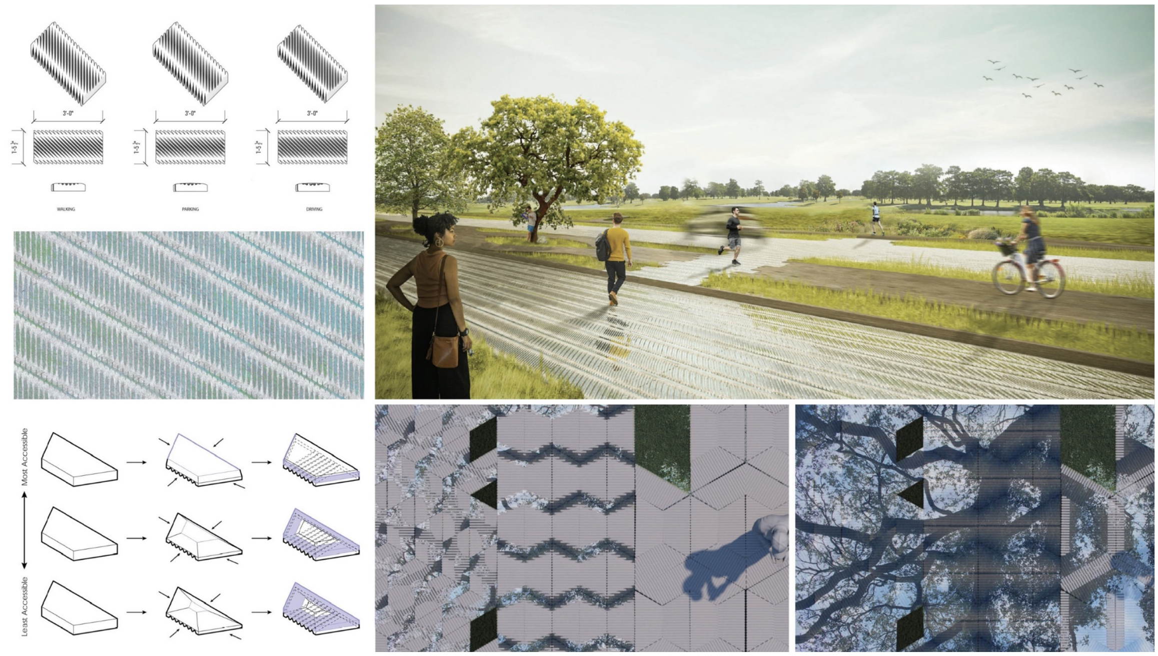

Figure 6: Student work examples of paving unit prototypes and the effect of reflective surfaces. Source: (Authors 2022)

3. URBAN SCALE

3.1 Reimagining the Laffite Greenway

On an urban scale, we explore the surface geometry of the existing urban park on an underutilized post-industrial infrastructure corridor parallel to the city's storm drainage system (Figure 7). Students are prompted to improve the park's function to serve the adjacent communities better while transforming it into a water detention infrastructure. The site context, including the community engagement outcomes from the Laffite Greenway project,[11] is thoroughly researched and diagramed. The performative application of the complex surface geometry is examined at both urban and component scales to guide, detain water and foster productive occupation of the ground plane (Figure 8).

Figure 7: Drone photo of the site. Source: (Authors 2022)

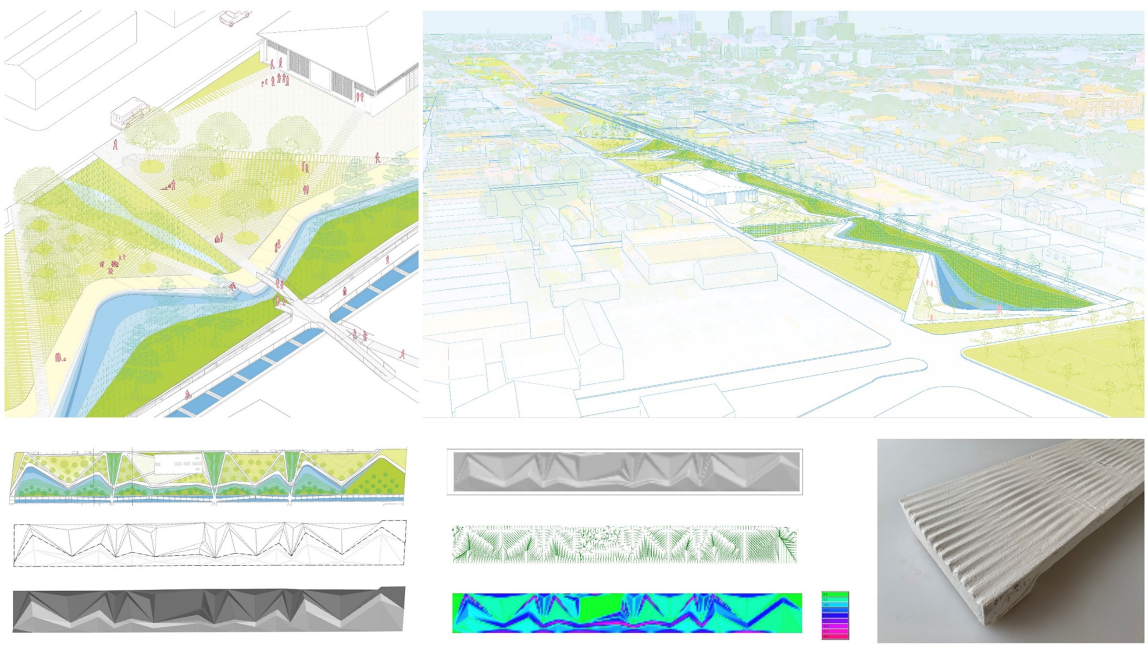

Figure 8: Student examples of the site scale surface geometry (modeling/analysis) and component application. Source: (Authors 2022)

RESULTS

The outcomes elucidate the general design approaches, tactics, and consequences of students' struggles with the complex water management and spatial program distribution challenges at urban scales. It also reveals individual authorship, the aesthetical agenda, fabrication techniques, and component-level invention distinguishing the projects. Representational techniques are explored and developed to consider and communicate the reflective surface quality of water in the urban landscape.

At the urban scale, the surface geometry of the outcomes reveals the following approaches and tactics:

- Carefully orchestrated distribution of floodable and non-floodable surfaces/programs.
- Mound, sloped or stepped landscape with equal cut and fill, leveraging the existing topography and coordinated with estimated groundwater elevation and expected water level of the city's stormwater drainage system.
- System of artificial basins, forebays, weirs, and swales combined with planting materials to slow and momentarily retain stormwater and foster microecology.

At the street scale, the surface geometry of the outcomes reveals the following approaches and tactics:

- Accommodating transverse community pedestrian paths, negotiated with longitudinal bicycle and recreational traffic.
- Purposeful distribution of gradated (blended) surface geometry, textures, and paving patterns.
- Carefully orchestrated edge conditions to delineate program zones.

At the component scale, the surface geometry and fabrication exploration reveal the following potential of the precast paving systems in tandem with the street and urban scale intentions.

- Studied unit and joint profiles to ascertain the surface flexibility as an aggregate to adapt and address the context and function.
- Leveraged unit surfaces to retain/detain or direct water toward the joints and induce vehicular vibrations or graphic illusions for attention.
- The purposeful joint design provides permeability and encourages medium growth.
- Exploration of flexible 3-d printed formwork and surface casting of the photo-luminescent aggregates.
- Consideration for tooling in CNC-milling in rationalizing the complex surface geometry

The authorship and the aesthetic agenda were not the primary concerns of the research studio. Nevertheless, spatial sensibility emerging from the discovery of fractured reflection and interest in illusionary graphics are two potent concepts. Although students became proficient in the representational techniques, further pedagogical consideration is necessary to elicit a more robust response for an aesthetic position (Figure 9).

Figure 9: Student examples of the component application. Source: (Authors 2022)

CONCLUSION

The research addresses the paradigm shift in urban stormwater management concerning climate change. The outdated engineering solution is to increase the drainage system's capacity by enlarging the conduits and pumps to accommodate the increase in peak demand. Instead, we systematically speculate a multi-faceted scenario to delay excess stormwater from entering the drainage system, reducing the peak demand over time. An underutilized post-industrial urban space is revitalized as an amenity for the community and a water management infrastructure for the city. Its ground surface is strategically sculpted to detain water and simultaneously foster accessibility and communal activities. Furthermore, the reintroduction of water as a surface quality strengthens the interlinkages between social and ecological systems by improving our understanding of the natural characteristics of the deltaic landscape.

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13. We used *Bison,* a landscape architecture plugin for Grasshopper and Rhino 6: https://www.bison.la/ Note that the slope analysis is relevant to identify occupant accessibility and flow speed. The water flow analysis is pertinent to determine the direction and convergence of the flow and the ground surface treatment.
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