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New Eyes on Waste
Transforming Waste Materials in New Building Design

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DEDICATION

To Tong, you are my motivation; and to my mom, for everything.

Chapter 1: Introduction

The motivation of this thesis can be traced back to 2006 when I was in Beijing, the city I had lived in for 20 years. In preparation for the 2008 Olympic Games, the demolition and reconstruction sites were throughout the city. My old grandparents' house, where I spent all my childhood, was torn down in order to build new apartment buildings. At that time, I wondered where those salvaged building materials from the old house were going; they just disappeared completely in a matter of hours without a trace. After I came to Seattle for my graduate study, I had the same question when I saw a five-story apartment building across the street of my studio being demolished.

Architects spend most of their time and effort involved with design and construction of new buildings. However, when a building is complete, its destiny is usually out of the control of architects. Architects typically cannot stop building from being demolished; it is a complicated social issue. However, they can develop new eyes on waste building material while inspiring others to reconsider the current use of limited natural resources. Hence the objective of thesis is established.

Fig. 1.1
Demolition of Goddess Temple, Beijing, China
01/18/2008
Photo: Jinze Cui



Fig. 1.2
Demolition of the Cavalier apartment building, Seattle
12/11/2010
Photo: John Stamets



1.1 The current condition of material flow and material reuse policies in the building industry

Building construction consumes a large amount of resources while most of these materials end up becoming waste debris and moved to landfills after demolition. *Environmental Building News Reports* points out that building construction accounts for nearly 30% of all raw material consumption; while nearly one-third of the waste in U.S. landfills comes from building construction and demolition debris, according to the U.S. EPA (1). In developing countries such as China and India, the amount of resources consumed in new construction and the waste generated by building demolition is skyrocketing and continue growing every year.

The linear material flow currently prevalent in building industry has been proved to be unsustainable. Reversing this linear trend requires effort from all the parties involved with each party playing different roles and having different responsibilities. This thesis explores how architects could strengthen the interaction between the design process and available existing material resources, in order to shortcut material flows and educate the public about the underutilized value of waste materials.

1.2 The meanings and opportunities of utilizing reused material in new building design

The primary motivation for reusing material is to reduce the environmental impact of the building industry. The first impact is to reduce the need for raw material and energy consumption related to extracting, manufacturing, and transporting process. The second impact is to reduce the amount of waste sent to landfills and preventing the degradation of natural landscapes (2 p. 5).

From the perspective of architects, reusing material provides new opportunities from the past in order to do more with less. By harvesting the waste material into architectural elements, new methods of material expression, tectonic logic and spatial organization can be developed. The reused material and components can become the unique feature of a project.

For developers and owners, reusing material can reduce costs while adding social value to the project. The LEED rating system has assigned credits for material reuse to encourage clients and the design team to embrace this idea. Reusing material in new building can educate the public and spread awareness about the underutilized value of waste material.



Fig. 1.3 Landfill site

1.3 Thesis overview

The purpose of this thesis is to explore how architects can strengthen the interaction between the design process and available existing resources, in order to shortcut material flows and educate the public the underutilized value of waste materials. Specific questions to be explored include how to incorporate reused materials into new building design while allowing the reused materials themselves influence the design process? What are the opportunities and constraints of using reused and recycled material in new construction? What is the architectural tectonic order of using reused materials compared to using new material? How can a building evolve over time and become metabolic in materiality? How to inspire others to rethink the potential of waste material through an architectural design?

Chapter 2: Theoretical Framework

2.1 Literature review

2.1.1 Consider a building as a hierarchy of ingredients

The Dutch architecture office 2012 Architects makes the argument that from the perspective of material composition, a building can be considered as a hierarchy of ingredients. (3 p. 6) Raw materials are processed into architectural elements, for example, the earth is heated to make brick. Various elements can be combined into architectural components with specific function and form. For example, a brick wall component consists of a certain number of bricks, mortar and rebar, functioning as a structural or partition wall. Its dimension and form is determined by strength requirements and spatial quality concerns. The architectural component usually defines the overall character of a building, indicating how an architect manipulates various material elements to enclose space. During the building demolition, architectural components are usually downgraded into element or material levels. Designing with reused material enables the design team revives the character and potential of reused materials while transforming them into architectural components in an innovative way.

Components with the same function consist of building systems. Carl Elefante sorts building elements into four categories: structure, building envelope, interior, and (mechanical) system (4). The life cycle of each category varies and the material usage strategies should be differentiated accordingly. The material usage for structure system should consider durability and safety as priority. The envelope system, as cloths for people, requires periodic renewal, ranging from simple maintenance to selective replacement. Interior element systems closely relate to how people use the building so it should be flexible to adapt various functional requirements.

2.2.2 Two material procedure approaches for assembling material elements into architectural components

In the article *Rappel a L'ordre: the case for tectonic*, Kenneth Frampton introduces the tectonic theory of Gottfried Semper. Semper divided built form into two separate material procedures: the first one is the tectonics of the frame in which members of varying lengths are conjoined in encompass

a spatial field, such as the wood or steel frame structure. The second one is the stereotomics of compressive mass that is constructed through the piling up of identical units, such as the brick or concrete structure. These two procedures also provide distinct spatial experiences: the tectonics present a framework tend toward the aerial, light and immateriality; the stereotomics emphasizes the earth, gravity and mass (5).

These two material procedures could also be applied to the treatment of reused materials. However, these procedures should also respond to the inherent properties of reused material, such as abrasion, low strength, and irregular dimension etc. The purpose and character of the material may need to be re-established in certain applications.

2.2.3 Change the concept of material life cycle from “cradle to grave” to “cradle to cradle” in the building industry

The issue of material reuse and recycling has been addressed in several manufacturing industries, such as the automotive industry and electronics industry. Manufacturers incorporate more and more reused components and recycled material in new product manufacturing; on the other hand the manufacturers have to address the end-of-life issue. The traditional material life cycle in building industry is linear; there is little to use of the waste materials and they tend to send to the landfill. Design with reused material in new construction converts the linear material flow into a closed loop and harvests the remained value embodied in the salvage materials.

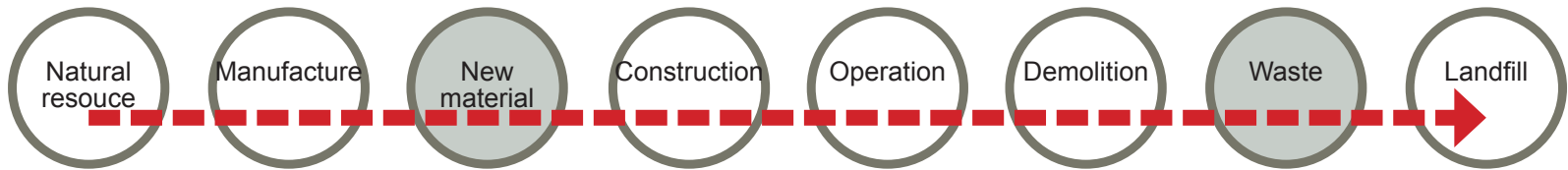
2.2.4 Three main types of material reuse in new building construction (2 p. 55)

a. Building adaptive reuse

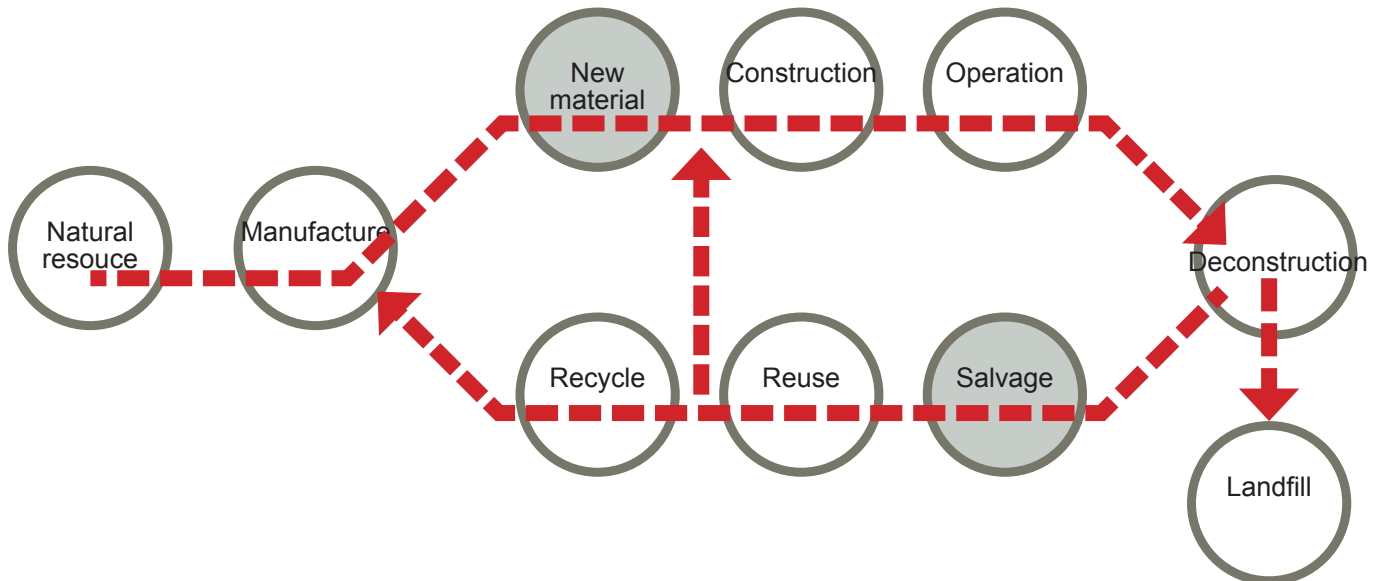
Requiring least amount of intervention, a certain degree of repair and refurbishment may be necessary. The structural system and much of the envelope system can be retained, while the interior and mechanical systems may need to be replaced and updated. This approach requires case-by-case assessment of the condition and the suitability for reuse so it is not within the scope of this thesis.

b. Architectural components reuse

Extracting materials, elements or components from the waste stream and repurposing without further processing or with only minor processing that do not alter the material’s nature. The



Design with new material - cradle to grave



Design with reused/recycling material - cradle to cradle

Fig. 2.1
Material flows comparison
between design with new
material and design with
reused/recycling material

building materials, elements or components from a demolished building could be reused in a different way to construct a building system in a new project. Usually these reused items need to be treated to meet the standards of new construction. This approach can have the most influence on new building design processes and has the broadest application, thus this type material reuse is the focus of this thesis.

c. Waste material recycling

Recycled materials refer to the use of waste materials, through a series of changes or treatments to make new products. The design process of using recycled materials is not very different compared to using new materials, so this approach is not the focus of this thesis.

2.2.5 The process of design with reused material

Compared to the normal design process with new material, in which the architects usually specify the material source after the initial design, the design process of incorporating reused material starts from identifying possible sources of the reused material. This step includes specifying the approximate quantities, sizes and assessing the condition and cost of the materials. Based on the condition of material source, architects will develop methods and strategies to assemble the reused elements into architectural components. The next step is schematic design, which includes incorporating these components of reused elements with other architectural components to enclose and define various spaces and complete the whole building design (2 p. 57).

2.3 Precedent Analysis

For the stereotomics system, pile reused material in new construction is not new an idea in Western architectural history. Until 19th century, masonry blocks would be reused many times before they were abandoned. The manpower and the cost of reusing such stones were much less than extracting new ones. In recent years, reused masonry materials have been selected by architects in building envelope design.

The wooden structures of Eastern architecture have had a long history of reusing wooden components in new construction. For example, large amount of the wood components used in the Forbidden City in Beijing are the reused wooden components from other demolished buildings.



Fig. 2.2
Dominus Winery, Napa, California,
Herzog and de Meuron

- Dominus Winery, Napa, California, Herzog and de Meuron

In the Dominus Winery project, Herzog and de Meuron successfully adopt gabion wall, which is usually used in civic infrastructure construction, as a building envelope system. Although Herzog and de Meuron did not use reused filling material in this project, they develop a building envelope system with great potential for utilizing reused materials. The stones of two sizes were packed into a cage to formulate a rainscreen which allows varying penetration of light. This gabion wall also acts as a thermal mass that retains cool air during night and releases it to regulate the hot temperature in the daytime.

- The Earth Center, Doncaster, UK, Bill Dunster

This project is another example of using gabion walls as building envelope, but choosing crushed concrete as infill. The recycled concrete was from buildings being demolished less than 20km from the site. The recycled concrete pieces were much cheaper than local sandstone and with more predictable structural strength (6). The gabion walls combine with reclaimed local steelwork and reclaimed timber make up the roof structure, which gives the building its distinctive look.



Fig. 2.3
The Earth Center, Doncaster, UK, Bill Dunster

- Ningbo Historic Museum, Ningbo, China, Wang Shu

The site of Ningbo Historic Museum used to be occupied by ten old villages, which were demolished during urban redevelopment. The architect Wang Shu adopted a local traditional construction method – the Wapan technique. The exterior envelope is made up of different types of recycled tiles and bricks that were recovered when the old villages were demolished. In order to increase the strength, recycled tiles and bricks were divided vertically into smaller divisions supported by concrete beams, which are attached to the reinforced concrete structure. The Wapan wall presents the collective memory of local history while preserving the traditional building craft.



Fig. 2.4
Ningbo Historic Museum, Ningbo, China, Wang Shu



Fig. 2.5
Nomadic Museum, New York, Shigeru Ban

- Nomadic Museum, New York, Shigeru Ban

The Nomadic Museum is, as the name describes, nomadic and can be easily taken apart and rebuilt in different places. The walls of this travelling exhibition building are made of 148 rented shipping containers. The steel containers are stacked in a checkerboard pattern 34 feet high to form the walls of the three wings of the museum. The openings between the containers are secured with a diagonal fabric-like membrane. The internal structure consists of triangular paper tubes trusses resting on a colonnade of 35-foot tall paper tube columns. The aluminum roof trusses and tensile roof fabric are engineered and fabricated to be easily deconstructed, stored and shipped to future locations. The interior structure and fittings could be packed into 37 containers for transporting to a new location (7).

Chapter 3: Methodology

3.1 Design goals and objectives

a. Architectural form

This thesis project focuses on transforming waste building materials into unique architectural resources in new building design. The architectural components with reused material will be the key features of the envelope and structure system; they will define the character of the whole new building.

b. Function and social impact

The project targets on providing a place that facilitates material reuse and recycle in people's daily life; enlightening public the underutilized value and potential use of waste materials.

c. Building life cycle

The project should consider flexibility of space and be able to adapt to different functional purposes in future. For the materiality aspect, the individual elements and components could be renovated and replaced. The building could evolve over time, expanding the building life cycle with high adaptivity both in function and materiality.

3.2 Design principles

a. Integration

The primary objective for this project is to maximize the inherent quality of waste material with minimal reprocessing to let the materials speak for themselves. The reused material will be incorporated with necessary new materials to build different architectural components, such as the wall, envelope, and roof; these components will enclose and shape various spaces based on the program requirement.

b. Adaptivity

The project will consider the life cycle of the building at the beginning of design process, the structure system and spatial layout will be able to adapt functional change and allow future expansion. Different material strategies will be implemented for each building system: the structure system should be durable and long life cycle; the building envelope could be renewed over time and

the deteriorated parts could be fixed individually. The building will keep evolving during the full life cycle.

c. Energy efficiency

The design will maximize passive climate control strategy such as day lighting and natural ventilation to reduce energy consumption, integrating energy efficiency with material reuse in sustainable design.

3.3 Site analysis and selection

3.3.1 Guiding principles

a. Availability

Since the program and construction methods are all related to waste material, a site adjacent to an existing waste management facility could provide civic utility and service, abundant material source, and connect the waste management facility with the community and public.

b. Visibility

The traditional attitude to waste treatment facilities is to put them behind the scene, isolating them from public accessibility. In order to convert people's bias towards waste material, a location within developed urban context would educate public the underutilized value of waste material and make a positive influence on people's attitude towards waste in their daily life.

c. Prototype

This project would try to explore a new prototype of a waste reuse and recycle complex in an urban context which could be adopted for new transfer station project in other cities in future.

3.3.2 Seattle North Transfer Station (NTS)

(1) Project background

The Seattle Solid Waste Facilities Master Plan intends to reduce waste reduction and increase resource conservation, expand local recycling markets, and improve sustainable waste management and resource conservation practices. According to this plan, the City's north and south stations will be demolished and rebuilt to improve customer service, reduce adverse environmental impacts, and to expand efforts to recycle and recover reusable materials (8).



Fig. 3.1
Existing Seattle North Solid Waste Transfer Center

(2) Current condition

The current Seattle Public Utilities' (SPU) North Recycling and Disposal Station (NRDS), is a large waste and recycling collection and transfer facility which was constructed in 1968-1969. The whole facility extends across two and a half blocks west of Carr Place North. Problems with the existing facility include the aging structure, inadequate treatment capacity, and lack of updated technology (9).

(3) Planning proposal

The proposed North Transfer Station rebuild site consists of four total properties: the existing station at 1350 N 34th Street, the former Oroweat Bakery property at 1550 N 34th

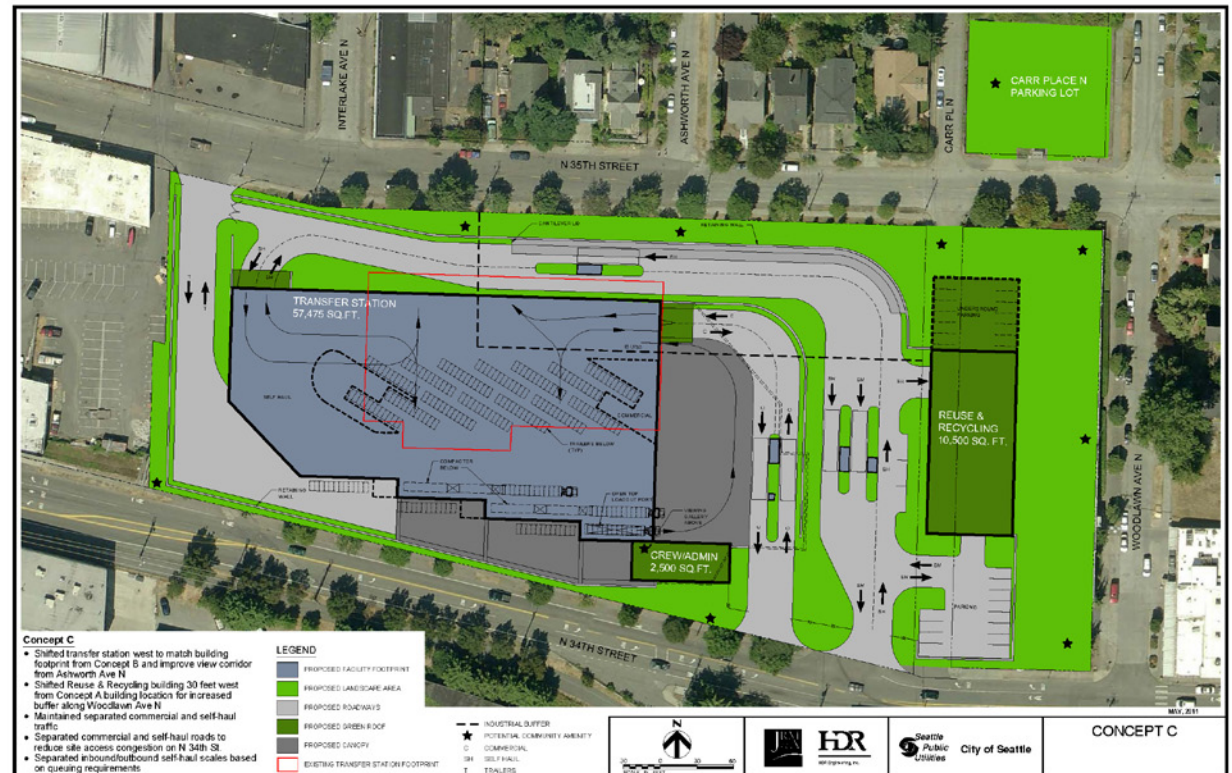


Fig. 3.2
Proposed North Transfer Station Project (NTS)

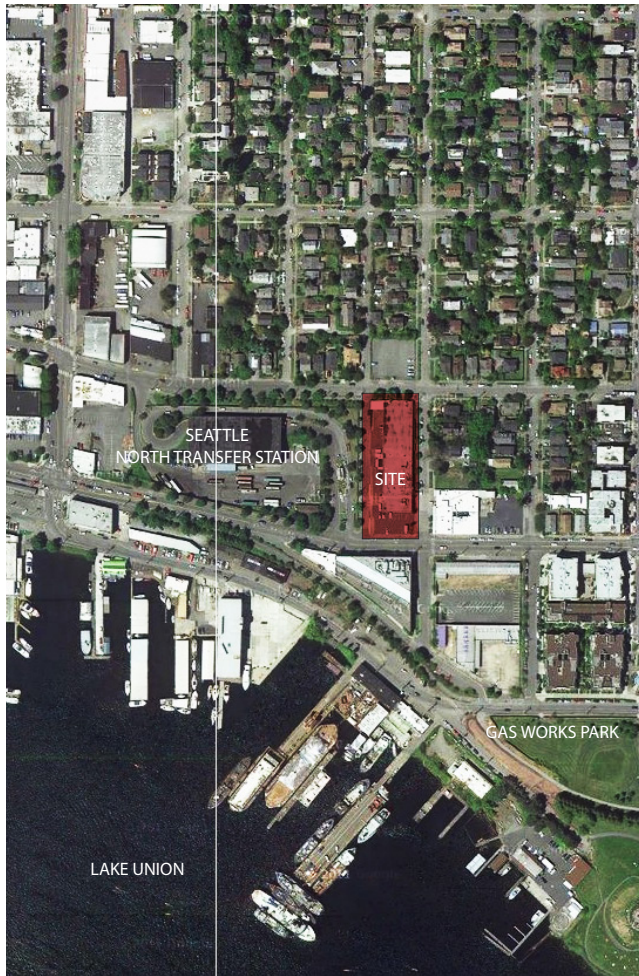


Fig. 3.3
Aerial view of the site

Street, Carr Place N between the 1350 and 1550 properties, and the property to the northeast corner of the existing facility, currently a parking lot at the N 35th Street and Woodlawn Avenue N intersection. The total size of the proposed rebuild footprint is 5.8 acres. The new facility replacement plan outlines the primary components to be included in the new North Transfer Station: scale facilities, transfer building, recycling and reuse drop-off area, administrative/employee facilities and roadways/landscape buffer area.

Besides the required program, the stakeholder group representing the surrounding neighborhood also recommends developing a campus for the transfer station, creating community amenities including a park and green space, public art installation, and education area for students and general public.

3.3.3 Site location

The site for this project is located at 1550 N34th Street, in Seattle's Wallingford neighborhood. The building on site was originally constructed for the Oroweat Baking Company in 1969 and currently is owned by Seattle Public Utilities for a temporary storage and transfer warehouse (SPU warehouse). The site is two blocks northwest of Gasworks Park and one block north of Lake Union, midway between Stone Way to the west and Wallingford Avenue to the east. The new waste reuse and recycle facility is proposed to be built on this block as a part of the new north transfer station.

Besides the program required by Seattle public utility and stakeholder group, the design will incorporate public education and art creation space to create a holistic public reuse and recycle facility.

3.3.4 Site analysis

(1) Neighborhood and zoning

The project site is located in the Seattle Wallingford neighborhood, which is a mix of commercial/industrial and retail buildings. The current zoning of the site is Commercial 2 (C2). This zoning is defined by the Seattle Land Use Code as: an auto-oriented, primarily non-retail commercial area, characterized by larger lots, parking, and a wide range of commercial uses serving community, citywide or regional markets (10). Zoning changes will require approvals from the Department of Planning and Development and the City Council.

Commercial buildings are concentrated near the waterfront area, north of N 35th Street and along Stone Way, with older residential housing and some newer mixed-use condominium buildings in close proximity to the commercial areas. The waterfront is characterized by industrial warehouses and marinas and the Burke-Gilman Trail, the former Seattle Lakeshore and Eastern Railroad corridor runs east-west adjacent to Northlake Way along the waterfront.

(2) SPU warehouse block

The site currently occupied by SPU warehouse takes up an entire block between Carr Place North and Woodland Avenue North at North 34th Street. The property measures 0.94 acres (41,040 Sq. Ft). The grade slopes down from north to south and additionally has a cross-slope down from east to west. The building is situated along the northeast boundary line of the property, set back 60 feet from the south property line at the sidewalk, and almost 34 feet from the west property line and is surrounded by asphalt on the south and west. The south end serves as parking with 16 stalls and is accessible via parking entries on the east, south and west sides, while the paved area along the west side serves as a driveway and loading area for trucks, with two additional driveway entries along the west side. The southeast corner of the site has a planting bed with evergreens and address signage. The eastern and northern edges of the site are planted with evergreen and deciduous trees and shrubs adjacent to a pedestrian sidewalk. The west edge of the site is void of sidewalks or plantings (11).

To the west is the site of new Seattle Public Utilities North Transfer Station. To the east of the SPU warehouse, across Woodland Avenue North, is a one story masonry building which has been used as a bakery since its construction in 1925; the rest of the block north of the original bakery consists of small wood-frame single family residences which date from the early 1900s. Immediately north of the warehouse site, across North 35th Street is a surface parking lot associated with the warehouse property and also owned by Seattle Public Utilities. To the north, east and west of the parking lot are residential and characterized by small lots with wood-frame houses primarily dating to the early 1900s.

(3) Access

Access to the site is provided by a range of transportation connections, including King

County Metro bus, Burke-Gilman Trail and vehicular access to major city arterials.

N 35th Street to the north of the site is the primary public transit corridor around the site. King County Metro bus NO. 26 which connecting Downtown Seattle and Green Lake community through Fremont and Wallingford stops north of the site.

Burke-Gilman Trail one block to the south is an important pedestrian and bicycle route linking the site to other high-density neighborhood, including University district, Wallingford, Fremont and Ballard.

Three blocks to the west of the site is Stone Way North, a significant local north-south arterial, and forms the western border between the Wallingford and Fremont neighborhoods. Stone Way North is characterized as a major commercial/retail area predominately hosting wholesale and retail outlets, and a few small workshops, associated with the construction industry. Aurora Avenue North, a major north-south transportation corridor, is located a few blocks further west. Interstate-5 is located several blocks to the east (12).

(4) Conclusion

The site provides opportunities that will have a positive influence on the building design. Its urban location and diverse industrial/commercial surroundings provides a strong public presence. The new building could share civil facility, material source, equipment, and technical staff with the new North Transfer Station. Views from the site include vistas of Lake Union and the Downtown Seattle skyline. The reuse and recycle building would act as a buffer between the new solid waste transfer station and the surrounding neighborhoods, while enhancing people's perception of the natural environment, and educating the public about waste management and a sustainable life style.



Fig. 3.4
Vicinity plan

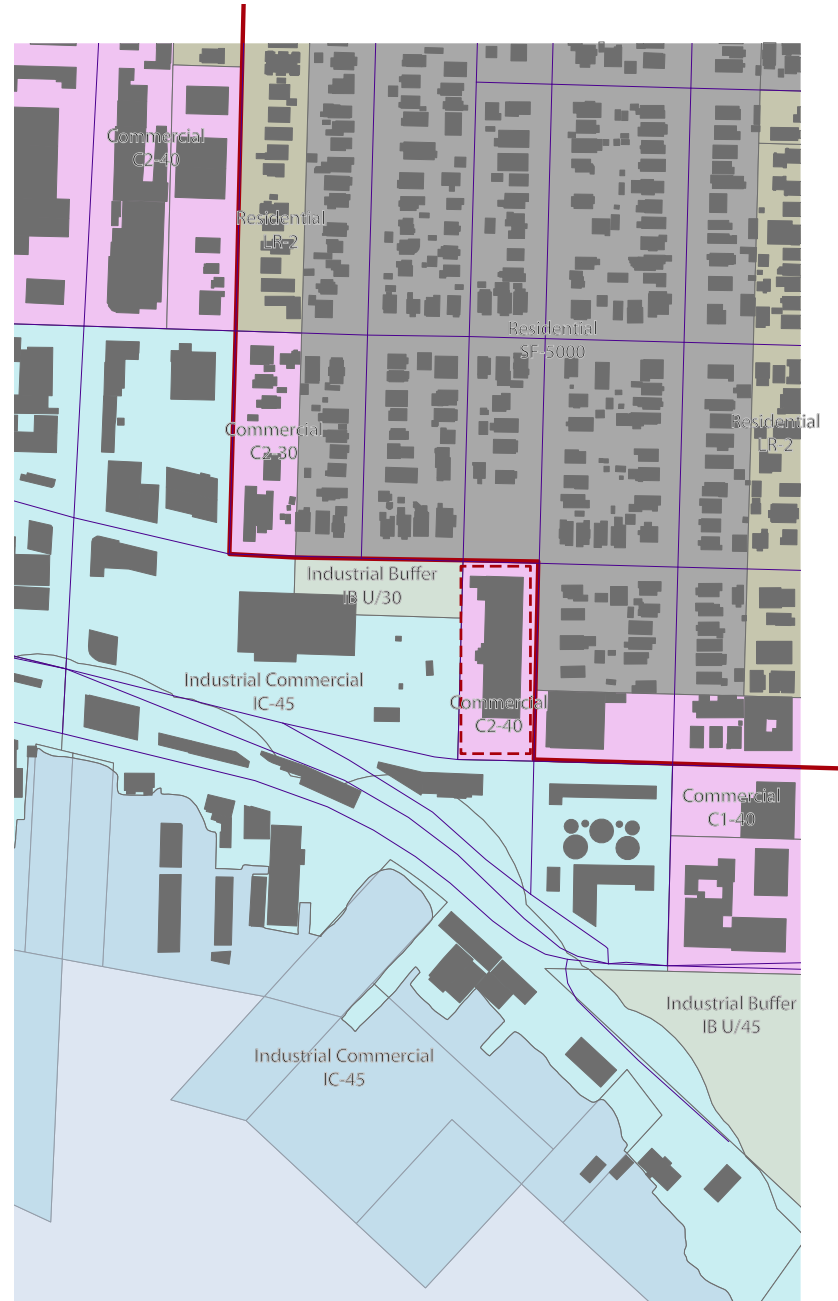


Fig. 3.5
Zoning map reference to project site

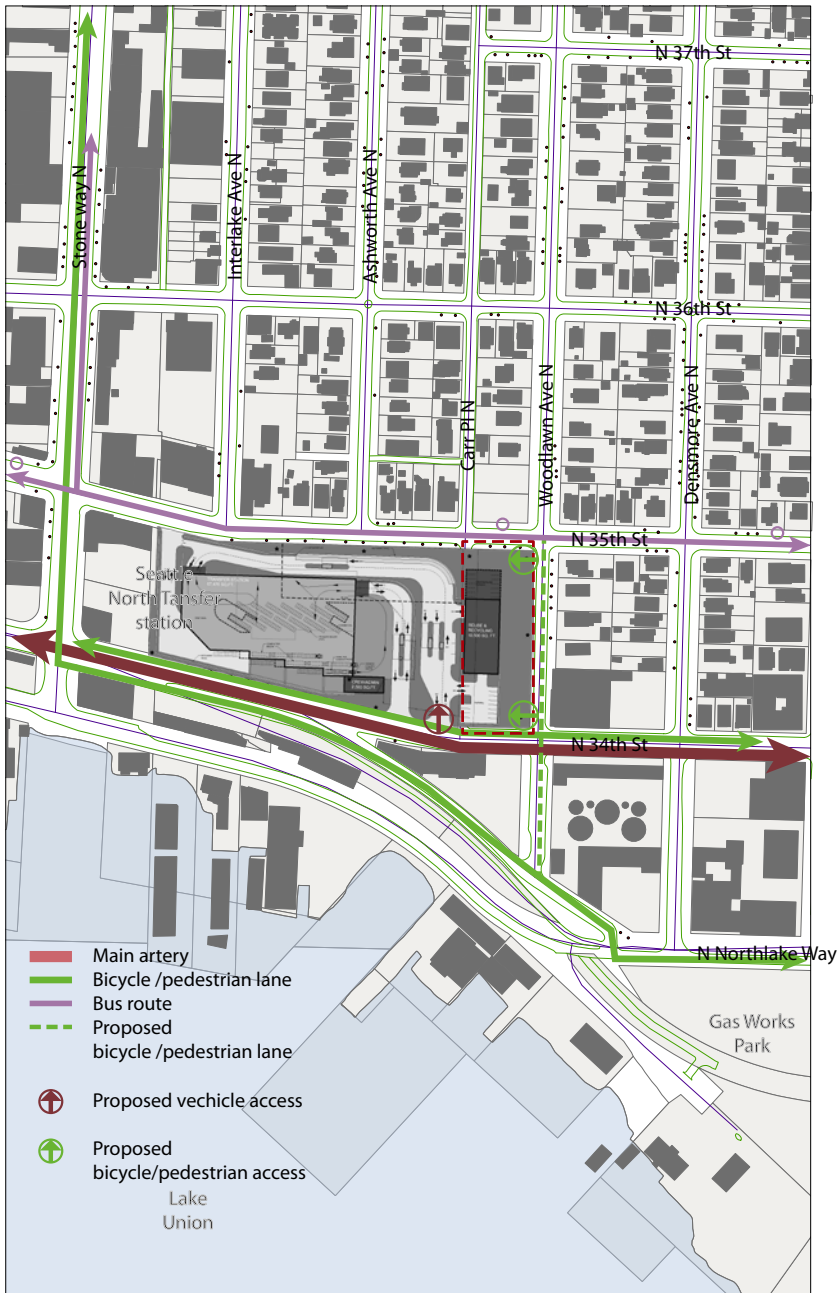


Fig. 3.6
Site traffic analysis for the site



Fig. 3.7
Solar and wind analysis for the site

3.4 Program of space

(1) Waste processing space

a. Staging and sorting area

Allows customers to unload different types of reusable and recyclable material; the recycling and reuse drop-off area houses containers for a variety of materials, vehicle lanes for parking and maneuvering

b. Material storage area

Restore the collected waste material as a resource for artists and craftsmen, which would include recycled paper, salvaged wood, and waste products from daily life

c. Administration and support area

Space includes administrative lounge and offices, conference room, locker and storage room, and mechanical and utility room.

(2) Art workshop space

a. Individual studios

Artists and craftsmen will have their own individual working space to create art works and products from reused and recycled material. This area includes space for drafting, model making, display and storage. There will be 2 to 4 individual workshop units.

b. Communal workshop space

Besides the individual workshop units, there will be a larger communal workshop space with equipment and facilities shared by artists and craftsmen. It will provide public access to help the people learn the potential utilization of waste material and establish the interaction between artists, craftsmen and the general public. The workshop may include both indoor and outdoor spaces depending on working process requirements.

(3) Public space

a. Exhibition space

The exhibition space will display art and handicraft works made from reused and recycled material; educating people about the potential utility of waste material.

b. Educational space

Includes classrooms for educating the public about the hidden value of waste material; allowing people to create some simple art works from waste material.

c. Commercial space

Sells and promotes products made from reused and recycled material; making the facility economically sustainable in the long term.

3.5 Material source

Finding the suitable material source is the first step of the design process and it is critical that the material be quick, cheap and viable to acquire (2). The material should have an adequate supply in quantity, flexible delivery time and lower price than new material. Moreover, the reused material should have enough quality and durability among other properties to meet the design requirements. This thesis will focus on two main sources to achieve the salvaged material.

(1) Local salvage yard and reused building material trade website

The salvaged building material trade business has been developed in Seattle for more than ten years. Many of the businesses work with contractors and demolition companies to collect useful and valuable waste building material and items including cabinets, doors, windows, flooring and hardware to restore and sell them back into the construction market. The potential reused materials for this thesis project would be mainly used for interior systems and partially for the envelope system, which includes bricks, glass blocks, wood flooring, doors, windows, etc.

(2) SPU warehouse building on site

According to the Landmark Nomination form of this building, the SPU building was constructed for the Oroweat Baking Company in 1969. The designer was Thomas Mackenzie, a structural engineer from Portland Oregon. The building is a reinforced concrete masonry structure composed predominately of poured-in place concrete pilasters and tilt-up concrete panels. It is rectangular in shape, measuring 80 feet wide from east to west and 300 feet deep from north to south, with a total footprint of 24,000 square feet.

The structure is composed of two sections. The front or south section, measuring 40 feet by 80 feet, was constructed using reinforced concrete and structural steel for use as a two story office and store. The rear section, measuring 80 feet by 260 feet, was constructed out of reinforced concrete



Fig. 3.8
Reused materials from Seattle local salvage yard



Fig. 3.9
Exterior view of the existing SPU warehouse

and structural glu-lam beams for use as a warehouse / garage with an 18 foot high open interior and two mezzanines. Glue-lam wood beams spaced at 20' on center span the 80 foot width and 2"x12" wood joists are set at 24" on center to support the flat roof. The two sections are divided by a steel wall on the north side of the office / store and a tilt-up concrete wall on the south side of the warehouse/garage that abut one another and have different finished floor levels. They are connected on the interior by a door opening on the second level of the office / store section that opens onto a short flight of stairs leading to the mezzanine of the warehouse / garage section (12).

The front, south facing façade of office section is composed of four 20 foot wide bays that are recessed at the ground level. The second level of each bay consists of four modular curtain wall sections. The sections are further divided as a row of four window panels set between concrete panels above and below, creating a horizontal ribbon of windows across the upper portion that extends around the west side.

For the north warehouse section, the eastern façade is composed of thirteen 20 foot wide bays of tilt-up concrete panels that present a predominately blank wall. The north rear façade consists of four 20 foot wide bays of tilt-up concrete panels. Other architectural elements which could be reused in new building include: 4 metal roll-up garage doors, 6 glass curtain walls, concrete foundation and wood flooring of the large area.

Currently, the office space is no longer being used and the storage space use is minimal. The existing structure and spatial layout can hardly meet the requirements for the new reuse and recycle facility. Since most of the architectural components are modular and in good condition, reusing those existing materials in site for a new building would be an appropriate approach to harvest the value of the existing building material, while meeting the requirements of the new program.



Fig. 3.10
Interior view of the existing SPU warehouse

Fig. 3.11
Plan, elevation and section of the existing SPU
warehouse

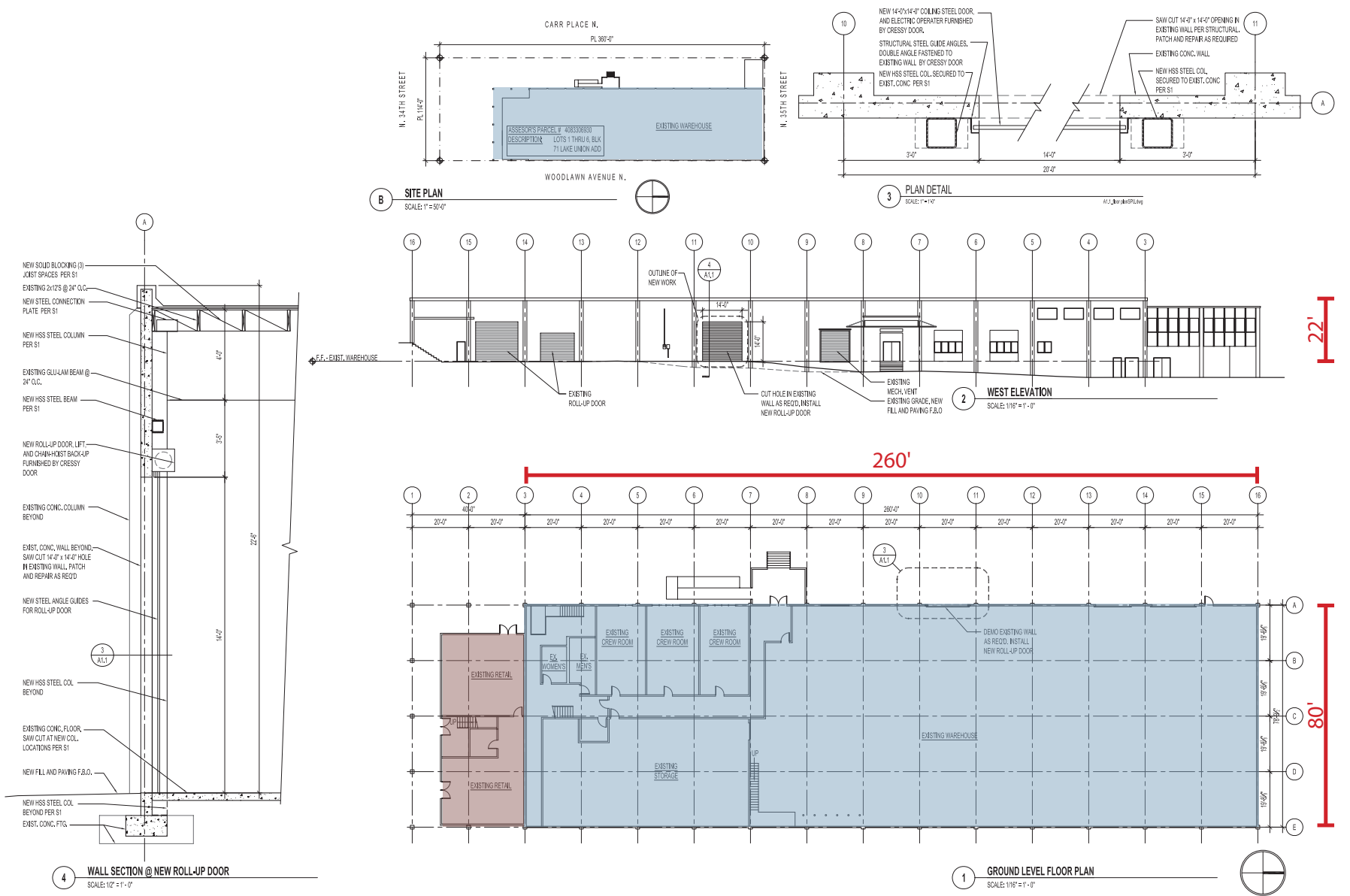
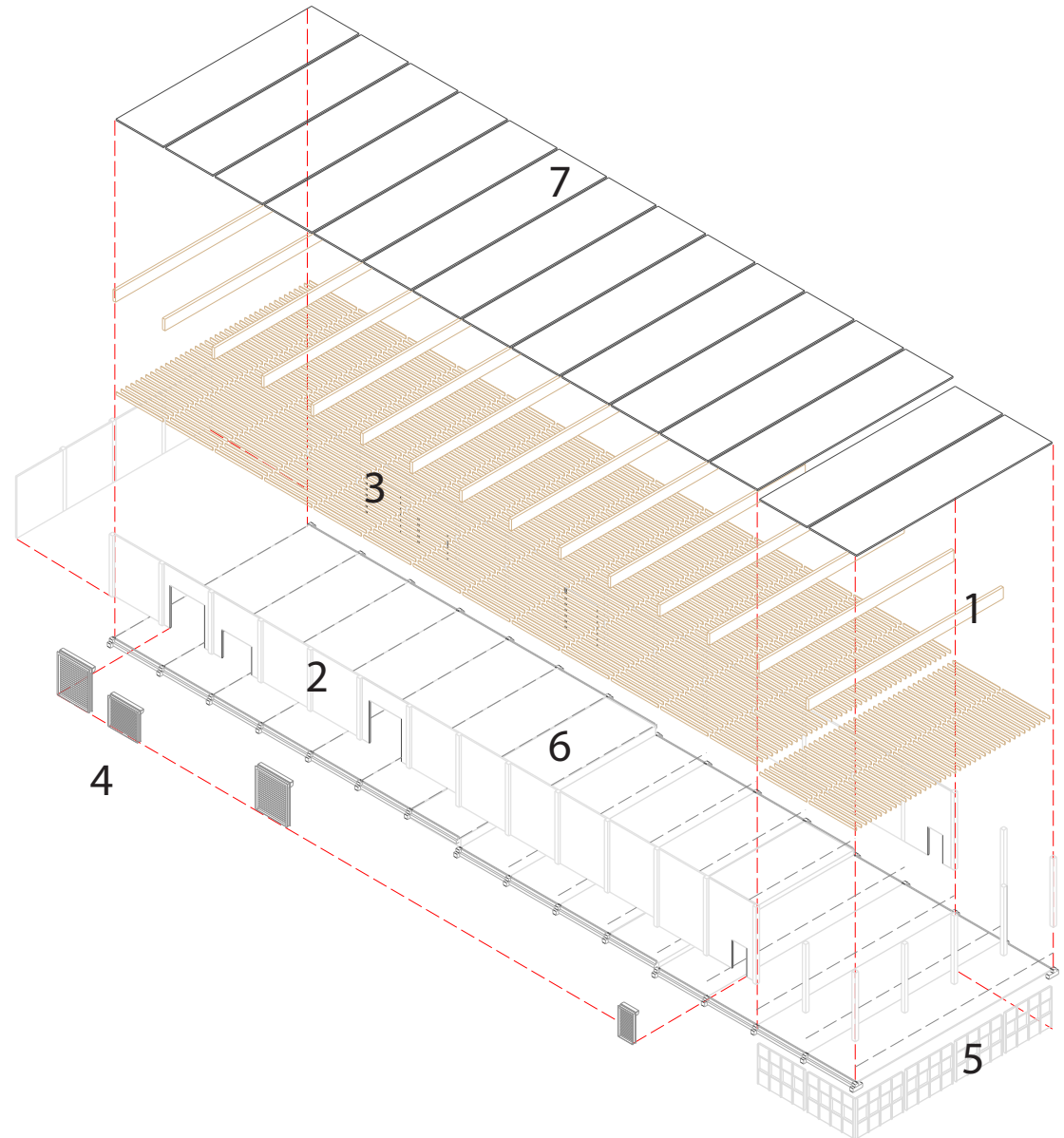


Fig. 3.12
 Kit of parts diagram of SPU warehouse:

- | | |
|---|----|
| 1. Glue-lam wood beams
16" * 48" L=80' | 14 |
| 2. Concrete pilaster
& tilt-up panels
20' * 24' D=6" (6600 cf.) | 30 |
| 3. Wood joist 520 (40 x 13)
2" * 12" L=19' | 4 |
| 4. Metal roll-up garage doors
14' * 15'
12' * 10'
14' * 14'
5' * 7' | 6 |
| 5. Curtain wall panel
5' * 14' | 6 |
| 6. Concrete footing & slab | |
| 7. Wood diaphragm roof | |



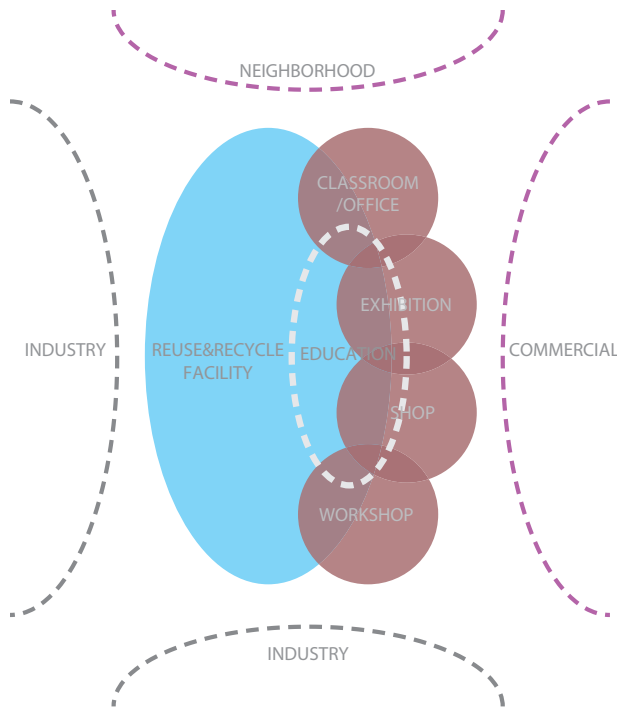


Fig. 4.1
Initial plan layout strategy

Chapter 4 Design Response

4.1 Design guideline

The purpose of this thesis is to explore how architects can strengthen the interaction between the design process and available existing resource, so developing a comprehensive design process is the focus of the project. Compared to the traditional design process, which starts from specific site and program issue and then selecting new materials to realize the design idea, design with reused materials require investigating existing available material sources at the early stage of design process. The inherited qualities of different reused materials will be the dominant factor informing the design development and the final design results (13). The reused material should be transformed to fit new function, integrated into the new building system, be visible to the public and define the character of the new building.

4.2 Design process

4.2.1 Initial design

An initial plan layout diagram responds the site and diagram requirements. Larger scale industrial space, including tipping and sorting area, parking and storage locate at the west side of the site, facing the new transfer station. All the public space, including exhibition space, store, artists' studio, and community room locates at east side of the site. The volume of these spaces will be separated to respond the surrounding neighborhood scale. The public educational space will locate in the middle so people could experience the industrial and artistic material reuse process at the same time. The initial layout is further developed into a "interlock" concept both in plan and section, each space unit will contain different function and provides opportunity for expressing different reused materials.

4.2.2 Material source investigation and deconstruction method

After the initial design, it is necessary to investigate of existing material source and feasible deconstruction method. There are four major elements in the existing building can be reused in building, including reinforced concrete panels, concrete footing and slab, Glulam beams and wood joists.

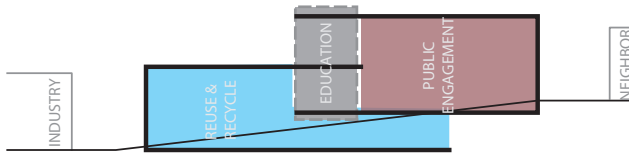


Fig. 4.2
Conceptual section diagram

a. Reinforced concrete panel

After discussing with structural engineering Tyler Sprague from UW architecture department, there are three possible methods to reuse the concrete panel. First, crush the concrete panel and recycle the rebar and concrete rubble. Second, saw cut the concrete panel to modular slates. Third, reuse the concrete panel as a whole element. A further feasibility study shows that each of the methods have its pros and cons and considering the purpose of this thesis is to explore a new design method, so the design will try to adopt all three methods responding different situation.

b. Concrete footing and slab

The most proper way to reuse the concrete footing and slab is to crush them and recycle the rebar and concrete rubble as the concrete panel. This method has been widely used by demolition contractors and it is of relatively low cost and energy consumption.

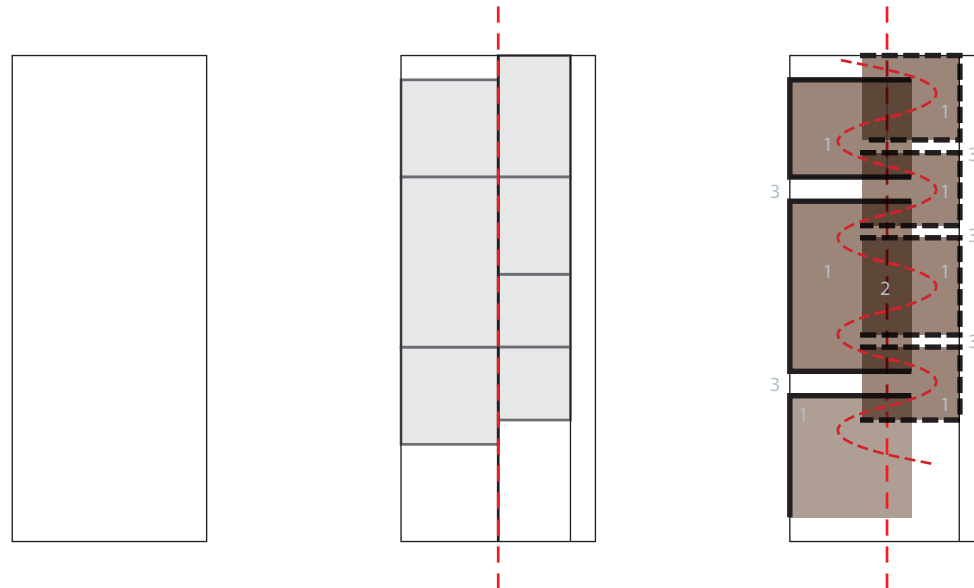
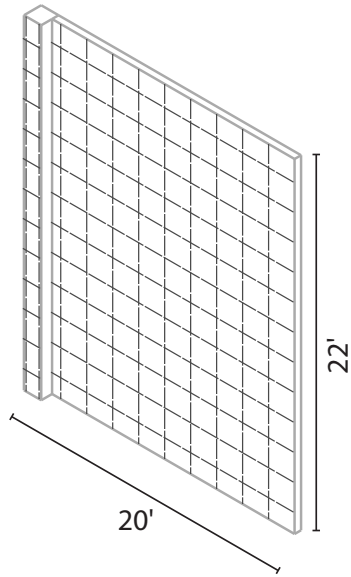


Fig. 4.3
The "interlock" concept evolved from initial plan layout

- 1 Enclosed space - Programed space
- 2 Transitional space - Connect two enclosures/Circulation/Flux
- 3 Slot space -Inbetween two enclosures/ Experiental



c. Glulam beam

The glulam beam is in good condition and could be reused as structural beam again in the new building. The 80' long span beam would be used in highly exposed public area and inform the dimension of the spaces.

d. Wood joists

Based on a case study of a barracks building deconstruction by Wood Waste Diversion in Fort Ord, California, a similar deconstruction method could also be applied in this situation (14). The roof structure will be removed to ground level, and then the shingles will be detached. Next the wood joists will be separated from sheathing with pry bars and the nails and screws will be removed. After this deconstruction process, the wood joists will be reclaimed as wood panels in new building design.



Fig. 4.4
The size and composition of the concrete panel

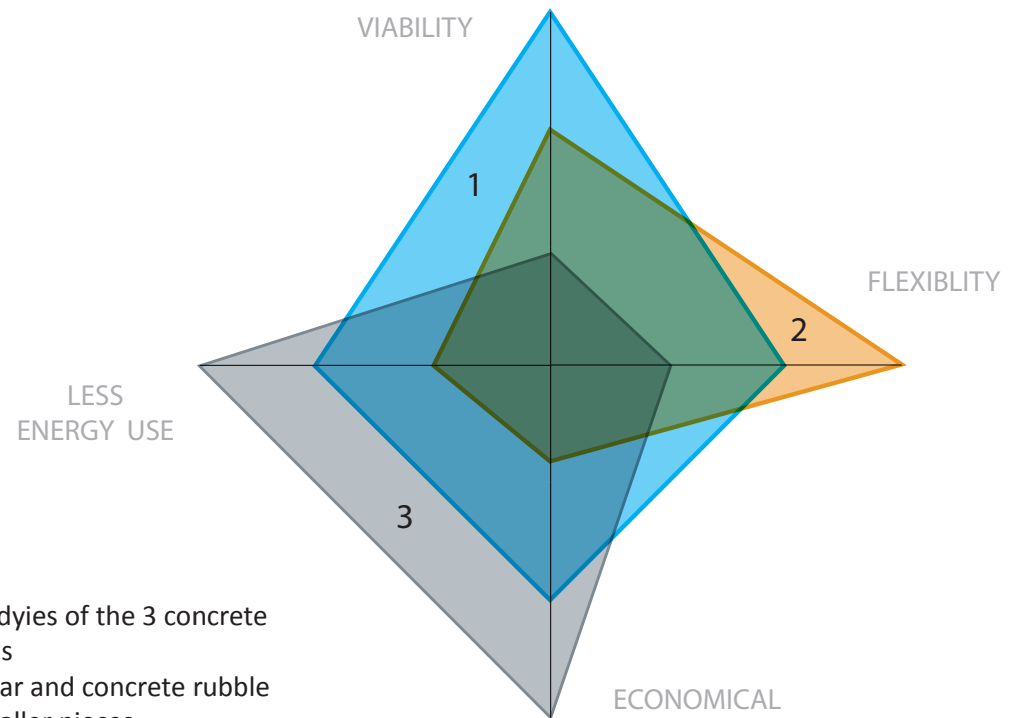
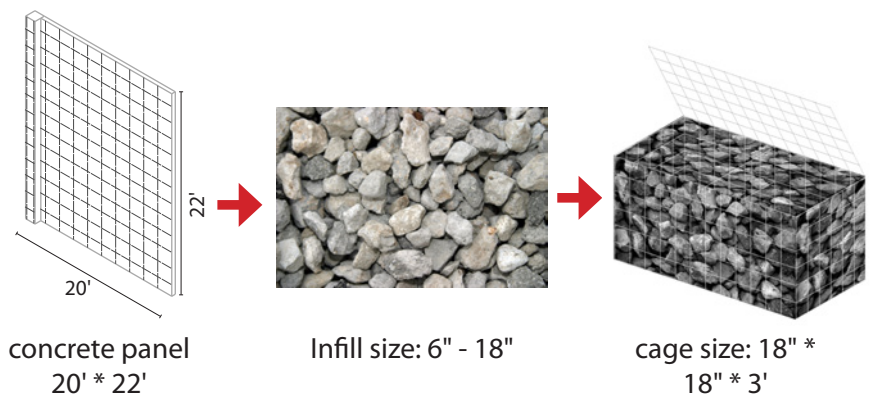
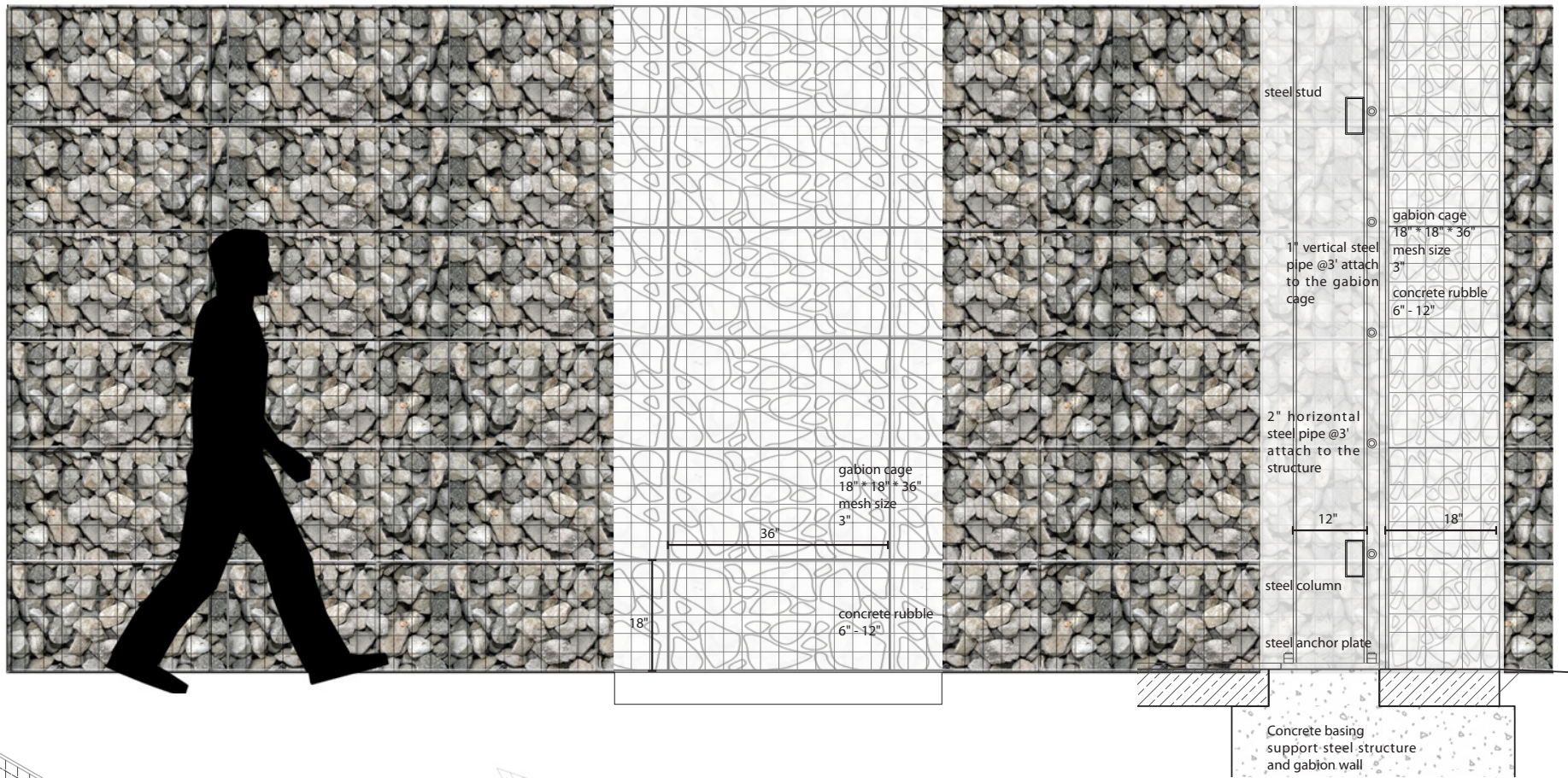


Fig. 4.5
Feasibility studies of the 3 concrete reuse methods
1. Recycle rebar and concrete rubble
2. Cut into smaller pieces
3. Reuse the whole panel

Fig. 4.6
Crushed concrete gabion wall system



4.2.3 Transform process

a. Crushed concrete gabion wall system

The crushed concrete from concrete footing and slab and concrete panels will be used as gabion wall. The concrete will be crushed on site by portable crusher into 6" to 18" rubble, and the rubble will be put in to wire mesh cages of 18" by 18" by 3'. The gabion wall is self-supporting cladding façade, secured back to steel structure frame. The gabion wall will act as a thermal mass to mediate the micro climate passively; this will also reduce the building operation energy consumption. The gabion wall will be mainly used in the west side of the building, where most of the space could be unconditioned. The gabion walls give the building a strong visual appearance and indicate the function and character of the new building.

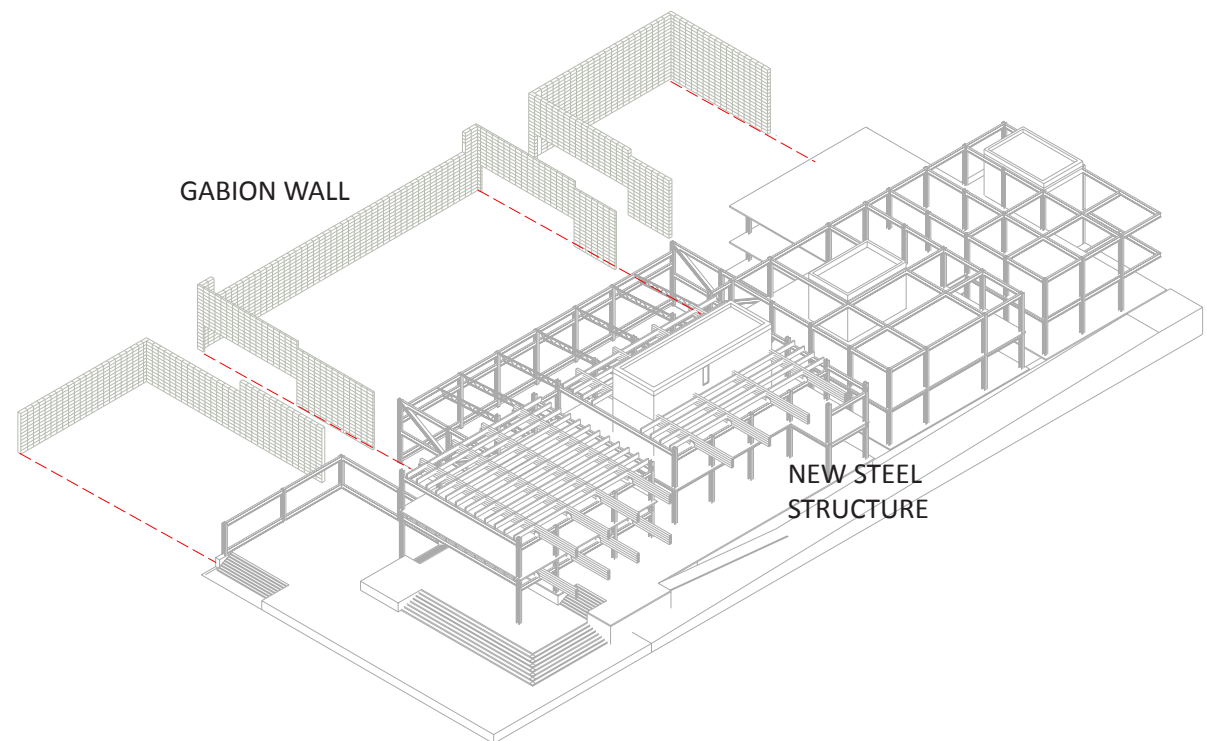
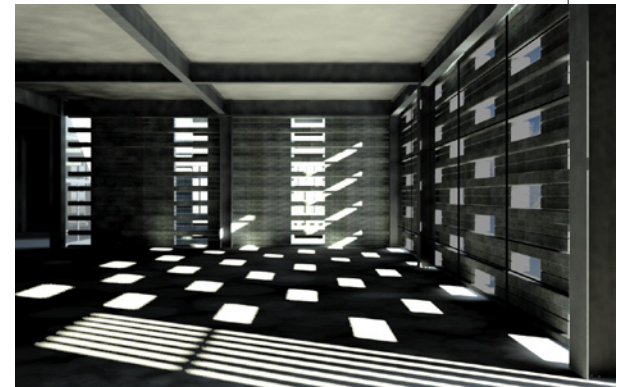
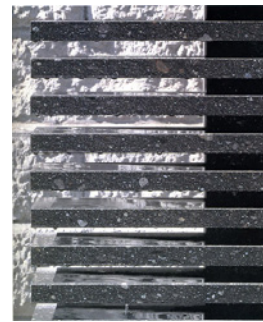
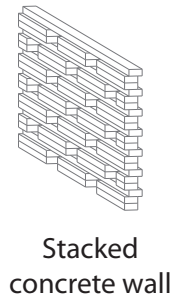
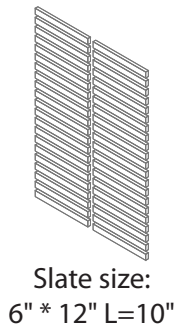
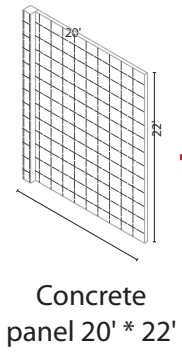
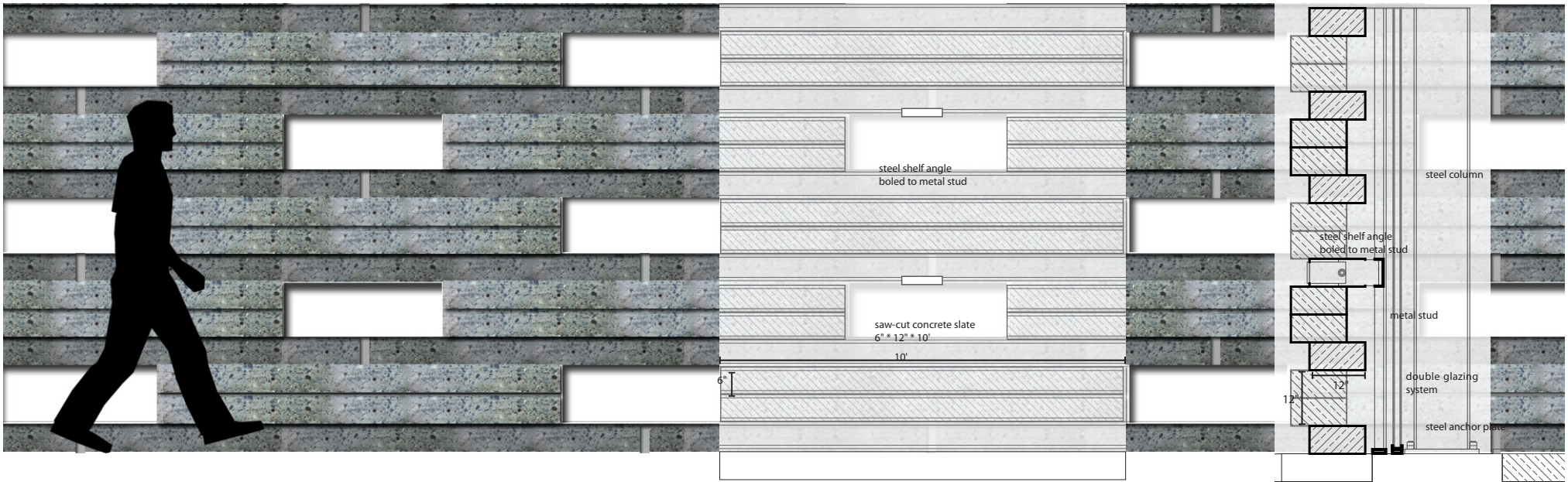


Fig. 4.7
Crushed concrete gabion walls attach to new steel
frame structure on the west side of the building

Fig. 4.8
Stacked concrete slate wall system



b. Stacked concrete slate wall system

9 of the reinforced panels will be saw cut into modular slates with the dimension of 6" by 12" by 10' off site. Then these slates will be stacked in a chalkboard pattern to create a permeable masonry wall. The stacked concrete masonry wall is a self-support cladding façade secured back to the steel structure. The hollows on the wall bring lights into the building and create a sense of lightness and rhythm from these heavy and rough materials. Considering the relatively high energy consuming of the concrete saw cutting, this system will only be used in limited area with high public visibility, such as the exhibition space and public recycled art workshop space.

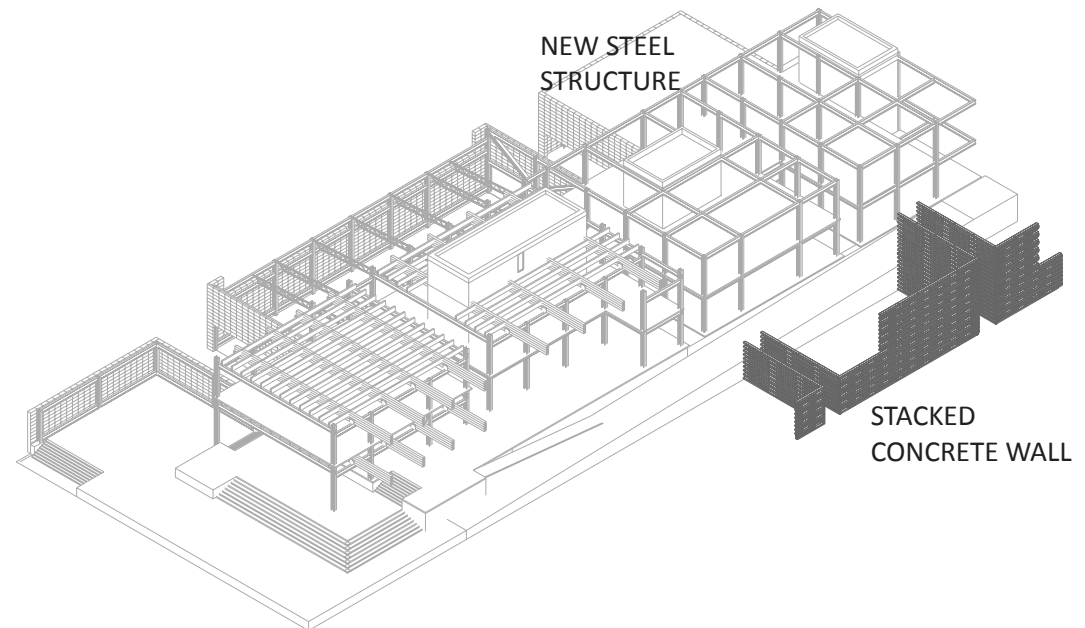


Fig. 4.9
Stacked concrete slate walls attach to new steel frame structure on the east side of the building

c. Reclaimed wood sunscreen louver

Considering the long east and west façade of the new building, reclaimed wood joists will be used as vertical louvers, provide sun shading for prevent extra heat gain. In the entry space, the louvers also define an outdoor porch area, a transitional space between outside and inside, creating a unique atmosphere before people entering the building. The reclaimed wood louvers also create a warm and intimate façade facing the neighborhood.

4.2.4 Integrate reused components in new building

The structure of the new building is steel frame system with a grid of 20' by 20'. The grid follows the old building grid in order to maximize the opportunity to reuse the existing components with their original dimension. The envelope systems with reused materials are integrated with new structure and enclose each functional space unit. The simple geometry of the new building makes the unique material stands out. Most of the reused components are used in highly visible public space and have a strong presence from the street view. By transforming the waste building material from the old building, the new building provides a tangible link with the community's past, meets the new program requirements and also responds to the site condition.

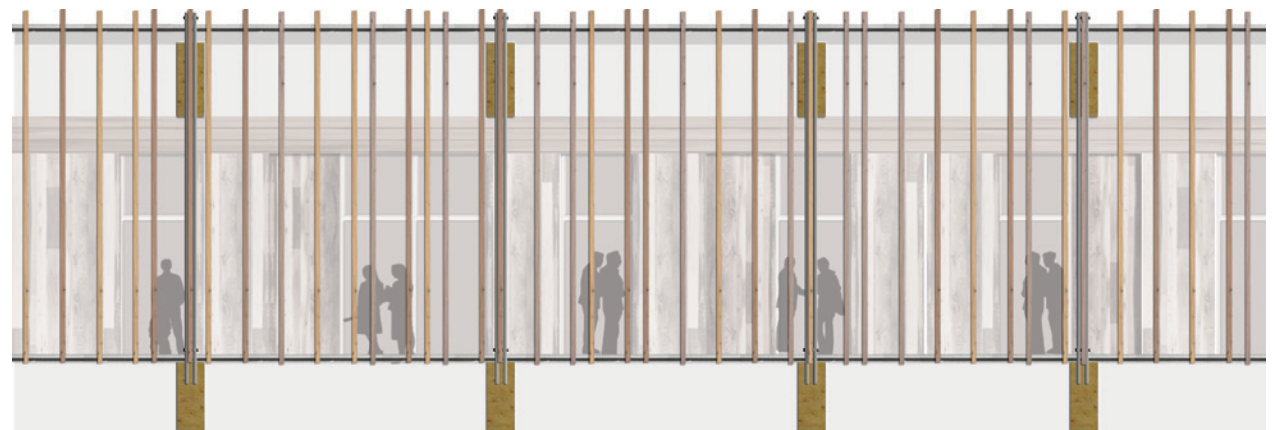


Fig. 4.12
Vertical sunscreen louver from reclaimed
wood joists

Fig. 4.16
Components transforming diagram

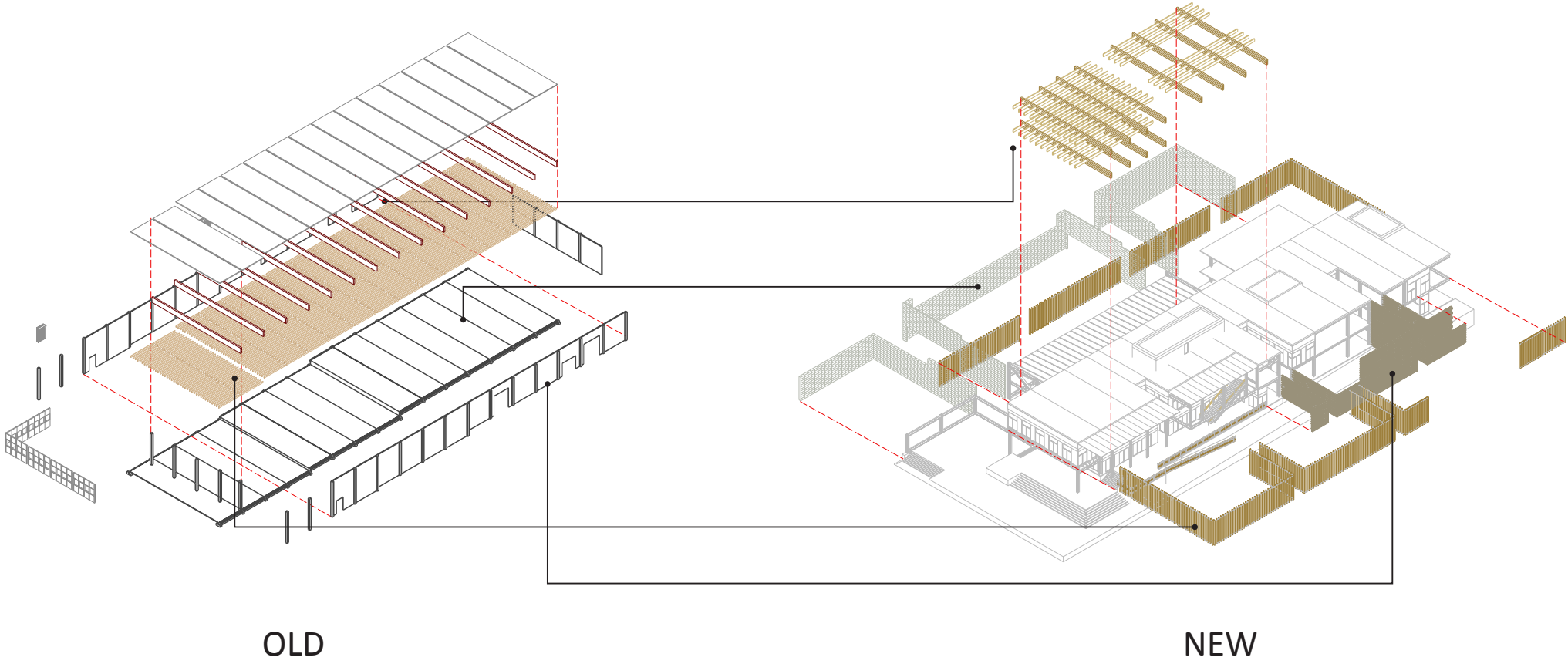


Fig. 4.13
Reused glulam beams and reclaimed wood louver
exposed at entry porch

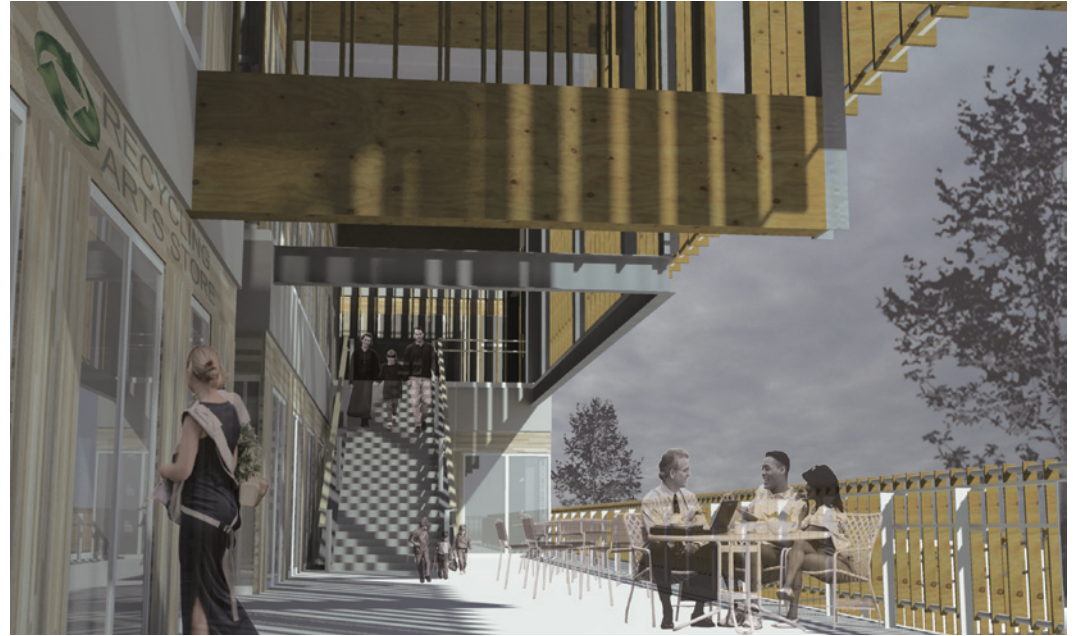


Fig. 4.14
Glulam beams reused
in new roof structure

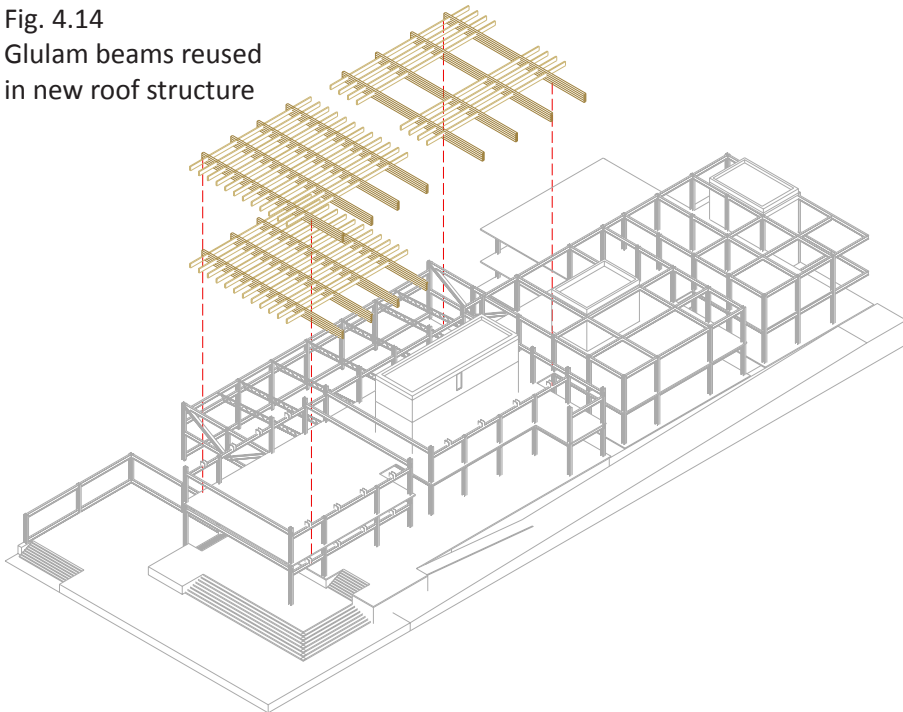


Fig. 4.15
Sunscreen louver from
reclaimed wood joists
on east and west facade

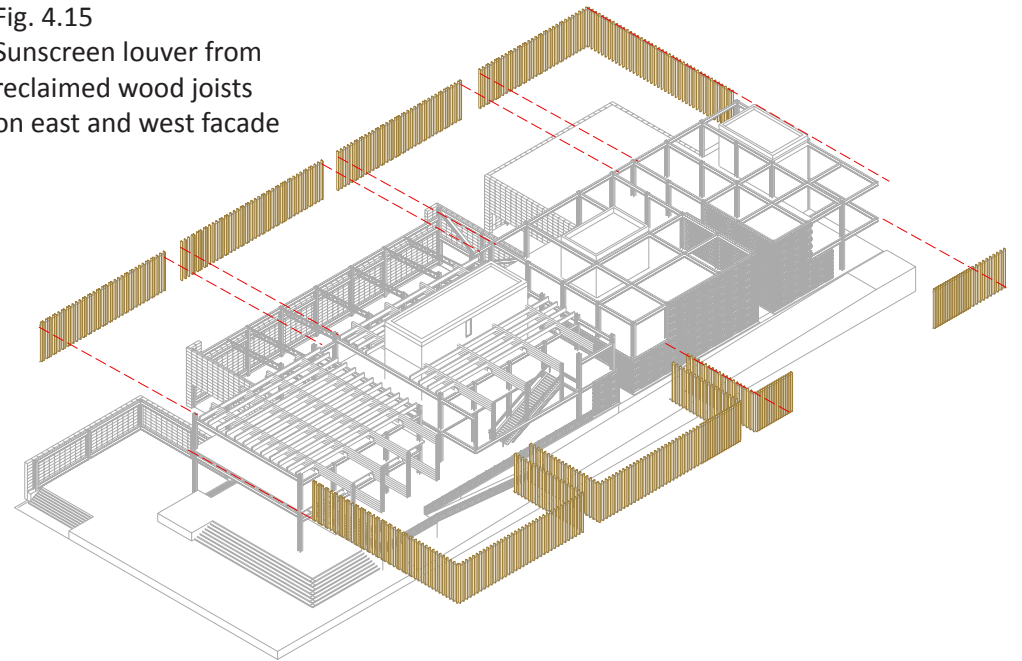




Fig. 4.10
Floor Plans

1. MATERIAL TIPPING & SORTING AREA
2. UNDERGROUND PARKING
3. EQUIPMENT AREA
4. RECYCLED ARTS & CRAFTS STORE
5. ENTRY & RECEPTION
6. EXHIBITION ROOM
7. COMMUNITY MEETING ROOM
8. STORAGE
9. OFFICE
10. CAFE
11. ARTIST'S STUDIO
12. RECYCLED ARTS&CRAFTS WORKSHOP
13. LIBRARY

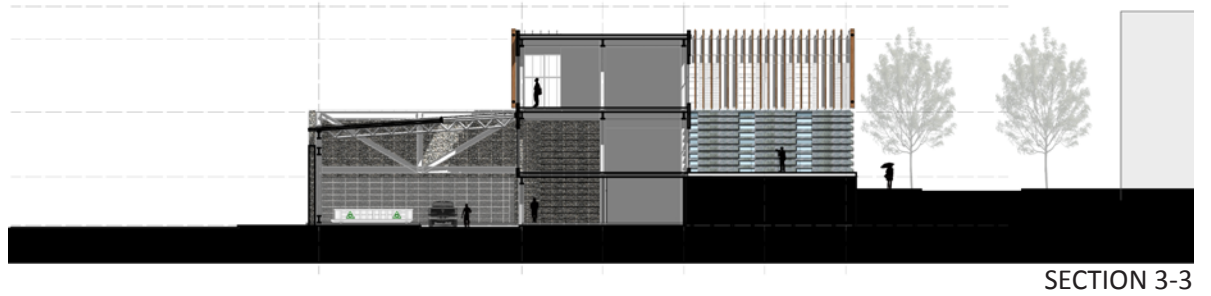
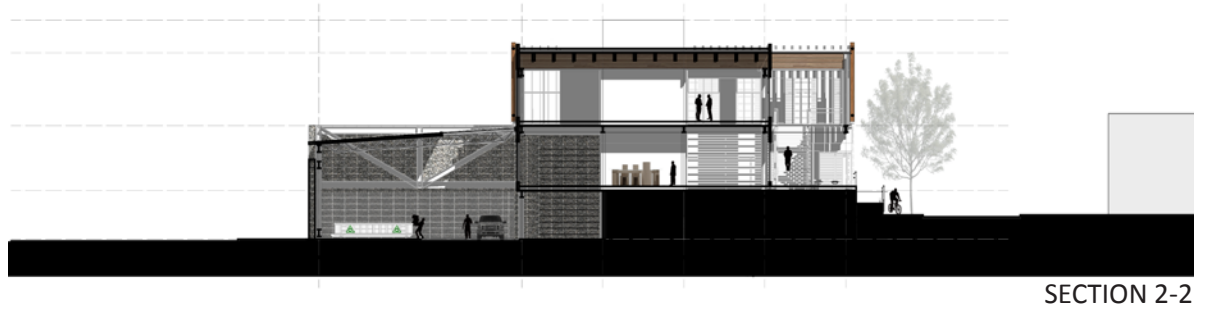
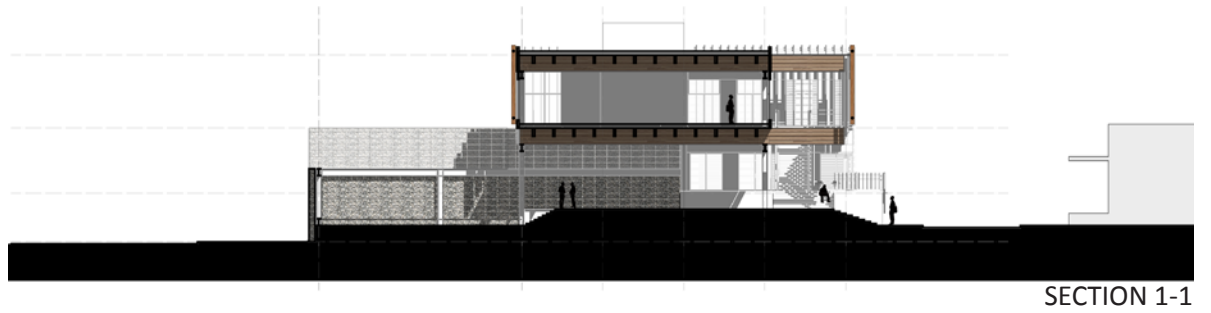


Fig. 4.11
Transverse sections

Fig. 4.17
Reuse and recycling space defined by crushed
concrete wall

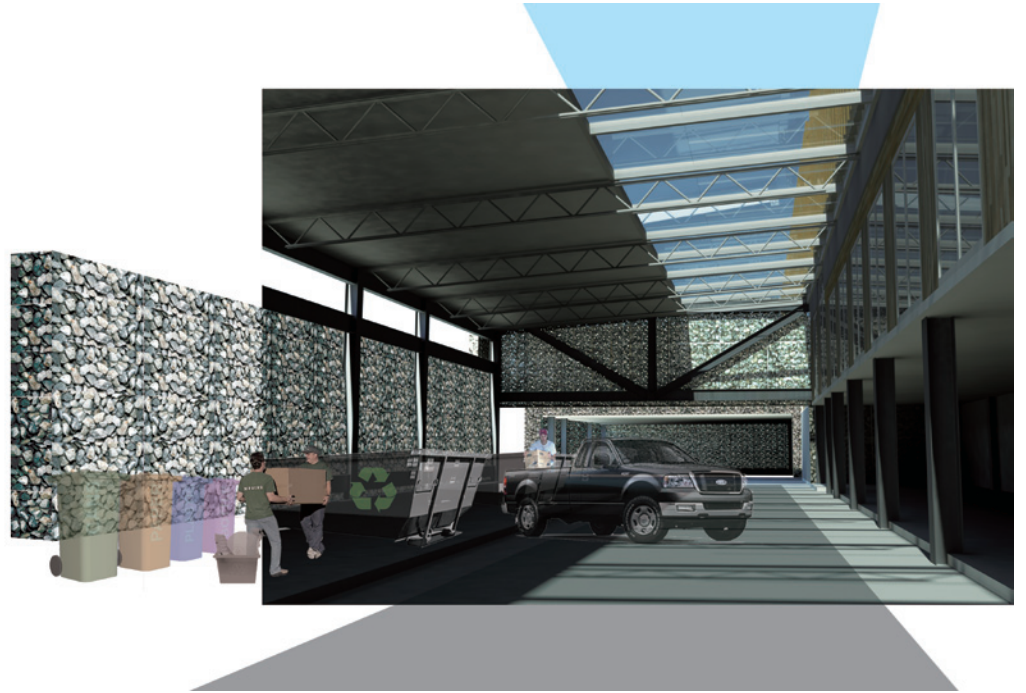
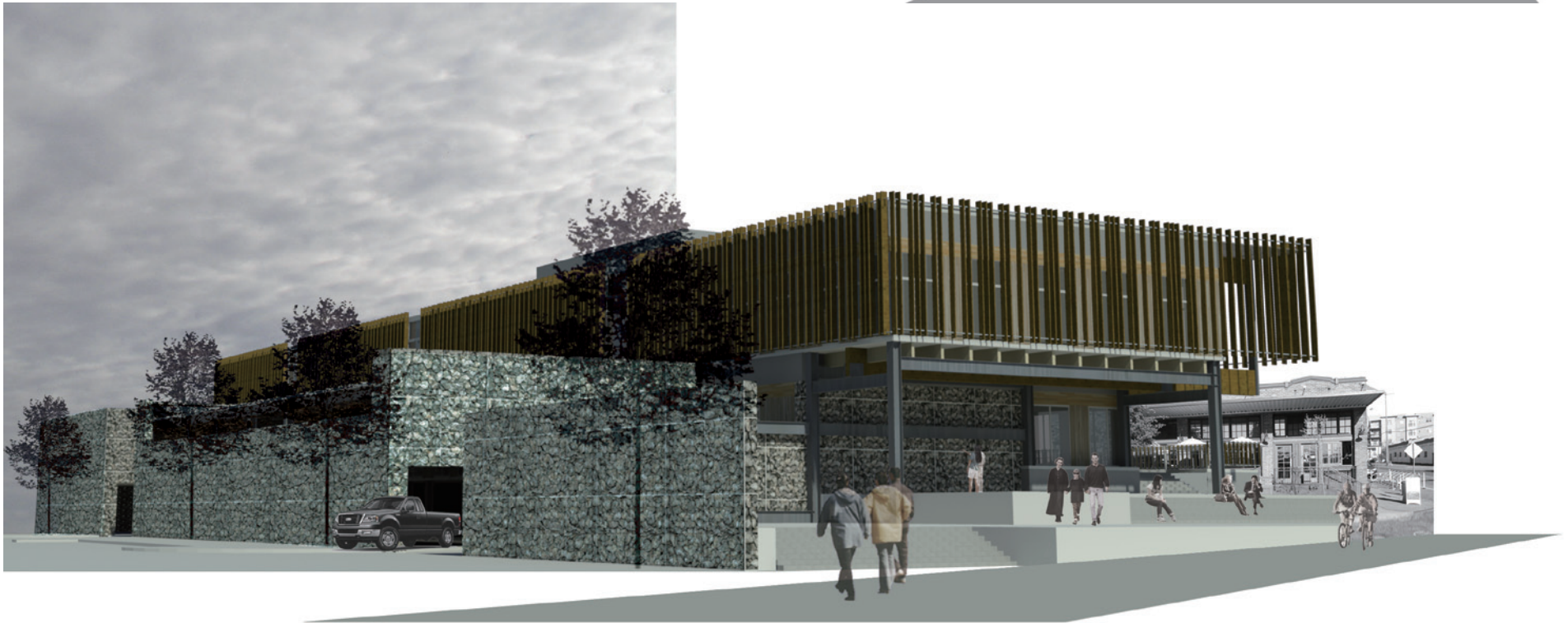


Fig. 4.18
Southwest view along N 34th St



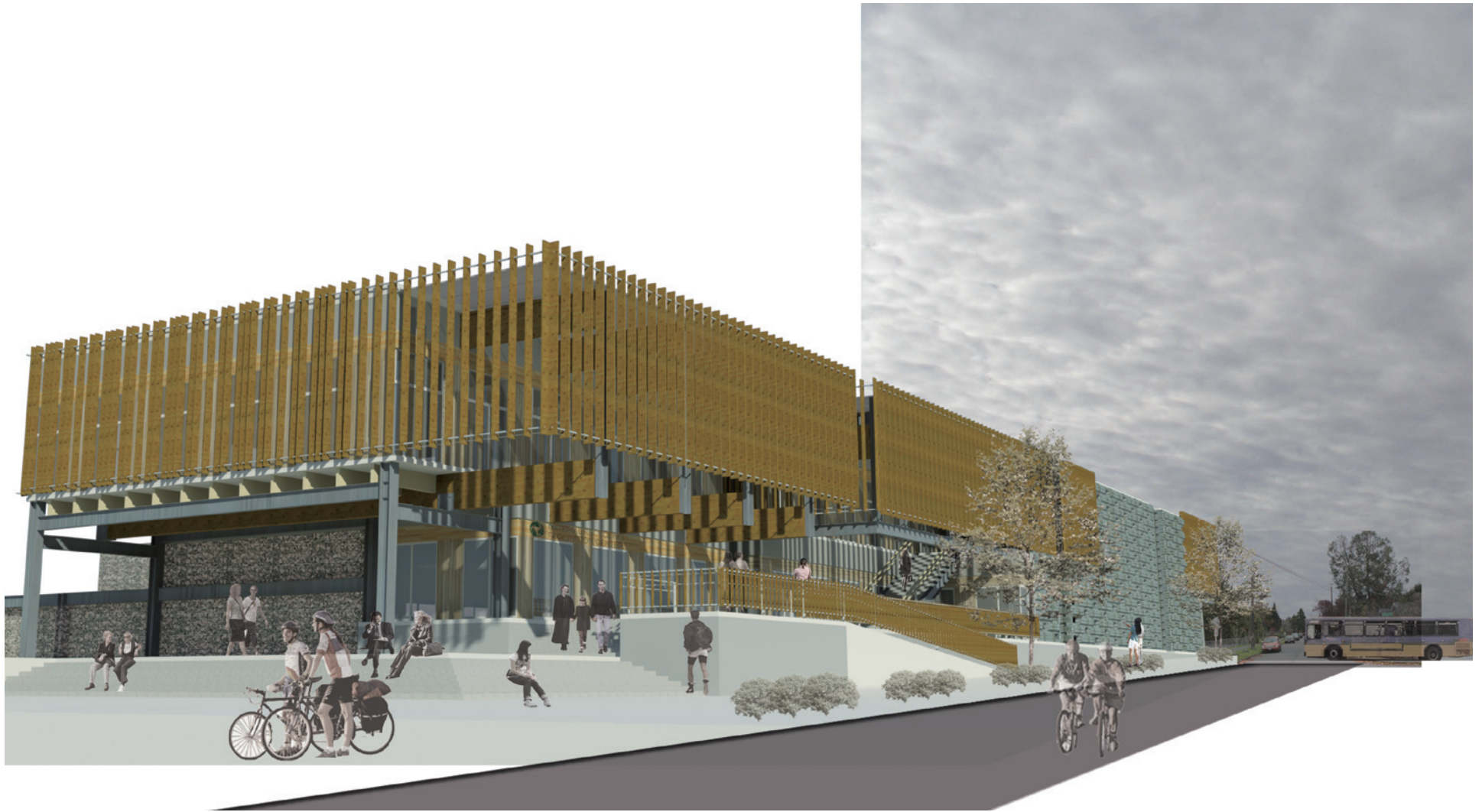


Fig. 4.19
Southeast view along Woodlawn Ave N

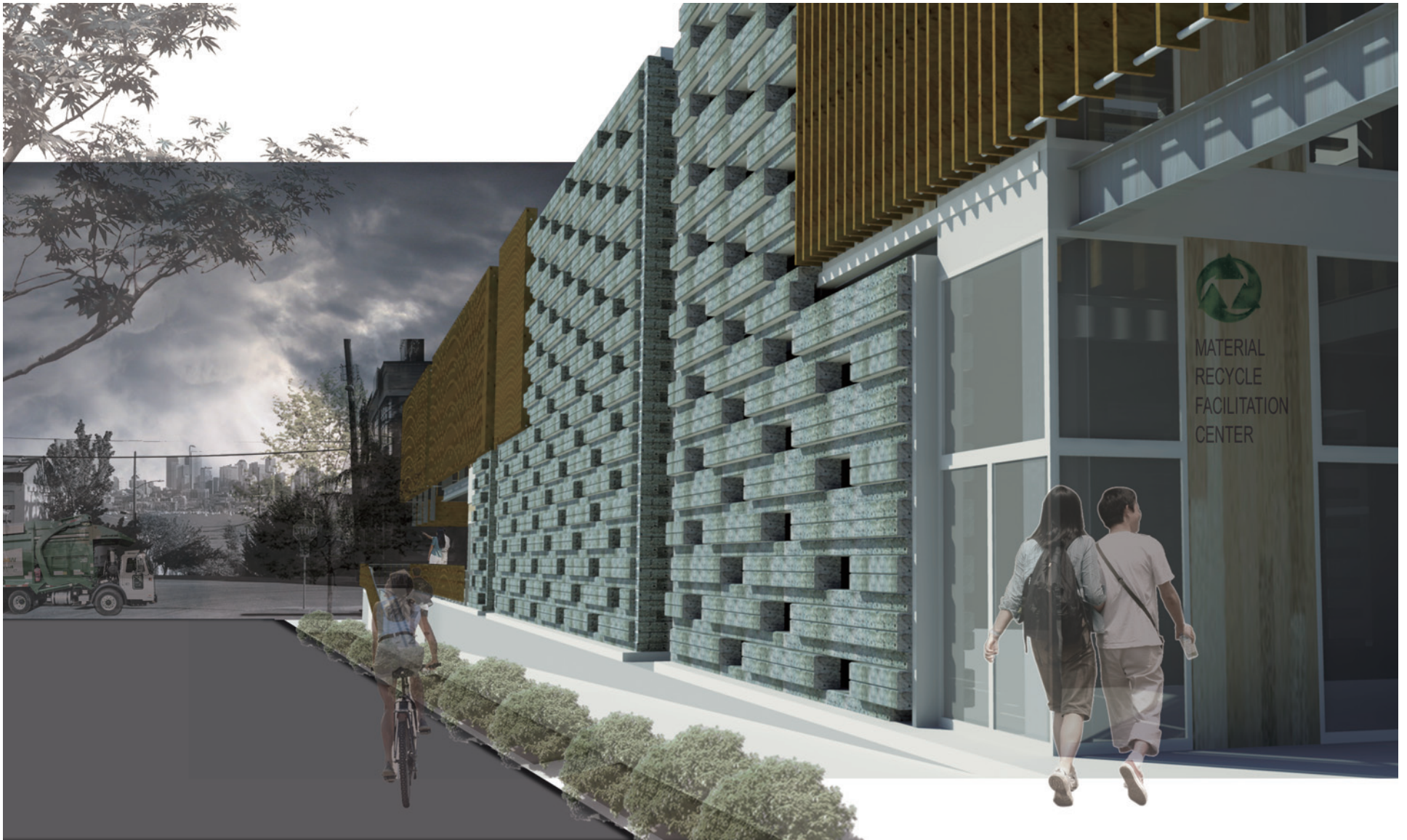


Fig. 4.20
Northeast view towards Lake Union and
Downtown Seattle

Fig. 4.21
Final model photo 01

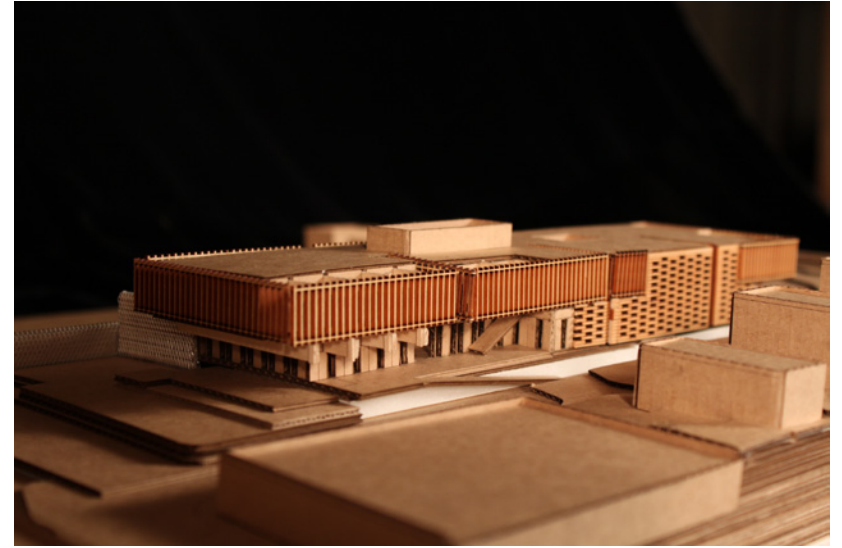


Fig. 4.22
Final model photo 02



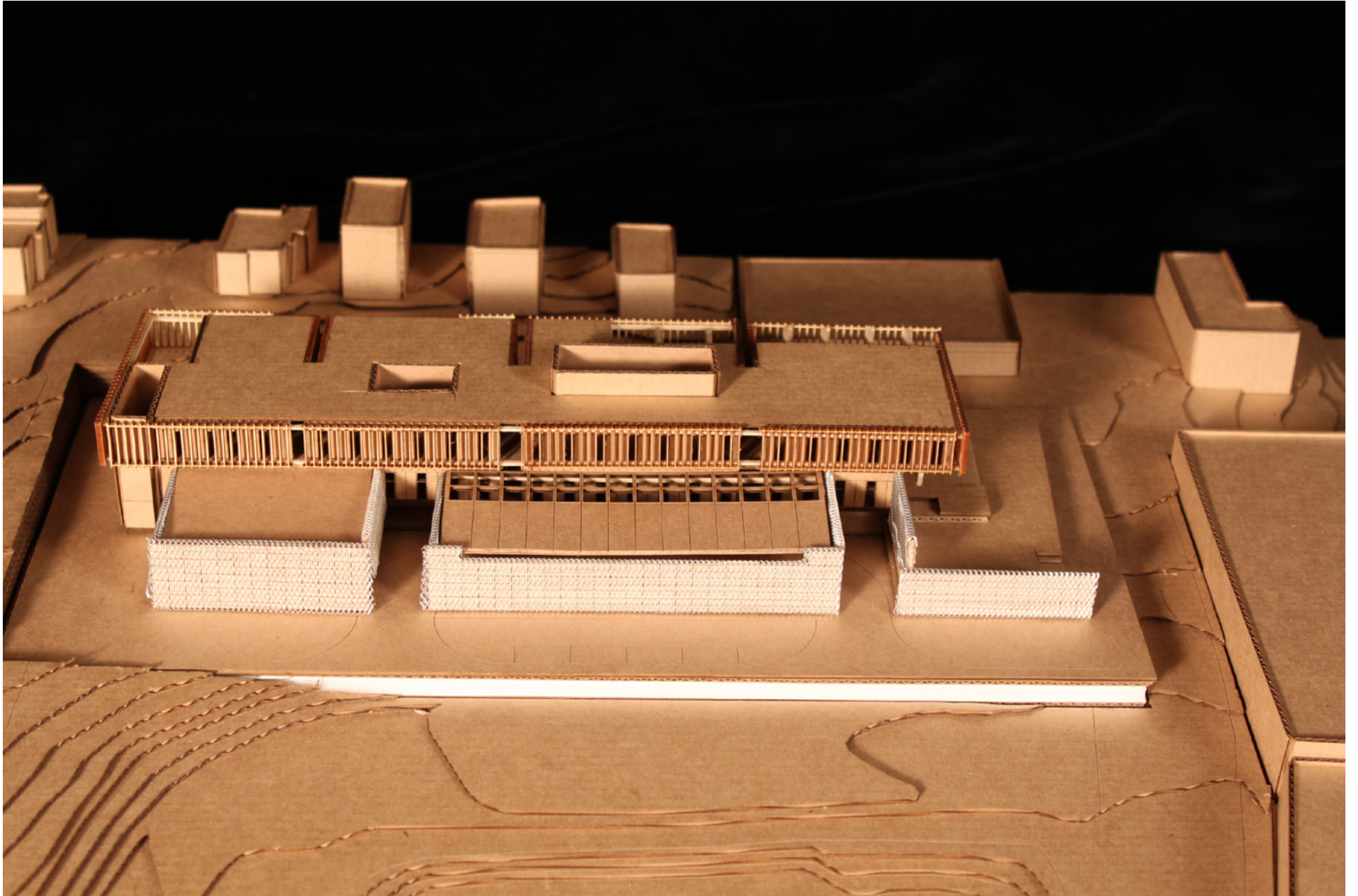


Fig. 4.23
Final model photo 03

Chapter 5 Conclusion

The thesis project targets on a typical industrial building and transforms the commonly used building material, such as reinforced concrete panel, concrete footing and slab, glulam beam and wood joists into new building envelope systems. Although the material source, the site and the program requirements are different in each case, design process and proposed methods have the potential to be applied to other projects in future.

Reclaimed materials are used to their best advantage when they are prominently featured. By providing a strong visible connection to the old building in a creative way, the reclaimed materials educate the public the underutilized value of waste materials, relay the importance of sustainability to the community, and inspire people to rethink the potential of reuse waste material in their daily life.

Design with reused materials is a simple idea, however, it requires large amount of work compared to the conventional design process. In architectural practice, incorporating reused materials cannot be achieved only by architects, but also requires collaborating effort of all project stakeholders - clients, demolition and construction contractors, engineers, and manufacturers – from the beginning of the process. The main challenges of material reuse include limited suitable resources, the storage of waste materials before construction, the potential extra cost, the unique assembly and installation detail and integrating waste materials with new materials. Rather than providing a perfect solution for one specific situation, the thesis explores one possibility of with the hope of informing other projects in future.

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