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*[NOTE TO SPECIFICATION WRITER: This guide specification for the use of segmental retaining walls was developed based on the use of an aggregate or unreinforced concrete leveling pad. **This guide specification must be edited to suit specific conditions of the project.** The design of the retaining wall based on specific site conditions should be prepared by a civil engineer in accordance with local procedures regarding the calculation of segmental retaining walls. The calculation guidelines and requirements concerning segmental retaining walls, mostly for commercial and private projects, can be found in the manual entitled "Design Manual for Segmental Retaining Walls" from the National Concrete Masonry Association.]*

## PART 1 GENERAL

### 1.01 DESCRIPTION

- A. Work shall consist of [designing and] constructing a [RAFFINATO] Segmental Retaining Wall (SRW) system, including furnishing of all materials, labor, equipment, testing and inspection, in accordance with these specifications and in reasonably close conformity with the lines, grades, design, and dimensions shown on the construction drawings. No other wall system will be considered.
- B. Work includes excavation and foundation soil preparation, furnishing and installing the leveling pad, drainage fill, drain pipe, geogrid (if required), reinforced fill (if required), retained soil/fill, and geotextile filter (if required) to the lines and grades shown on the construction drawings.

### 1.02 RELATED SECTIONS

- A. Section 01 33 00 – Submittals Procedures
- B. Section 31 00 00 – Earthwork
- C. Section 33 46 26 – Geotextiles Subsurface Drainage Filtration

### 1.03 REFERENCE DOCUMENTS

- A. National Concrete Masonry Association (NCMA)
  - 1. NCMA Design Manual for Segmental Retaining Walls, [3rd Edition]
- B. American Society for Testing and Materials (ASTM)
  - 1. Segmental Retaining Wall Units
    - a. ASTM C140/C140M Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units
    - b. ASTM C1262 Standard Test Method for Evaluating the Freeze-Thaw Durability of Manufactured Concrete Masonry Units and Related Concrete Units
    - c. ASTM C1372 Standard Specification for Dry-Cast Segmental Retaining Wall Units
    - d. ASTM C881/C881M Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete
    - e. ASTM D6916 Standard Test Method for Determining the Shear Strength Between Segmental Concrete Units (Modular Concrete Blocks)

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2. Geosynthetic Reinforcement
    - a. ASTM D4603 Standard Test Method for Determining Inherent Viscosity of Poly(Ethylene Terephthalate) (PET) by Glass Capillary Viscometer
    - b. ASTM D4873 Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples
    - c. ASTM D5262 Standard Test Method for Evaluating the Unconfined Tension Creep and Creep Rupture Behavior of Geosynthetics
    - d. ASTM D5321/D5321M Standard Test Method for Determining the Shear Strength of Soil-Geosynthetic and Geosynthetic-Geosynthetic Interfaces by Direct Shear
    - e. ASTM D5818 Standard Practice for Exposure and Retrieval of Samples to Evaluate Installation Damage of Geosynthetics
    - f. ASTM D6637 Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi-Rib Tensile Method
    - g. ASTM D6638 Standard Test Method for Determining Connection Strength Between Geosynthetic Reinforcement and Segmental Concrete Units (Modular Concrete Blocks)
    - h. ASTM D6706 Standard Test Method for Measuring Geosynthetic Pullout Resistance in Soil
    - i. ASTM D6992 Standard Test Method for Accelerated Tensile Creep and Creep-Rupture of Geosynthetic Materials Based on Time-Temperature Superposition Using the Stepped Isothermal Method
    - j. ASTM D7409 Standard Test Method for Carboxyl End Group Content of Polyethylene Terephthalate (PET) Yarns
  3. Soils
    - a. ASTM D422 Standard Test Method for Particle-Size Analysis of Soils
    - b. ASTM D448 Standard Classification for Sizes of Aggregate for Road and Bridge Construction
    - c. ASTM D698 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft<sup>3</sup> (600 kN-m/m<sup>3</sup>))
    - d. ASTM D1241 Standard Specification for Materials for Soil-Aggregate Subbase, Base, and Surface Courses
    - e. ASTM D1556/1556M Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method
    - f. ASTM D1557 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56 000 ft-lbf/ft<sup>3</sup> (2 700 kN-m/m<sup>3</sup>))
    - g. ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
    - h. ASTM D3080/3080M Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions
    - i. ASTM D4318 Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
    - j. ASTM D4767 Standard Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils
    - k. ASTM D4972 Standard Test Method for pH of Soils
    - l. ASTM D6913 Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis

- m. ASTM D6938 Standard Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
- 4. Drainage Pipe
  - a. ASTM F667/F667M Standard Specification for 3 through 24 in. Corrugated Polyethylene Pipe and Fittings
  - b. ASTM F758 Standard Specification for Smooth-Wall Poly(Vinyl Chloride) (PVC) Plastic Underdrain Systems for Highway, Airport, and Similar Drainage
- 5. Geotextile Filter
  - a. ASTM D4873 Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples
  - b. ASTM D4632/D4632M Standard Test Method for Grab Breaking Load and Elongation of Geotextiles
  - c. ASTM D4491/D4491M Standard Test Methods for Water Permeability of Geotextiles by Permittivity
  - d. ASTM D4751 Standard Test Method for Determining Apparent Opening Size of a Geotextile
  - e. ASTM D5261 Standard Test Method for Measuring Mass per Unit Area of Geotextiles
- C. The [Owner's Representative] shall make the final determination where specifications and reference documents conflict.

#### 1.04 SUBMITTALS/ CERTIFICATION

- A. Submit manufacturer's certification, at least [30] days before start of SRW construction, attesting that the retaining wall system components meet the requirements of Part 2 of this specification.
- B. Submit technical data sheets and installation instructions for each manufactured product specified.
- C. [Submit [ ] set(s) of shop drawings and design calculations for the retaining wall system prepared, signed and sealed by a Professional Engineer licensed in the state of wall installation. Design shall meet all requirements established in NCMA Design Manual for Segmental Retaining Walls, 3rd Edition.]

[NOTE TO SPECIFICATION WRITER: Retain paragraph to suit the project]

#### 1.05 QUALITY ASSURANCE

- A. The Contractor shall provide a list of [5] successful completed projects by the wall installer of similar scope and size with references, at least [30] days before the start of the SRW construction.
- B. [The Contractor shall provide evidence that the design Engineer has a minimum of [5] year of documental experience in the design of segmental retaining wall structures. The design Engineer shall provide proof of current professional liability insurance with an aggregate coverage limit of not less than [\$ 2 000 000]].

[NOTE TO SPECIFICATION WRITER: Retain paragraph to suit the project]

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1.06 DELIVERY, STORAGE, AND HANDLING

- A. The Contractor shall inspect the materials upon delivery to assure that proper type, grade, color, and certification have been received.
- B. The Contractor shall store and handle all materials in accordance with manufacturer's recommendations and in a manner to protect all materials from damage due to job site conditions. Damaged materials shall not be incorporated into the SRW.
- C. During delivery and storage, the Contractor shall protect geogrids from direct sunlight, ultraviolet radiation, heat and any other condition of the environment that would damage the geogrids.
- D. All geosynthetic material labeling, shipment and storage shall follow ASTM D 4873.
- E. The Contractor shall prevent chipping and cracking of SRW units, and protect against any damage the connectors between the SRW units. Replace damaged SRW units as directed by the [Owner's Representative] [Engineer].
- F. The Contractor shall prevent staining or otherwise damaged of the exposed face of the SRW units during storage and handling. Repair or replace, as directed by [Owner's Representative] [Engineer].

**PART 2 PRODUCTS**

## 2.01 DEFINITIONS

- A. Segmental Retaining Wall (SRW) system: a system where the basic components are the foundation soil, the leveling pad, the concrete wall units, the geogrid reinforcement (if required), the reinforced fill (if required), the retained soil/fill, the drainage fill, and the drain pipe.
- B. Raffinato SRW unit: a dry-stacked concrete retaining wall unit manufactured by Techo-Bloc or by a Techo-Bloc licensed manufacturer.
- C. Geogrid reinforcement: a geosynthetic material formed by a regular network of intersecting ribs with apertures of sufficient size to allow interlock with surrounding soil, stone, or other materials and designed specifically to reinforce soil mass.
- D. Drainage fill: a free-draining aggregate material placed in the cavities, between and extending behind the SRW units.
- E. Drain pipe: a perforated pipe used to collect and convey water to an outlet, removing incidental water from the drainage fill.
- F. Geotextile filter: a geosynthetic material comprised of textiles used adjacent to soil, allowing water to pass through it while retaining the soil on the upstream side.
- G. Reinforced fill: fill soil placed directly behind the drainage fill. It contains horizontal geogrid reinforcement as outlined on the plans.
- H. Retained soil/fill: an undisturbed native soil or fill soil placed directly behind the reinforced fill in reinforced soil SRW systems or behind the drainage fill in non-reinforced soil SRW systems.

- I. Leveling pad: a level surface consisting of aggregate material or unreinforced concrete placed to provide a working surface for placement of the SRW units.
- J. Foundation soil: Soil mass supporting the leveling pad and the reinforced fill soil zone of a SRW system.

## 2.02 RAFFINATO SEGMENTAL RETAINING WALL UNITS

- A. Raffinato SRW unit shall conform to the requirements of ASTM C1372 and the following:
  - 1. Compressive strength  $\geq 5050$  psi (35 MPa)
  - 2. Water absorption  $\leq 9$  lb/ft<sup>3</sup> (144 kg/m<sup>3</sup>)
  - 3. Durability to freeze-thaw cycles:
    - a. Mass loss  $\leq 1\%$  after 100 cycles
    - b. Mass loss  $\leq 1.5\%$  after 150 cycles
  - 4. Dimensional tolerances:
    - a. Height:  $\pm 1/16$  in. (1.5 mm)
    - b. Width and length:  $\pm 1/8$  in. (3.2 mm)
  - 5. Unit size, in (mm):
    - Raffinato (Smooth) 90 mm: 3 9/16 (90) (H) x 9 13/16 in (249) (D) x 15 5/8 (397) (L)
    - Raffinato (Smooth) 180 mm: 7 1/16 (180) (H) x 9 13/16 in (249) (D) x 15 5/8 (397) (L)
    - Raffinato (Polished) 90 mm: 3 9/16 (90) (H) x 9 3/4 in (248) (D) x 15 5/8 (397) (L)
    - Raffinato (Polished) 180 mm: 7 1/16 (180) (H) x 9 3/4 in (248) (D) x 15 5/8 (397) (L)
  - 6. Face color: [            ]
  - 7. Face finish: [Smooth] [Polished]
  - 8. Batter:
    - Near vertical (tilt wall back slightly to achieve a slight positive batter);
    - Raffinato 90 mm: 9/32 in. (7 mm), 4.4-degree inclination from vertical;
    - Raffinato 180 mm: 9/16 in. (14 mm), 4.4-degree inclination from vertical.

## 2.03 SHEAR CONNECTORS

- A. Shear connectors shall be 9/16-inch (15 mm) diameter by 2-inch (51 mm) long made of high density polyethylene (HDPE) to provide connection between wall units and geogrid reinforcement (if required).

## 2.04 GEOSYNTHETIC REINFORCEMENT

- A. Geosynthetic reinforcement shall consist of geogrids manufactured for soil reinforcement applications and shall be manufactured from high tenacity polyester (PET) multifilament yarns which are woven and coated for dimensional stability and for protection. These geogrids shall be manufactured with a molecular weight (Mn) exceeding 25,000 g/mol and a carboxyl end group (CEG) count less than 30 mmol/Kg.
- B. The Long-Term Allowable Tensile Strength of the geogrid shall be determined as follows:
  - $T_{al} = T_{ult}/(RF_{CR} \cdot RF_D \cdot RF_{ID})$
  - 1.  $T_{ult}$ : Ultimate tensile strength conducted per ASTM D6637 and based on minimum average roll value (MARV).
  - 2.  $RF_{CR}$ : Creep reduction factor based on a minimum duration of 10,000-hour creep testing according to ASTM D5262 extrapolated to a 75-year service life.  $RF_{CR} = 1.45$  minimum.
  - 3.  $RF_D$ : Durability reduction factor shall be determined from specific polymer and expected environment exposure.  $RF_D = 1.1$  minimum.

4. RF<sub>ID</sub>: Installation damage reduction factor shall be determined from product specific testing using on site soils or more severe soil type source. RF<sub>ID</sub> = 1.05 minimum.

## 2.05 LEVELING PAD MATERIAL

- A. The leveling pad material shall be non-frost susceptible, well-graded sand and gravel with unified soil classification GW with dimensions as shown on the construction drawings. [The aggregate leveling pad shall meet the requirements of ASTM D1241, gradation C:]

Sieve Size	Percent Passing
1 inch	100
3/8 inch	50-85
No. 4	35-62
No. 10	25-50
No. 40	15-30
No. 200	5-15

- B. The leveling pad material shall consist of a non-reinforced concrete base with dimensions as shown on the construction drawings. Unreinforced concrete leveling pad shall be cured a minimum of [12] hours prior to placement of the precast modular block wall retaining units and exhibit a minimum 28-day compressive strength of [2,500 psi (17.2 MPa)].

*[NOTE TO SPECIFICATION WRITER: Retain paragraph to suit the project. Gradation may be substituted for a gradation readily available in the locality, such as state standard specifications for road construction.]*

## 2.06 DRAINAGE FILL

- A. The drainage fill material shall be a clean crushed stone meeting the requirements of ASTM D448, size [No 5] [No 56] [No 57] [No 6] [No 67] [No 7].

*[NOTE TO SPECIFICATION WRITER: The aggregate gradation may be defined based on locally available materials, consistent with the design. The drainage fill material generally consists of a uniform particle size smaller than 1 in. and greater than 1/4 in.]*

## 2.07 REINFORCED FILL

- A. The reinforced fill soil shall be free of debris and consist of one of the following inorganic USCS soil types: GP, GW, SW, SP, SM meeting the following gradation as determined in accordance with ASTM D422:

Sieve Size	Percent Passing
1 inch	100
No. 4	100-20
No. 40	0-60
No. 200	0-35

- B. The maximum size shall be limited to 1 inch, unless tests have been performed to evaluate potential strength reduction in the geogrid due to installation damage.
- C. The pH of the backfill material shall be between 3 and 9 when tested in accordance with ASTM D 4972. Reinforced fill shall not be comprised of crushed or recycled concrete, recycled asphalt,

bottom ash, shale, or any other material that may degrade, creep, or experience a loss in shear strength or a change in pH over time.

- D. The reinforced fill material shall be free of sod, peat, roots, or other organic or deleterious matter including, but not limited to, ice, snow, or frozen soils. Soils with a plasticity index (PI) greater than 20 or a liquid limit (LL) greater than 40 shall not be used in the reinforced soil mass.
- E. Material can be site excavated soils where the above requirements can be met.

#### 2.08 DRAINAGE PIPE

- A. The drainage collection pipe shall be perforated or slotted polyvinyl chloride (PVC), or corrugated polyethylene (PE) pipe.
- B. The drain pipe shall be manufactured in accordance with ASTM F758 and/or ASTM F667.

#### 2.09 GEOTEXTILE FILTER

- A. The geotextile filter fabric shall be as specified on the construction drawings.

#### 2.10 CONCRETE ADHESIVE

- A. Concrete specific construction adhesive shall provide sufficient strength and shall be used to permanently secure the cap unit on the uppermost course of the SRW.

### PART 3 EXECUTION

#### 3.01 EXCAVATION

- A. Contractor shall excavate to the lines and grades shown on the construction drawings.
- B. Contractor shall take precautions to minimize over-excavation and assure that safe excavations and embankments are maintained throughout the course of the project.
- C. Over-excavation and replacement of unsuitable foundation soils with approved compacted fill will be compensated as agreed upon with the [Owner][Owner's Representative][Engineer].
- D. Contractor shall verify location of existing structures and utilities prior to excavation and shall ensure all surrounding structures are protected from the effects of wall excavation.
- E. Excavation support, if required, shall be designed by the Contractor.
- F. All excavation shall be done in full accordance with the prevailing trench and excavation safety laws applicable to the project site.

#### 3.02 FOUNDATION PREPARATION

- A. Following the excavation, the foundation soil shall be examined by the [Owner's Representative] [Engineer] to assure the actual foundation soil strength meets or exceeds the assumed design bearing strength. Soils not meeting the required strength shall be removed and replaced with soil meeting the design criteria, as directed by the [Owner's Representative] [Engineer].



- B. Should testing and observations of the foundation soil by the [Owner's Representative] [Engineer] verify that actual foundation soil strength is deficient, foundation soil correction work will be considered extra and performed under a separate change order to the contract.
- C. Contractor shall obtain approval from the [Owner's Representative] [Engineer] for the foundation bearing surface prior to proceeding with construction.

### 3.03 GEOTEXTILE PLACEMENT

- A. If specified in the construction drawings, the approved geotextile shall be set [over the prepared foundation soil extending towards the back of the excavation, up the excavation face and eventually over the top of the drainage fill to the back of the SRW units near the top of the wall.] [as shown in the construction drawings.]

### 3.04 LEVELING PAD PREPARATION

- A. A minimum of [6 inch (150 mm)] thick layer of compacted granular material shall be placed for use as a leveling pad up to the grades and locations as shown on the construction drawings. The leveling pad shall extend laterally a minimum of [6 inch (150 mm)] in front and behind the SRW unit.
- B. The granular leveling pad material shall be compacted to a minimum of [95 % of the maximum standard Proctor density (ASTM D698)] [92 % of the maximum modified Proctor density (ASTM D1557)]. The leveling pad shall provide a firm, level bearing surface on which to place the first course of the SRW units.
- C. A leveling pad consisting of [4 inch (100mm)] unreinforced concrete shall be placed for use as leveling pad up to the grades and locations as shown on the construction drawings. The leveling pad should extend a minimum of [4 inch (100mm)] from the toe and from the heel of the SRW unit.

[NOTE TO SPECIFICATION WRITER: Retain paragraph to suit the project]

### 3.05 RAFFINATO SRW UNIT INSTALLATION

- A. Install SRW units in accordance with manufacturer's instructions and recommendations, and as specified herein.
- B. The first course of SRW units shall be placed on the prepared leveling pad at the proper elevation and orientation as shown on the construction drawings or as directed by the [Owner's Representative] [Engineer]. Alignment and level shall be checked in all directions and insure that all units are in full contact with the base and properly seated.
- C. Place the front of the SRW units side-by-side. No gaps shall be left between the fronts of adjacent units.
- D. Drainage pipe shall be installed to maintain gravity flow of water outside of the reinforced/retained soil zone. Slope the drainage pipe [1 % minimum] to provide gravity flow to daylight [at the lowest



point of the pipe with outlets at a maximum of 50 feet (15 m); or 100 feet (30 m) if the pipe is crowned between the outlets] [into an underground drainage system].

- E. Place and compact drainage fill in and between adjacent units, and to a minimum depth of [14 inches (360 mm)] directly behind the units. Place and compact backfill soil behind drainage fill. Drainage fill shall be separated from other soils by the specified geotextile filter (if required).
- F. The top of each SRW unit shall be cleaned and free of foreign material before adding the next course.
- G. Install geogrid (if required) and install next course of SRW units with staggered joints. Ensure drainage fill and backfill are compacted before installation of next course.
- H. Install shear connectors per manufacturer's recommendations. Pull the SRW units forward until they are locked in place.
- I. Secure SRW units at exterior corners with the adhesive specified.

### 3.06 GEOGRID INSTALLATION

- A. Geogrid reinforcement shall be installed in accordance with manufacturer's recommendations.
- B. Geogrid reinforcement shall be placed at the strengths, lengths, and elevations shown on the construction drawings or as directed by the [Owner's Representative] [Engineer].
- C. Geogrid shall be oriented with the highest strength axis perpendicular to the wall face.
- D. The top of the SRW units shall be clean and free of debris before installing the geogrid reinforcement. Geogrid shall be laid horizontally on top of the SRW units and the compacted backfill. Geogrid shall extend to the front of the wall units but shall at no time be visible on the front face. Place the next course of SRW units over the geogrid.
- E. Geogrid shall be placed under tension and free from wrinkles prior to backfill placement on the geogrid. A nominal tension shall be applied to the reinforcement and maintained by staples, stakes, or pins until the reinforcement has been covered by at least 6 inches (150 mm) of backfill.
- F. Geogrid reinforcement layers shall be continuous throughout their embedment lengths. Splicing of the geogrid in the design strength direction (perpendicular to the wall face) is not permitted. Adjacent sections of reinforcement shall be butted in a manner to assure 100 percent coverage at each level.
- G. Tracked construction equipment shall not be operated directly upon the geogrid reinforcement. A minimum backfill thickness of 6 inches (150 mm) is required prior to operation of tracked vehicles over the geogrid. Turning of tracked vehicles should be kept to a minimum to prevent displacing the fill and damaging or moving the geogrid.
- H. Rubber-tired equipment may pass over the geogrid reinforcement, if in accordance with the manufacturer's recommendations, at speeds of less than 10 mph (16 kph). Sudden braking and sharp turning shall be avoided.

- I. Follow manufacturer's guidelines and construction drawings for overlap requirements in curves and corners.

### 3.07 REINFORCED FILL PLACEMENT

- A. Reinforced fill shall be placed as shown on the construction drawings. Backfill shall be placed, spread and compacted in such a manner that minimizes the development of wrinkles, movement or installation damage of the geogrid.
- B. Frozen materials shall not be incorporated into the work. Material shall not be placed over frozen ground, ice or snow.
- C. Reinforced fill shall be placed in maximum compacted lift thickness of 7 inches (180 mm) and shall be compacted to [95 % of the maximum standard Proctor density (ASTM D698)] [92 % of the maximum modified Proctor density (ASTM D1557)] [at a moisture content within +/- 2% of optimum.].
- D. Only hand-operated compaction equipment shall be allowed within 3 feet (0.90 m) of the back of the SRW units.
- E. At the end of each day's operation, the Contractor shall slope the last level of reinforced fill away from the SRW units to direct water runoff away from the wall face. The Contractor shall not allow surface water runoff from adjacent areas to enter the wall construction site.

### 3.08 CAP UNIT INSTALLATION

- A. Cap units shall be bonded to the SRW units below using an all-weather concrete adhesive. The cap and SRW units shall be dry and swept clean prior to adhesive placement.
- B. Cut cap units as necessary to obtain proper fit.

### 3.09 CONSTRUCTION TOLERANCES

- A. Vertical alignment control:  $\pm 1.25$  in. (32 mm) maximum over a 10 feet distance; 3 in. (75 mm) maximum
- B. Horizontal alignment control:  $\pm 1.25$  in. (32 mm) maximum over a 10 feet distance; 3 in. (75 mm) maximum
- C. Rotation: within 2 degrees from the established plan wall batter

### 3.10 FIELD QUALITY CONTROL AND ASSURANCE

- A. Quality Assurance
  - 1. The Owner [shall][may] retain the services of an independent testing and inspection firm to provide soil testing and quality assurance inspection for wall construction. This does not relieve the Contractor from securing the necessary construction quality control testing and inspection.
  - 2. Quality assurance shall include sufficient testing and observation to verify that wall construction substantially conforms to the design drawings and specifications.

**B. Quality Control**

1. The Contractor shall engage inspection and testing services to perform the minimum quality control testing described in the retaining wall design plans and specifications.
2. Quality control testing shall include soil and backfill testing to verify soil types and compaction and verification that the retaining wall is being constructed in accordance with the design plans and project specifications.