Construction Specification for Permeable Interlocking Concrete Pavers

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TS 861.01 SCOPE

This specification covers the requirements for the installation of permeable interlocking concrete pavers.

TS 861.02 REFERENCES

This specification refers to the following standards, specifications or publications:

City of Toronto Standard Specifications

TS 2.10	Construction Specification for General Excavation
TS 3.80	Construction Specification for Concrete Unit Pavers
TS 501	Construction Specification for Compaction
TS 856	Construction Specification for Pipes in Green Infrastructure
TS 1350	Amendment to OPSS.MUNI 1350 – Material Specification for Concrete – Materials and Production

City of Toronto Standard Drawings

T-310.020-2	Sidewalk Paved with Unit Paver Band at Curb
T-310.050-2	Vehicular Crossing of Sidewalk with Unit Paver Installation

Ontario Provincial Standard Specifications

OPSS.MUNI 180	General Specification for the Management of Excess Materials

Canadian Standards Association

A23.2-16A	Resistance to Degradation of Small-size Coarse Aggregate by Abrasion and Impact
A23.2-17A	Resistance to Degradation of Large-size Coarse Aggregate by Abrasion and Impact
A23.2A	Sieve Analysis of Fine and Coarse Aggregates
A231.2	Precast Concrete Pavers

American Society for Testing and Materials

D448	Standard Classification for Sizes of Aggregate for Road and Bridge Construction
D698	Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lb/ft3 (600 kN-m/m3))
D3385	Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer

American Association of State Highway and Transportation Officials

M288	Geotextiles

Interlocking Concrete Pavement Institute

Tech Spec 3 Edge Restraints for Interlocking Concrete Pavements
Tech Spec 18 Construction of Permeable Interlocking Concrete Pavement Systems
Tech Spec 22 Geosynthetics for Segmental Concrete Pavements

TS 861.03 DEFINITIONS

For the purpose of this specification, the following definitions apply:

Aspect Ratio means the overall length of a paver divided by its thickness. Example: A 100 mm wide by 200 mm long by 80 mm thick paver has an aspect ratio of 2.5. Compare to Plan Ratio.

Bedding Course means a layer of coarse crushed and washed stone screeded smooth as bedding for the pavers.

Choker Course means a layer of aggregate placed or compacted into the surface of another layer to provide stability and a smoother surface. The particle sizes of the choker course are generally smaller than those of the surface into which it is being pressed but are not too small to pass through the underlying layer.

Concrete Paver means a precast concrete paving product according to CSA A231.2.

Edge Paver means a precast concrete unit made or field cut with a straight side for placement flush with a concrete curb or other edge restraint.

Edge Restraint means a curb, edging, building or other appurtenance that is intended to confine the bedding sand and concrete pavers so that the pavers do not spread and lose interlock.

Jointing Aggregate means small aggregates swept into the openings between pavers. The aggregate size varies based on the joint width.

Laying Face means the exposed vertical face of a row of pavers on the bedding sand.

Plan Ratio means the overall length of a paver divided by its width. Example: A 100 mm wide by 200 mm long by 80 mm thick paver has an aspect ratio of 2.0. Compare to Aspect Ratio.

TS 861.04 DESIGN AND SUBMISSION REQUIREMENTS

TS 861.04.01 Permeable Concrete Pavers

Submit five labelled representative full-size samples of each paver type, thickness, colour and finish expected in the finished installation. The Contract Administrator shall inspect the pavers for conformance. The City may require permeable concrete pavers to be tested according to CSA A231.2 for dimensional tolerance, compressive strength and freeze thaw durability by an independent testing laboratory. Testing shall be at no extra cost to the City.

TS 861.04.02 Bedding and Jointing Aggregate

Submit sieve analysis for the bedding and joint aggregate according to CSA A23.2A.

TS 861.04.03 Base and Subbase

Submit sieve analysis for the base and subbase according to CSA A23.2A.

TS 861.04.04 Manufacturers Materials

Provide manufacturer's certification of permeable concrete pavers having met all applicable CSA standards. Provide manufacturer's catalog product data, installation instructions and material safety data sheets for the safe handling of the specified materials and products. Manufacture’s certification meeting ASTM standards. Manufacturer’s material safety data sheets for safe handling of the specified paving materials and other products. Written quality control procedures that ensure conformance of paving products to the product specification.

TS 861.05 MATERIALS

Store all materials for permeable interlocking concrete paver installation in areas free from mud, dirt and other foreign materials.

TS 861.05.01 Granular Subbase

The granular subbase material shall be open-graded crushed stone with 90% fractured faces and LA abrasion less than 40 as per CSA A23.2-16A or A23.2-17A. Rounded material or recycled concrete is not acceptable for vehicular applications. All materials shall be washed, with less than 2% passing the 0.075 mm sieve. Aggregate gradation for the granular subbase shall be according to CSA A23.1 Table 11, Group II, 80-40 mm as shown in Table 1. The ASTM D448 approximation is No. 2 Stone.

Table 1: 80-40 mm Granular subbase gradation

Sieve number	Percent passing
112 mm	100
80 mm	90-100
56 mm	25-60
40 mm	0-15
20 mm	0-5

TS 861.05.02 Granular Base

The granular base material shall be open-graded crushed stone with 90% fracture faces and LA abrasion less than 40 as per CSA A23.2-16A or A23.2-17A. Rounded material or recycled concrete is not acceptable for vehicular applications. All materials shall be washed, with less than 2% passing the 0.075 mm sieve. Aggregate gradation for the granular base shall be according to CSA A23.1 Table 11, Group II, 28-14 mm as shown in Table 2. The ASTM D448 approximation is No. 57 Stone.

Table 2: 28-14 mm Granular base gradation

Sieve number	Per cent passing
40 mm	100
28 mm	90-100
20 mm	30-65
14 mm	0-15
5 mm	0-5

TS 861.05.03 Bedding Course and Joint Aggregate

The bedding and jointing aggregate material shall be open-graded crushed stone with 90% fracture faces and LA abrasion less than 40 according to CSA A23.2-16A or A23.2-17A. Rounded material or recycled concrete is not acceptable for vehicular applications. All materials shall be washed, with less than 2% passing the 0.075 mm sieve. Aggregate gradation for the bedding and jointing aggregate shall be according to CSA A23.1 Table 11, Group II, 5-2.5 mm as shown in Table 3. The ASTM D448 approximation is No. 8 Stone.

Table 3: 5-2.5 mm Jointing aggregate gradation

Sieve number	Per cent passing
10 mm	100
5 mm	70-100
2.5 mm	10-40
1.25 mm	0-10

If smaller jointing aggregate material is required due to paver type with narrow joints, smaller stone to be supplied by the manufacturer. Contractor to demonstrate to the Contract Administrator that choking criteria with the underlying base gradation is satisfied. For guidance, see Interlocking Concrete Pavement Institute Tech Spec 18.

TS 861.05.04 Geotextile Fabric

Geotextile fabric shall be non-woven needle punch, woven monofilament or woven multifilament, Class II according to AASHTO M288. For roadway applications use non-woven needle punch Class I according to AASHTO M288. Overlay of geotextile shall be according to AASHTO M288. For guidance, see Interlocking Concrete Pavement Institute Tech Spec 22.

TS 861.05.05 Edge Restraints

Where not otherwise restrained, provide edge restraints installed around the perimeter of all interlocking concrete paving unit areas. Timber shall not be used as an edge restraint. Edge restraints requiring spiking shall provide adequate depth of aggregate base for anchorage. Edge restraints shall be as specified in the Contract Documents. For guidance, see Interlocking Concrete Pavement Institute Tech Spec 3.

The materials for the production of concrete edge restraints shall be according to TS 1350 and the following:

1)	Cement type	Normal Portland GU / Portland limestone GUL
2)	Minimum 28 day cylinder compressive strength	32 MPa
3)	Class of exposure	C-2
4)	Nominal maximum size of coarse aggregate	19 mm
5)	Slump at point of discharge (formed concrete)	80 ± 30 mm
6)	Total air content	6.5 ± 1.5%
7)	Maximum water/cementing materials ratio	0.45

TS 861.05.06 Underdrain

Piping shall be perforated PVC or HDPE according to TS 856. Size of perforations shall be sized to prevent migration of base material or surrounding aggregate into the pipe.

TS 861.05.07 Permeable Concrete Pavers

Permeable concrete pavers shall be according to TS 3.80. According to CSA A231.2, permeable concrete pavers shall have the following material characteristics:

(a) Minimum average cube or core compressive strength of 50 MPa for laboratory cured specimens or 40 MPa for unconditioned field samples.

(b) Resistance to 28 freeze-thaw cycles while immersed in a 3 per cent solution with no greater mass lost than 225 g/m² if surface area after 28 cycles, or 500 g/m² after 49 cycles.

(c) Permeable concrete pavers shall be uniform in size and texture.

The permeable concrete pavers shall not differ in length or width by −1.0 to +2.0 mm and in height by more than ± 3.0 mm.

Failure to meet any of the requirements (a) through (c) shall result in the rejection of all of the permeable concrete pavers represented by the failed set. All rejected pavers shall be replaced, with all associated costs, including the testing of the replacement set, at no extra cost to the City.

All units shall be free of defects that would interfere with the proper placing of the units or impair the strength or permanence of the construction. Minor cracks incidental to the usual methods of manufacture, or minor chipping resulting from customary methods of handling in shipment and delivery, shall not be deemed grounds for rejection of the lot. Individual permeable concrete pavers having visually significant imperfections, chipped edges or cracks shall not be used and shall be rejected.

TS 861.05.07.01 *Permeable Concrete Paver Types*

The type, size, colour, joint width and finish shall be as specified in the Contract Documents. City standard permeable paver types shall meet the following.

Permeable Interlocking Precast Concrete Paver	
Sizes*	Minimum 100 mm x 100 mm x Depth**
	Maximum 570 mm x 570 mm x Depth**
**Paver size will vary by product module layout, structural capacity and hydraulic performance requirements. Paver sizing shall not exceed the limits above.* ***Paver depth varies based on application. Depth of paver in pedestrian clearway shall be 60 to 80mm. Depth of paver in roadway with traffic loading shall be 80 to 100mm.*	
Colours	Medium Grey
	Light Grey
	Dark Grey
	Dark Red
	Light Red
Joint Width	5 – 12.5mm joint width with spacer

TS 861.06 EQUIPMENT

Permeable concrete pavers shall be set into the bedding course using a high frequency, low amplitude, mechanical flat plate vibratory compactor. The plate compactor shall transmit an effective force of not less than 60 kN. The frequency of vibration shall be within the range of 75 to 100 Hz to vibrate the pavers into the sand.

TS 861.07 CONSTRUCTION

TS 861.07.01 Excavation

Prior to any excavation, the Contractor shall have all utilities located and clearly marked.

The excavation shall be to the lines and grades shown on the Contract Drawings. All surplus or unsuitable material is to be disposed of, off the site, according to OPSS.MUNI 180.

The subgrade shall be prepared according to TS 2.10. Subgrade grading shall be as per the Contract Drawings.

The Contractor shall be required to make good all damage caused during the course of the construction to any part of the roadway, boulevard and private property and to restore the same, to as good or better condition as existed prior to commencement of work.

Subgrade compaction may be required and is to be determined by the Contract Administrator. Should compaction be required, compact to a minimum of 95% SPMDD according to ASTM D698. Care should be made to avoid compacting the subgrade during excavation. If compaction is required, estimate the infiltration rate according to ASTM D3385. Contractor shall provide density results to the Contract Administrator.

Do not install in heavy rain, on frozen aggregates, or on frozen soil subgrade. Verify that the soil subgrade is free from standing water. Keep excavation area free from sediment during the entire construction duration. Any geotextile, base or subbase installed contaminated with sediment shall be removed and replaced with clean material.

The Contractor shall obtain written confirmation that the subgrade preparation is sufficient prior to further installation.

TS 861.07.02 Edge Restraints

Install edge restraints as indicated on the Contract Drawings. Edge restraint base shall be placed to a depth of 75 mm and shall be compacted to a minimum of 95% of maximum dry density according to TS 501.

TS 861.07.03 Geotextile

Geotextile shall be placed on bottom (optional) and sides of soil subgrade. Geotextile shall be secured in place and overlap a minimum of 0.3 m in the direction of drainage.

TS 861.07.04 Underdrainage

If noted on the Contract Drawings, install underdrainage according to TS 856.

TS 861.07.05 Granular Subbase

Aggregate subbase shall be placed in maximum lifts of 200 mm. Protect geotextile during placement of aggregate subbase. For each lift, two passes of the vibratory mode shall be made, followed by two passes in the static mode with minimum 9 ton vibratory roller until there is no visible movement of the aggregate. Do not crush aggregate with the roller.

Use 60 kN (minimum) plate compactor for areas that cannot be reached by the roller.

The surface of the compacted base shall be such that when tested with a 3 m long straightedge, placed in any direction on the surface, the gap between the straightedge and the surface of the compacted subbase shall not be greater than 65 mm, at any point.

TS 861.07.06 Granular Base

Aggregate base shall be placed in a maximum lift of 100 mm. For the lift, two passes of the vibratory mode shall be made, followed by two passes in the static mode with minimum 9 ton vibratory roller until there is no visible movement of the aggregate. Do not crush aggregate with the roller.

Use 60 kN (minimum) plate compactor for areas that cannot be reached by the roller.

The surface of the compacted subbase shall be such that when tested with a 3 m long straightedge, placed in any direction on the surface, the gap between the straightedge and the surface of the compacted base shall not be greater than 25 mm, at any point.

TS 861.07.07 Bedding Course

Bedding course shall be placed on top of the compacted base. Place depth as shown on the Contract Drawings. Fill voids with bedding aggregate and smooth to conform to adjacent bedding material.

The surface of the bedding layer shall be such that when tested with a 3 m long straightedge, placed in any direction on the surface, the gap between the straightedge and the surface of the bedding shall not be greater than 10 mm, at any point.

Do not compact or load the bedding course.

TS 861.07.08 Permeable Concrete Pavers and Joint Fill Material

Permeable concrete pavers shall be placed in the patterns as identified below or on the Contract Drawings. Joint or bond lines shall not deviate more than 15 mm over 15 m from string lines.

Where permeable concrete pavers require trimming, they shall be cut with a dry diamond blade with vacuum abatement measures, wet cut or a guillotine, to give a straight edge. Fill gaps at the edges of the paved area with cut pavers or edge units. For gaps at edge conditions, use cut units. All cut pavers exposed to vehicular tires shall be no smaller than one-third of a whole paver. Joint spacing to be between 5 – 12.5 mm or as specified on the Contract Drawings.

Edge pavers shall be compacted within 2 m of unrestrained edges of the paving units using a low-amplitude (75 to 90 Hz) plate compactor capable of a minimum of 22 kN. Compact the pavers in a perpendicular direction with a minimum of two passes using a plate compactor.

Fill joints with jointing aggregate. Remove access aggregate on the surface by sweeping pavers clean.

Compact and seat the pavers into the bedding material by using a low-amplitude (75 to 90 Hz) plate compactor capable of a minimum of 22 kN. Compact the pavers in a perpendicular direction with a minimum of two passes using a plate compactor.

Apply additional aggregate to openings and joints if needed. Remove excess aggregate by sweeping.

At the end of each construction day, all pavers beyond 2 m of the laying face must be left fully compacted.

The surface of the pavers shall be such that when tested with a 3 m long straightedge, placed in any direction on the surface, the gap between the straightedge and the surface of the compacted pavers shall not be greater than 10 mm, at any point. The paver elevation shall be between 3 mm and 10 mm above adjacent drainage inlets, concrete collars, or channels.

TS 861.07.08.01 *Permeable Concrete Paver for Walkways, Sidewalks and Boulevards*

Permeable concrete pavers for walkways, curb edges and boulevards shall be permeable interlocking precast concrete paver and shall have an aspect ratio of 4:1 or less.

Permeable concrete pavers on sidewalks and boulevards shall be installed in either a running band pattern according to T-310.020-2 or 90-degree herringbone pattern. For vehicular crossings of sidewalks, see T-310.050-2.

Permeable concrete pavers along the curb edge shall be installed as a double row in a stack bond pattern.

TS 861.07.08.02 *Permeable Concrete Paver for Roads*

Permeable concrete pavers for roads shall be permeable interlocking precast concrete paver. Permeable concrete pavers for roads shall have an aspect ratio of 3:1 or less.

TS 861.07.09 Sediment Control

The Contractor shall be responsible for protecting work from sediment deposition and damage caused by subsequent construction activity on the site.

TS 861.08 QUALITY ASSURANCE

TS 861.08.01 Surface Tolerance

The surface of the permeable concrete pavers shall be such that when tested with a 3 m long straightedge, placed in any direction on the surface, the gap between the straightedge and the surface of the pavers shall not be greater than 10 mm, at any point.

The surface elevation of pavers shall be 3 mm to 10 mm above adjacent drainage inlets, concrete collars or channels at the completion of construction, in anticipation of post construction consolidation of the base and bedding materials.

Lippage: No greater than 3 mm difference in height between adjacent pavers.

The infiltration rate shall be tested to conform to the requirements of the Contract Documents.

TS 861.08.02 Acceptance

If any pavers are loose, chipped or unevenly cut, these permeable concrete paver units shall be rejected. Areas failing to meet the requirement for surface tolerance shall be rejected.

Any rejected permeable concrete pavers or areas shall be removed and either reinstalled or replaced by the Contractor. All costs associated with the removal, reinstallation and replacement of rejected permeable concrete pavers shall be at no extra cost to the City.

The permeable interlocking concrete paver installation Contractor shall return to the site six months following completion of the work and provide the following as required: fill paver joints with stones, replace broken or cracked pavers, re-level settled pavers. This work shall be considered base scope.

TS 861.09 MEASUREMENT FOR PAYMENT

TS 861.09.01 Permeable Interlocking Concrete Pavers

Measurement of unit pavers shall be of the surface area, including any edge restraint, in square metres (m^2). No deduction will be made for poles or utility frames and covers.

TS 861.10 BASIS OF PAYMENT

TS 861.10.01 Permeable Interlocking Concrete Pavers – Item

Payment at the Contract Price for the above tender item shall be full compensation for all labour, Equipment and Material to do the work. Payment shall include all excavation, the supply, placing, levelling and compacting of all stone, the supply and placement of concrete edge restraints, the supply and placement of drains, the supply and placement of permeable concrete pavers and bedding course, and the filling of all joints.