Technical Note

BELGARD
PAVES THE WAY

PAVER SELECTION GUIDANCE FOR VEHICULAR APPLICATIONS

Belgard pavers are an excellent choice for pavement wearing courses providing a low maintenance heavy duty pavement system. Both interlocking concrete pavers (ICP) and permeable interlocking concrete pavers (PICP) provide superior performance as a roadway surface, while PICP combines structural performance with the benefits of a revolutionary stormwater control measure reducing runoff and improving water quality. This Technical Note provides guidance in selecting the correct paver, thickness, and laying pattern to ensure long-term structural performance of Belgard paver systems.

TECHNICAL GUIDANCE

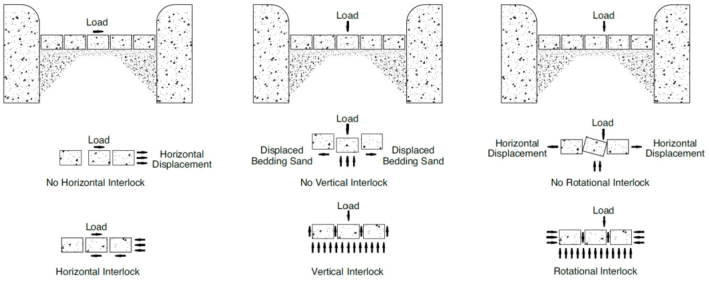
The success of any pavement is dependent on proper design, construction, and maintenance. Fortunately, ASCE has published design standards for both ICP and PICP. ASCE 58-16 is the latest edition of the ICP standard for structural design, and ASCE 68-18 is the recently published standard for PICP including both structural and hydrologic design of permeable paver systems.

ASCE developed both design standards based upon the 1993 AASHTO Guide for Design of Pavement Structures, which is used to calculate the thickness of a road cross section required to withstand the damage of repetitive dynamic loading from traffic over the lifespan of the pavement taking into account the native soil's bearing capacity. Equivalent single axle loads (ESALs) are used to determine the pavement damage done by each vehicle type compared to the damage caused by an 18,000-pound axle load. For example, passenger cars have a vehicle load factor of 0.0004 (it takes 2,500 cars to equal one ESAL) while a fully loaded fire truck can be as many as 10 ESALs. Once the traffic loading is calculated, paver thickness and aspect ratio must be selected to maximize performance and durability. The heavier the expected traffic, the thicker the paver needs to be to prevent rotation. Key factors for design of both ICPs and PICPs are subgrade strength, thickness of the base materials, paver thickness, paver aspect ratio, and laying pattern.

THE BASICS

The principle of interlock governs segmental pavement performance and ensures that the finished paver wearing course acts as a pavement surface instead of individual units. Three types of interlock must be achieved to enable load transfer from unit to unit creating a pavement surface: horizontal, vertical, and rotational.

Horizontal interlock is achieved through the laying pattern and is achieved by dispersing the forces generated by turning, braking, and accelerating. The most effective laying pattern for maintaining horizontal interlock is herringbone and should be used in vehicular applications especially where traffic frequency and/or loading are high. Vertical interlock is achieved through paver to paver load transfer, primarily through the joint material, preventing the paver from moving up and down separately from the adjacent pavers. Rotational interlock is achieved using rigid edge restraints, paver thickness meeting proper aspect ratio requirements, and by utilizing a slight crown in the pavement. The diagram below helps illustrate each type of interlock:



PAVER SELECTION

When selecting a paver for a commercial vehicular application, it is important to ensure that the selected product is a paver and not a plank or slab. The following chart helps to show the difference between pavers, planks, and slabs:

PRODUCT	AREA (SQ. IN.)	MINIMUM THICKNESS (IN)	MAXIMUM LENGTH OR WIDTH (IN)	ASPECT RATIO	PLAN RATIO	ASTM STANDARD	TYPICAL APPLICATION
Paver	≤ 101	2.4"	N/A	≤ 4:1	N/A	C936	Pedestrain or Vehicular
Slab	> 101	1.2"	48	> 4:1	N/A	C1782	Pedestrian
Plank	≤ 288	2.4"	48	≥ 4:1	≥ 4:1	N/A	Pedestrian

NOTE: *Reference the Canadian Standards Association A231.1 and A231.2 for unit concrete definitions applicable in Canada*

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It is important to note that planks do not have a designated ASTM standard so any product not meeting all the physical requirements of a paver, as shown in the table above, should follow the slab standard.

Most planks and slabs are not suitable for vehicular applications, so when in doubt the project designers should confirm that the product can support the expected loads.

Thickness

For commercial vehicular applications, both ASCE 58-16 and ASCE 68-18 for ICPs and PICPs respectively, recommend a minimum paver thickness of 80mm (3-1/8 inches). However, in some cases and in some climates 60mm pavers have been used in light vehicular commercial and residential applications.

Aspect & Plan Ratios

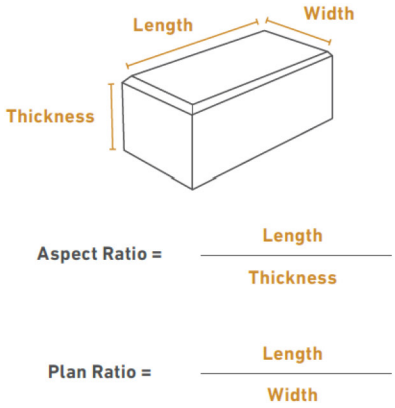
Aspect ratio is the length of the paver divided by the thickness and is used to ensure that pavers will provide proper rotational interlock and cannot be rotated out of place from point loads. Pavers, by definition, cannot have an aspect ratio greater than 4:1, but for most commercial vehicular applications we recommend a maximum aspect ratio of 3:1.

Plan ratio is length of the paver divided by the width and is not typically cited by the industry as a design parameter. However, when designing paver systems with frequent heavy vehicular loads we recommend a plan ratio of 2:1 and a herringbone laying pattern which provides the best geometry for creating horizontal interlock.

The chart below provides several examples of aspect and plan ratios for different shapes:

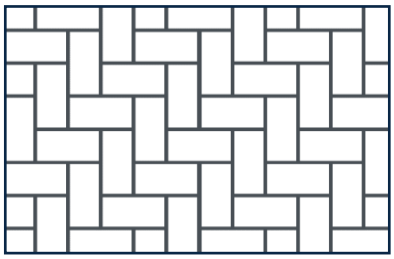
Sample Aspect & Plan Ratios

	WIDTH	LENGTH	THICKNESS	ASPECT RATIO	PLAN RATIO
	6"	12"	60 mm (2⅜")	5.1:1	2:1
			80 mm (3⅛")	3.8:1	
			101.6 mm (4")	3:1	
	6"	6"	60 mm (2⅜")	2.5:1	1:1
			80 mm (3⅛")	1.9:1	
			101.6 mm (4")	1.5:1	
	6"	9"	60 mm (2⅜")	3.8:1	1.5:1
			80 mm (3⅛")	2.9:1	
	4"	24"	80 mm (3⅛")	7.7:1	6:1

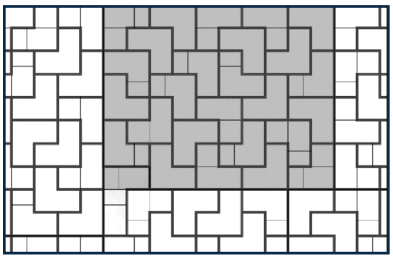


Laying Pattern

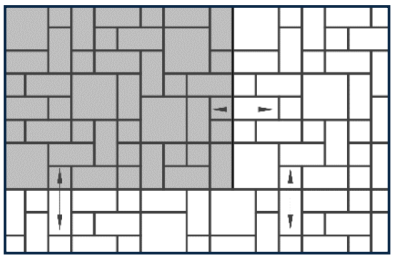
Versatility is one of the most appealing aspects of unit pavement systems providing designers with infinite possibilities. When selecting a laying pattern for a vehicular application, the designer must assess the traffic loading and movements, the edge restraint, and lateral forces, and determine if the pattern selected will provide proper horizontal interlock for the site conditions. For projects where frequent heavy vehicles will access the pavement and when in doubt, we recommend the use of a herringbone pattern, either 90 or 45 degree, which provides the best possible interlock. Below are a few patterns recommended for vehicular use (Contact your Belgard Sales Representative for more options):



HERRINGBONE
4.5 x 9



L-SHAPE
9 x 9



ASHLAR
4.5 x 4.5 (14%)
4.5 x 9 (29%)
9 x 9 (57%)

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Paver Application Recommendations

The following chart contains general recommendations for both interlocking and permeable concrete pavement systems including minimum thickness and maximum aspect ratio for several traffic types and uses. While this chart provides general recommendations, a pavement design professional should confirm that the product selected meets local standards and site-specific traffic and use conditions.

TRAFFIC TYPES	TYPICAL USES	TYPICAL LIFETIME DESIGN ESALS	TRAFFIC INDEX	MAXIMUM ASPECT RATIO	MINIMUM THICKNESS	ICP[1]	PICP[2]	HEAVY VEHICLES[3] PER DAY
Pedestrian	Pedestrian Commercial Plaza Residential Driveways	0 ≤ 10,000	0 5.2	N/A 4:1 or 5:1[4]	60 mm 60 mm	✓ ✓	✓ ✓	0 < 1
Light Vehicles	Commercial/Business Parking Access Ways	≤ 30,000	5.9	4:1	80 mm	✓ ✓	✓ ✓	≤ 5
Occasional Heavy Vehicles	Facility Parking Residential Roadways	≤ 90,000 ≤110,000	6.7 6.9	3:1 3:1	80 mm 80 mm	✓ ✓	✓ ✓	≤ 10 ≤ 10
Frequent Heavy Vehicles	Local Roads Commercial Roads & Bus Parking Minor Collector Major Collector Arterial	≤ 330,000 ≤ 500,000 ≤ 1,000,000 ≤ 5,000,000 ≤ 9,000,000	7.8 8.3 9.0 10.2 11.6	3:1 3:1 3:1 3:1 3:1	80 mm 80 mm[5] 80 mm[5] 101.6 mm 101.6 mm	✓ ✓ ✓ ✓ ✓	✓ ✓ ✓	>10 >10 >10 >10 >10

1. Consult ASCE 58-16 Structural Design of Interlocking Concrete Pavement for Municipal Streets and Roadways for ICP design guidance
2. Consult ASCE 68-18 Permeable Interlocking Concrete Pavement for PICP design guidance
3. Heavy vehicles are defined as any vehicle larger than a single unit truck as defined by AASHTO.
4. Areas subject to occasional maintenance or emergency vehicles shall have a maximum aspect ratio of 4:1 for 60 mm pavers and 5:1 for 80 mm pavers
5. Projects with high volumes of heavy vehicles should consider using 101.6 mm pavers
6. Concrete grid pavers can be used in parking lot and emergency access ways up to a maxiumum of 7,500 lifetime ESALs and a maximum of ≤ 2 heavy vehicles per day. (Aspect ratio is not applicable for grid pavers)
7. The above chart is for general guidance. When selecting pavers for site-specific conditions, please consult your local Belgard Sales representative for assistance

FLOW CHART