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Best Practices for Concrete Sidewalk Construction

by *Balvant Rajani*

Concrete sidewalks often fail prematurely. This Update describes practices that will help ensure good long-term performance, safety and comfort.

The average service life of concrete sidewalks is 20 to 40 years, but failure can occur as early as one to five years after construction. Many of the problems are the result of lack of attention to detail during the design and construction stages.

Over the past decade, NRC's Institute for Research in Construction has conducted a number of investigations into the performance of sidewalks and the causes of failure.^{1,2}

This Update describes practices that

Many of the best practices described here apply to other types of sidewalks.

prolong sidewalk life and in so doing, advance the four key sidewalk attributes: safety, comfort, appearance, and life-cycle cost performance.

Subgrade

The subgrade is the native soil that is graded and compacted to provide an even surface to support the sidewalk. The subgrade material should have uniform stiffness to avoid differing frost or expansion characteristics. In some cases, the concrete is placed directly on the subgrade, but it is strongly recommended that a granular sub-base be

placed between the native soil and the concrete slab.

IRC studies show that in the harsh conditions of the Prairie Provinces, most sidewalks crack in both longitudinal and transversal directions. In general, longitudinal cracks can be attributed to seasonal changes, and transversal cracks

A concrete sidewalk is typically a 100 to 150 mm thick slab on grade. Usually, the distance between construction joints (slab length) is marginally larger than the width of the sidewalk.

to non-uniform compaction of the subgrade rather than the degree of compaction. The studies also showed that sidewalks overlying higher plasticity soils had a higher incidence of longitudinal cracks.

Clay soils with a moisture content higher than optimum have less tendency to swell after compaction because the soil structure becomes more oriented. Consequently, adding moisture to a clay subgrade prior to compaction will reduce the tendency of the soil to swell after the sidewalk has been constructed. It is also known that a moisture content higher than optimum increases subgrade shrinkage, another cause of sidewalk deterioration. Even so, experience shows that in clay soils, the advantage of wetting the clay outweighs the risk of sidewalk cracking due to shrinkage in the subgrade.

Rigid body uplift is the tendency for a sidewalk slab to rise equally or tilt as a result of expansive native soils or frost action. Removing known frost-susceptible materials and replacing them with granular sub-base material can reduce movement.

For optimum long-term performance, proper preparation of the subgrade is essential. This means that levelling and compaction should be avoided when frost is present. When the subgrade is shaped, large embedded objects should be removed and the soil compacted to 95% Standard Proctor density. The *uniformity* of the compaction is just as important as the *degree* of compaction. Good uniform compaction

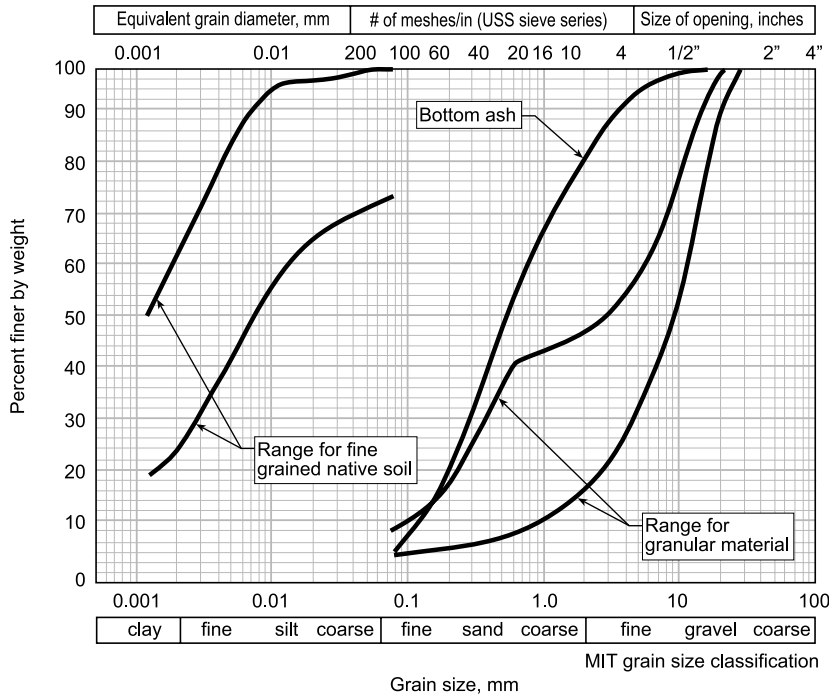


Figure 1. Gradation for subgrade and sub-base materials.

diminishes the differential settlement of the concrete sidewalk and hence reduces the development of longitudinal, transverse, and D-cracks.

Sub-base

A sub-base is a layer of granular material (usually 150 mm) placed on top of the prepared subgrade to provide a cushion for uniform support by bridging over minor subgrade defects. The granular sub-base

also diminishes the development of suction that leads to tensile-shrinkage failures. This is particularly important where the underlying subgrade soil is susceptible to shrinkage due to moisture depletion. The gradation of the granular sub-base should be within a specified range. In Ontario, sub-base material termed "Granular A" is used and its gradation falls within the range shown in Figure 1. The sub-base should be uniform in depth and be compacted to 95% Standard Proctor density.

A sub-base is not always provided but the best practice for sidewalk construction includes a sub-base. The additional expenditure will be recouped through increased service life.

In Canada, the predominant mode of sidewalk deformation is hogging,² which is accentuated in the cold season. Hogging can be reduced by increasing the amount of insulation under the middle third of the sidewalk. This can be achieved by providing a deeper granular sub-base (Figure 2) or installing insulation such as expanded or extruded polystyrene insulation boards (Figure 3). The insulation promotes uniform vertical movement and minimizes differential movement. Where the sidewalk is too narrow to practically install insulation only along the middle third, the insulation can extend to the edges.

Concrete

The quality of the concrete mostly affects the top 6 mm (the wearing surface) of a sidewalk. No special attributes are necessary for sidewalk concrete, but specifications should include the following information: strength (25 to 35 MPa), minimum cement content (333 kg/m³), maximum size of coarse aggregate (19 mm), slump (50 to 100 mm) and air entrainment (5.5 to 8%).

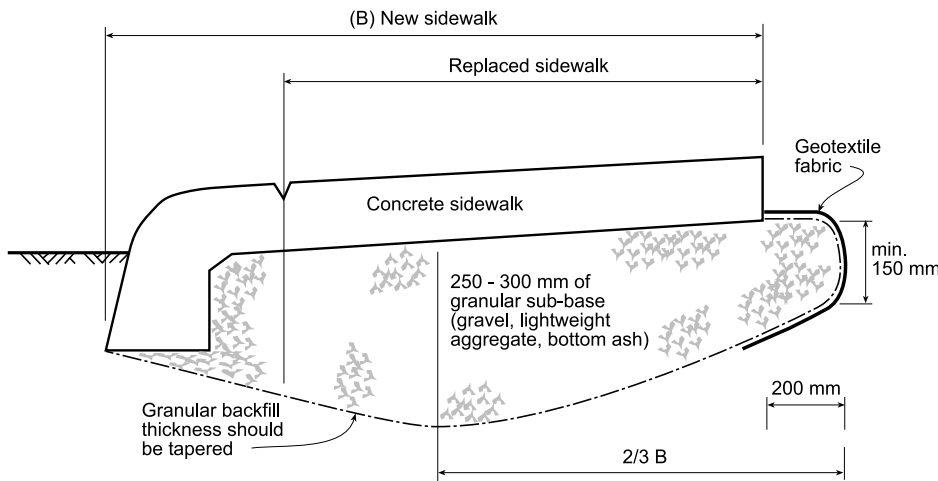


Figure 2. Typical cross-section of sidewalk with enhanced granular sub-base.

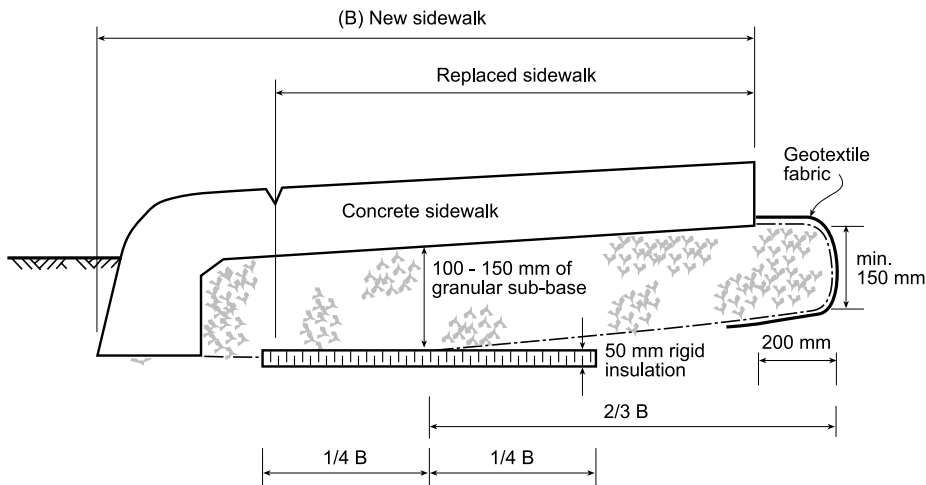


Figure 3. Typical cross-section of sidewalk with rigid insulation-enhanced sub-base.

Most concrete sidewalks in Canada are constructed without using steel reinforcement. In fact, deformation, the main cause of concrete failure, cannot be effectively eliminated through reinforcement.² For this reason, best practices do not call for reinforcement. However, sidewalks that traverse driveway entrances will experience normal vehicle loads and occasional truck loads. It is preferable to use steel reinforcement mesh for these locations. Far greater benefits can be realized through stricter attention to the subgrade preparation.

The general practices of good concrete construction that apply to floor slabs³ also apply to sidewalks and can be summarized as follows:

1. Formwork: Forms should be straight, free from warping, and strong enough to resist the lateral pressure of the concrete. A form release agent should be applied to ease stripping. (Formwork is not required for sidewalks constructed using the extrusion process.)
2. Concrete placement: Concrete should be placed continuously as close as possible to its final position and be consolidated.
3. Finishing: After the concrete is levelled, the desired surface finish is applied and should be protected from damage during the curing period.
4. Curing: Curing has a significant influence on the wear resistance of the surface. The type of curing required is determined by weather conditions as follows:

- a) In cold temperatures, concrete needs to be protected from freezing for at least five days after placement. For forecast temperatures around 0 to -3°C, the concrete needs to be covered with polyethylene sheeting. For colder temperatures, two sheets of polyethylene separated by 300 mm of straw or a similar degree of insulation needs to be provided.

- b) For warm temperatures, wet-curing or the application of a liquid membrane-forming

curing compound is needed to ensure there is adequate moisture in the concrete while its strength is developing. The curing should be initiated immediately after finishing because the concrete surface will dry within 20 to 30 minutes in sunny, windy and warm conditions.

Joints

Expansion joints consisting of 12 mm of compressible material should be placed at 15-m intervals along the sidewalk and wherever the sidewalk abuts another rigid structure. The joints allow the sidewalk to move independently without damage.

Control joints (cut lines) should be provided at intervals of about 1.2 to 2 m transversely along the length of the sidewalk. The joint is a saw cut or trowel cut about one quarter the depth of the slab that provides a weak plane in the slab where cracking can occur without marring the appearance of the sidewalk on the upper surface.

Changing the geometry of the slab is an easy and economical method for reducing sidewalk damage compared to remedies like adding reinforcing steel, which don't necessarily help. As most cracking occurs longitudinally along the centreline, providing a control joint along the centreline will provide a plane for controlled cracking to occur without marring the appearance of the surface.

Sample Sidewalk Condition Rating Form

Sidewalk Survey

City: _____

Date: _____

Area _____

Street / avenue _____

Other flag points _____

Street block length _____

Sidewalk width _____

Construction material for sidewalk _____

Type of sidewalk construction _____

Appearance of sidewalk construction _____

Soil type _____

Moisture content and index properties _____

Ground cover on either side of sidewalk _____

Principal failure mode _____

Comments _____

	1		2	Roll # / photo # _____
	3	Neighbourhood / community _____	NE / NW / SW / SE	
	4	Street _____	Avenue _____	
	5	1st house # _____	last house # _____	
	6	lateral stress _____	& _____	
	7	_____ m	8	% Damaged _____ %
	9	_____ m	10	Weakened plane joints spacing _____ m
	11	Concrete / asphalt	12	other _____
	13	Curb-gutter & sidewalk separate / monolithic / slab-on-grade	14	New / old / renewed (repaired) patches
	15	built (year) _____	16	built by _____
	17	Clay / silt / sand / other _____	18	Sample id _____
	19	Moisture content _____	20	LL & PL _____
	21	Moisture content _____	22	Colour _____
	23	Gutter & grass / grass & grass / grass and building / gutter & building	24	Gutter & grass / grass & grass / grass and building / gutter & building
	25	Buckling / blowup (B)	26	Popouts (P)
	27	Corner break (CB)	28	Scaling, crazing (C)
	29	Longitudinal cracking (L)	30	Faulting (F)
	31	Transversal cracking (T)	32	Joint spalling (JS)
	33	Shattering (S)	34	Shrinkage cracking (SH)
	35	"D" cracking (D)	36	Corner Spalling (CS)
	37	_____	38	_____
	39	_____	40	_____
	41	_____	42	_____

CW - crack
 FH - faulting
 WPJ - weakened
 NF - no faulting

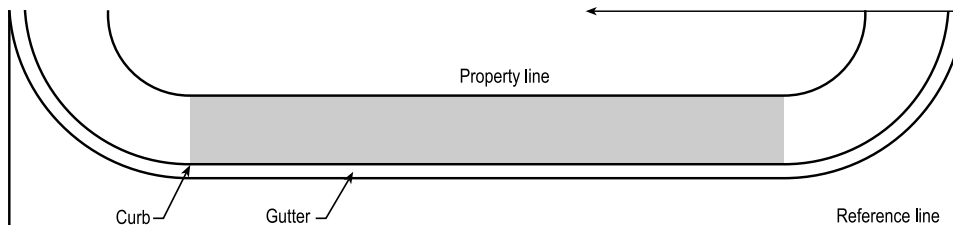


Figure 4. Sample sidewalk condition rating form.

In effect, a centreline control joint breaks the slab into smaller segments, allowing the concrete slab-on-grade sidewalk to function more like a paver stone sidewalk. There is some resistance to this recommendation because it alters the familiar appearance of the sidewalk. In areas where longitudinal cracking is not a concern, the centreline control joint could be omitted. However, where there is a strong likelihood of longitudinal cracking, the appearance of a centreline control joint is far more acceptable than the jagged appearance of cracks.

Landscaping

Trees can damage sidewalks by causing uplift. Generally, this damage occurs after many years when the tree and roots are large. Once the damage begins to occur, it is difficult to repair the sidewalk without removing the problem roots, action that could damage the health of the tree or make it less wind-firm.

For this reason, forethought is recommended at the planting stage. Trees should be selected that will tolerate the moisture, soil and air quality characteristics of the site. In general, trees should be kept back from the edge of sidewalks about two sidewalk widths. Where they are located closer to the sidewalk, shrubs or trees that are moderately sized upon maturity should be selected. Deep-root trees such as oaks and maples are preferable to shallow-rooted trees like spruces and poplars.

Condition Monitoring

The ability of a sidewalk to resist deformation is predetermined by the quality of the construction and preventative maintenance cannot alter this.

It is important for municipalities to protect the public by knowing the condition of sidewalks through regular inspections. It is recommended that inspection and



Figures 5a and 5b. Sidewalk before and after mud jacking repair of a fault.

condition ratings occur at an interval of four to five years. For sidewalks subject to high pedestrian traffic or a large number of senior citizens, inspection intervals of one to two years may be warranted. Condition rating recording will help ensure the best repair and replacement decisions are made. A sample sidewalk condition rating form is shown in Figure 4. Some Canadian municipalities employ field manuals⁴ to establish sidewalk condition.

Many municipalities are using geographical information systems (GIS) to catalogue infrastructure information. The inclusion of sidewalk inventory is recommended, and will be particularly useful when road and buried utility work near sidewalks is planned.

Repairs

As a crack widens or faulting (differential elevation across a crack) increases, a tripping hazard develops. A crack 10 to 12 mm will entrap stroller wheels, roller blades, pointed shoe heels, and walking canes. A fault height of 20 to 25 mm is a tripping hazard that can expose pedestrians to serious injury. Sidewalks with cracks and faults of this magnitude should be repaired as soon possible. The use of a regular condition reporting system will help schedule repairs before defects become a safety problem.

Sidewalks with crack widths exceeding 10 to 12 mm should be corrected by replacement or repair. Some crack-filling cement-based products are available but their long-term performance has not been proven. It is likely that the longevity of the repair will be related to how well the surfaces of the existing concrete are prepared.

A trip edge less than 20 mm high can be removed by grinding using the same specialized equipment used to refurbish existing sidewalk-street interfaces for wheelchair access.

Sidewalks that have undergone rigid body movement (tilt or uniform movement) can be re-levelled using mud jacking (Figures 5a and 5b) as long as the sidewalk is free of cracks and has no significant loss of slab thickness from spalling or crumbling of concrete.

A grout or slurry injected into holes (63 to 75 mm in diameter) cored in the concrete sidewalk first fills any voids beneath the slab and then the hydrostatic pressure forces the slab to rise. The core holes should be strategically placed and the slabs should be lifted in small increments to avoid damage to the slab and adjoining slabs. It may also be necessary to saw cut the sidewalks at cut joints to reduce the risk of lifting adjacent slabs.

Mud jacking is about 10 to 50% the cost of new construction and requires careful application. The cost of mud jacking can vary dramatically between jurisdictions depending on locally available expertise and equipment.

Summary

Sidewalks are important for the safe movement of pedestrians. The long-term performance of sidewalks is determined by the quality of the materials and construction methods. Regular condition inspection and rating at four- or five-year intervals will help protect the public and ensure the best decisions for repair or replacement are made.

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Dr. Balvant Rajani is a senior research officer in the Urban Infrastructure Rehabilitation Program of the National Research Council's Institute for Research in Construction.

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