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Builder Insight

Concrete Driveways

Homeowner Protection Office
Branch of BC Housing

Overview

Concrete driveways can be long lasting and durable provided proper design, materials and construction methods are followed. This bulletin describes common issues encountered with concrete driveways and provides information on how to select materials, build and maintain driveways.

Various factors can lead to surface imperfections and cracks in concrete driveways. For example, hot or cold weather conditions during concrete placement may lead to rapid surface drying or freezing which may result in imperfections. Other factors include: starting the finishing too early, over finishing or using improper finishing tools, using deicing salts, and inadequate use of control joints or subgrade preparation.

Typical concrete crack.

Concrete driveway cracks may be covered under certain circumstances by home warranty coverage. It is advisable to consult the HPO *Residential Construction Performance Guide* for more details.

As the Building Code has few requirements for driveways, extra care may be needed to differentiate Code requirements from better building practices.

Builder Insight is a series of bulletins designed to provide practical information on new technologies, research results, good building practices and emerging technical issues in residential construction to Licensed Residential Builders and others in the industry.

This bulletin is produced by the Homeowner Protection Office (HPO), a branch of BC Housing, and was prepared in collaboration with BC Ready-Mixed Concrete Association, Ontario Ready Mixed Concrete Association and other industry organizations and experts.

The following table presents typical deficiencies encountered with concrete driveways.

Deficiency	Definition
Plastic shrinkage cracks 	Plastic shrinkage cracks are caused by the rapid loss of water from the surface of the concrete before the concrete has had time to set. These cracks form after concrete placement and consolidation, while the concrete is still plastic. They are relatively shallow in depth and tend to form parallel to one another. The cracks are unappealing but rarely impact strength or durability due to their shallow depth.
Blistering 	Blistering is the irregular raising of a thin layer at the surface of concrete during or soon after finishing. Blisters form just under the surface of the concrete when either bleed water or entrapped air is prevented from escaping. They typically occur when the top surface of the concrete has been sealed prematurely during the finishing operations. It can also occur if the gradient in temperature or moisture between top and bottom is too large or if the outside temperature is too cold during installation.
Scaling 	Scaling is local flaking or peeling away of the near-surface portion of hardened concrete. Typically caused by freeze-thaw exposure, scaling begins as small localized patches that can expand and merge together to produce large scaled areas. Scaling can range from light scaling, where no coarse aggregate is exposed, to very severe scaling that involves loss of coarse aggregate particles generally to a depth of greater than 20 mm. Scaling can also be caused by improper material selection, finishing or curing, or if outside temperature is too cold during installation.
Crazing 	Crazing is the development of a network of fine random cracks extending below the surface of hardened concrete. It is caused by shrinkage of the drying surface layer. The cracks do not affect the structural integrity of the concrete, but are unsightly. Typically, crazing occurs at an early age and is apparent by the end of the first week after the concrete is placed. It can be caused by certain chemical admixtures, rapid surface drying and/or improper curing.
Pop-outs 	Pop-outs are fractures of the concrete surface caused by the expansion of water inside porous coarse aggregates located just below the concrete surface. If the local aggregate contains soft, porous particles (like chert) it can absorb significant quantities of moisture and fracture during freeze-thaw cycles. Pop-outs are distinguished from mortar flaking by the presence of fractured aggregate in the pop-out. Pop-outs can also occur due to improper curing or if outside temperature is too cold during installation.
Mortar flaking 	Mortar flaking is the drying of small sections of concrete mortar directly on top of the coarse aggregate particles. It typically occurs when the concrete is not cured properly during the first seven to 28 days. Mortar flaking is typically shallow in depth and consists of distinct loss of mortar (flakes) that occur directly on top of the coarse aggregate particles in the concrete.
Dry Shrinkage Cracks 	Uncontrolled dry shrinkage cracking of a structure can result from failure in tension, caused by external or internal restraints from reduced moisture content. Concrete both expands and contracts with changes in moisture and temperature, and deflects depending on the element size, reinforcing, loading force and support conditions. All these factors can lead to uncontrolled cracking if the proper design and joint details are not addressed prior to construction. Other factors can include inadequately prepared subgrade, adding too much water to the concrete mixture and improperly finishing or curing.

In addition to the surface deficiencies listed in the table, discolouration can also be an issue. Discolouration can take many forms including: colour changes over large areas of concrete, light patches of efflorescence, dark blemishes or a mottled surface appearance. Not all surface deficiencies are considered warrantable defects, refer to the HPO *Residential Construction Performance Guide* for more details.

Concrete Slab Design

A number of issues can arise without the proper design of the concrete slab thickness and control joints. This section provides a few design recommendations.

Generally, it is recommended that the subgrade material for concrete driveways is a granular "A" material to a minimum thickness of 100 mm on stable grade. Concrete thicknesses are normally recommended based on intended use:

Cars and pick-ups	100 mm
Light trucks	125 mm
Heavy truck usage	150 mm

Steel reinforcements can be added. These reinforcements will not prevent cracks, but will help hold them together if they occur. Reinforcements can be either wire mesh or steel rebar placed in a grid pattern centered within the concrete.

As concrete ages, initially it shrinks due to water evaporation and cooling of the concrete, which can cause cracking. Proper placement of control joints can help control the location and the extent of cracking.

Control joints should be:

- Placed with a maximum joint spacing not exceeding 24 to 36 times the thickness of the slab.
- Cut as soon as possible without pulling the aggregate out, usually within four to 12 hours after the concrete has been placed. Newer early entry (green cutting) concrete saws allow for earlier cutting.
- Cut to a minimum depth of one third the thickness of the slab to ensure that the concrete cracks at the saw-cut location.
- Placed such that the resulting panels created by control joints are approximately square since panels with an excessive length-to-width ratio (more than 1.5 to 1) are likely to crack at intermediate locations. Determination of the exact control joint layout is dependent on the exact geometry of concrete placement and should be performed by experienced concrete designers or contractors.

Adding a control joint to a freshly poured section of concrete.

Subgrade and Site Preparation

Properly preparing the subgrade and site for the concrete driveway is important to prevent a number of deficiencies. If the subgrade is not properly prepared and compacted, uncontrolled shrinkage cracks can occur.

To prepare the subgrade, topsoil needs to be excavated to the native soil before placing the granular material to a minimum 100 mm (4 in) thickness. The granular material needs to be compacted to achieve a uniform top surface.

There should be no frozen material in the natural soil and granulars. The grade must be a minimum of 2% sloped away from the building to allow for water drainage beneath the surface. Ensuring proper drainage of the aggregate base material is a critical component of the design.

After the subgrade is prepared, the following preparations are needed for concrete placement:

- Isolation joints need to be installed against any existing concrete surfaces (house walls, garage floors, etc.)using asphalt-impregnated boards.
- Driveway should be shaped using stiff wood forms kept in position with stakes spaced not more than 1 m (3 ft) apart. The top of the stakes should be flush with, or slightly below the top of the form at finished grade.
- The exact location of control joints need to be planned before starting the project and their locations marked on the formwork prior to concrete placement.

Foundation of a driveway before pouring the concrete.

Materials and Specifications

Use of improper materials may cause numerous deficiencies, from scaling due to improper concrete selection to uncontrolled shrinkage cracks if too much water is added to the mix at the site. Chemical admixtures such as calcium chloride added to the concrete can cause discolouration and crazing. Pop-outs can occur if the aggregate contains soft porous materials.

Concrete selection should follow guidelines outlined in CAN/CSA A23.1 "Concrete Materials and Methods of Concrete Construction/ Methods of Test for Concrete." The concrete supplied should be a Class C-2, 32 MPa, 0.45 water/cement ratio, with 5-8% air entrainment (assuming 20 mm coarse aggregate is used in the concrete mix design).

For coloured concrete, it is recommended that the colour be integrally mixed at the time of batching. Air entrainment should be measured after the colour has been mixed in. It is recommended that the contractor prepare a sample colour batch to ensure the customer's expectations for colour are met.

Concrete driveway.

Concrete as a material can be produced using by-products of other industries, such as fly ash and slag (referred to as supplemental cementing materials or SCMs), to provide a more sustainable approach to building construction. These materials, when used in the appropriate proportions, can increase both the strength and durability of the concrete. SCM options can be discussed with the concrete supplier.

Concrete Placement and Finishing

Proper concrete placement and finishing are important in preventing deficiencies. These can include:

- Discolouration if the flatwork finisher improperly estimates the timing of the finishing operations, resulting in a hard-troweled surface.
- Scaling when finishing operations are completed while the bleed water is still on the concrete surface.
- Blisters if the concrete surface is prematurely sealed due to improper finishing procedures or tools, a dry shake is prematurely applied to the concrete surface, or insufficient or excessive vibrations are used during concrete placement.

Concrete coming out of the chute onto graded gravel.

- Uncontrolled dry shrinkage cracks when improper finishing procedures are implemented or the installation of contraction joints is not completed in a timely fashion.

One of the critical elements in proper placement and finishing is to ensure there is sufficient labour on site when the concrete is delivered. Three or more people are generally required, depending on the size of the driveway, the weather, particular design aspects, etc.

In addition, a number of steps should be followed during placement and finishing:

- The subgrade should be dampened without leaving free-standing water so the water is not drawn prematurely from the concrete.
- The proper amount of form release should be applied to the forms before placing concrete.
- A maximum 100 mm slump is usually adequate for placement. Adding water to increase the slump or workability has a very detrimental effect on both the strength and durability of the concrete. Admixtures are available from the concrete producer to provide additional workability and slump without affecting the concrete, should a higher slump be desired.
- The concrete should be placed using wheelbarrows (or directly from concrete mixer if possible) and moved with shovels to rough grade, avoiding segregation.
- The concrete can be placed to finish grade using a straight board on edge between forms in a "sawing motion." The edges of the forms should be tapped with a hammer to consolidate the concrete along the edges.
- The surface should be smoothed using a long-handled bullfloat (use an edging tool to finish edges). Steel or fresno trowels should not be used at any time, as they work the air out of the concrete surface, leaving a weakened surface. Air entrained concrete should never be power troweled.
- The final non-slip finish can be applied using a concrete broom, burlap drag, magnesium float or impressed mat finish.
- Overworking the fresh concrete causes scaling. This extra finishing is not required and will reduce the durability of the slab.

Weather Considerations

Rapid concrete surface drying can occur if there is low outdoor relative humidity or if it's very sunny, windy and/or hot outside. Without proper protection, this can cause deficiencies including: crazing, plastic shrinkage cracks and flaking. Placing the concrete in cold conditions can also lead to pop-outs, scaling, blistering and weakened concrete strength.

If placing concrete during a hot, dry or windy day, the following special precautions should be taken:

- Protect fresh concrete from rapid moisture loss by covering it with plastic sheets after screeding, or use wind screens, fog nozzles, vapour retardants, chemical curing compounds etc.
- Be prepared for faster setting times during warm weather.
- Protect hardening concrete by curing the concrete immediately after final finish.

Exterior concrete should not be placed when the air temperature is less than or equal to 5°C unless extra precautions are taken. If concrete freezes, then the durability and strength can be reduced by up to 50%.

If placing concrete in cold weather:

- Allow a longer time before final finishing.
- Do not perform final finishing before concrete stops bleeding.
- Insulating concrete blankets may be necessary to prevent the concrete from freezing in its plastic state.
- Ensure that plastic sheeting used for curing purposes does not come in direct contact with the concrete. Plastic sheeting tends to leave colour streaks on the concrete surface where it is in direct contact with the concrete.
- Never place concrete on frozen ground.

Curing and Sealing

Deficiencies often occur when concrete is insufficiently cured, when curing is started too late or early, or when concrete is improperly cured. These deficiencies may include discolouration, crazing, scaling, pop-outs, uncontrolled dry shrinkage cracking, and mortar flaking. For proper curing to occur, it is essential to maintain the required moisture condition and concrete temperature.

Curing must start immediately after the final finish and can be accomplished by the following methods:

- Roll or spray on curing membranes/compounds applied as soon as the finishing operations are complete following manufacturer's application instructions, or
- Wet burlap, soaking hoses, waterproof paper, or polyethylene can be used to keep the surface constantly wet for seven days. Hoses should not be placed in direct contact with the surface until the concrete has obtained sufficient strength to prevent surface damage.

Masonry construction workers smooth freshly poured concrete using bullfloat tool.

Worker using concrete trowel to smooth driveway.

If concrete is placed when temperatures can fall below 5°C, polyethylene sheets, insulated blankets or other cold weather curing methods should be used.

Under normal conditions, the concrete may be sealed with a penetrating sealer according to the recommendations of the manufacturer:

- After 30 days if a curing membrane is used, or
- After a period of air drying if water has cured.

Long-term Maintenance

Deicers (e.g. salt) of any kind should not be applied until the concrete has gone through its first winter. If surface finishing and curing are done properly, the slab's resistance to deicers will be improved over the long term. Ammonium-based deicers or products that contain nitrates or magnesium chlorides should not be used at any time. Damage from salts, deicers, including melt-off slush from vehicles is typically not covered under warranty. So it may be best to simply avoid the use of deicers. Sand, kitty litter or other environmentally friendly granular products that do not include nitrates or chlorides can be used instead of deicers for anti-slip/traction purposes.

Snow and deicing salts should be removed from the concrete driveway so that they do not sit on the slab for an extended period of time. The driveway should be power washed or hosed down in spring to rinse off winter residues (salt and debris).

Concrete sealers should be applied to prevent the ingress of chlorides from roads and sidewalks. Sealers should be reapplied as required (generally every two years for acrylic sealers and every five years for penetrating sealers). Ensure the use of compatible sealers over time: the use of an acrylic sealer initially is not compatible with future use of a penetrating sealer.

Tools Required

- Large roll of plastic for rain protection
- Wheelbarrows and shovels (Note: If using a rake, use a concrete rake, otherwise separation of the aggregate will occur)
- Water supply for curing and wetting subgrade
- Long-handled (wood or magnesium for air entrained concrete) bullfloat about 120 mm wide minimum
- Edging tool
- Straight rigid board for screeding
- Vapour retardant compound (which can be applied to the surface between finishing operations following manufacturer's recommended use)
- Concrete broom for texturing
- Curing materials (burlap, water, chemical curing compound, insulated blankets)

Repairs and Resurfacing

If concrete is properly placed, concrete driveways should require minimal repairs. If only the surface has failed, the underlying concrete will typically be acceptable for long-term performance. In this case, the top can be reground and a top layer of concrete can be bonded to the older layer. Most admixture suppliers carry products for the top repair of driveways. Care must be taken to prepare the surface and remove any loose concrete. In some cases, a sealer may need to be applied prior to the repair mortar being applied.

Sometimes, major cracks can occur due to a subgrade movement and subsequent failure of the slab. Depending on the severity of the problem, crack sealers are available which may diminish the aesthetic value of the driveway but will allow continued performance. Should a major failure occur, then the section will have to be removed and the subgrade restabilized prior to placing the replacement piece. This section should be doweled into the existing slab to minimize any movement between sections.

Crack filled with crack sealer

Key Points to consider

- ❑ Subgrade must be uniform and compact.
- ❑ Proper drainage needs to be maintained to prevent frost heaving.
- ❑ Proper concrete selection is important – Class C-2, 32 MPa, 0.45 water/cement ratio, 5-8% air entrainment.
- ❑ Water should not be added in the finishing process for "wetter" feeling. If desired, a superplasticizer can be added that will maintain good water-to-cement ratio.
- ❑ Ensure that enough experienced crew members are on hand to handle the volume of concrete ordered for a quick installation.
- ❑ Do not overwork the surface of concrete in the finishing process.
- ❑ Cure and protect concrete once it has been placed and finished.
- ❑ Take precautions if the weather is too hot or too cold for proper curing.

For More Information

- ❑ CAN/CSA A23.1 *Concrete Materials and Methods of Concrete Construction/Methods of Test for Concrete.* Available at www.csa-international.org.
- ❑ *Design and Control of Concrete Mixes,* Cement Association of Canada. Available at www.cement.ca.
- ❑ *British Columbia Ready-Mixed Concrete Association Technical Resources.* Available at www.bcrmca.ca.
- ❑ *Ready Mixed Concrete Association of Ontario Technical Bulletins.* Available at www.rmcao.org.
- ❑ *Residential Construction Performance Guide,* Homeowner Protection Office, 2011. Available at www.hpo.bc.ca.

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