EASTERN INTERLAKE PLANNING DISTRICT

Serving the RM of Gimli, Municipality of Bifrost-Riverton, Town of Arborg and the Town of Winnipeg Beach

Building Code Summary

Summary of the Manitoba Building Code and Good Construction Practices for Residential Dwellings and Small Buildings: Foundations, Floor Slabs and Crawl Spaces

March 2024

CONTENTS

NOTE: This booklet is a simplified reference to the Manitoba Building Code (MBC) requirements for Part 9, as applied to housing and small buildings. This booklet can provide the builder or general contractor a guide as to what the Eastern Interlake Planning District (EIPD) monitors for compliance with the MBC. This booklet is not a replacement for the MBC.

The following documents were referenced for this booklet:

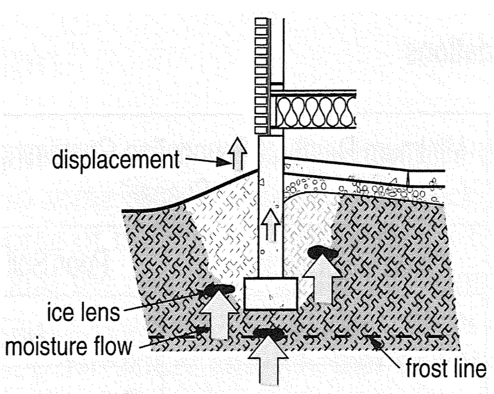
- The National Building Code of Canada
- The Manitoba Amendments to the National Building Code of Canada
- National Housing Code of Canada 1998 and Illustrated Guide
- CAN/CSA - A23.1-09 Concrete Materials and Methods of Concrete Construction
- CAN/CSA Standard A23.3 Code for the Design of Concrete Structures for Buildings
- Placing Reinforcing Bars CRCI-WCRSI Recommended Practices

Frost Heaving and Adfreezing

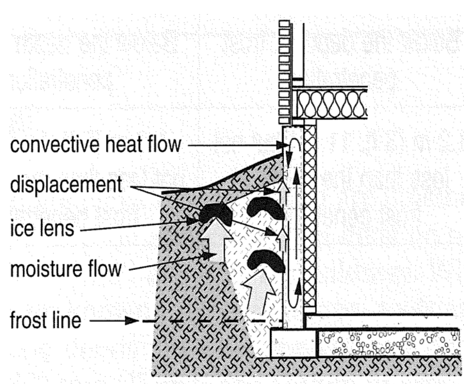
Frost heaving of building footings and foundations can create major problems. Frost heaving can occur when moisture in the soil below the footings freezes and expands. Frost heaving will not occur if there is no moisture in the soil, or if frost is prevented from reaching the footing by providing sufficient footing depth or by providing heat to the footings.

Locating footings below the level of frost penetration is one of the most common methods of preventing frost damage. The required depth of footings is usually based on local knowledge of frost penetrations. Frost penetration will increase with lower air temperatures and decreased snow coverage. The depth of frost penetration can be reduced locally through the placement of insulation above and around the exterior of the footings. The amount of insulation required to protect footings must be designed according to Part 4 of the MBC and be approved by the Engineer involved.

Adfreezing is more likely to occur in heavy soils that are more difficult to drain. When heat from the building is restricted from reaching the outside of the foundation wall, the soil adjacent to the foundation wall can freeze to it. This can result in lifting (frost jacking) or cracking of the foundation wall. Friction piles of insufficient diameter or depth can be also be subject to Adfreezing and frost jacking. Adfreezing can be eliminated by ensuring that water in the soil does not come into contact with the wall, or by placing a slip plane (polyethylene) between unheated foundation walls and the soil.



Frost Heaving of Foundation



Adfreezing and Frost Jacking

FOUNDATIONS AND FLOOR SLABS

1. 9.12.1. Excavation: The topsoil and vegetable matter in all excavated area under a building shall be removed and the bottom of every excavation shall be free from all organic material. Excavations shall be kept free of standing water and the bottom of the excavation shall be kept free from freezing throughout the entire construction period.
2. 9.12.2. Depth: Excavations for foundations shall extend to undisturbed soil or rock. Footings shall rest on undisturbed soil or rock or compacted granular fill. The depth and size of cast in place footings and foundations shall be designed and sealed by a structural Engineer.
3. In addition to the minimum reinforcement specified by the Engineer, there shall be not less than two 15 mm bars or equivalent around all window or door openings and such bars shall extend at least 24 inches beyond the corner of the openings.
4. Foundations of Wood Frame Construction are permitted to be used if they conform to CAN/CSA-S406 and are certified by an engineer.
5. Insulated concrete form (ICF) foundations that do not meet the minimum requirements of Figures 9.15.4.5. (A), (B), and (C) are to be certified by an engineer.
6. Footings that do not meet the depth requirements of Figures 9.15.4.5.A., 9.15.4.5.B., 9.15.4.5.C. are to be certified by an engineer.
7. 9.15.3.4.3) Where a foundation rests on gravel, sand or silt in which the water table is less than the width of the footings below the bearing surface, the footing is not to be less than twice the width normally required.

Table 9.15.4.5.-A
Vertical Reinforcement for 150 mm Flat Insulating Concrete Form Foundation Walls
Forming Part of Sentence 9.15.4.5.(2)

Max. Height of Finished Ground Above Finished *Basement* Floor, m	Minimum Vertical Reinforcement		
	Maximum Unsupported *Basement* Wall Height		
	2.44 m	2.75 m	3.0 m
1.35	10M at 400 mm o.c.	10M at 400 mm o.c.	10M at 400 mm o.c.
1.6	10M at 400 mm o.c.	10M at 380 mm o.c.	10M at 380 mm o.c.
2	10M at 380 mm o.c.	10M at 380 mm o.c.	10M at 380 mm o.c.
2.2	10M at 250 mm o.c.	10M at 250 mm o.c.	10M at 250 mm o.c.
2.35	n/a	10M at 250 mm o.c.	10M at 250 mm o.c.
2.6	n/a	10M at 250 mm o.c.	10M at 250 mm o.c.
3	n/a	n/a	15M at 250 mm o.c.

Table 9.15.4.5.-B
Vertical Reinforcement for 190 mm Flat Insulating Concrete Form Foundation Walls
Forming Part of Sentence 9.15.4.5.(2)

Max. Height of Finished Ground Above Finished *Basement* Floor, m	Minimum Vertical Reinforcement		
	Maximum Unsupported *Basement* Wall Height		
	2.44 m	2.75 m	3.0 m
2.2	None required	10M at 400 mm o.c.	10M at 400 mm o.c.
2.35	n/a	10M at 300 mm o.c.	10M at 300 mm o.c.
2.6	n/a	10M at 300 mm o.c.	15M at 400 mm o.c.
3.0	n/a	n/a	15M at 400 mm o.c.

Table 9.15.4.5.-C
Vertical Reinforcement for 240 mm Flat Insulating Concrete Form Foundation Walls
Forming Part of Sentence 9.15.4.5.(2)

Max. Height of Finished Ground Above Finished *Basement* Floor, m	Minimum Vertical Reinforcement		
	Maximum Unsupported *Basement* Wall Height		
	2.44 m	2.75 m	3.0 m
2.2	None required	None required	None required
2.6	n/a	15M at 400 mm o.c.	15M at 400 mm o.c.
3.0	n/a	n/a	15M at 400 mm o.c.

9. In areas which soil movement caused by changes in soil moisture content is known to occur to the extent that it may cause significant damage to a building, measures are to be taken to minimize this effect.

10. 9.15.3.5.1)A - The strip footing sizes for exterior walls shown in Table 9.15.3.4. shall be increased by 65 mm for each storey of masonry veneer over wood frame construction supported by the foundation wall.

11. 9.15.3.5.1)B - The strip footing sizes for exterior walls shown in Table 9.15.3.4. shall be increased by 130 mm for each story of masonry construction supported by the foundation wall.

12. 9.15.3.6(1) - The minimum strip footing sizes for interior walls shown in table 9.15.3.4. shall be increased by 100 mm for each story of masonry construction supported by the footing.

13. 9.15.3.7.(1) - The footing area for column spacing other than shown in Table 9.15.3.4. shall be adjusted in proportion to the distance between the columns.

14. 9.15.4.6. - Exterior foundation walls shall extend at least 150 mm (6 in.) above the finished grade.

15. 9.13.2.3 5). - Foundation walls below ground are to be dampproofed with a material conforming to 9.13.2.2. Holes and recesses resulting from the removal of form ties are to be sealed with mortar or dampproofing material prior to damp proofing.

16. 9.14.3.3. - The bottom of every exterior foundation wall shall be drained by installing 100 mm (4 in.) drain tile or perforated drain pipe, laid with perforations down, on undisturbed or well compacted soil. The top and sides of the pipe to be covered with not less than 150 mm (6 in.) of crushed stone or other coarse granular material containing not more than 10 % of material that will pass through a No. 4 sieve. Drainage connections to the inside of the building every 15 m (49 ft.) or part thereof to be made by placing non perforated pipe through the footing in one continuous length with a slope of 1 in 50 to the sump. Where gravity drainage is not practical, a covered sump with an automatic pump will discharge the water. A granular drainage layer as per 9.14.4. may also be used.

Table 9.15.3.4.
Minimum Footing Sizes
Forming Part of Sentence 9.15.3.4.(1)

No. of Floors Supported	Minimum Width of Strip Footings, mm		Minimum Footing Area for Columns Spaced 3m o.c.,[1] m^2
	Supporting Exterior Walls	Supporting Interior Walls	
1	250[2]	200[3]	0.4
2	350[2]	350[3]	0.75
3	450[2]	500[3]	1.0

Notes to Table 9.15.3.4.:
[1] See Sentence 9.15.3.7.(1).
[2] See Sentence 9.15.3.5.(1).
[3] See Sentence 9.15.3.6.(1).

Table 9.15.4.2.A.
Thickness of Solid Crecrete and Unreinforced Concrete Block Foundation Walls Forming Part of Sentence 9.15.4.2.

Type of Foundation Wall	Minimum Wall Thickness mm	Maximum Height of Finished Ground Above Basement Floor or Crawl space Ground Cover, m			
		Height of Foundation Wall Laterally Unsupported at the Top [1] [2]	Height of Foundation Wall Laterally Supported at the Top [1] [2]		
		≤ 3.0 m	≤ 2.5 m	> 2.5 m and ≤ 2.75 m	> 2.75 m and ≤ 3.0 m
Solid Concrete, 15 MPa Minimum Strength	150 200 250 300	0.8 1.2 1.4 1.5	1.5 2.15 2.3 2.3	1.5 2.15 2.6 2.6	1.4 2.1 2.5 2.85
Solid Concrete, 20 MPa Minimum Strength	150 200 250 300	0.8 1.2 1.4 1.5	1.8 2.3 2.3 2.3	1.6 2.3 2.6 2.6	1.6 2.2 2.85 2.85
Unreinforced Concrete Block	140 190 240 290	0.6 0.9 1.2 1.4	0.8 1.2 1.8 2.2	- [3] [3] -	- [3] [3] -

Notes to Table 9.15.4.2.A.:
[1] See Article 9.15.4.3.
[2] See Article 9.15.4.6.
[3] See Table 9.15.4.2.B.

9.15.4.2. LATERAL SUPPORT

1. For the purpose of article 9.15.4.3., foundation walls shall be considered laterally supported at the top is such walls support solid masonry superstructure or if the floor joists are embedded in the top of the foundation walls.
2. Foundation walls shall also be considered supported at the top if the floor system is anchored to the top of the foundation walls with anchor bolts, in which case the joists may run either parallel or perpendicular to the foundation wall.

3. When a foundation wall contains an opening more than 1.2m (4 ft.) long or contains openings in more than 25% of its length, that portion of the wall beneath such opening shall be considered laterally unsupported, unless the wall around the opening is reinforced to withstand the earth pressure.
4. When the length of solid wall between windows is less than the average length of the windows, the combined length of such windows shall be considered as a single opening for the purpose of sentence 3.

CONCRETE NOTES

1. Concrete is to be designed, mixed, placed, cured and tested in accordance with CAN/CSA-A23.1-09 Concrete Materials & Methods of Concrete Construction.
2. Sulfate resisting cement is to be used for concrete in contact with sulfate soil deleterious to normal cement.
3. The compressive strength of unreinforced concrete after 28 days shall be not less than:
   a) 15 MPA for walls, columns, fireplace and chimneys, footings, foundation walls, grade beams and piers;
   b) 20 MPA for floors other than those in garages and carports; and
   c) 32 MPA for garage and carport floors, and the exterior steps.
4. Concrete used for garage and carport floors and exterior steps shall have air entrainment of 5 to 8%.
5. When the air temperature is below 5C (41F), concrete is to be kept at a temperature of not less than 10C (50F) or more than 25C (77F) while being mixed and placed, and maintained at a temperature of not less than 10C (50F) for 72 hours after placing. No frozen material or ice is to be used in the mix.

6. Aggregates for concrete are to consist of gravel or sand and crushed rock that is clean and free of injurious amounts of organic and other deleterious material. Aggregate size shall not exceed 1/5 the distance between the sides of vertical forms, or 1/3 the thickness of flatwork.
7. Water for concrete is to be clean and free of injurious amounts of oil, organic matter, sediment or any other deleterious material.

FORMWORK

1. Formwork and falsework is to be constructed and braced so that leakage of cement paste is minimized and visible bulging during concrete placement does not occur and the finished concrete will conform to the shape, dimensions, and tolerances shown on the drawings.

2. The following tolerances are permissible if not specified on drawings:
   a) Plumbness of columns and walls shall be within 1:400 but not more than 40mm for total height.
   b) The variation from a straight line in the plan view not to exceed values in Table 15.
   c) The variation from level or specific grade for walls and flatwork, suspended floors shall be within 1:400 and not to exceed 40mm for total length.
   d) The variation in wall thickness should not exceed ± 8mm for walls.3m and less in thickness, ± 12 mm for walls .3m to 1m and ± 20 mm for 1m and up.

3. 9.23.8.1. Beam pockets: beams shall have even and level bearing of not less than 89mm (3 1/2") length of bearing at end supports. Beam size and support length may require larger bearing support.

4. Formwork should be constructed to take additional loads from construction practices (eg. pumping concrete, wheeling concrete in buggies on walkways, or by internal vibration).

5. Slabs on ground shall not bear directly on wall or column footings, but shall be isolated from these supports by bond breaking material. (This allows for slight movement of the concrete flatwork due to the shrinkage of the slab).

TABLE 15: General Dimensional Tolerances
Clauses 6.4.6.1, 6.4.6.3, and Figure 1

For dimensions equal to or above, m	But below, m	Allowable variation, mm
0	2.4	±5
2.4	4.8	±8
4.8	9.6	±12
9.6	14.4	±20
14.4	19.2	±30
19.2	57.6	±50
57.6	As specified by the designer	

DEPOSITING, FINISHING AND CURING CONCRETE

1. The time between the start of mixing and the complete discharge of the concrete from the mixer shall not exceed 120 minutes, unless the concrete has been modified by the supplier to suit the application.
2. Concrete shall be deposited as close as possible to its final location in such a way as to avoid cold joints. Handling or moving concrete in forms by the use of vibrators or the addition of water at the job site to facilitate placement shall not be permitted.
3. Concrete shall not be deposited into mud, standing water or snow.
4. Concrete shall not be placed on, against, or above any frozen material.
5. Each lift of concrete shall be consolidated by the use of a mechanical vibrator or a hand held puddling stick inserted at intervals of not more than 300mm using an up and down motion. The complete lift shall be consolidated before the next lift is deposited. When consolidating subsequent lifts, the vibrator or puddling stick shall completely penetrate the lift and extend into the upper portion of the previous lift, to ensure mixing of the concrete at the interface between lifts. *(Mechanical vibrators should penetrate the concrete in a vertical direction under their own weight without being forced into the concrete. The time for insertion should be from 5 to 10 seconds until a smooth mortar surface appears around the vibrator head or cable).*
6. Concrete for walls shall be deposited continuously in approximately equal horizontal lifts not exceeding 1.2m high.
7. When depositing concrete on a sloped surface, begin at the base of the slope to minimize segregation and plastic cracking caused by gravity flow of the concrete before initial set occurs

FINISHING

1. Immediately after depositing and consolidation, the concrete shall be struck off to finished elevation using a straight edge or other suitable means. Initial finishing can be accomplished by floating with a darby, bullfloat, or other hand tool, except a steel trowel, before any bleed water appears on the surface. Any minor imperfections on the surface, such as high or low spots, can be corrected during the floating operation. *(Any floating operation performed while bleed water is present may cause dusting or scaling off the concrete surface. Excessive bleed water on the surface may be removed by the careful use of burlap or a squeegee or by carefully dragging a garden hose over the surface).*
2. Final finishing and trowelling shall commence only after the water sheen has disappeared and the concrete has stiffened to the point that a footprint will penetrate only about 5mm into the concrete. *(The use of polyethylene below floor slabs will increase the drying period of concrete especially at temperatures below 5 C).*
3. The finished surface of concrete floor slabs shall be trowelled smooth and even. Dry cement shall not be added to the floor surface to absorb excess bleed water.
4. The edges and joints of sidewalks, driveways, and patios should be finished with hand tools right after floating. The finished surface of sidewalks, driveways, patios and parking areas shall be textured to create a non-slip surface with a wood or magnesium float, a wet burlap drag, or a light broom. *(For large areas, it is recommended that control joints be sawed or formed using appropriate forming inserts).*
5. For flatwork exposed to freeze-thaw cycles or deicing chemicals, power floats or steel trowels shall not be used. *(Excessive finishing can destroy the integrity and durability of the concrete. Garage floor areas exposed to freeze-thaw cycles should not be finished using power floats or steel trowels).*

CURING AND PROTECTION

1. Curing of concrete shall begin as soon as the finished concrete surface will allow the process to be carried out without damage. Concrete shall be cured for 3 days (72 hr.) at a minimum temperature of 10 C, or for the time necessary to attain 40% of the specified 28 day compressive strength of the concrete.
2. When the air temperature is below 5 C the concrete can be protected from rapid temperature change and cured by covering all surfaces, including formwork left in place, with insulation blankets, straw and polyethylene or tarpaulin, or other satisfactory means to keep the concrete at 10 C for the indicated period of time.
3. The required curing for garage floors and all concrete flatwork exposed to freeze-thaw cycles and deicing salts shall be an additional 4 days at a minimum temperature of 10 C or the time necessary to attain 70% of the specified 28 day compressive strength. *(At the end of the additional curing time a period of at least one month of air drying time should elapse before the application of deicing chemicals).*
4. When the air temperature is above 27 C at the time of placing, measures shall be taken to prevent the evaporation of moisture from the concrete. Forms shall be kept in place for 3 days (72 hr.) and the unformed surfaces of the concrete can be protected by shading the exposed surfaces from the sun and sheltering it from the wind. Flatwork can be protected from the heat by covering with polyethylene sheeting between the finishing operations. *(In periods of extremely hot weather, it is suggested that concrete be place at night or early in the morning to minimize problems associated with concrete work in hot weather)*.
5. Curing of the concrete can be provided by one or a combination of the following methods:
    a) forms in contact with the concrete kept in place
    b) ponding or continuous sprinkling
    c) absorptive mat or fabric continually kept wet
    d) damp sand, earth, or similar moist material
    e) curing compounds
    f) waterproof paper or plastic film
    g) vapour mist bath

PLAIN AND REINFORCED CONCRETE

9.3.1.9 Reinforced concrete shall be designed to conform to the requirements of Part 4. Part 4: 4.3.3.1.(1) states that buildings and their structural members made of plain, reinforced or pre-stressed concrete shall conform to CSA A23.3, "Design of Concrete Structures".

1. When working with certified drawings (drawings that bear an architect's or engineers stamp) the installation of reinforcing steel shall be carried out as per drawings. Any changes to the size or quantity of reinforcing steel will require a change order from the architect or engineer prior to installation of the reinforcing steel.
2. If the drawings are not required to be certified, the reinforcing steel shall meet the minimum requirements of Figures 9.15.2.5. A, B, C, D, E and F.

REINFORCING BARS: SIZE, CROSS-SECTION AREA AND GRADE

10 mm	#3	3/8 in	78.5 mm sq	grade min 300	min bend dia. 60 mm
15 mm	#5	5/8 in	176 mm sq	grade min 400	min bend dia. 100 mm
20 mm	#6	¾ in	314 mm sq	grade min 400	min bend dia. 120 mm
25 mm	#8	1 in	490 mm sq	grade min 400	min bend dia. 150 mm

HOOKS AND BENDS

The inside diameter of 90^{o} bends for stirrups and ties shall be not less than 4 bar diameter, and for 135^{o} bends the greater of 20mm, 4 bar diameter or the diameter of enclosed bar.

CSA A23.3 "Design of Concrete Structures". Construction drawings for reinforced concrete shall clearly indicate:

a) Type size and position of all steel reinforcement;
b) Strength and kind (type or aggregate) of concrete at a specified age for which the various parts of the structure were designed; and
c) Locations and details of expansion or contraction joints and the permissible locations and details for construction joints.

SURFACE CONDITIONS OF REINFORCEMENT

1. Reinforcement bars at the time concrete is placed shall be free from mud, oil and other non-metallic coatings that adversely affect bonding.
2. Reinforcing bars with rust, mill scale, or a combination of both shall be considered as satisfactory providing the height of deformations and the weight of a cleaned sample is not less than specifications require.

PLACING REINFORCEMENT

Reinforcement shall be accurately placed and adequately supported with proper accessories before concrete is placed, and shall be secured against displacement within permitted tolerances.

1. When tolerances are not specified, the minimum clear cover for reinforcing bars in cast in place concrete shall be:
   a) 3 inches bottom of footings
   b) 1½ inches pile caps
   c) 3 inches exterior faces of walls exposed to earth or weather
   d) 1½ inches bottom of grade beams and columns
   e) 1½ inches grade beams and columns
   f) 1 inch interior face of walls
   g) 2 x bar diameter in structural slabs or slabs not exposed to weather or in contact with the ground.
   h) When the length of lap splice is not specified on a drawing, the length of the lap splice will be 450 mm for 10mm bar, 650mm for 15 mm bar, 900mm for 20mm bar.
2. In concrete grade beams, the top reinforcement bars shall be lapped between the supports and the bottom reinforcement bars shall be lapped at the supports.
3. In concrete grade beams, bend the horizontal reinforcing a minimum of 24 inches around corners or use extra corner bars.
4. The clear distance between parallel bars shall be not less than the nominal diameter of the bars, 1 1/3 times the maximum size of course aggregate, but not less than 1 inch.
5. In grade beams all compression reinforcement shall be enclosed by ties or closed stirrups completely around all longitudinal bars ands such stirrups or ties shall be used throughout the distance where the compression reinforcement is required.

DEFINITION OF REINFORCED CONCRETE

Concrete is a mixture of one part of cement, of about 1 ¾ to 2 parts of a fine aggregate (usually sand) and of about 2 to 3 ½ parts of a coarse aggregate (such as gravel, crushed stone or blast-furnace slag) and clean water. By varying the proportions of the mixture, concrete with different crushing strengths may be obtained. These strengths can be varied from about 2,000 to 6,000 lbs. per square inch. The mixture is plastic, and in normal temperature will set up firm in hours (known as an initial set), will be self-supporting in a few days, and will attain full rated strength in 28 days. Concrete is strong in compression and shear but weak in tension.

High early strength cement is sometimes used in concrete where a faster rate of hardening is required. It will cause the concrete to attain about the same strengths in about one-half or one-third of the time required with ordinary cements.

Air-entraining cement creates tiny air bubbles in the concrete, resulting in a more plastic mixture which is easier to place, and more resistant to freezing and thawing.

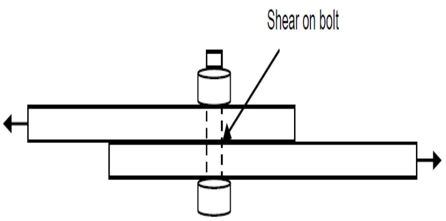
Steel for reinforced concrete is usually deformed bars, varying from 3/8 inch (10mm) to 2 ¼ inches (57 mm) in diameter. Welded wire fabric is also used, either in place of or in combination with bars. Steel is strong in tension.

Reinforced concrete is a combination of both steel and concrete using the best properties of each, namely the crush resistant strength of concrete and the tension, or pull resistance, of steel. The adhesion of the concrete to the surface of the bars, plus the resistance provided by the bar deformations or lugs, keeps the bars from slipping through the concrete and so makes the two materials act as one. This gripping of the bars by concrete is known as bond.

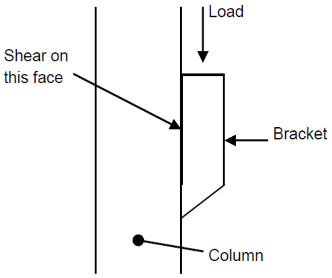
REINFORCING STEEL: PURPOSE AND LOCATION IN CONCRETE

As previously explained, concrete is strong in compression and shear, but weak in tension. Wherever tension is present, the concrete is reinforced with steel.

Shear is more complex force than simple tension or compression. A common example of almost pure shear is illustrated by a bolted lap joint in steel plates, producing what is called **single shear**. In concrete, this is best illustrated by a loaded column bracket.

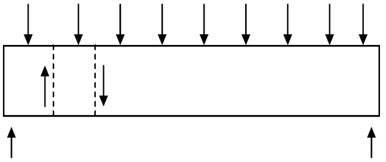


Bolted Joint-Single Shear

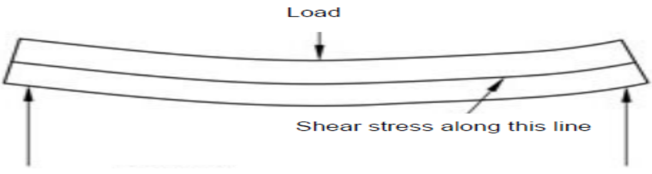


Column Bracket

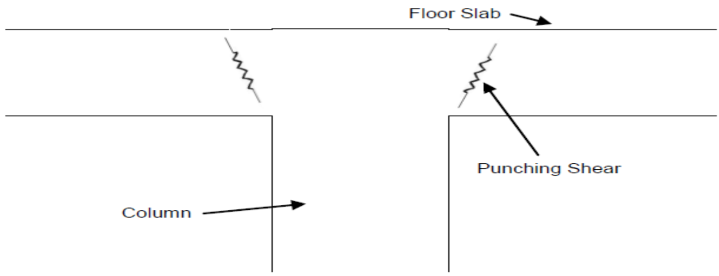
If a set of books were carried horizontally as shown, they would have to be squeezed tightly together or they would slip and fall. In a beam, each imaginary vertical slice (as the case of a single book) with a load on top tends to slip down due to what is called **vertical shear**.

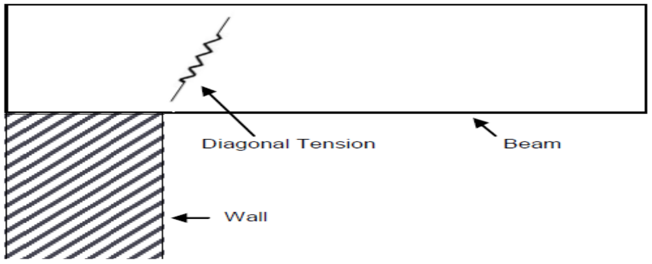


If several boards are laid flat across two supports and loaded, they will bend downward but will also slip along each other horizontally. The horizontal slippage is caused by a force known as **horizontal shear**.

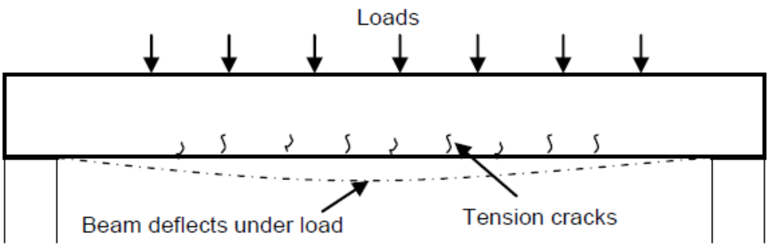


In a loaded beam or slab both vertical and horizontal shear are present and the net result of the two forces is called **diagonal tension**. A crack resulting from these forces always occurs near the support and extends upward and outward at an angle of approximately 45 degrees to the top. These forces also are present in a slab floor around supporting columns and the result is called punching shear.





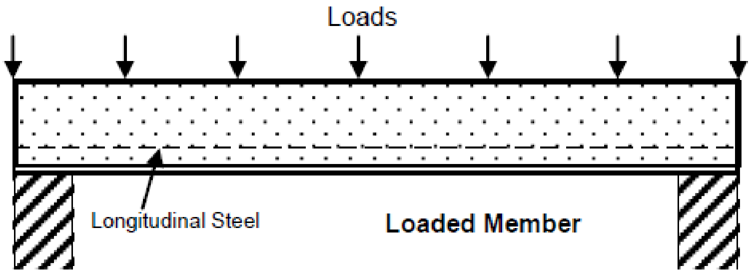
Tension in concrete can be caused by bending or shear as in beams, by drying shrinkage after concrete hardens and by temperature changes. An example of bending tension is shown below. As a beam is loaded, tension cracks will appear at the bottom of the beam and would develop rapidly in an unreinforced concrete beam with the cracks developing near mid-span. Plain concrete would be weak and brittle and would fail suddenly without warning shortly after the first crack appeared.

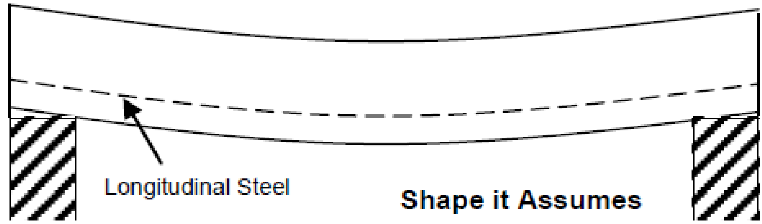


Steel provides reinforcement to the concrete where forces exist that the concrete cannot take and from this comes the term reinforcing steel, which is usually a deformed steel bar. The following paragraphs will illustrate in a general way the location in concrete where the bars can be most effectively used.

LONGITUDINAL STEEL IN SIMPLE BEAMS

Simple beams (also simple slabs, joists, girders) carrying loads assume the shape as shown:

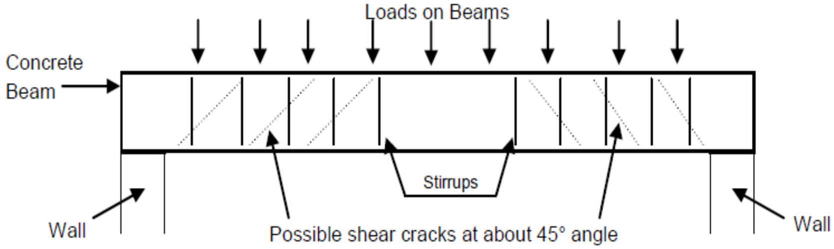




The top of the beam is in compression and the bottom is in tension, so longitudinal steel is located near the bottom to prevent the failure of the concrete in tension.

STIRRUPS IN BEAMS

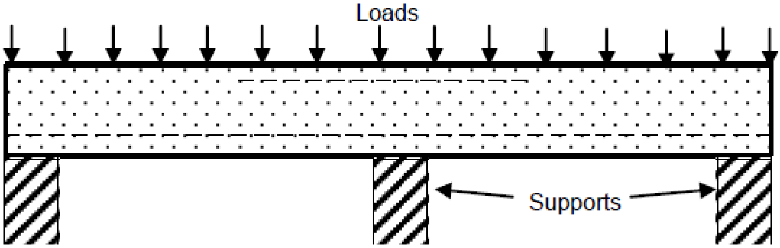
When a beam deflects under a load, shear stresses are also present. To resist the diagonal tension, small U-or W-shaped bars called **stirrups** are used and are placed vertically across the beam.



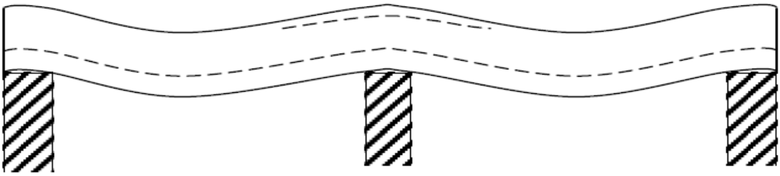
Since shear is usually at a maximum near the support and decreases toward mid-span, the stirrups are more closely spaced near the support and spaced increasingly farther apart toward mid-span. Since the concrete is able to take some shear, stirrups can often be omitted near mid-span.

STEEL IN CONTINUOUS BEAMS

Continuous beams (or slabs) which extend over more than one span, deflect downward between supports and have an upward thrust over the supports. This requires tension steel in the bottom between supports and in the top over the supports.

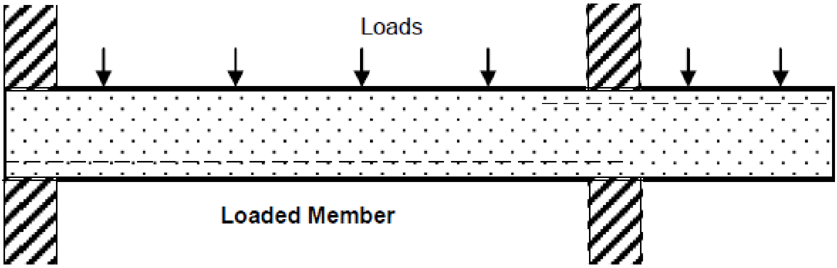


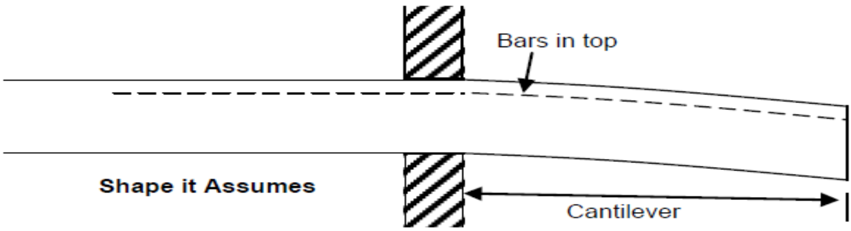
Loaded Member



Shape it Assumes

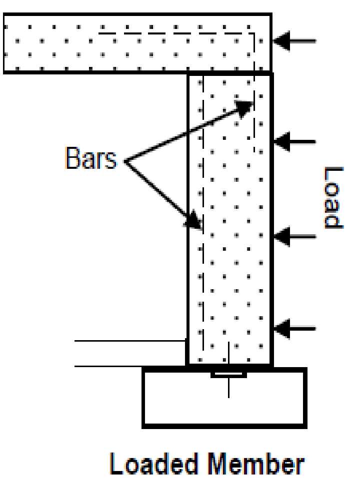
Cantilever beams (or slabs) loaded at the top (deflect as shown in the next two illustrations) and in the cantilever (or overhang) tension bars must be placed in the top. They must be carried back into the main span whenever possible, otherwise they must be securely anchored by bending or hooking into an outside beam or column.

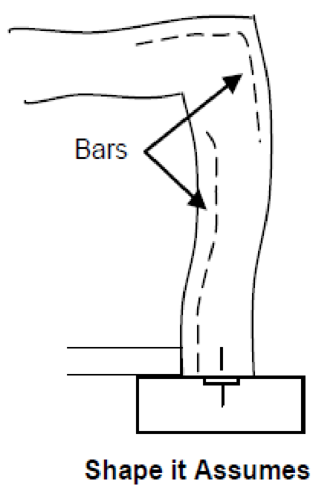




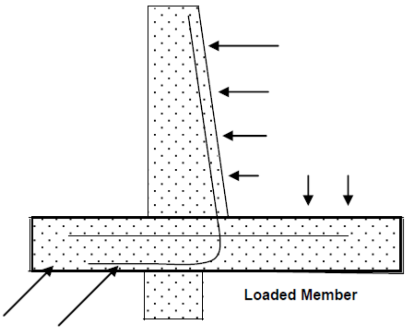
WALLS

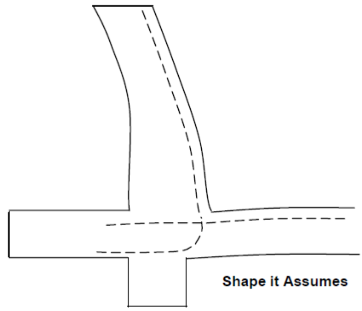
Walls, braced at top and bottom by floor slabs and loaded with horizontal pressures on the outside face, deflect inward. This requires bars on the inside face where there is tension. Sometimes, when specified by the engineer, bars may be required around the outside top corner.





Cantilever retaining walls deflect as shown and usually require main bars on the side toward the earth, but this is not always true. Other forces may be involved. Bars should be placed where called for on the placing plans since the proper location of bars in such structures is very important.

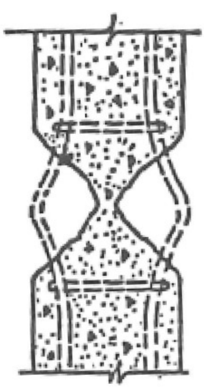




COMPRESSION REINFORCEMENT- COLUMNS

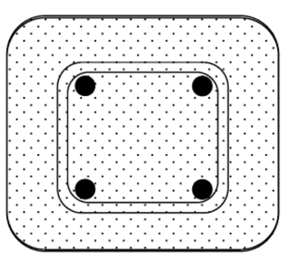
While the main purpose for steel in concrete is to resist tension forces, it is also used to resist compression forces.

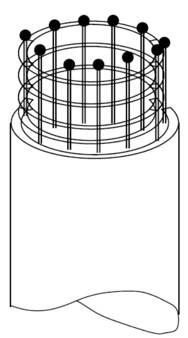
The most common use of steel for compression forces is in columns. If concrete alone were used, the size of column required would be so large as to be impractical and would add considerably to the weight of a structure. Since bars are about twenty times stronger than an equivalent area of concrete, they are used to carry part of the column load. The concrete and the steel work together and the resulting column is much smaller in size and lighter in weight.



Buckled Column Bars

Column Ties



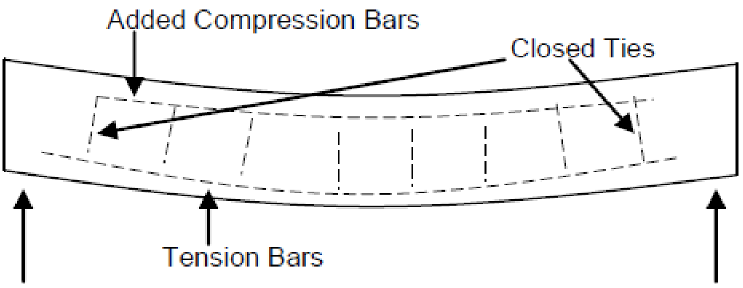


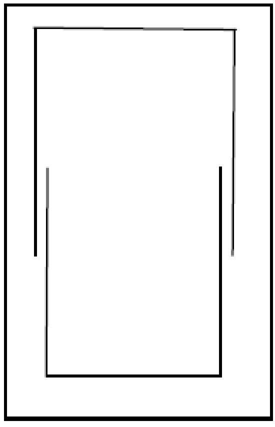
Column Spirals

Column vertical bars are in compression, and if not restrained in some manner the compression load would allow the bars to buckle and break out of the concrete. Column ties are spaced to prevent this. They are in tension, holding the vertical bars in position.

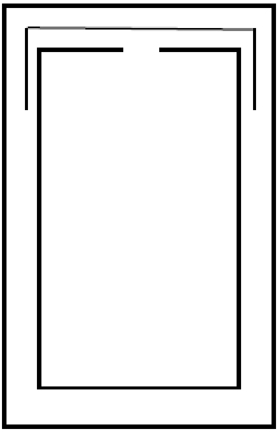
COMPRESSION REINFORCEMENT-BEAMS

In some beams, where compression is high or where the size of beam needs to be restricted, it may be necessary to use bars in the top of the beam. These bars take the place of some of the concrete, very much the same as the column vertical bars. When used in this manner, the bars are always restrained by closed stirrups which may be in two pieces as shown.





Two Piece Tie

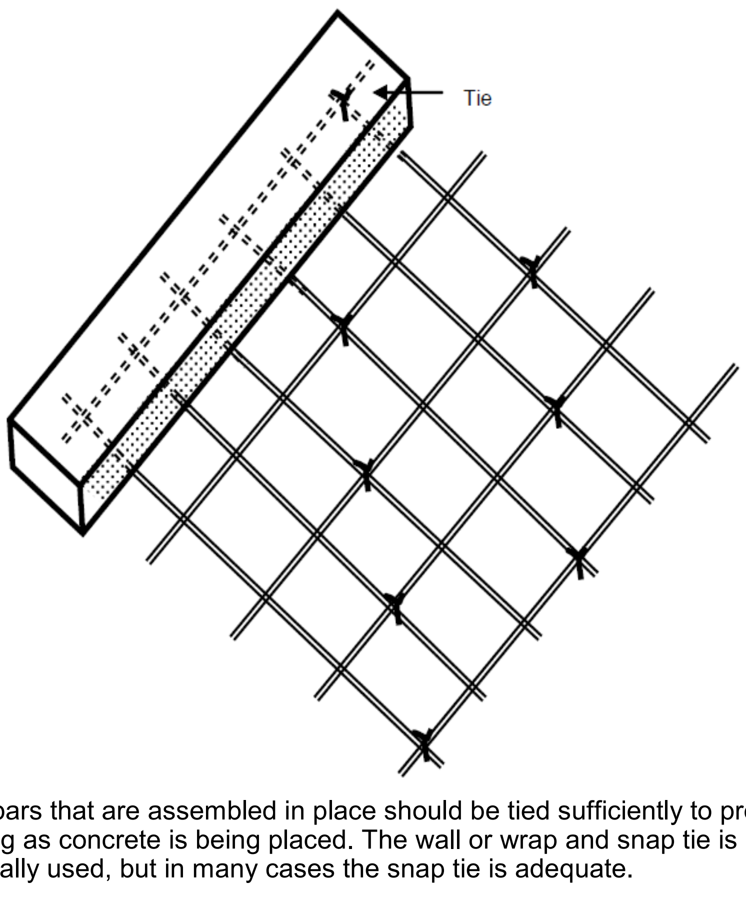


Cap Stirrup

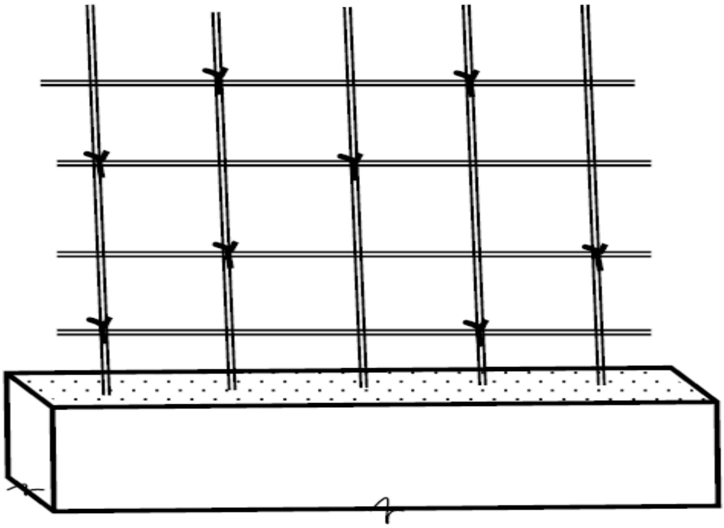
In continuous beams (those which have more than two supports), the compression in concrete is sometimes high in the bottom near a support. For this reason bottom bars are sometimes extended and lapped with those of an adjacent span.

GENERAL PRINCIPLES OF TYING BARS

The proper tying of bars is essential in order to maintain their position during work done by other trades and during concrete placing. *It is not necessary to tie bars at every intersection. Tying adds nothing to the strength of the finished structure.* In most cases, every 4th or 5th intersection is all that is necessary. Ends of finished ties must be kept clear of the face of the concrete.

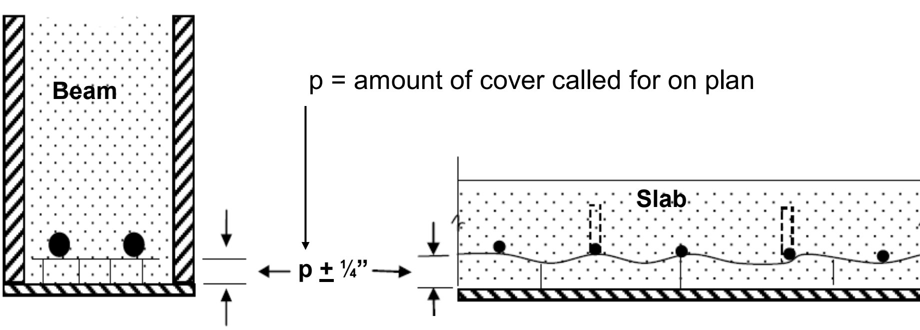


Wall bars that are assembled in place should be tied sufficiently to prevent shifting as concrete is being placed. The wall or wrap and snap tie is generally used, but in many cases the snap tie is adequate.

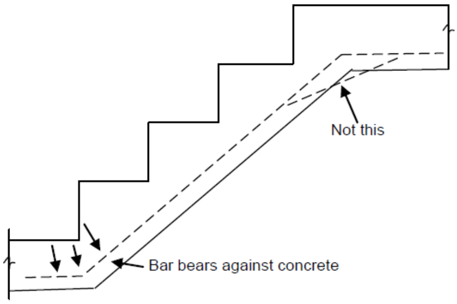


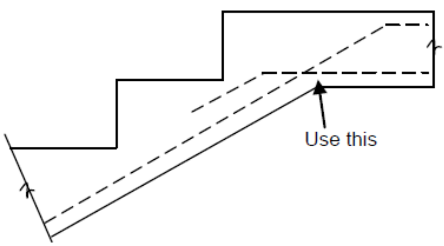
TOLERANCES IN PLACEMENT

General - It is important that bars be placed and held in position as shown on the placing drawings. The strength of any concrete member can be affected by the improper positioning of the reinforcing bars. For example, lowering the top bars or raising the bottom bars by ½ in. more than specified in a 6 in. deep slab could reduce its load carrying capacity by 20%.
A tolerance of ¼ in. plus or minus (1/4 in. plus / minus) is a generally accepted practice in the positioning of bars above forms in the bottom of beams, joists and slabs. Wire bar supports, spaced according to the CRS1 Specifications for Placing Bar Supports should be sufficient to locate the bars where they are intended to be.



For **Stair Landings** a similar condition exists as for inside corners. The illustration below shows the wrong and the right way. The bars are in tension and should not be bent continuously around the "break" in the slab, but should continue across this point and be bent into the stair and landing slabs as shown. This is not necessary at the point where the bottom landing and the stair slab meet because here the bar bears against the concrete.





<u>Tread</u>

Rise:

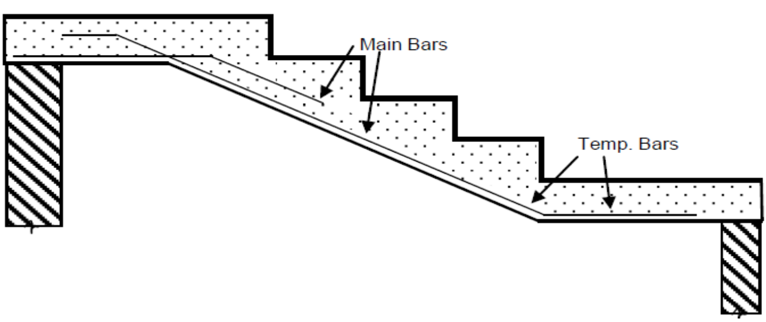
- Private: Max. 200 mm
Min. 125 mm
- Public: Max. 180 mm
Min. 125 mm

Run:

- Private: Max. 355 mm
Min. 210 mm
- Public: Max. no limit
Min. 280 mm

Depth:

- Private: Max. 355 mm
Min. 235 mm
- Public: Max no limit
Min. 280 mm



9.8.4.4. Risers shall be of uniform height in any one flight with a maximum tolerance of 5mm between adjacent treads or landings and 10 mm between the tallest and shortest risers in a flight.
Treads shall have a uniform run with a max. tolerance of 5 mm between adjacent treads and 10 mm between the deepest & shallowest treads in a flight. Tread slope not to exceed 1 in 50.

SLABS ON GROUND

In building construction, slabs on ground are used for basement floors, or for floors at grade where there is no basement. The subgrade must be properly prepared, provisions made for drainage and all sewer pipes and underground duct work must be completed to the top of the top of slab elevation. The installation of the soil gas barrier and steel placement can begin. Slabs on ground are reinforced with bars of the same size and spacing in both directions, or with welded wire fabric. The size and spacing of the reinforcement as well as the slab thickness will depend on the usage planned for the floor. Structural slabs and slabs used for heavy commercial applications may require two mats, one near the bottom of the slab and the other near the top.

Methods used in supporting steel vary. Pre-cast concrete bricks or blocks can be used to support single mats or bottom mats. Top mats can be supported on chairs or dowels.

Controlling Cracking in Concrete Slabs

To reduce and / or control the cracking of concrete slabs, it is necessary to understand the nature and causes of volume changes of concrete and in particular those relating to drying shrinkage. The total amount of water in the mix is by far the largest contributor to the amount of drying shrinkage and resulting potential cracking that may be expected from a given concrete. To lessen the volume change and potential cracking due to drying shrinkage, a mix with the lowest total amount of water that is practical should always be used. To lower the water content of a mix, super plasticizers are often used to provide the needed workability of concrete during the placing operation. The water / cement materials ratio of slabs-on-ground should be no higher than 0.45

Finishing Slabs on Ground with Polyethylene Soil Gas Barrier

Finishing a concrete slab placed directly on polyethylene can cause problems for the finisher. A rule of finishing, whether concrete is placed on polyethylene or not, is to never finish or "work" the surface of the slab while bleed water is present or before all the bleed water has risen to the surface and evaporated. If finishing operations are performed too early, such as before all the bleed water has risen and evaporated, surface defects such as blisters, crazing, scaling and dusting can result. This is often the case with slabs placed directly on polyethylene. The excess water from the bottom portion of the slab cannot bleed downward into the granular layer because of the polyethylene and must rise through the slab to the surface. Quite often in such cases, finishing operations are begun too soon and surface defects result.

BACKFILLING

The concrete should be cured until it has attained 75% of the specified 28 day strength before backfilling. If the wall is designed to have lateral support, the top of the foundation wall shall be provided with adequate lateral support before backfilling.

1. 9.12.3. Backfill shall be placed to avoid damaging the foundation wall, the drainage tile, externally applied thermal insulation, damp -proofing or waterproofing of the wall.
2. Backfill within two feet of the foundation shall be free of deleterious debris and boulders larger than 10 inches.
3. Backfill shall be graded to prevent drainage towards the foundation after settling.

NOTE: In areas of problem soils and for wood frame basements, the backfill material should be course sand or gravel, extending from the drainage to a point approximately one foot below the finished grade. The top foot of backfill material should be of no greater porosity than the existing soil.

FLOORS ON GROUND:

Granular Layer, Damp-proofing, Soil Gas Barriers and Waterproofing

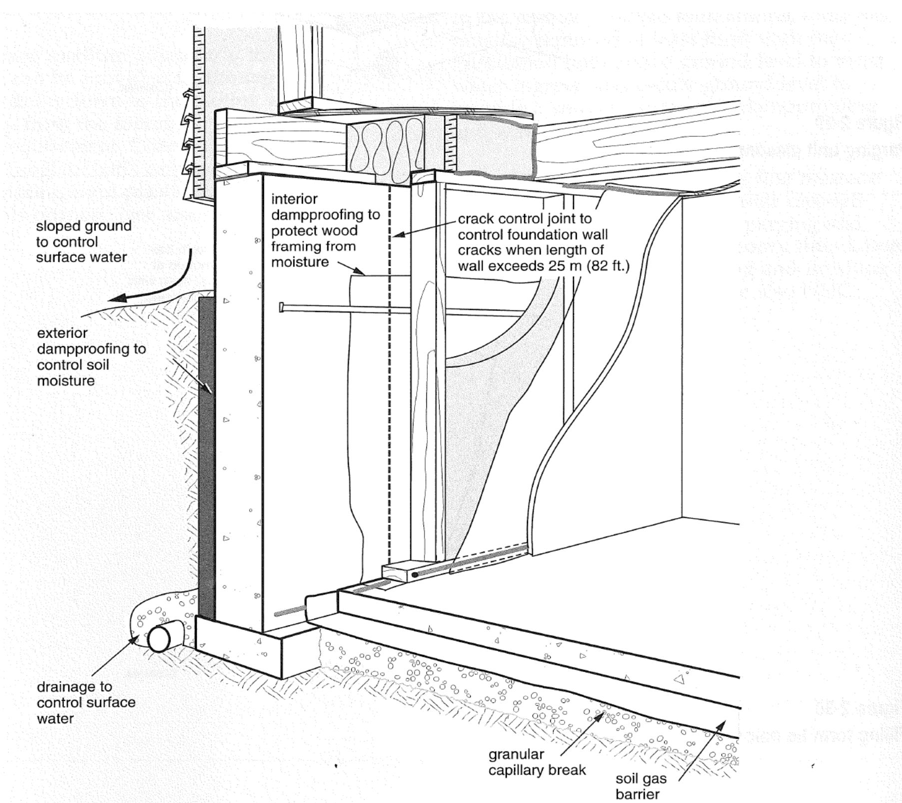
1. 9.16.2.1 Not less than 100 mm of course clean granular material containing not more than 10% of material that will pass a 4 mm sieve shall be placed beneath floors on ground.
2. The bottom of the excavation drained by a granular layer shall be graded so the entire area is drained to a sump pit. The sump pit shall be:
    a) not less than 750 mm deep (28 in.)
    b) not less than 0.25 m sq. (2.7 sq. ft.)
    c) provided with an air tight cover as per 9.25.3.3 (7) and resistant to removal by children
3. 9.13.2.1. Floors-on-ground shall be damp-proofed. Damp-proofing is not required for floors in garages and floors in unenclosed portions of buildings.
4. 9.13.4.1 Required Soil Gas Control: All wall, roof and floor assemblies in contact with the ground shall be constructed to resist the leakage of soil gas from the ground into the building. Crawlspaces with concrete skim coats and basement floors to be provided with the rough in for a subfloor depressurization system as per 9.13.4.3. Construction to resist soil gas leakage is not required for garages and unenclosed portions of buildings.
5. When installed below the floor, damp-proofing and soil gas control membranes consisting of polyethylene conforming to control membranes consisting of polyethylene conforming to CAN/CGSB-51.34-M shall be lapped not less than 300 mm.

6. For damp-proofing applications only, type S roll-roofing lapped 100 mm can be used in place of 6 mil poly.
7. When a soil gas barrier is installed in conjunction with a framed floor-on-ground, it shall be installed in accordance with 9.25.3.3. (Continuity of Air Barrier Systems).
8. The soil gas barrier for a floor on ground shall be:
   a) Sealed around its perimeter to the inner surfaces of walls using flexible sealant.
   b) Sealed around all penetrations of a floor on ground by pipes or other objects.
   c) Sealed around all penetrations of a floor-on-ground which are required to drain water from the floor surface. These shall be sealed in a manner which prevents the upward flow of soil gas without preventing the downward flow of water. See illustrations.
9. Soil gas barriers to be installed over 100 mm (4 in.) granular layer as per 9.16.2.1.
10. 9.13.3.1. Where hydrostatic pressure occurs, floors-on-ground and exterior walls below ground level shall be waterproofed. See 9.13.3.6. Floor Waterproofing System in the Manitoba Building Code.

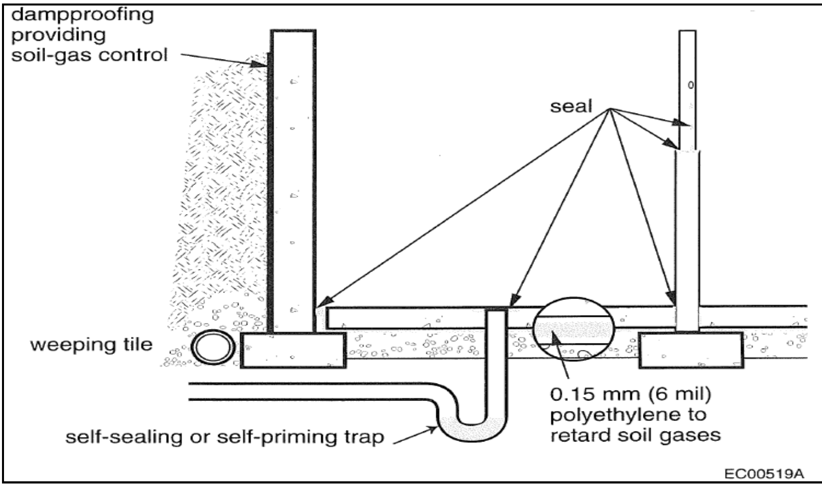
CRAWL SPACES

1. 9.18 Foundations enclosing crawl spaces shall conform to 9.15.
2. Ingress of water into the crawl space shall be controlled by grading and drainage.
3. Unheated crawl spaces ventilated by natural means shall be provided with not less than .1 m sq. of unobstructed vent area for every 50 m sq. of floor area (1 sq. ft. for every 500 sq. ft.) The vents shall be uniformly distributed on opposite sides of the building, and designed to prevent the entry of snow, rain and insects.
4. 9.18.6.1. Ground Cover in Unheated Crawl Spaces: Where a crawl space is unheated, a ground cover shall be provided consisting of not less than:
   a) 50 mm of asphalt,
   b) 100 mm of 15 MPA Portland cement concrete,
   c) Type s roll roofing lapped not less than 100 mm and weighted down, or
   d) 0.15 mm (6 mil) polyethylene lapped not less than 100 mm and weighted down.

5. 9.18.6.2. Ground Cover in Heated Crawl Spaces: Where a crawl space is heated, a ground cover consisting of not less than 0.15 mm (6 mil) CSGB polyethylene sheets shall be provided. The joints in the ground cover shall be lapped not less than 300 mm (12 in.) and
   a) sealed and weighed down **or** covered with a concrete skim coat not less than 50 mm (2 in) thick.
   b) The perimeter of the ground cover shall be sealed to the foundation wall.
   c) Insulation, an air barrier system and a vapour barrier shall be installed in the walls in accordance with 9.25 of the Manitoba Building Code.
6. Crawl spaces whose exterior walls have more than 25% of their total area above exterior ground level open to the outdoors do not require a ground cover.
7. Crawl spaces shall be considered to be heated where the space:
   a) is used as a hot air plenum;
   b) contains heating ducts that are not sealed and insulated to minimize heat loss to the space; or
   c) is not separated from heated space in accordance with 9.25. of the Manitoba Building Code (Insulation, Air and Vapour Barrier).



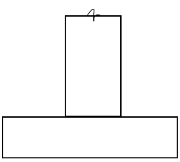
Sealing Floor Perimeter and Penetrations



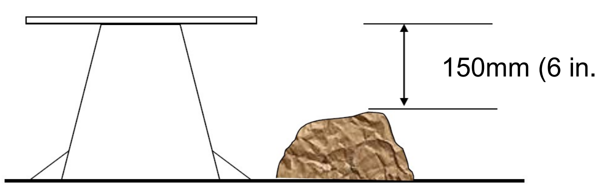
Concrete Strength and Durability
Poor construction practices can dramatically lower the strength of concrete. The addition of water on-site, poor placement practices and inadequate curing can reduce strength by as much as 75%.
The addition of water on-site, often done to ease movement of concrete around the forms (4 - corner slump), changes the water / cement ratio, reduces concrete strength and durability and increases the potential for shrinkage, cracking and corrosion of reinforcing bars. Adding 4 liters of water to a cubic metre of concrete will decrease its strength by more than 1 MPA (150 psi). Addition of water is prohibited as it results in slumps greater than the maximum slumps shown below.

Building Element

Maximum Slump

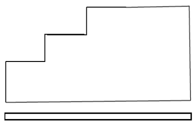


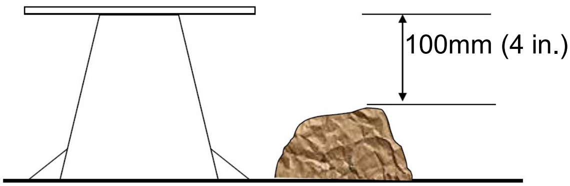
Footings for walls, columns, fireplaces, chimneys, foundation walls, grade beams, etc.



Building Element

Maximum Permitted Slump





Slabs on ground basement, garage floors, driveways, patios, steps, walkways.

Poor placement of concrete, high drops and excessive vibration, will result in segregation of the aggregates in the mix, resulting in a loss of strength.
Inadequate curing of the concrete will dramatically affect concrete strength. Early stripping of forms without providing alternative curing measures is a prime cause of loss of design strength. Forms should be left in place for a minimum of 48 hours, and slabs should be moist cured (spraying or fogging, or covered with suitable material) to prevent premature loss of moisture in the concrete. Leaving forms in place is especially important in both hot and cold weather to slow evaporation losses in the summer and to protect against freezing in the winter. Concrete should be kept at a temperature of not less than 10 C for at least 72 hours in cold weather. Moist curing for seven days will ensure the concrete reaches its intended design strength.

For more information on the Manitoba Building Code regulations for foundations, floor slabs and crawl spaces, please contact:

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