Joints in Concrete Work

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2022

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Properly creating and locating joints keeps concrete looking its best

Abstract. Joints in concrete are an important way to produce acceptable concrete structures. With right technical Joints, it develops a perfect work. This paper introduces the research status of joint types in concrete works. Bad execution of joints led concrete to some troubles. This paper explores the joints with their different types according to their function and issue in concrete frame structure. By referring to the analysis methods of joints in concrete, the service task of concrete structure raises to a high level.

Contents

General

Concrete is not a ductile material, it doesn't stretch or bend without breaking. That's both its greatest strength and greatest weakness. Its hardness and high compressive strength is why we use so much of it in construction. But concrete does move, it shrinks, it expands, and different parts of a building move in different ways. This is where joints come into play.

As concrete moves, if it is tied to another structure or even to itself, we get what's called restraint, which causes tensile forces and invariably leads to cracking. Restraint simply means that the concrete element (whether it's a slab or a wall or a foundation) is not being allowed to freely shrink as it dries or to expand and contract with temperature changes or to settle a bit into the sub-grade. Joints allow one concrete element to move independently of other parts of the building or structure. Joints also let concrete shrink as it dries-preventing what's called internal restraint. Internal restraint is created when one part of a slab shrinks more than another, or shrinks in a different direction. Think how bad you feel when part of you wants to do one thing and another part wants to do something else! Concrete feels the same way.

Figure (1): Joints in concrete can serve both to prevent cracking and as a decorative element

Therefore it’s necessary due to that reasons and for certain advantages, to separate between the constructions units, partially or completely, by making joints, according to special details.

Joints are effecting by certain shapes and details, and it is separate completely or partially between the parts of the structure unit. Joints are divided by their differ types and according to the purpose used for, to many groups:

1. Construction Joints.
2. Movement Joints.
3. Longitudinal Joints in Concrete Pavements.
4. Isolation Joints.
5. Fire Resistant Joints.

1. Construction Joints

In mega projects there is a starting and stopping points, the entire concrete work may not be done at once, hence concrete pouring need to be stopped causing a joint in element known as (Construction Joint). Construction joints are placed at points of ending and beginning of construction for provision of a smooth transition between pours. These joints are formed between successive building element parts during construction work, in which one part is allowed to harden before the next is placed, at the same time, they have to transfer flexural stresses produced in the slab by external loads. These joints may be intentional or unintentional.

Reasons for intentionally providing construction joints are;

- Certain time of a day i.e. Labour Hours (e.g. 8:00 am to 6:00 pm)
- Certain day of a week (e.g. Sunday, or Friday)
- Certain Months of an year (e.g. extreme weather in Winter or Summer)
- Religious Holidays (e.g. Eid or Christmas etc.)

Unintentional provision may occur due to

- Unexpected shortage of material
- Equipment Failure
- Bad weather

Thus it is including all the joints that necessary to make in the floors, slabs, beams, and the connections between the different parts of the building, and according to the construction stages.

These joints are weak zones in the concrete, and the number of construction joints shall be kept as few as possible consistent with reasonable precaution against shrinkage. Concreting shall be carried out continuously up to construction joints. The joints shall be at right angle to the general direction of the member.

Construction joints shall be so made and located as not to impair the strength of the structure. In the locations that moment and shear force is low. Provisions shall be made for transfer of shear and other forces through construction joints. Construction joints in floors shall be located within the middle third of spans of slabs, beams, and girders. Joints in girders shall be offset a minimum distance of two times of intersecting beams. Construction joints location must not be at middle of slabs or beams, or near columns or supports that the slabs or beams sitting on.

Surface of concrete construction joints shall be cleaned and laitance removed. Immediately before new concrete is placed, all construction joins shall be wetted and standing water removed.

In some structures, water stopper must be provided at the construction joint, such half of the stopper is placed in the first casting, and the other part is in the second casting, for e.g.: water tanks, sewerage systems. Construction joints have no thickness, therefore any joint filling materials not used.

Thus the construction joint is made in certain shapes and details; there are some types of construction joints:

1) Construction joint with continues rectangular space in the upper part, filled with elastic material.
2) Construction joint with a plastic or metallic water stopper, see fig. (2).
3) Construction joint with un straight section, which is called key joint, see fig. (3).

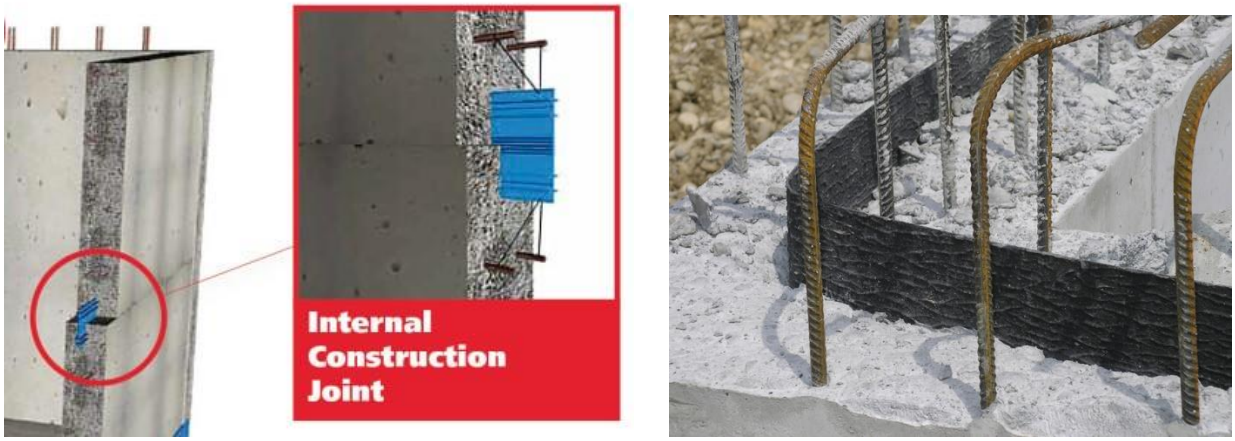

Figure (2): Construction Joints with Water Stopper

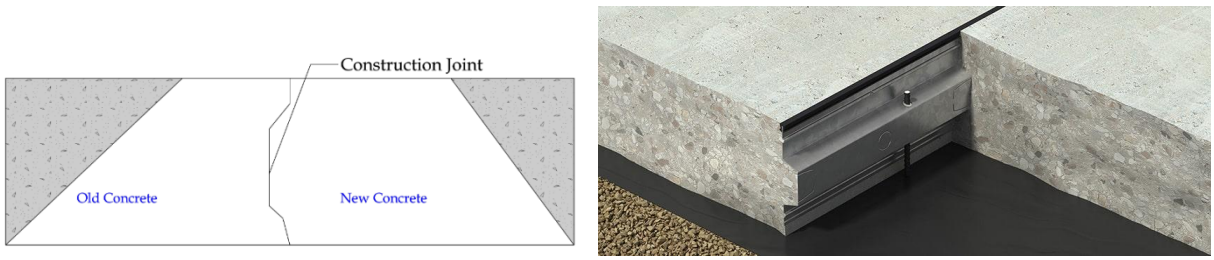

Figure (3): Construction Joints with un straight section (key joint)

2. Movement Joints

Movement joints are those specifically designed and provided to permit relative movement of adjacent parts of a member or structure to occur without impairing the functional integrity of the member or structure. The general function is to permit controlled movement to occur so as to prevent the structure up of harmful stresses. They may also be the connection joint between the several parts of a member or structure, or they may be provided solely to permit translation or rotation or both.

Provision of Movement Joints

Cracking can be minimized by reducing the restraints on the free movement of the structure, and the control of cracking normally requires the subdivision of the structure into suitable lengths separated by the appropriate movement joints.

The effectiveness of movement joints in controlling cracking in a structure will also depend upon their precise location, this latter is frequently a matter of experience and may be characterized as the place where cracks would otherwise most probably develop, e.g. at abrupt changes of cross section.

The location of all movement joints should be clearly indicated on the drawings, both for the individual members and for the structure as a whole. In general, movement joints in the structure should pass through the whole structure in one plane.

Types of Movement Joint

Movement joints may be of the following types:

A. Contraction (Control or Dummy) Joint.
B. Expansion Joint.
C. Sliding (Slip) Joint.
D. Hinged Joint.
E. Settlement Joint.

A. Contraction (Control or Dummy) Joint

The most important type of joints—certainly the most likely to cause problems. Both isolation and construction joints are formed before the concrete is poured; contraction joints (or control joints) are "placed" in the fresh concrete before it has a chance to create its own joints—also known as cracks. What a contraction joint really is in the end is a crack in the slab that we force to follow a line of our own choosing. We create a weakened line across the slab and let nature take its course. When the slab does crack, that's called "joint activation".

Contraction/ control joints are placed in concrete slabs to control random cracking. A fresh concrete mixture is a fluid, plastic mass that can be molded into virtually any shape, but as the material hardens there is a reduction in volume or shrinkage. When shrinkage is restrained by contact with supporting soils, granular fill, adjoining structures, or reinforcement within the concrete, tensile stresses develop within the concrete section. While concrete is very strong in compression the tensile strength is only 8 to 12 percent of the compressive strength. In effect, tensile stresses act against the weakest property of the concrete material. The result is cracking of the concrete, see fig. (4).

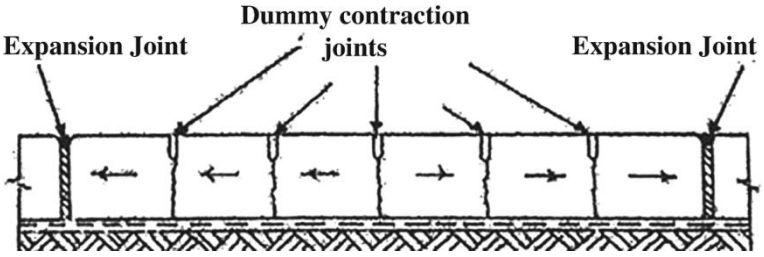

Figure (4): Contraction Joints in Slab

There are two basic strategies to control cracking for good overall structural behavior. One method is to provide steel reinforcement in the slab which holds random cracks tightly. When cracks are held tightly or remain small, the aggregate particles on the faces of a crack interlock thus providing load transfer across the crack. It is important to recognize that using steel reinforcement in a concrete slab actually increases the potential for the occurrence of random hairline cracks in the exposed surface of the concrete.

The most widely used method to control random cracking in concrete slabs is to place contraction/control joints in the concrete surface at predetermined locations to create weakened planes where the concrete can crack in a straight line. This produces an aesthetically pleasing appearance since the crack takes place below the finished concrete surface. The concrete has still cracked which is normal behavior, but the absence of random cracks at the concrete surface gives the appearance of an un-cracked section. In other words contraction or control joints are pre-planned cracks, see fig. (5).

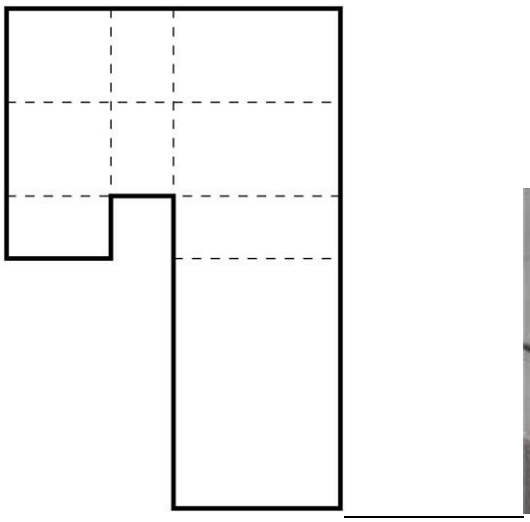

Figure (5): Correctly laid out joints.
Note: Inside corners, where cracks would typically occur, have correctly placed joints.

Concrete slabs-on-ground have consistently performed very well when the following considerations are addressed. The soils or granular fill supporting the slab in service must be either undisturbed soil or well compacted. In addition, contraction joints should be placed to produce panels that are as square as possible and never exceeding a length to width ratio of 1.5 to 1. Joints are commonly spaced at distances equal to 24 to 30 times the slab thickness, see table (1). Joint spacing that is greater than (4.5) meters (15 feet) require the use of load transfer devices (dowels or diamond plates).

Slab thickness, mm	Maximum-size aggregate less than 19 mm	Maximum-size aggregate 19 mm and larger
100	2.4	3.0
125	3.0	3.75
150	3.75	4.5
175	4.25	5.25
200	5.0	6.0
225	5.5	6.75
250	6.0	7.5

Table (1): Joint Spacing in Meters

A contraction joint is a joint with a deliberate discontinuity but no initial gap between the concrete on both sides of the joint, the joint being intended to permit contraction of the concrete.

Contraction joints may be tooled into the concrete surface at the time of placement. Joints may be tooled into the surface (first pass) prior to the onset of bleeding or immediately with the first pass of the floating operation. The longer the first pass for jointing is delayed the more difficult it will be to shape clean straight line joints. Tooled joints should be re-established with each successive pass of finishing operations, see fig. (6).

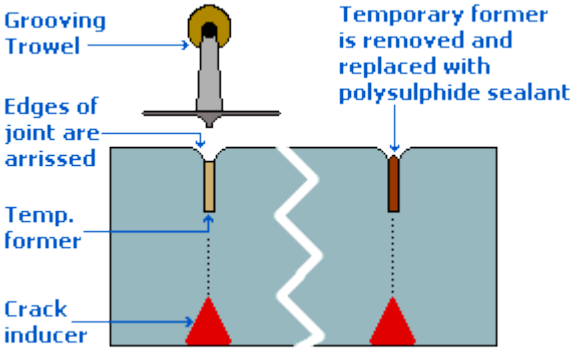

Figure (6): Tooled Contraction Joint

Joints may also be sawed into the hardened concrete surface, see figures (7 & 8). It is important to understand that the longer sawing is delayed the higher the potential for cracks to establish themselves before sawing is complete. This means that any cracks that occur before the concrete is sawed will render the sawed joint ineffective. Timing is very important. Joints should be sawed as soon as the concrete will withstand the energy of sawing without raveling or dislodging aggregate particles. For most concrete mixtures, this means sawing should be completed within the first six to 18 hours and never delayed more than 24 hours. Early-entry saws are available which may allow cutting to begin within a few hours after placement, see figures (9 & 10).

Figure (7): Early entry saws cut a contraction joint before the concrete has a chance to begin shrinking

Figure (8): Slabs crack directly beneath saw cut contraction joints and transfer load between panels by aggregate interlock

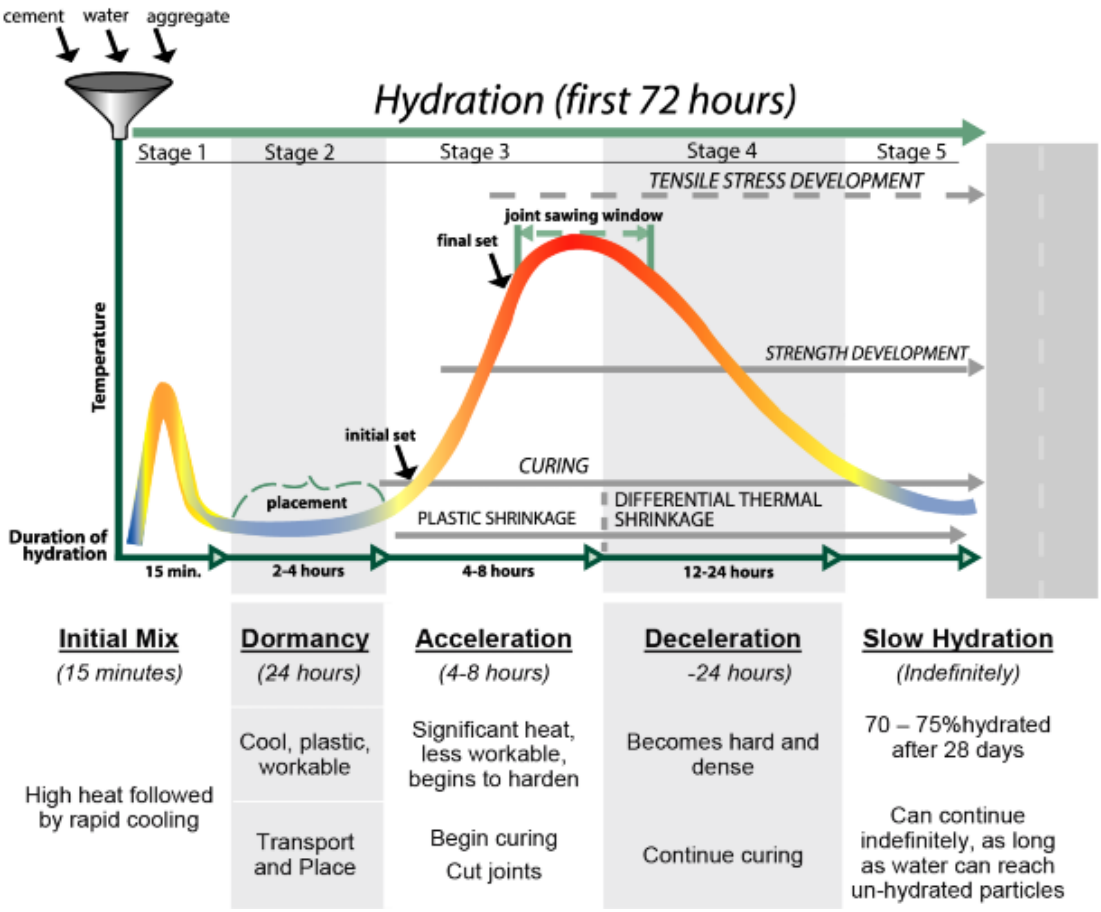

Figure (9): Sawing Window Details

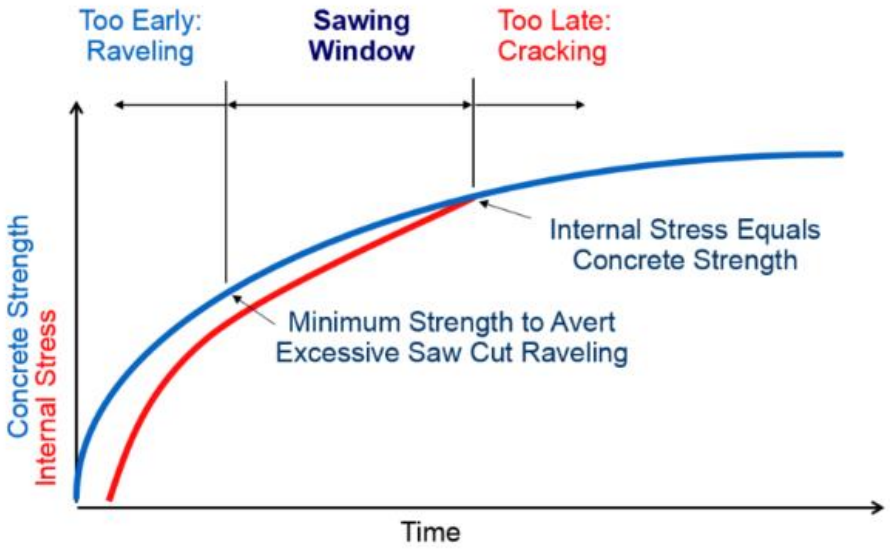

Figure (10): Sawing Window Diagram

Figure (11): Late Saw Cuts

Contraction/control joints must be established to a depth of ¼ the slab thickness, see fig. (12). Proper joint spacing and depth are essential to effective control of random cracking.

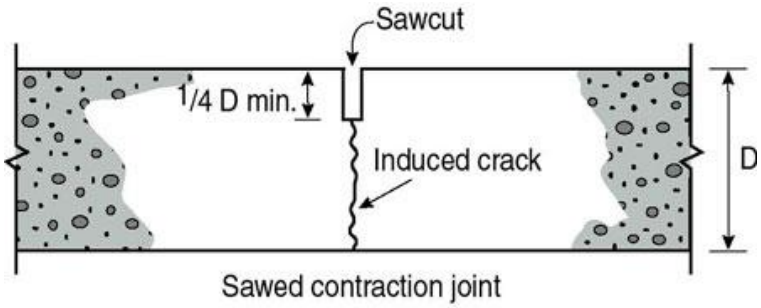

Figure (12): Minimum Depth of Contraction Joints

B. Expansion Joint

The concrete is subjected to volume change due to many reasons. So we have to cater for this by way of joint to relieve the stress. Expansion is a function of length. The buildings longer than (45) m are generally provided with one or more expansion joint.

An expansion joint is a joint with complete discontinuity in both reinforcement and concrete and intended to accommodate either expansion or contraction of the structure.

In general, such a joint requires the provision of a sufficiently wide gap between the adjoining parts of a structure to permit the amount of expansion expected to occur. Design of this joint so as to incorporate sliding surfaces is not, however, precluded and sometimes be advantageous. At execution of these joints, the differential settlement of the adjacent parts of concrete must be kept as few as possible.

There are some cases that expansion joints are required in broad based buildings which are designed as independent blocks to prevent the damages that may occur in the building structure due to expansions, contractions or ground settlements, such as; shopping malls, hotels, business centers, factories, stadiums, hyper markets:

1. Expansion joint in a building consist of a low parts and high parts:
   At very high buildings, expansion joints must be kept between the high and low blocks. The places and widths of expansion joints must be determined by the structural engineer by considering the horizontal and vertical movements of the buildings.
2. Expansion joint in a long building.
3. Expansion joint between old and new building.
4. Expansion joint in buildings that consist of perpendicular parts, in shape of T, L, or U.

The width of this joint is calculated according to this equation:

$$Width\ of\ Expansion\ Joint = Span * \begin{pmatrix} Avg.\ of\ difference \\ of\ teprature \end{pmatrix} * \begin{pmatrix} Coefiicient\ of \\ thermal\ expansion \end{pmatrix}$$

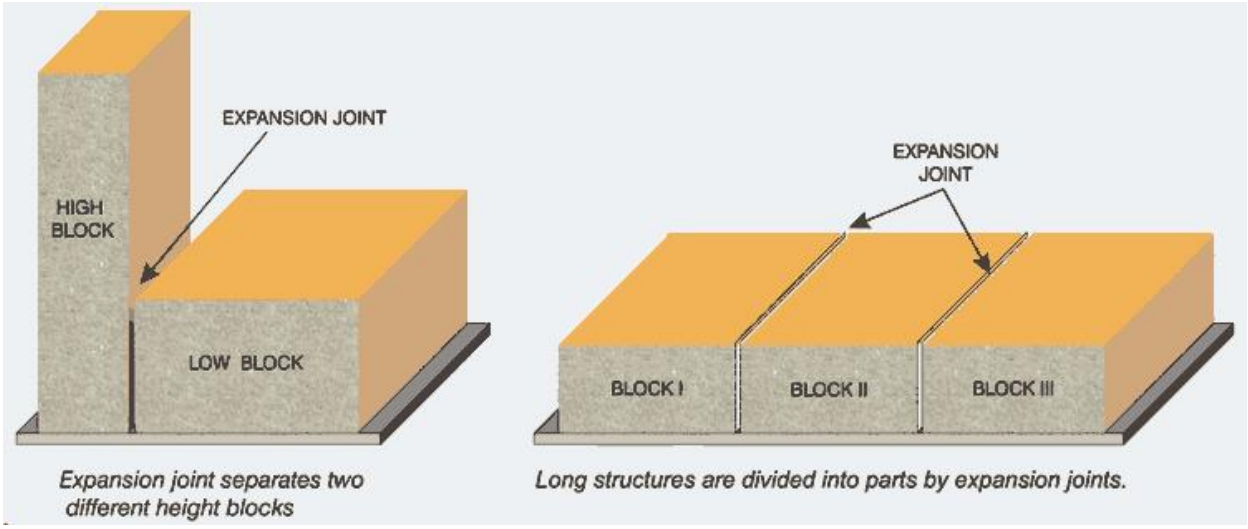

Figure (13): Expansion Joints

C. Sliding (Slip) Joint

A sliding joint is a joint with complete discontinuity in both reinforcement and concrete at which special provision is made to facilitate relative movement in the plane of the joint.

Also in load bearing structure, a roof slab undergoes alternate expansion and contraction due to the gain of heat from the sun and loss of heat by radiation into the open sky. Due to expansion and contraction, the horizontal cracks or shear cracks may occur in the walls. Slip joints are provided to mitigate the sliding movement at the joints of RCC slab and top of supporting walls.

How to Provide Slip Joint?

The bearing portion or top of the wall is furnished smooth with plaster. The wall is allowed to set and partly dry.

The top of the wall or the bearing portion of the wall is painted with white wash before casting the slab. Hence there is a minimum bond between the slab and the support due to paint layer.

To ensure the more efficient functioning of this joint, in place of white washing 2 or 3 layers of tarred paper are placed over the top of the wall to allow the easy sliding between RC slab and the supporting masonry. When the slab expands due to rise in temperature, or contracts due to falling in temperature (also due to shrinkage of concrete) some movement can take place.

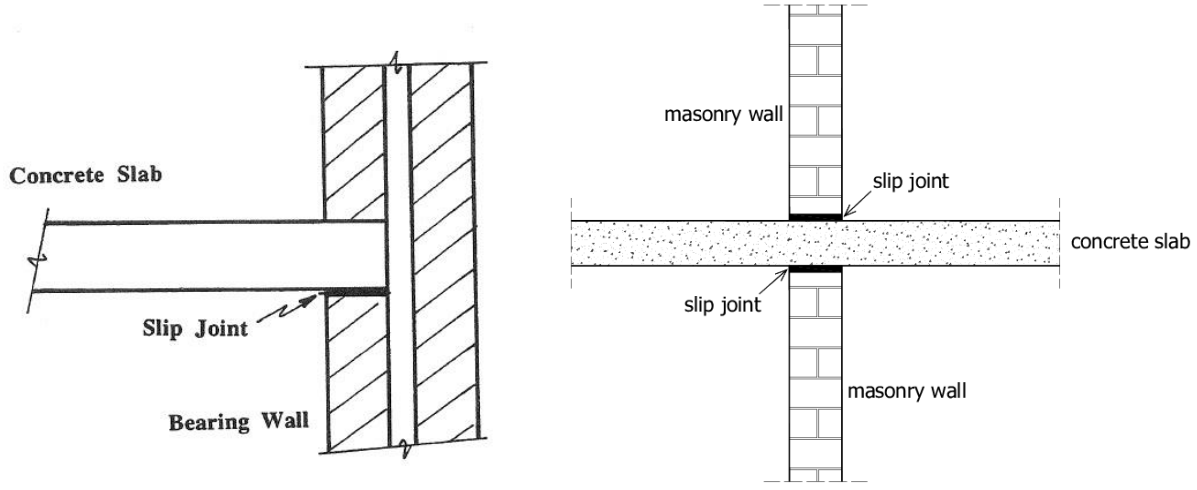

Figure (14): Slip Joints in Building

The slip joints in construction depend on the degree of exposure of the house or its components to heat and cold and experience gained in the behavior of the similar house built in the past in a particular region. The provision of the slip joints in the house is helpful for prevention of cracks, not only due to thermal effects but also due to some other causes, namely, moisture movement, creep and elastic deformation.

D. Hinged Joint

A hinged joint is a joint specially designed and constructed to permit relative rotation of the members at the joint. This type of joint is usually required to prevent the occurrence of reverse moments or of undesirable restraint, for example in a three-hinged portal.

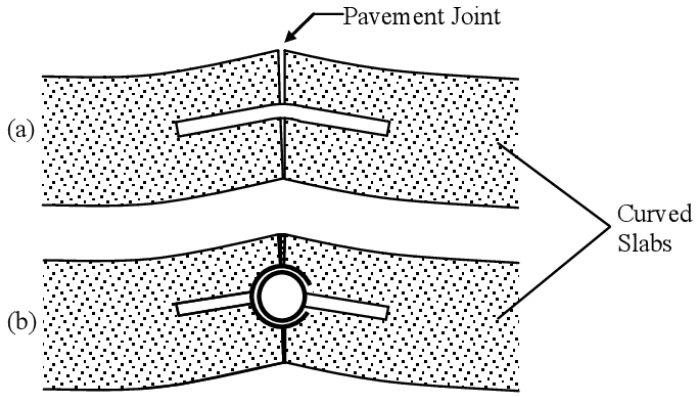

Figure (15):
Curling of a Concrete Pavement Slabs with:
a) Conventional Dowel Bars
b) Hinged Dowel System

The hinged slab bridge is widely used in medium- and small-span bridges because of its simple structure and convenient construction.

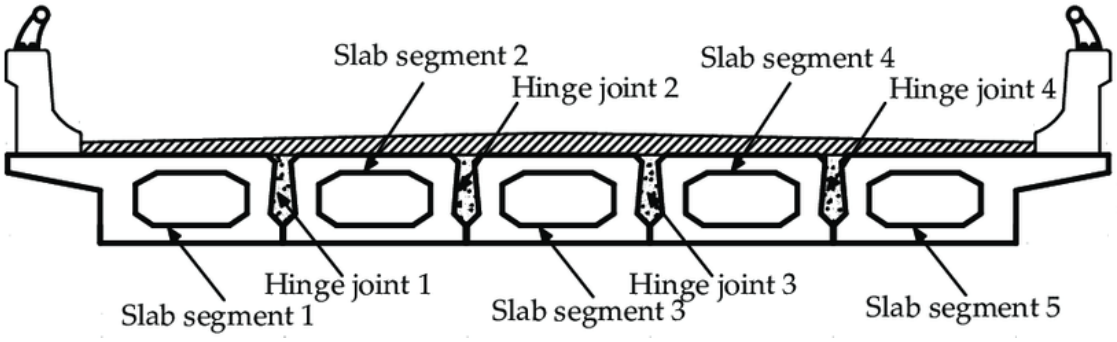

Figure (16): Hinged Slab Bridge

E. Settlement Joint

A settlement joint is a joint permitting adjacent members or structures to settle or deflect relative to each other in cases, for example, where movements of the foundation of a building are likely due to mining subsidence. The relative movements may be large.

Settlement joint introduced by providing vertical butt joints (without mortar) between the walls of an existing building and that of an additional portion constructed subsequently. The settlement joints enable the newly built portion of the building to settle and slide down without causing any unsightly shear cracks at the junction of the new work with the old.

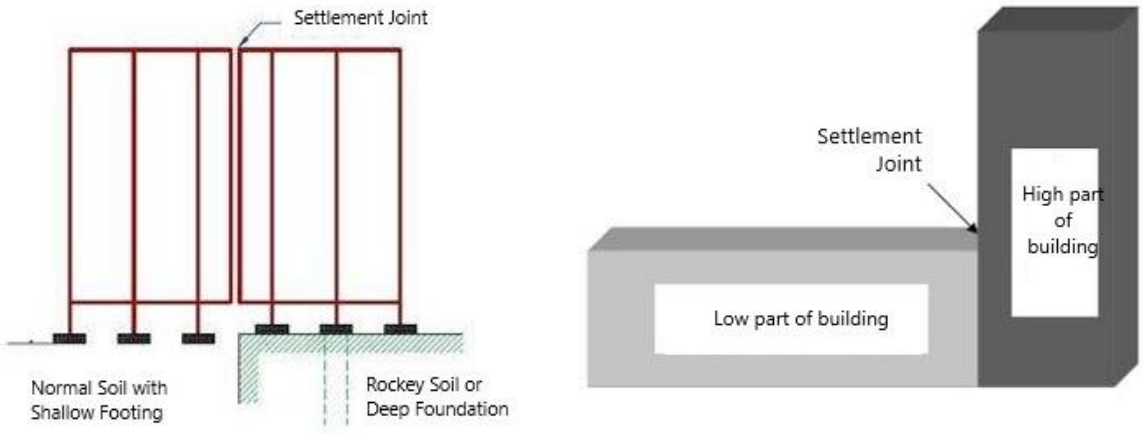

Figure (17): Settlement Joints

Design of Movement Joints

A movement joint should fulfill all necessary functions. It should possess the merits of simplicity and freedom of movements, yet still retain the other appropriate characteristics necessary, e.g. weather profess, fire resistance, resistance to corrosion, durability and sound insulation.

The design should also take into consideration the degree of control and workmanship and the tolerances likely to occur in the actual structure of the type being considered.

3. Longitudinal Joints in Concrete Pavements:

Longitudinal Joints shall be of two types, namely: longitudinal construction joints and longitudinal dummy joints.

a) Longitudinal construction Joints are to be used wherever one longitudinal strip of the pavement is to be constructed against another separately laid strip of pavement.

b) Longitudinal dummy type joints are to be used only when the contractor is permitted to construct the pavement to its full width in a single construction operation.

Figure (18): Longitudinal Joint

4. Isolation Joints

Joints that isolate the slab from a wall, column or drainpipe

Isolation joints have one very simple purpose—they completely isolate the slab from something else. That something else can be a wall or a column or a drain pipe. Here are a few things to consider with isolation joints:

Walls and columns, which are on their own footings that are deeper than the slab subgrade, are not going to move the same way a slab does as it shrinks or expands from drying or temperature changes or as the subgrade compresses a little.

Isolation joints are formed by placing preformed joint material next to the column or wall or standpipe prior to pouring the slab.

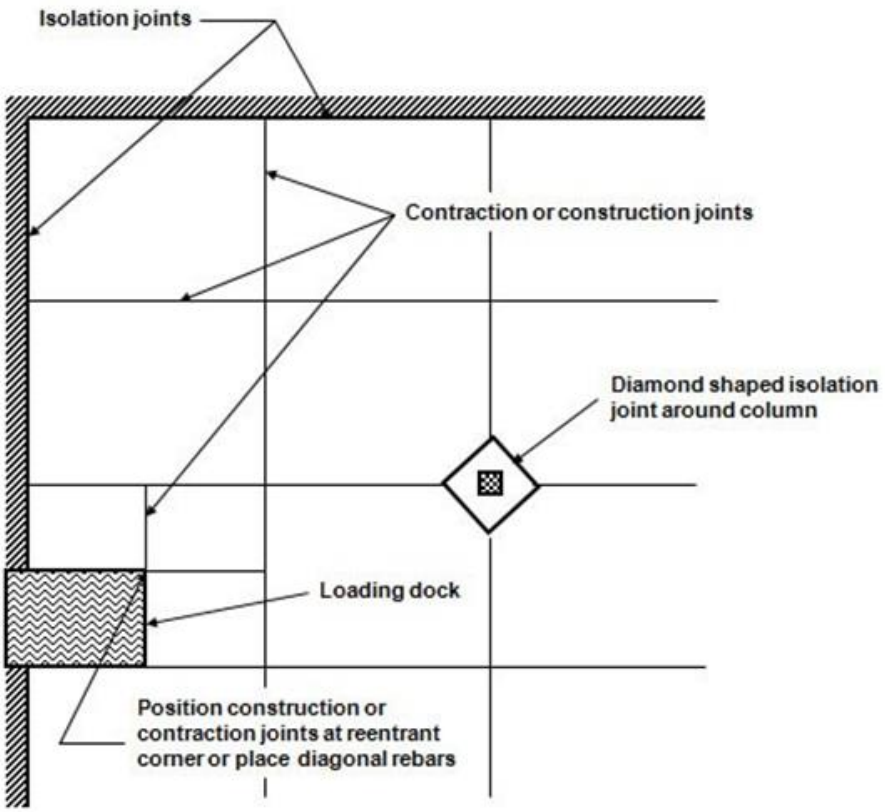

Figure (19):

Different joints in concrete slabs all have the same bottom-line purpose of preventing cracks

5. Fire Resistant Joints

Joints In fire resistant walls or floors should be fire stopped to an equivalent degree of fire resistance.

These joints installed in or between fire-resistance-rated walls, floor or floor/ceiling assemblies and roofs or roof/ceiling assemblies shall be protected by an approved fire-resistant joint system designed to resist the passage of fire for a time period not less than the required fire-resistance rating of the wall, floor or roof in or between which it is installed.

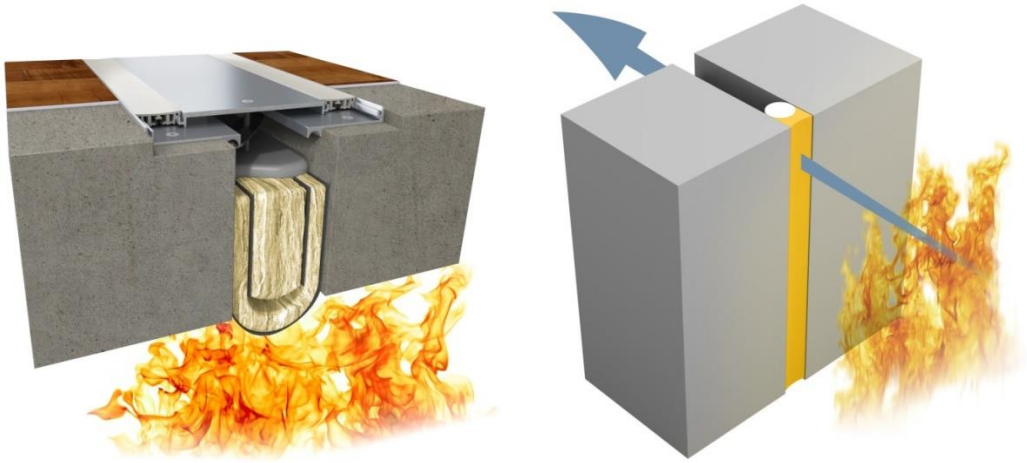

Figure (20): fire-resistant joint system

The void created at the intersection of a floor/ceiling assembly and an exterior curtain wall assembly shall be protected.

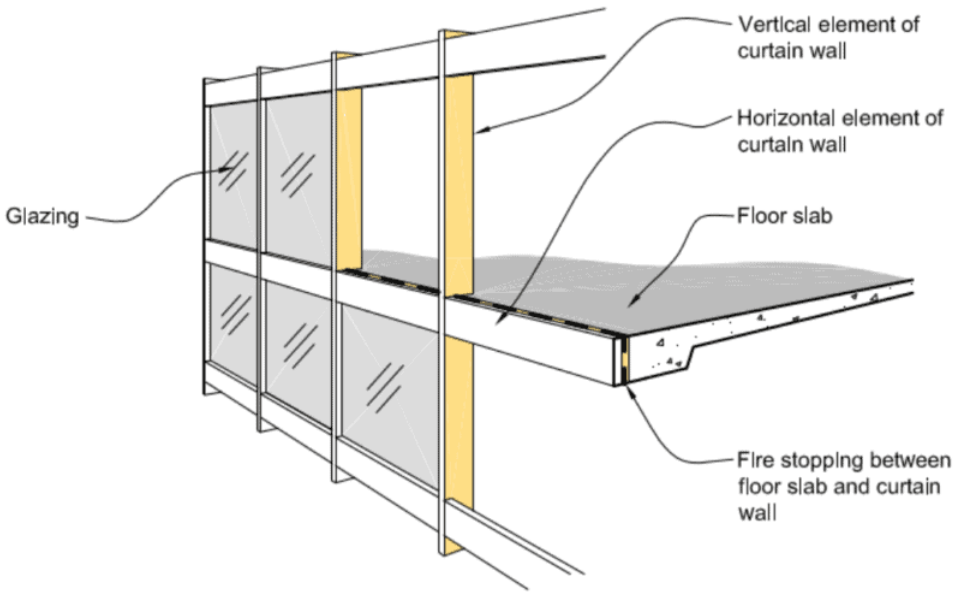

Figure (21): Protected void at the intersection of a floor an exterior curtain wall

Exception:

Fire-resistant joint systems shall not be required for joints in all of the following locations:

1. Floors within a single dwelling unit.

2. Floors where the joint is protected by a shaft enclosure.

3. Floors within atriums where the space adjacent to the atrium is included in the volume of the atrium for smoke control purposes.

4. Floors within malls.

5. Floors within open parking structures.

6. Mezzanine floors.

7. Walls that are permitted to have unprotected openings.

8. Roofs where openings are permitted.

9. Control joints not exceeding a maximum width of 0.625 inch (15.9 mm).

Installation:

Fire-resistant joint systems shall be securely installed in or on the joint for its entire length so as not to dislodge, loosen or otherwise impair its ability to accommodate expected building movements and to resist the passage of fire and hot gases.

Exterior curtain wall/floor intersection:

Where fire resistance-rated floor or floor/ceiling assemblies are required, voids created at the intersection of the exterior curtain wall assemblies and such floor assemblies shall be sealed with an approved material or system to prevent the interior spread of fire.

Such material or systems shall be securely installed and capable of preventing the passage of flame and hot gases sufficient to ignite cotton waste.

Dowel Bars

Dowel bars shall be cut from mild steel bars. One end of each dowel bar in all joints, except bonded construction joints, shall be sawn and not sheared so that no irregularities likely to interfere with its sliding action in the concrete shall occur.

Dowel bars for expansion and construction joints shall be placed on an axis parallel to the surface of the slab and to the center line of the slab (90^{o} to the side form for longitudinal joints).

The Parts of the lengths of straight dowel bars in expansion and contraction joints which are to be in the slab of concrete laid second, shall:

a) Be coated with oil, grease or bituminous paint immediately before laying the concrete.
b) Be straight and free from indentations or other deformations of cross-section.
c) Have sawn ends.
d) Be coated with a corrosion inhibiter. Oil coat shall not be applied until the inhibiter has completely dried.

Expansion Caps: Expansion caps for dowel bars in expansion joints shall consist of cardboard or pressed metal sleeves plugged at one end by punching the specified joint filler board or a wad of cotton waste of similar compressibility and sealed at the end against entry of mortar. The tube shall have an external diameter permitting sliding on the dowel bar but close enough to prevent entry of mortar.

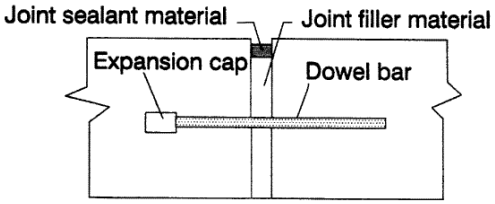

Figure (22): Dowel Bar Detail

Joint Filler

Joint filler shall consist of cane or other suitable long fibers of a cellular nature uniformly impregnated with asphalt. The asphalt content of the joint material shall be between thirty and fifty per cent. The joint material will not deteriorate under any weather conditions and is to be of such a character as not to be permanently deformed or broken by moderate twisting, bending or other ordinary handling.

Joint Sealing Compound

Joint sealing compound shall meet the requirements for cold –application type, hot – application elastomeric type and jet-fuel resistant hot – poured elastic type.

The compound is to be impermeable, is to withstand all weather conditions and is to be capable of adhering to the concrete without cracking, spilling or disintegrating and will not require an impracticable condition of dryness or cleanliness of the concrete slabs.

Where recommended by the manufacturer of the sealing compound, a primer supplied by him is to be used to improve adhesion.

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