General Information for Joints

A. General Information

The need for a jointing system in concrete pavements results from the desire to control the location and geometry of transverse and longitudinal cracking. Without jointing, uncontrolled cracking occurs due to stresses in the pavement from shrinkage, temperature and moisture differentials, and applied traffic loadings.

A good jointing plan will ease construction by providing clear guidance. The development of a jointing plan requires the designer to think about not only the specific project requirements but also the entire project jointing system. Jointing layouts in some parts of a project can have a substantial impact on other parts. In order to control concrete pavement cracking and subsequently maintain structural integrity, designers need to develop an understanding of how to complete jointing layouts of mainline pavements and intersections to obtain a comprehensive jointing system. This will allow a check on the pattern, type of joints, and matching joints to their purpose.

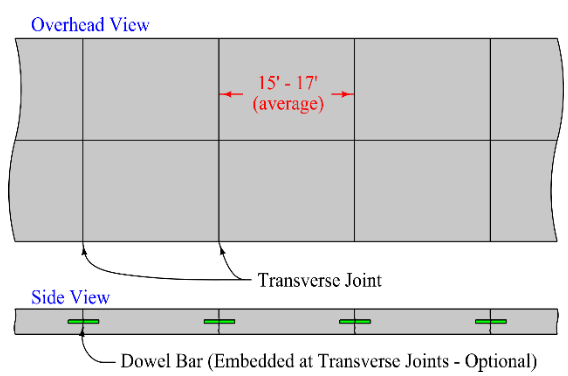
There are three types of jointing systems for concrete pavements, including:

- Jointed plain concrete pavement
- Jointed reinforced concrete pavement
- Continuously reinforced concrete pavement

This section deals primarily with jointed plain concrete pavements (JPCP) with tie bars or dowel bars only at joints as shown in Figure 5G-1.01. The function of the bars in JPCP is to provide load transfer across the joints, either through tie bars that hold the adjacent slabs together and maintain aggregate interlock or through dowel bars that provide mechanical load transfer even with slab movement.

Some cities specify jointed reinforced concrete pavements (JRCP), sometimes referred to as distributed steel reinforcing pavements. Section 5G-2 discusses jointed reinforced pavements. Jointed reinforced pavements allow for longer spacing between transverse joints by utilizing bar mats to hold midpanel cracks together and maintain structural integrity of the slab. Jointed reinforced pavements should not be confused with continuously reinforced concrete pavement, CRCP, which has very few or no joints.

Figure 5G-1.01: Jointed Plain Concrete Pavement (JPCP)



The primary benefits of jointing include:

- Crack control.
- Accommodating slab movements.
- Providing desirable load transfer.

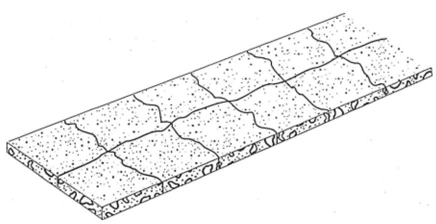
Secondary benefits of jointing include:

- Dividing the pavement into practical construction increments (i.e. traffic lanes, pavement widening).
- Providing traffic guidance.

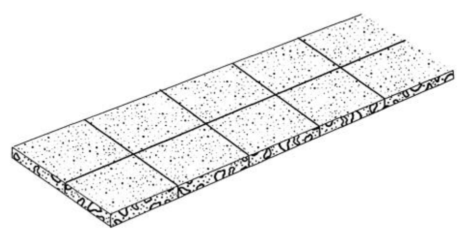
B. Crack Development

Crack development results from stress that exceeds the strength of the concrete due to concrete drying shrinkage, subgrade restraint, temperature/moisture differentials, applied traffic loads, and the combined effects of restrained curling and warping. It is highly desirable to control the location and geometry of transverse and longitudinal cracking in pavements by using properly designed and constructed joints. Without this control, cracking occurs in a random pattern similar to Figure 5G-1.02.

Figure 5G-1.02: Effect of Jointing on Crack Control



Crack Pattern Without Jointing



Properly Jointed Pavement

Cracking can be broken into two categories - initial and mature.

1. **Initial Cracking:** Initial cracking occurs within a few hours to a few months after the pavement has been placed. It may be caused by the following conditions.

   a. **Concrete Shrinkage (loss of volume):** Concrete shrinkage is caused by contraction of concrete from the following.

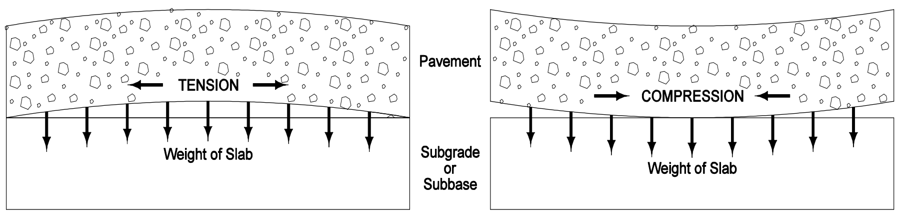
      1) **Temperature Change During Hydration:** The heat of hydration and temperature of pavement normally peak a short time after final set. After peaking, the temperature of concrete declines due to reduced hydration activity and lower air temperature during the first night of pavement life. As the temperature of concrete drops, the concrete contracts or shrinks. If severe air temperature changes occur within the first few hours after construction, high tensile stresses may cause transverse cracking to occur.

      2) **Loss of Water During Hydration (drying shrinkage):** Drying shrinkage results from the reduction of volume through loss of mix water. Concrete mixes for roadway applications require more mix water than is required for hydration (water consumed through chemical reactions with cement). The extra water helps provide adequate workability for placing and finishing operations. During consolidation and hardening, most of the excess water bleeds to the surface and evaporates. With the loss of the water, the concrete has less volume.

b. **Subgrade and Subbase Restraint:** Subgrade or subbase friction resists the contraction of the pavement from reduced volume and temperature. This resistance produces tensile stresses within the concrete.

c. **Curling and Warping:** Curling is the result of temperature changes through the depth of the pavement. Daytime curling occurs when the top portion of the slab is at a higher temperature than the bottom portion. Because of the higher temperature, the top expands more than the bottom, causing the tendency to curl. Subgrade and subbase friction and the weight of the slab are factors that help to counteract the daytime curling. During the night, the effects of curling are reversed. See Figure 5G-1.03.

Figure 5G-1.03: Daytime and Nighttime Curling



Daytime Curling Nighttime Curling

Warping results from a moisture differential from the top to the bottom of the slab. The top of the slab is normally drier than the bottom. The decrease in moisture content causes contraction at the top of the slab, which helps to counteract daytime curling. This contraction causes stresses in the concrete, which can lead to cracking.

2. **Mature Cracking:** Mature cracking occurs several months or years after pavement is placed. As traffic loads are applied to the pavement, along with temperature and moisture changes, tensile strain/stress will develop in concrete as the result of:

   a. Curling and warping in combination with repetitive traffic loads.

   b. Poorly designed and constructed pavement joints that do not provide proper load transfer across the joints and pavement slab.

   c. Poor foundation support due to unsuitable or non-uniform soils and excessive subgrade moisture.

C. Crack Control

Cracking can be minimized by the following:

1. Properly designed and constructed joints and joint layout that account for load transfer.
2. Proper timing of sawing of joints.
3. Sawing of joints in the correct locations.
4. Proper curing of concrete to prevent high initial shrinkage and cracking of hardening concrete.
5. Constructing a quality foundation with uniform, stable subgrade, drainable subbase, and longitudinal subdrains. See Chapter 6 - Geotechnical for additional guidance.

D. Considerations for Good Pavement Jointing

In order to design a suitable pavement jointing system, the following considerations have been included in the jointing layout steps covered in this design section. The following elements need to be considered for adequate jointing:

1. **Joint Purpose:** Transverse and longitudinal joints are used to control cracking of the pavement by relieving internal curing and loading stresses. Transverse joints serve to control cracking resulting from contraction of the pavement.

2. **Climate and Environmental Conditions:** Depending upon temperature and moisture changes that occur at the time of construction, expansion and contraction of the slab will occur, resulting in stress concentrations, warping, and curling.

3. **Slab Thickness:** Pavement thickness counteracts curling stresses and deflections. Thicker pavements are less prone to curling.

4. **Load Transfer:** Load transfer is desirable across any concrete pavement joint. However, the amount of load transfer provided varies for each joint type, aggregate interlock, and the type of bar.

5. **Joint Spacing vs. Thickness:** Maximum joint spacing is dependent on pavement thickness; thinner pavement requires closer joint spacing than thick pavement.

6. **Traffic:** Traffic is an extremely important consideration in joint design. Traffic classification, channelization, and, particularly, the amount of truck traffic influence the load transfer requirements for long-term performance.

7. **Concrete Material and Construction Characteristics:** Specific materials and their combinations can affect concrete strength and joint requirements. When special mixes outside of standard mixes are proposed to meet project conditions and requirements, the materials selected for the concrete can influence slab shrinkage. Substandard materials and construction practices can have a detrimental effect on joint performance. For example, poor coarse aggregate can lead to D-cracking, which initially occurs along pavement joints, or over-vibration can lead to low air content, which can lead to early deterioration of pavement joints.

8. **Subbase Type:** The support values and interface friction characteristics of different subbase types affect movement and support of the slabs.

9. **Shoulder Design:** The shoulder type (curb, tied concrete, asphalt, granular, or earth) affects edge support and ability of mainline joints to transfer load. Widened outer lanes are also effective for helping maintain load transfer.

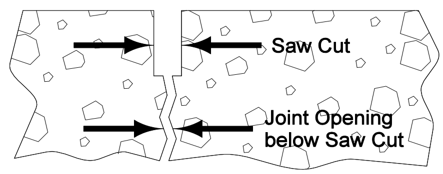
10. **Past Performance:** Performance observations and records can be used to establish standard joint design (what has worked and what has not).

E. Load Transfer

For jointed concrete pavement to perform adequately, traffic loadings must be transferred effectively from one side of the joint to the other. This is commonly referred to as load transfer, which is measured by joint effectiveness. If a joint is 100% effective, it will transfer approximately one half of the applied load. Field evaluation of load transfer is calculated by measuring the deflection on each side of a joint from the applied load. Load transfer is necessary for jointed concrete pavements to perform well. Adequate load transfer lowers deflections and reduces faulting, spalling, and corner breaks. Table 5G-1.01 shows that joint efficiency drops considerably when the joint opening below the sawcut line starts to exceed 1/8 inch.

Table 5G-1.01: Joint Opening Below the Saw Cut vs. Joint Efficiency

Joint Opening Below Saw Cut	Joint Efficiency
1/16”	> 50%
1/8”	< 50%
1/4”	0%



The following factors contribute to load transfer across joints:

- Aggregate interlock
- Mechanical load transfer devices
- Uniform, stable foundation, including quality subgrade and drainable subbase

1. **Aggregate Interlock:** Aggregate interlock is the interlocking action between aggregate particles at the face of the joint. It relies on the shared interaction between aggregate particles at the irregular crack face that forms below the sawcut. This form of load transfer has been found to be the most effective form of load transfer on streets with short joint spacings and low truck volumes. Increased aggregate interlock load transfer and minimized faulting will result from the following:

   a. Longitudinal tiebars and/or keyways.
      1) Typically used in longitudinal contraction and construction joints.
      2) Tiebars provide little load transfer themselves, but they do hold the slabs relatively tight together to maintain aggregate interlock.

   b. Shorter joint spacings (e.g. 15 feet or less).

   c. Larger crushed stone in the concrete mix
      1) Larger (greater than 1 inch) aggregates are helpful in maintaining load transfer, especially for larger joint openings.
      2) Generally, crushed stone aggregates perform better for aggregate interlock than rounded aggregates because the angular aggregates create a rougher joint face.

2. **Mechanical Load Transfer:** Aggregate interlock alone may not always provide sufficient load transfer in transverse joints for highway pavements and streets subject to heavy truck traffic. Under these circumstances, dowel bars should be used.

   a. Dowel Bar Benefits: Dowel bars are smooth round bars placed across joints to transfer loads without restricting horizontal joint movement. The benefits of dowel bars are as follows:
      1) They keep slabs in horizontal and vertical alignment.
      2) Since dowel bars span the joint, daily and seasonal joint openings do not affect load transfer across doweled joints as much as they do undoweled joints.

3) Dowel bars lower deflection and stress in concrete slabs, and reduce the potential for faulting, pumping, and corner breaks.
4) Dowel bars increase pavement life by effectively transferring the load across the joint.

b. Dowel Bar Use: Historically, dowel bars have been used to provide additional mechanical load transfer where traffic exceeds 200 trucks per day (or 100 trucks per lane), or accumulated design traffic exceeds 4 to 5 million ESALs. Typically, this truck traffic level will require at least an 8 inch thick slab, which is generally regarded as the minimum thickness to accommodate dowels.

3. **Quality Subgrades and Subbases:** A proper foundation for pavements reduces joint deflection, assists in aggregate interlock, and improves and maintains joint effectiveness under repetitive loads. Quality subgrades and subbases not only provide this support but also provide an all-weather working platform and stable smooth trackline for paving equipment. For design guidance for pavement subgrades and subbases, see Chapter 6 - Geotechnical.

It should be noted the subbase type and the subgrade support *k*-value have an effect on stresses in pavement slabs. The stiffer the foundation, the greater the slab's curl and warping stresses will be. Therefore, a shorter transverse joint spacing should be used.

4. Skewed Joints: Upon approval of the Jurisdictional Engineer, transverse contraction joints for undoweled pavements may be skewed counterclockwise (right ahead) 4 to 5 feet. Skewed joints are effective in decreasing the dynamic loading in the joint area by distributing the transfer of load. Each wheel on an axle crosses a skewed joint at a separate time. This reduces stresses and deflections in the concrete slab and helps reduce pumping and faulting. Also, the joints are 4 or 5 inches longer which increases the slab support area. The use of skewed joints is more appropriate for rural low volume roads and is not as practical for urban conditions due to the need to have right angle jointing patterns at intersections. A word of caution: If random cracks occur, they normally are at somewhat right angles and can create a pie shaped piece of pavement when they cross a skewed joint.