

A PAVEMENT JOINT

FIELD OF THE INVENTION

5 The present invention relates generally to the construction of pavements and to jointing systems for use in such pavements. The invention has particular application to pavements that are susceptible to differential movement by out-of-plane action such as for
10 example by tree root invasion, or soil movement, and which usually bear traffic that can accept some irregularity in the pavement surface and the invention is herein described in that context.

15 BACKGROUND OF THE INVENTION

 Pavements are used to facilitate the passage of wheeled or pedestrian traffic along or over roads, footpaths (sidewalks), playgrounds, and areas used for
20 storage or parking. To do its job well, such a pavement should be relatively smooth and flat. For reasons of economy, such pavements are often cast in substantial lengths, with construction joints between them. However, in some forms, pavements may be formed from preformed
25 slabs made from a settable material, such as concrete, or formed from other rigid material such as steel or wood. Footpaths are pavements that carry relatively light, low speed traffic such as pedestrians and pedestrian vehicles such as wheelchairs, strollers and bicycles. Other
30 categories of light duty pavement include cycle ways, domestic driveways, playgrounds and the like. These pavements generally do not need to be as smooth or flat as those used to carry heavy or high speed traffic.

35 A pavement is subject to both direct and indirect actions. Direct actions include traffic loads and forces deriving from soil or foundation movement, and tree roots.

In the case of footpaths, cycle ways and domestic driveways for example, which are frequently built alongside trees, uplifting actions caused by tree roots are common. Uplifting or depressing actions can be seen as
5 out-of-plane, relative to that of the pavement.

Indirect actions include drying (moisture) and temperature change. When a pavement is made from concrete, these actions cause both temporary and permanent
10 volumetric changes that manifest in the form of expansion and contraction. Shrinkage, which is caused by drying, can be seen in this sense as a form of permanent contraction. The effect of these actions is most significant in the plane of the pavement. For example,
15 the unrestrained drying shrinkage of concrete is commonly in the order of 800 micro strain or 1.2 mm for a slab 1500 mm long. The coefficient of thermal expansion of concrete is commonly in the order of 12 micro strain per degree Celsius or approximately 0.4 mm in a slab 1500 mm long
20 subjected to a temperature change of 20 deg C. If contraction is restrained, it may lead to cracking of the concrete. If expansion is restrained it may lead to any or all of spalling and crushing of the concrete and buckling and warping of the pavement.

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Commonly, provision for contraction of concrete pavements is made by incorporating contraction joints at relatively close intervals effectively dividing the pavement into a series of contiguous slabs. In the case
30 of an un-reinforced concrete pavement such as a footpath, for example, contraction joints are commonly spaced at between 15 and 20 times the thickness of the pavement. For a 75 mm thick pavement, this implies joints at 1000 to 1500 mm. Provision for the expansion of concrete
35 pavements, which are subjected to solar heating, such as roads and footpaths, is made by incorporating expansion joints, also known as isolation joints, at relatively wide

intervals, commonly 4 to 5 metres. Thus external pavements commonly take the form of a series of contiguous slabs, both separated and linked by a combination of contraction and expansion joints.

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For reasons of economy, contraction joints are commonly formed by creating a plane of weakness in the top surface of the concrete, by trowelling grooves in the fresh concrete or cutting grooves in the partially or
10 fully hardened concrete. This encourages cracking to occur at such grooves rather than in a random fashion, which would be unsightly, and helps to create many narrow cracks rather than few large cracks, which would be detrimental. In practice, the effectiveness of this
15 method is subject to variations in the concrete, in the friction between the pavement and the soil or subgrade upon which it rests, workmanship, climatic conditions and other factors, and contraction often accumulates over two or more slabs so that cracks do not occur at some planes
20 of weakness and relatively wide cracks occur at others.

Localised direct actions such as uplifting caused by tree roots or soil heave cause flexural stresses in the pavement. In the case of un-reinforced concrete footpaths
25 for example, which have relatively closely spaced contraction joints, the uplifting action of a tree root will typically lead to the opening or creation of a crack emanating from the top surface of the footpath at a contraction joint adjacent to the point of uplifting.
30 However, the cracking of this construction joint only reduces the flexural strength of a slab significantly in one direction and the aforementioned lifting may lead to the sudden, uncontrolled fracture of the footpath at distances from the point of lifting corresponding to the
35 flexural strength of the concrete. Further, if a crack is relatively wide, a lifted slab may not engage its neighbour with the result that a vertical discontinuity or

step will be created in the pavement. In the case of footpaths this often leads to steps of sufficient height to impair the passage of pedestrian vehicles and to cause pedestrians to trip or fall.

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Expansion joints usually consist of a sheet of compressible material extending the full thickness of a pavement so as to allow the pavement to expand without inducing excessive compressive stresses in the concrete from which the pavement is made, which could lead to crushing or spalling of the concrete or warping or buckling of the pavement. Such joints have no ability to transfer load or to limit differential displacement within a pavement.

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SUMMARY OF THE INVENTION

In a first aspect the present invention provides a pavement joint disposed between two contiguous pavement slabs, the joint being elongate and extending along a joint axis and incorporating a shear key and co-operating bearing surfaces that form at least one hinge, the shear key and the at least one hinge being operative when at least one of the slabs is subjected to out-of-plane action with the shear key transferring shear between the slabs, and the at least one hinge accommodating angular displacement of the slabs relative to the joint axis in at least one direction by movement of one bearing surface relative to the other.

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In the context of the specification, the term "pavement" relates to any hard surface especially of a public area or thoroughfare that will bear travel. Further, the pavement slabs may be formed from any suitable material and may be formed as precast units or cast in-situ. Examples of pavement slabs include, concrete slabs, hard and rigid materials like concrete,

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slabs formed from timber, or metal, such as expanded metal mesh, or from any combination of those materials.

5 In accordance with the invention, the joint provides
a load transfer mechanism that inhibits differential
vertical movement of the slabs when at least one of those
slabs is affected by an out-of-plane action such as by
tree root invasion or by soil movement. By reducing the
differential vertical movement of the contiguous slabs,
10 potential tripping hazards to pedestrians are reduced.
Along with this, as pavements are less likely to require
repair or replacement, there is a future cost saving to
users and a reduction in waste of resources.

15 In general, this load transfer mechanism is provided
by the shear key. The shear key provides a means of
transferring or equalising vertical displacement between
the slabs and may take many different forms to affect that
transfer. The at least the one hinge provides a means of
20 accommodating angular displacement relative to the joint
axis so as to provide a mechanism whereby the pavement may
articulate to relieve stress induced by the out-of-plane
action.

25 The inventors have found that the magnitude of
angular displacement that needs to be accommodated in
pavements that are subjected to localised actions from
tree roots and the like and which are comprised of
relatively short slabs, is an order of magnitude greater
30 than that required in other pavements such as roads. For
example, a tree root may lift one end of a footpath slab
by 25mm to 50mm which implies, for a 1500mm long slab, a
rotation of 1° to 2°. This level of rotation may be
accommodated by the joint according to the present
35 invention through the at least one hinge whereas such
rotation could not be accommodated by a conventional
contraction joint. However, it is to be appreciated that

the out-of-plane action may result from other than specific localised action. For example, this action may result from ground subsidence, or even from more violent action such as earth tremors and the like.

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In a particular embodiment, the joint may be formed through interengagement of the respective edge surfaces of the slabs. In that arrangement, the edges are profiled to form, by the interengagement, the shear key and the at least one hinge.

In one form, the shear key is provided by at least one portion of the edge surface of one slab locating within a recess formed in the other edge surface so that shear is able to be transferred across that connection. In one form, a tongue and groove connection is formed between the contiguous slabs.

In the arrangement where the joint is formed at least substantially from the profile of the edge surfaces of those slabs, the mechanism used in the hinge to enable angular displacement may take various forms. In one embodiment, each slab may have a bearing surface along its edge surface with the interengagement of those bearing surfaces providing a hinge of the joint.

The bearing surface may be formed from an exposed edge surface of the slabs. Alternatively a covering such as a metal or polymeric skin, film or the like may extend over that edge surface to form the bearing surface. The advantage of using such a covering may be to improve the surface properties of the bearing surface, or to increase the joint strength or to facilitate manufacture of the joint.

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In one form, one bearing surface may be able to slide within another bearing surface so that the hinge action is by sliding rotation.

5 In another form, the ends of the slab may have a cross section akin to that of gear teeth, so as to enable shear to be transferred in the manner of gear teeth, and rotation to be accommodated by rolling, in the manner of a gear wheel.

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When a slab of finite thickness rotates, say from a horizontal plane, it initially lengthens in plan. This means that when a slab is lifted close to one end and lifts its adjacent slab, the joint between the slabs opens at the top and closes at the bottom, and the joint between the slabs and their non-lifted adjacent slab close at the top and open at the bottom.

Typically in use, the lifted slabs are prevented from moving horizontally by their non-lifted adjacent slabs. As such, because of this lengthening effect compressive stresses may be induced in both the lifted and the non-lifted slabs unless there is some facility to accommodate this lengthening or at least minimising its affect. Typically, the result of this lengthening is that a pinching effect may occur between the slabs as they are angularly displaced. This effect may be offset by shrinkage in certain circumstances where the slabs are formed from concrete or similar material. In other circumstances, the joint between the slabs needs to accommodate the lengthening effect so that there is not undue stress occurring at the joint which would cause failure of at least one or more of the slabs.

35 In the arrangement as described above where the slabs may be akin to gear wheels, if the radii of the slab ends are established to equal the distance from the contacting

surface to the fulcrum about which the slabs rotate, the pinching effect described above is obviated.

5 In one form, the joint may include at least two hinges, with one hinge allowing angular displacement about the joint axis in one direction whereas the other hinge allowing angular displacement of the joint axis in an opposite direction. In one form, these hinges are displaced towards a respective outer surface the slabs. In 10 one form, each of these hinges use a hinge action of sliding rotation with each hinge being formed from cooperating arcuate bearing surfaces that slide one within the other.

15 In one form, the joint includes only a single hinge which is disposed on or about the neutral axis of the slabs. When located in that position, the relative lengthening of the slabs that occurs during rotation needs to be accommodated. In one form this may be accommodated 20 by incorporating sufficiently sized gaps within the joint at the outer margins of the slab so as to allow adequate clearance for the slab to rotate through a predetermined angular displacement (typically less than 5° and more typically less than 3°). However depending on the 25 thickness of the slab, the gap required may be excessive and may in fact cause a tripping hazard to the pavement. As such, in another form, the joint may include a compressible member disposed between the contiguous slabs and arranged to accommodate the lengthening of the slabs 30 under the angular displacement.

In a particular embodiment, the pavement slabs may be pre-formed and the compressible members may be fixed to one or both of the slabs prior to installation or located 35 within the joint on interconnection of the respective slabs.

In a particular embodiment, the pavement joint incorporates a joint member.

5 In one form, where the contiguous slabs are cast in-situ, this joint member may act as formwork for both of the pavement slabs. In one form, the joint member may be formed from a sheet material such as sheet steel and if necessary may include other elements such as the one or more compressible members mounted thereon. The joint
10 member in this form may be fixed to one of the slabs so that the joint hinge is formed through engagement of a surface of the joint member and the other slab to which that joint member is connected.

15 In one form, the shear key of the joint is provided by interengagement of the contiguous slabs with the joint member. In a particular embodiment, the joint member incorporates opposite lateral portions that extend into respective ones of the slabs so as to locate the jointing
20 member within the slab sufficiently to enable shear to be transferred across the contiguous slabs through said jointing member.

In one form, at least one of the lateral portions is
25 profiled to incorporate an arcuate bearing surface. In this arrangement, the at least one lateral portion forms part of the hinge that operates by sliding rotation with the arcuate surface forming a bearing surface of that hinge.

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In a particular embodiment, the joint member includes a core and the lateral portions extend outwardly from the core and are spaced apart about the joint axis through approximately 180°. With this arrangement, one lateral
35 portion projects into one slab, whilst the other lateral portion projects into the other slab.

In one arrangement, the joint member also includes at least one spacer that projects from the core. The at least one spacer locates between the contiguous slabs and is angularly spaced about the joint axis from the lateral portions.

In a particular embodiment, the joint member includes two spacers which are angularly spaced apart about the joint axis through approximately 180°. In a particular embodiment, the joint member is configured so that the spacers extend generally in a direction which is substantially perpendicular to the lateral portions. However, it is to be appreciated that the configuration of the joint member may vary so that the spacers are not at right-angles to the lateral portions.

The spacers of the joint member may be incorporated to accommodate the effects of lengthening of the at least one slab on angular displacement of the slabs about the at least one hinge. In this way, the spacers may be made from a material which is able to be compressed to at least some extent to accommodate this lengthening effect.

In a further form, the joint member may be arranged so that it completely separates and links the contiguous slabs. In this arrangement, the joint member includes two spacers that project from the core and extend to a respective one of the outer surfaces of the slabs. In this arrangement, the spacers may be sufficiently compressible so as to provide an expansion joint for the pavement to accommodate in-plane expansion of the slabs.

The configuration of the joint member with the core, lateral portions, and two spacers may incorporate a hinge action that operates through an arrangement where there is sliding or rolling rotation between a bearing surface of

the joint member and a corresponding bearing surface formed on the edge of abutting slab.

5 In a particular embodiment of the above form of joint member, the joint member is formed with a plurality of bearing surfaces, each of which cooperate with a corresponding bearing surface on its opposing slab so as to form a plurality of hinges within the pavement joint.

10 In one form, at least one face of the joint member includes two hinge bearing surfaces, these bearing surfaces extending from a distal end of the lateral portion of the joint member to a respective distal end of the spacers. In a particular form, these bearing surfaces
15 are concave.

In one form, the joint member includes a pair of hinges of the above type on each of its opposite faces. Therefore in this arrangement, the joint member
20 incorporates four (4) concave bearing surfaces each of which are part of a hinge of the joint.

In a particular embodiment, the joint member is elongate having a constant cross-section. In a particular
25 form, the joint member is formed in continuous lengths typically by an extrusion process.

In one form, the joint member is formed from a rigid polymeric material, such as PVC, HDPE, or a high
30 hardness rubber. In an alternative embodiment, the joint member from metal such as aluminium or made of composite construction, such as a steel reinforced polymeric material.

35 In a further aspect, the invention relates to a joint member for a pavement joint, the joint member having a joint axis and being arranged to be disposed between

contiguous pavement slabs, the joint member comprising opposite first and second faces that in use oppose respective ones of the edge surfaces of the slab, the first face incorporating a lateral portion that projects
5 outwardly from the face and is arranged to inter-engage with an edge surface of its opposing slabs so as to enable shear to be transferred from that slab to the joint member, and at least one bearing surface that engages with a bearing surface of its opposing slab and wherein the
10 inter-engagement of those bearing surfaces provides one of at least one hinge of the joint for accommodating angular displacement of the slabs relative to the joint axis in at least one direction.

15 In a particular embodiment, the second face also incorporates a lateral portion that projects from that face and is able to inter-engage with an edge surface of its opposing slab so as to enable shear to be transferred between that slab and the joint member. In one form, both
20 the first and second faces incorporate two bearing surfaces disposed on respective opposite sides of the lateral portions disposed on that face, the bearing surfaces being arranged to engage with respective bearing surfaces of the edge surfaces of the opposing slabs to
25 form four hinges of the joint.

In yet a further aspect, the present invention provides a method of inhibiting differential out-of-plane movement of contiguous slabs in a pavement under an out-
30 of-plane action applied to at least one of the slabs by incorporating pavement joints between the contiguous slabs, the joints being elongate and each extending along a joint axis and being capable of transferring shear between the slabs and accommodating angular displacement
35 of the slabs relative to the joint axis in at least one direction.

In yet a further aspect, the invention relates to a pavement slab that incorporates at least one profiled end surfaces which in use form a part of a joint with a contiguous pavement slab to allow shear to be transferred
5 across the joint and angular displacement of the slabs is accommodated. In one form, a joint member is disposed between the slabs.

BRIEF DESCRIPTION OF THE DRAWINGS

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It is convenient to hereinafter describe embodiments of the present invention with reference to the accompanying drawings. It is to be appreciated that the particularity of the drawings and the related description
15 does not supersede the generality of the preceding broad description of the invention.

In the drawings:

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Fig. 1 is a perspective view of a joint member according to a first embodiment;

Fig. 2 is a schematic elevation view of a pavement having joints incorporating the joint member of Fig. 1;

25 Fig. 3 is the pavement of Fig. 2 when subjected to an out-of-plane action;

Fig. 4 is a schematic view to an enlarged scale of a connection detail of the joint member of Fig. 1;

Fig. 5 is a variation of the joint member of Fig. 1;

30 Fig. 6 is a further variation of the joint member of Fig. 1;

Fig. 7 is a sectional view of an expansion joint for use in the pavement of Fig. 2;

Fig. 8 is a modified version of the expansion joint of Fig. 7;

35 Fig. 9 is a sectional elevation view of a pavement joint incorporating a joint according to a second embodiment;

Fig. 10 is a sectional elevation view of a pavement joint according to a further embodiment;

Fig. 11 is a variation of the joint of Fig. 10;

Fig. 12 is an schematic elevation view of a pavement joint according to a further embodiment;

Fig. 13 is a variation of the pavement joint of Fig. 12; and

Fig. 14 is a schematic plan view of a pavement testing rig; and

DETAILED DESCRIPTION

Fig. 1 illustrates a the joint member 20 arranged to be used in pavement joints 101, 102 (see Fig. 2 and Fig. 3). The joint member 20 allows shear to be transferred through the joints 101, 102 to the adjoining slabs and to accommodate angular displacement of those slabs about the joint axes CA^1 and CA^2 .

The joint member 20 incorporates a core 21, lateral portions 22 and 23 which extend outwardly from the core and which are angularly spaced apart about the axis CA by about 180° so as to extend on opposite sides of the core. The joint member also includes spacers 24 and 25 that project from the core. These spacers 24 and 25 are also spaced apart approximately through 180° about the core and also generally are at right angles to the lateral portions 22, 23 again giving the joint member 20 a cross-section that is somewhat akin to a crucifix.

The joint member 10 is elongate and typically formed from an extrusion process. The joint member 20 is of rigid construction and is formed from a suitable material such as PVC. In addition, in the illustrated form, the joint member includes a central cavity 26 which facilitates extrusion and which may be filled by another

extrusion if required with the joint member being made by a co-extrusion process.

Because of its rigid construction, the joint member
5 is not able to accommodate angular displacement of the
slabs about the joint axis CA by flexing or deformation of
the joint member which would otherwise enable the lateral
portions 22 and 23 to be angularly displaced relative to
one another. In contrast, in joint member 20 this angular
10 displacement is accommodated by relative movement of the
pavement slabs about the joint member.

To allow this movement, the joint member 20
incorporates a plurality of bearing surfaces 27, 28, 29
15 and 30. Two of the bearing surfaces 27, 28 are disposed
on one face 31 of the joint member 20 whereas the other
two bearing surfaces 29 and 30 are disposed on the
opposite face 32 of the joint member. Furthermore, the
bearing surfaces are arranged so that on any one face,
20 those bearing surfaces are disposed on opposite sides of
the lateral portions 22 and 23. With this arrangement,
the bearing surfaces of one face are arranged to inter-
engage with corresponding bearing surfaces disposed on the
edge surface of its opposing slab. These respective
25 inter-engaging surfaces each provide a hinge (37, 38, 39,
40), in the pavement joint 101 and 102.

As best illustrated in Fig. 1, the respective bearing
surfaces extend substantially from a distal end 33, 34 of
30 the respective lateral portions 22, 23 to a respective one
of the distal ends 35, 36 of the spacers 24 and 25.
Furthermore, each of the bearing surfaces are arcuate
(being concave). In particular, the arcuate surfaces are
shaped so that the action of the respective hinges (37,
35 38, 39, 40) formed by inter-engagement of the bearing
surfaces with corresponding bearing surfaces in the
pavement slabs is one of sliding rotation. This will be

discussed in more detail below with reference Figs. 2 and 3.

Fig. 2 illustrates a concrete pavement 100 formed from contiguous slabs 103, 104, 105 and having pavement joints 101, 102. The pavement joints 101 and 102 incorporate joint members 20. For convenience, reference to these joint members are given the superscript 1, or 2, with the features of those joint members given similar designations.

In the illustrated form, the pavement 100 is formed by casting of the slabs 103, 104 and 105 across the joint members 20^1 , 20^2 . In this way, the joint members both link and separate the slabs 103, 104 and 105. Specifically, the lateral portions 22^1 , 23^1 , 22^2 , 23^2 are embedded into the edge surface of respective slabs 103, 104 and 105 whilst the spacers 24^1 , 25^1 , 24^2 and 25^2 separates the slabs 103, 104 and 105 with the spacers extending to the respective slab surfaces 110, 111 of the pavement 100.

As illustrated in Fig. 2, the end surfaces 106, 107, 108 and 109 of the slabs 103, 104 and 105 are cast onto respective ones of the faces 31^1 , 32^1 and 31^2 , 32^2 and as a result, each of those end surfaces are formed with arcuate bearing surfaces 112, 113 which correspond to respective ones of the bearing surfaces 27, 28, 29 and 30 of the joint member 20.

The bearing surfaces of the joint member 20 are designed to be smoothly curved and in one form, the curve has a constant radius so as to form a hinge which operates by sliding rotation of the inter-engaging surfaces. This surface profile allows good even respective load distribution across the hinges. In one form, the shape of the bearing surfaces on the joint member is such that there is a change in radius. The purpose of this change

of curvature enables the effective point at which the pinching force is applied to one lifted slab to the joint member to be raised or lowered along that surface. For example, the curvature of these surfaces may be other than
5 circular such as elliptical and change over the length. In one form, there is a gradual increase in the radius from the respective distal ends 33 and 34 of the lateral portions 22, 23 towards the distal end of the spacers 24 and 25.

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In general, a pavement is subject to both direct and indirect actions. Direct actions include traffic loads and forces deriving from soil or foundation movement, and tree roots. In the case of footpaths, cycle ways and
15 domestic driveways for example, which are frequently built alongside trees, uplifting actions caused by tree roots are common. Uplifting or depressing actions can be seen as out-of-plane, relative to that of the pavement.

20 Indirect actions include drying (moisture) and temperature change. When a pavement is made from concrete, these actions cause both temporary and permanent volumetric changes that manifest in the form of expansion and contraction. Shrinkage, which is caused by drying,
25 can be seen in this sense as a form of permanent contraction. The effect of these actions is most significant in the plane of the pavement. For example, the unrestrained drying shrinkage of concrete is commonly in the order of 800 micro strain or 1.2 mm for a slab 1500
30 mm long. The coefficient of thermal expansion of concrete is commonly in the order of 12 micro strain per degree Celsius or approximately 0.4 mm in a slab 1500 mm long subjected to a temperature change of 20 deg C. If contraction is restrained, it may lead to cracking of the
35 concrete. If expansion is restrained it may lead to any or all of spalling and crushing of the concrete and buckling and warping of the pavement.

Commonly, provision for contraction of concrete pavements is made by incorporating contraction joints at relatively close intervals effectively dividing the pavement into a series of contiguous slabs. In the case of an un-reinforced concrete pavement such as a footpath, for example, contraction joints are commonly spaced at between 15 and 20 times the thickness of the pavement. For a 75 mm thick pavement, for example this implies joints at 1000 to 1500 mm. Provision for the expansion of concrete pavements, which are subjected to solar heating, such as roads and footpaths, is made by incorporating expansion joints, also known as isolation joints, at relatively wide intervals, commonly 4 to 5 metres. Thus external pavements commonly take the form of a series of contiguous slabs, both separated and linked by a combination of contraction and expansion joints.

In the embodiment illustrated in Fig. 2, the joints 101, and 102 form the contraction joints for the pavement 100. However, unlike conventional contraction joints, the joints 101 and 102 are able to accommodate out-of-plane action, typically by tree root invasion or by soil heave so as to inhibit differential vertical movement of the slabs. The mechanism by which the joints accommodate this action is best explained with reference to Fig. 3.

Turning to Fig. 3, the pavement 100 is shown displaced after the application of an out-of-plane action P, such as may occur through tree root invasion under slab 104.

Following the application of the force P to the slab 104, the load in that slab is transferred both to the slab 103 and to slab 105 through the respective joints 101, 102. In particular, in relation to joint 101, the slab 103 applies loading to the joint member 20¹ through the

bearing surface 27¹ as represented by the arrow p¹ and a reaction force p² is induced in its diagonally opposite bearing surface 29¹ by the other slab 103. As such, the joint member 20¹ transfers shear between the slabs 103 and 104 across the joint 101.

Again, if the load P is of sufficient magnitude, the slab 104 will lift. This lifting action will reduce the magnitude of the load and as such, this slab will continue to lift until such time as an equilibrium position is reached. This lifting action is not planar but rather is accommodated through the hinge mechanisms incorporated in the joints 101 and 102 that result in rotation of the slab 104. As such, again the threshold loading under which the slab 104 will lift is in part a function of the resistance provided to rotation through the joints 101 and 102 particularly as shear is able to be transferred to adjoining slabs so that individual slabs are not free to lift independently of one another.

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To enable the slab 104 to lift through rotation (in a clockwise direction as illustrated in Fig. 3) the hinges 39¹ and 39² become activated with the bearing surfaces 113¹ and 112² of the slab 104 moving across the bearing surfaces 27¹ and 29². With this movement, there is also a corresponding movement of the bearing surface 112¹ of slab 103 moving across bearing surface 29¹.

With this movement, as illustrated in Fig. 3, there is a tendency for the bearing surfaces 112¹ and 29¹ to come apart. The inventors have found that under increased angular displacement the joint member 20 may actually "flip" whereby in the context of the embodiment of Fig. 3, the bearing surface 27¹ moves out of contact with the bearing surface 113¹ of slab 104 and moves so that the bearing surface 29¹ moves into contact with the bearing

surface 112¹ of slab 103. With the action, the joint member 20 acts as a rocker.

Under this angular rotation, there is effective
5 lengthening of the slab 104. This rotation causes a closing up of the gap between the slabs 103 and 104 at the lower end of the joint 101 and a closing up of the gap between the slabs 104 and 105 of the upper end of the joint 102. Conversely, the gap at the upper end of the
10 joint 101 opens up whereas the gap at the lower end of the joint 102 closes.

This change in the gap distance between the slabs can be used to assist shear transfer across the joint 101 and
15 102 as the slabs are caused to pinch the joint member. Furthermore the amount and position of this "pinching force" can be modified by the radius of curvature provided in the respective bearing surfaces. In general, the pinching force is designed so that it is not greater than
20 that which would cause damage to the slab or the joint member.

Accordingly, under this operation the pavement 100 again effectively articulates about its respective joints
25 so as to accommodate the out-of-plane action. Through this articulation movement, there is minimal vertical differential movement at the joints 101, 102 between the adjoining slabs. The likelihood of damage to the slabs is greatly reduced as the joints 101 and 102 are able to
30 accommodate the rotation which effectively relieves the stress induced by this out-of-plane action P.

It is to be appreciated that whilst the above embodiment illustrates the pavement slabs 103, 104 and 105
35 of the pavement being cast in-situ, it will be appreciated that those slabs could be provided as pre-formed elements.

Fig. 4 shows a side view of the joint member 20 during installation. The joint member 20 incorporates voids 37 and bears against a face of the formwork 500 such that voids 37 of the joint member 20 align with the voids 501, 502 in the formwork 500. A peg 90 is then able to be inserted into the aligned holes. The peg 90 includes prongs 91, 92 that locate in aligned formwork voids and joint member voids. The pegs stabilise and support the joint member to inhibit it moving during a concrete pour. On curing of the concrete, the pegs are removed, and the formwork stripped leaving the contiguous slabs linked and separated by the joint members.

As will be appreciated, other methods can be utilised to support the joint member during casting. For example:

- a. Steel pegs are used and driven through near vertical pre-drilled holes in the joint member. The joint member may be laid in an excavated trench and pegs are driven into the earth holding the joint member in place;
- b. A "notched inserter tool" is used which goes over the top of the joint member and drives the joint member into the wet concrete; or
- c. An "inserting tool" is used which captures the top of the joint member by means of a number of "cams" that are tuned and locked on to the joint member holding the joint member in place.

Fig. 5 shows a further embodiment of the joint member 20. The joint member 45 shown in Fig. 5 shares many of the features of the joint member 20 and like features have been given like reference numerals.

The joint member 45 incorporates soft end portions 46, 47. These may be soft enough to accommodate compression on installation, such that the formulation of a gap may lead to the soft end portion expanding with the formation of the gap, and so maintaining a seal. In this

way the ingress of detritus into the gap is reduced. Further, at the lower portion, the soft end portions provide a compressive membrane which enables the joint member to better accommodate the lengthening effect of the
5 slabs as they angularly displace about the joint axis.

These end portions 46, 47 may be fitted using a mechanical engagement, like a clip 48, and 49. Alternatively, the end portions may be bonded to the joint
10 member 45 using adhesive or welding. In one embodiment, the end portions and joint member may be co-extruded, providing a seamless join between the differing materials of the joint member and the end portions.

15 Fig. 6 shows a further embodiment of the joint member 50, whereby, to add further rigidity, the joint member has a rigid core 51, surrounded by a softer coating 52. The rigid core 51, such as uPVC, steel etc provides the required rigidity for installation and shear force
20 resistance, and the outer coating of rubber, polypropylene, HDPE etc provides a positive grip with the concrete, when the joint member transfers the displacement.

25 Figs. 7 and 8 show alternative embodiments of the joint member 20 that are modified for providing expansion joints and construction joints between the contiguous slabs of the pavement. As indicated above, to permit a concrete slab to expand and contract thermally, it is
30 common practice to include expansion joints at predetermined intervals in the pavement. To ensure a gap does not appear through movement in the horizontal plane, expansion joints have the effect of a gasket between the slabs, for movement within the plane of the slabs. The
35 joint members 60 and 65 shown in Figs. 7 and 8 have been modified over the joint member 20 to provide this function. Nevertheless, the members 60 and 65 include many

of the features of the earlier embodiment 20, and like features have been given like reference numerals. Specifically, the joint members 60 and 65 include the lateral portions 22 and bearing surfaces 27, 28 on one face 32 of those members.

The joint members 60 and 65 include a second face 62, 67 that is generally planar so that those members may further act as partial stops for temporary cessation of construction. In conducting a partial pour of a pavement, it is beneficial to seamlessly continue the construction at a later time, either the following day, or months into the future. To ensure the process can continue smoothly, it is useful to form the desired shape in the free end of the slab, so that the new joint member can be fitted.

Fig. 7 shows the joint member 60 having an expansion portion 61 for bearing against an adjacent slab, or complimentary expansion joint. The expansion portion may be of rigid construction for acting as an end stop, or a softer material such as EPDM, to act as an expandable joint against the adjacent slab.

Fig. 8 shows a similar joint member 65 with expansion joint characteristics. In this embodiment an expansion portion 66 is bonded to the second face. In one form, the expansion portion is made from an expanded foam. Again, the expansion portion acts by bearing against an adjacent slab, or against a complimentary expansion joint.

Further, variations of the joints 101, 102 and corresponding joint members are illustrated in Figs. 9 to 13. As the pavement construction shown in these drawings include many of the features of the earlier embodiments like features have been given like reference numerals.

In the embodiment as illustrated in Fig. 9, the joints 101 and 102 incorporate a generally cylindrical joint member 70 which is embedded in the end surfaces of the slabs opposing the respective joints. The respective
5 joints also include compressible members 71, 72 which extend from the cylindrical joint member 70 to the outer surfaces 110, 111 of the pavement 100.

In the embodiment of Fig. 9, the shear is able to be
10 transferred through the joints 101, 102 through the cylindrical joint member 70¹, 70². In addition, the joint members are able to rotate about both joints with the outer surface 73¹ and 73² acting as bearing surfaces for the joint. Effective lengthening of the rotated slabs is
15 accommodated by the compressible material 71 and 72.

In the embodiment of Fig. 10 a somewhat similar arrangement is disclosed as to Fig. 10 except that rather than including a specific joint member 70, a tongue and
20 groove arrangement 75, 76 is provided at the joints 101 and 102. With this arrangement, one end surface of the slabs 103, 104 and 105 incorporate a groove 75 whereas the other end surface incorporates the tongue 76. Again compressible materials 71, 72 is provided between the
25 slabs and extend from the tongue and groove connection to the outer surfaces of the pavement 110, 111. The tongue and groove provide arcuate engaging surfaces that allow rotation of the slabs about the connection.

30 Fig. 11 shows a similar embodiment to that disclosed in Fig. 10. Again the joints 101 include a tongue and groove connection 75 and 76, compressible material 71 and 72 are provided between adjoining slabs 103, 104 and 105. In the embodiment in Fig. 11, at least one of those edge
35 surfaces of the slab is provided with a sheet covering. In the embodiment of Fig. 11 that sheet covering is formed from steel which provides permanent formwork for casting

of one edge surface of the slabs. Further, this sheet covering 77 is embedded within the cast slab so that it is secured in place. In addition, if required the compressible members 71, 72 can be applied to the outer surface of the sheet covering 77. It is to be appreciated that the arrangement of Fig. 11 could be further modified so that both surfaces incorporate a sheet covering so that the bearing surfaces within the tongue and groove connection are provided by inter-engagement of the surfaces of the sheet coverings.

Fig. 12 illustrates a simplified version of the joints 101, 102 as disclosed in Figs. 10 and 11. Specifically, in the arrangement of Fig. 12, the joints 101 and 102 are formed from solely from a tongue and groove connection 75, 76. Furthermore, in the embodiment of Fig. 15 the members include a gap 78 which allows for limited angular displacement of the respective slabs.

Fig. 13 discloses yet a further arrangement of joint 101 and 102. In the embodiment of the Fig. 13 the end surfaces of the respective slabs 103, 104 and 105 are shaped as gear teeth which enable shear to be transferred in the manner of gear teeth, and rotation to be accommodated by rolling, in the manner of a gear wheel. As the amount of rotation that needs to accommodate a relatively small angle (typically less than 5°) in the embodiment of Fig. 13 at joint 101, the end surface of one slab 104 includes a single gear tooth 79 whilst the opposing end surface of the slab 103 is profiled to include opposite shoulders 80, 81 which allow the gear tooth 79 to roll between the shoulders 80 and 81 through the limited angular displacement.

EXAMPLE

It is convenient to illustrate the operation of one of the embodiments of the pavement joint with reference to the following non-limiting examples.

Example

A full scale prototype concrete footpath was constructed at RMIT University, Melbourne, Australia. The prototype was 5m long, 1.5m wide and 75mm thick. It was cast on a steel frame, designed in such a way that the formwork could be removed from underneath and so that the prototype could be jacked up from virtually any point - to simulate various scenarios of tree root invasion and soil expansion/movement. Four joint members made from rigid PVC were installed in the footpath. They were 1.5 m apart from each other thus dividing the footpath into three 1.5 m long slabs, plus two 250 mm long end slabs. The ends of the footpath were restrained by steel angles. The cross-sectional shape of the joint member was substantially as the same as shown in Fig. 1.

The prototype was cast using concrete with a nominal strength of 40 MPa. Prior to casting, the slump of the concrete was measured at 90 mm. All tests were conducted after the cylinder strength of concrete of slabs exceeded 20 MPa. The 7 day mean compressive strength of the concrete was found to be 22.9 MPa.

A series of tests was conducted on the prototype, with both concentrated and distributed loads ranging from 0 to 490 kg, applied at different locations, to assess differential displacement between slabs.

First, the slabs were pushed up from underneath using a long piece of solid timber, a timber packer and a

hydraulic jack. The slabs were jacked up to a maximum of approximately 50 mm, measured at the central joint. No additional load was applied to the slabs at this point. The self-weight of each slab was about 400kg. Then,
5 uniformly distributed loads of 200kg, 400kg and 490kg were added to Slab 1. The layout of the test is shown in Fig. 14.

As the slabs were jacked up, the displacements at the
10 locations G3 to G6 were recorded by LVDT's. The displacements at the locations G1, G2, G7 and G8 were negligible. The maximum differential displacement without additional load on the slabs was 0.73 mm. The maximum displacement when 490 kg of distributed load was put on
15 Slab 1 was 2.03 mm.

In a 'worst case scenario' slab 2 was jacked up close to point G6 while a 200kg concentrated load was applied to slab 1 close to point G4. The maximum differential
20 displacement at point G6 was 2.49 mm.

When a slab was jacked up and no additional load was applied to the pavement, the joint member acted as if attached to jacked slab. As load was added, at a certain
25 point, the member flicked across to the other slab. It is felt that this indicates that the member acts as a rocker; a double hinge having a short range of rotation and which acts so as to distribute localised stresses favourably.

30 No distress was observed in the concrete in any of the above tests.

Accordingly, the present invention provides pavement joints, joint members and profiled slabs that allow a load
35 transfer mechanism that inhibits differential vertical movement of slabs when at least one of those slabs is affected by an out-of-plane action. This load transfer

mechanism is provided by the shear key which provides a means for transferring or equalising vertical displacement between the slabs. In addition one or multiple hinges are provided within the joint to provide a means of
5 accommodating angular displacement relative to the joint axis so as to provide a mechanism whereby the pavement may articulate to relieve stress induced by the out-of-plane action. The joints may incorporate joint members which locate between contiguous slabs or may be formed from a
10 profile of the slabs themselves.

The joint has widespread application for pavements of different types. These pavements may be formed from slabs which are cast in-situ or may be constructed using
15 preformed components or by a combination of both. The pavements may be used for light traffic such as footpaths or sidewalks or may find application in heavier traffic environments such as on roadways or the like.

20 In the claims which follow and in the preceding description of the invention, except where the context requires otherwise due to express language or necessary implication, the word "comprise" or variations such as "comprises" or "comprising" is used in an inclusive sense,
25 i.e. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the invention.

Variations and modifications may be made to the parts
30 previously described without departing from the spirit or ambit of the invention.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A pavement joint disposed between two contiguous pavement slabs, the joint being elongate and extending
5 along a joint axis and incorporating a shear key and co-operating bearing surfaces that form a plurality of hinges disposed on respective opposite sides of the shear key, the bearing surfaces being arcuate in cross-section so that the action of the hinges formed by the inter-engaging
10 bearing surfaces is by sliding rotation, the shear key and the hinges being operative when at least one of the slabs is subjected to out-of-plane action with the shear key transferring shear between the slabs, and the hinges accommodating angular displacement of the slabs relative
15 to the joint axis with the one or more hinges disposed on one side of the shear key accommodating angular displacement of the slabs about the joint axis in one direction and the one or more hinges disposed on the other side of the shear key accommodating angular displacement
20 of the slabs about the joint axis in the opposite direction.

2. A pavement joint according to claim 1, wherein each slab includes a profiled edge surface, and wherein the
25 profile edge surfaces inter-engage to form the shear key and the plurality of hinges.

3. A pavement joint according to claim 2, wherein the profiled edge surfaces form a tongue and groove
30 connection, the tongue being formed on one slab edge surface, and the groove being formed on the other edge surface.

4. A pavement joint according to claim 2, wherein each
35 slab has a respective one of the bearings surface along its edge surface.

5. A pavement joint according to any preceding claim, wherein the pavement incorporates a neutral axis and the plurality of hinges are spaced from, and disposed on opposite sides of, the neutral axis.

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6. A pavement joint according to any preceding claim, wherein the joint further comprises at least compressible member between the slabs, the member being arranged to be compressed by the slab edge surfaces on angular
10 displacement of the slabs about the hinge in the at least one direction.

7. A pavement joint according to claim 1, further comprising a joint member that is disposed between the
15 contiguous slabs.

8. A pavement joint according to claim 7, wherein each slab includes a profiled edge surface and wherein the joint member is formed from sheet material and is mounted
20 to one of the slabs so as to at least partially cover the edge surfaces of that slab, wherein the profiled edge surface of one slab incorporating the joint member inter-engages with the profiled edge surface of the other slab to form the shear key and the plurality of hinges.

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9. A pavement joint according to claim 8, wherein at least one of the slabs is formed from settable material and the joint member is cast into an end surface of that slab.

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10. A pavement joint according to claim 8 or 9, wherein the joint member forms at least part of one of the bearing surfaces of the hinges, and wherein its co-operating bearing surface is formed on the other slab.

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11. A pavement joint according to claim 9, wherein the shear key of the joint is at least partially provided by

inter-engagement of at least one of the contiguous slabs with the joint member.

12. A joint member for a pavement joint, the joint member
5 having a joint axis and being arranged to be disposed
between contiguous pavement slabs, the joint member
comprising opposite first and second faces that in use
oppose respective ones of the edge surfaces of the slab,
the first face incorporating a lateral portion arranged to
10 inter-engage with an edge surface of its opposing slabs so
as to enable shear to be transferred from that slab to the
joint member, and two bearing surfaces disposed on
respective opposite sides of the lateral portion, the
bearing surfaces being engageable with respective bearing
15 surfaces of the edge surface of its opposing slab to form
two hinges of the joint, the bearing surfaces of the joint
member being arcuate in cross-section, so that the action
of the hinges formed by the inter-engaging bearing
surfaces is by sliding rotation with the one hinge
20 accommodating angular displacement of the slabs about the
joint axis in one direction and the other hinge
accommodating angular displacement of the slabs about the
joint axis in the opposite direction.

25 13. A pavement joint or joint member according to any one
of claims 7 to 12, wherein the joint member incorporates a
core, and first and second lateral portions that project
from the core, the lateral portions being angularly spaced
apart about the joint axis and inter-engage with the edge
30 surfaces of respective ones of the slabs so as to enable
shear to be transferred across the contiguous slabs
through the joint member.

14. A pavement joint or joint member according to any one
35 of claims 7 to 13, wherein the joint member further
comprises at least one spacer that projects from the core,
the at least one spacer locating between the contiguous

slabs and being angularly spaced about the joint axis from the lateral portions.

5 15. A pavement joint or joint member according to any one of claims 7 to 14, wherein the joint member includes two spacers that are angularly spaced apart about the joint axis with a respective spacer being disposed between respective ones of the lateral portions.

10 16. A pavement joint or joint member according to any one of claims 7 to 15, wherein the joint member incorporates opposite first and second faces that are in opposing relation with respective ones of the edge surfaces of the slabs, each face incorporating respective one of the
15 lateral portions and wherein the first face incorporates two bearing surfaces disposed on respective opposite sides of the lateral portion, the bearing surfaces engaging with respective bearing surfaces of the edge surface of the opposing slab to form two hinges of the joint.

20 17. A pavement joint or joint member according to any one of claims 7 to 16, wherein both the first and second faces incorporate two bearing surfaces disposed on respective opposite sides of the lateral portions disposed on that
25 face, the bearing surfaces engaging with respective bearing surfaces of the edge surfaces of the opposing slabs to form four hinges of the joint.

30 18. A pavement joint or joint member according to any one of claims 7 to 17, wherein the bearing surfaces have a constant radius.

35 19. A pavement joint or joint member according to claim 19, wherein the radius of curvature varies across the bearing surfaces.

20. A pavement joint or joint member according to any one of claims 7 to 19, when dependent on claim 15, wherein the

bearing surfaces of the joint member extend from a distal end of the lateral portion to a respective distal end of the spacers.

- 5 21. A pavement joint or joint member according to claim 20, wherein the radius of curvature of the bearing surfaces increases from the distal end of the lateral portions towards the distal ends of the joint member.
- 10 22. A pavement joint or joint member according to any one of claims 11 or 12, wherein the joint member incorporates opposite first and second faces that oppose respective ones of the edge surfaces of the slab, wherein the first face incorporates a lateral portion that is able to inter-engage with an edge surface of its opposing slabs so as to enable shear to be transferred between that slab and the joint member.
- 15 23. A pavement joint or joint member according to any one of claims 7 to 22, wherein the joint member incorporates compressible material so that said joint is able to act as an expansion joint.
- 20 24. A pavement joint or joint member according to any one of claims 7 to 23, wherein the bearing surfaces are profiled as gear teeth, the gear teeth inter-engaging to provide the shear key and the hinges, and wherein the hinges accommodate angular displacement by rolling contact between the inter-engaging gear teeth.
- 25 25. A pavement joint or joint member according to any one of claims 7 to 24, wherein the joint member has a constant cross section perpendicular to the joint axis.
- 30 26. A pavement joint or joint member according to any one of claims 7 to 25, wherein the joint member is formed from a polymeric material.
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27. A pavement slab having at least one profiled edge surface that in use forms part of a joint between that slab and another slab, the joint allowing shear to be transferred to the other slab, and to accommodate angular displacement of the slabs about an axis of the joint, the profiled edge surface incorporating a lateral portion arranged to inter-engage with an edge surface of an opposing slab so as to enable shear to be transferred from that slab to the joint, and two bearing surfaces disposed on respective opposite sides of the lateral portion, the bearing surfaces being engageable with respective bearing surfaces of the edge surface of its opposing slab to form two hinges of the joint, the bearing surfaces being arcuate in cross-section, so that the action of the hinges formed by the inter-engaging bearing surfaces is by sliding rotation with the one hinge accommodating angular displacement of the slabs about the joint axis in one direction and the other hinge accommodating angular displacement of the slabs about the joint axis in the opposite direction.

28. A method of inhibiting differential out-of-plane movement of contiguous slabs in a pavement under an out-of-plane action by incorporating pavement joints between the contiguous slabs, the joints being elongate and each extending along a joint axis and being capable of transferring shear between the slabs and accommodating angular displacement of the slabs relative to the joint axis at a plurality of hinges formed by sliding rotation of cooperating arcuate bearing surfaces of the joint, the pavement incorporating a neutral axis and the plurality of hinges being spaced from, and disposed on opposite sides of, the neutral axis.

29. A method according to claim 28, wherein the joints include respective joint members and the shear is transferred between the slabs through the joint members.

30 . A method according to claim 28, wherein the joints accommodate angular displacement of the slabs about their joint axes by sliding rotation of a bearing surface of one slab with a bearing surface of a contiguous slab.

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31 . A method according to claim 29, wherein the joints accommodate angular displacement of the slabs about their joint axes by sliding rotation of bearing surfaces of respective contiguous slabs with bearing surfaces disposed on opposite faces of the joint members disposed between those slabs.

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32 . A pavement joint disposed between two contiguous pavement slabs, the joint being elongate and extending along a joint axis and incorporating a shear key and co-operating bearing surfaces that form at least one hinge, the bearing surfaces being arcuate in cross-section so that the action of the at least one hinge formed by the co-operating bearing surfaces is by sliding rotation, the shear key and the at least one hinge being operative when at least one of the slabs is subjected to out-of-place action with the shear key transferring shear between the slabs, and the at least one hinge accommodating angular displacement of the slabs relative to the joint axis in at least one direction by movement of one bearing surface relative to the other, wherein the joint further comprises at least one compressible member between the slabs, the member being arranged to be compressed by the slab edge surfaces on angular displacement of the slabs about the hinge in the at least one direction.

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