Nov. 19, 1963 A. B. FARBISH **3,111,069**

PAVING JOINT CONSTRUCTION

Filed Aug. 13, 1962 2 Sheets-Sheet 1

FIG.1.

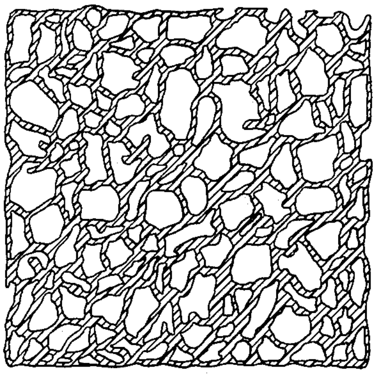

FIG.2.

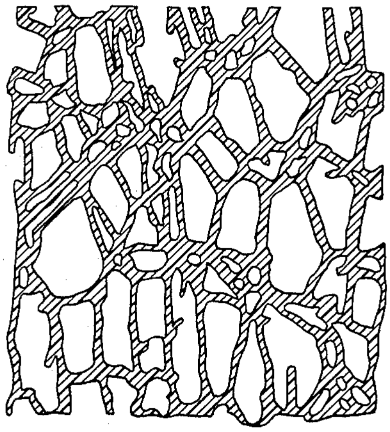

FIG.3.

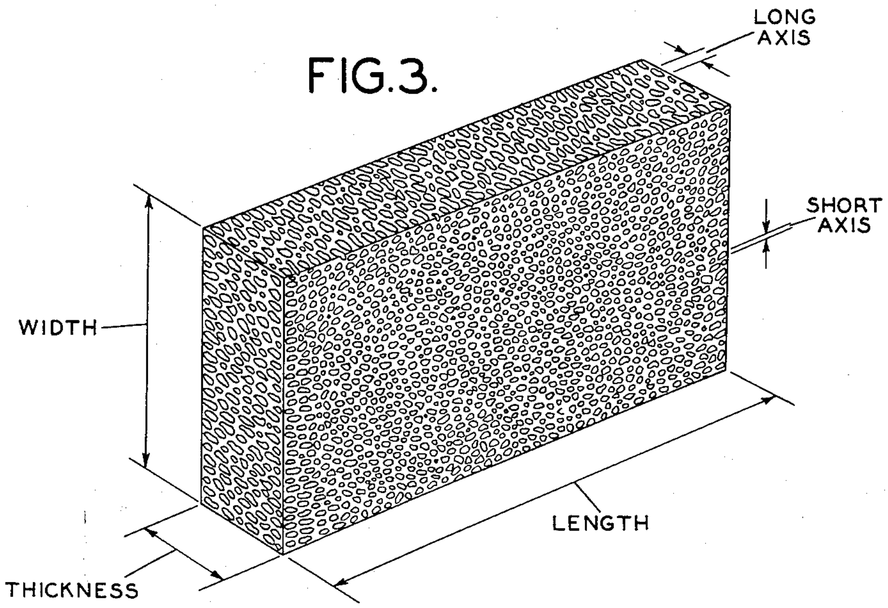

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FIG.4.

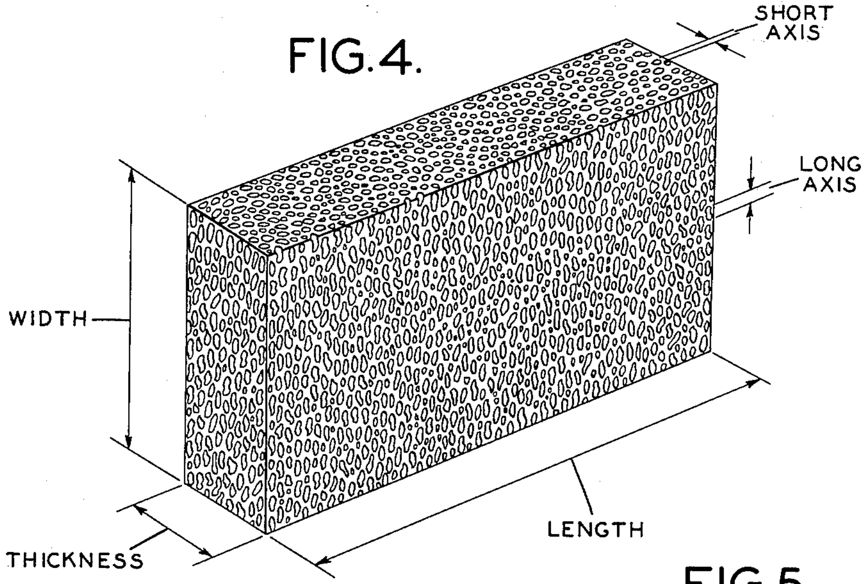


FIG.5.

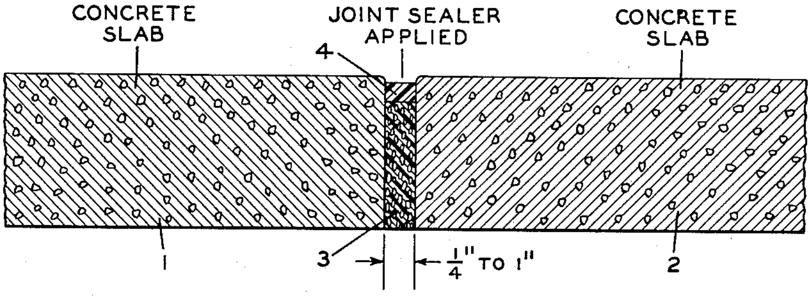
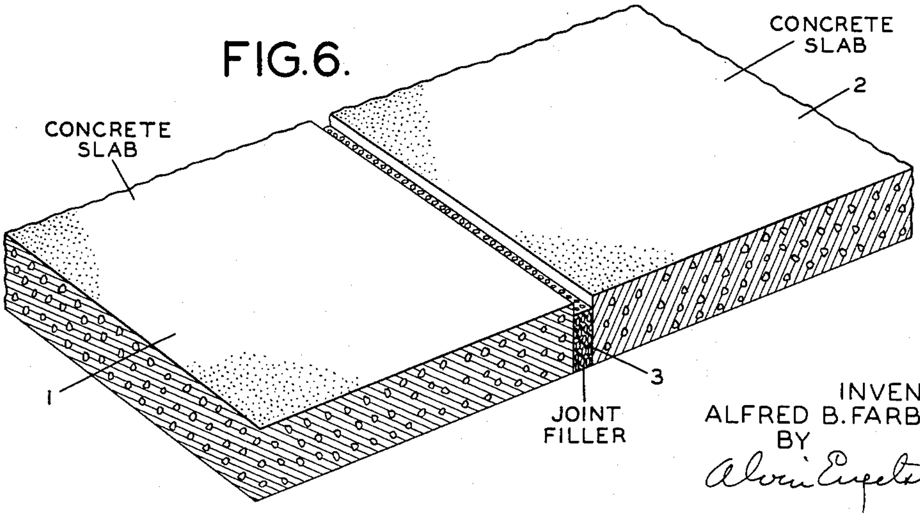


FIG.6.



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3,111,069
PAVING JOINT CONSTRUCTION

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2 Claims. (Cl. 94—18)

This invention relates to paving joint construction and more particularly refers to a new and improved traffic construction material for expansion joints and a paving joint construction in which abutting concrete slabs are spaced apart with the new traffic joint positioned in the space between the abutting concrete sections.

Traffic joint fillers are materials positioned between concrete sections, generally while the concrete is being poured in place. Such fillers are designed to form resilient buffers between the abutting slabs of concrete to take up the shock of expansion and to keep the joints substantially water-tight during periods of contraction of the concrete. If these fillers are not employed the slabs will warp and/or buckle, crack or "spall." The provision for movement which these units permit at predetermined locations prevents the development of stresses which may warp the concrete.

In the United States and Canada the approximate use of expansion joint fillers exceeds 50,000,000 square feet per year. The most common applications are in transverse and longitudinal expansion joints for concrete highways, airfields, bridges, floors and sidewalks. Wherever concrete abuts concrete or steel or other construction materials, expansion joints are customarily employed.

The types of materials used for expansion joints are usually divided into three groups. The first is by far the most widely used and is employed where the joint is not expected to enlarge beyond its original width; it includes moderately resilient products typical of which are bituminous fibers, fiber glass and cork and asphalt compositions. In addition, a filled asphalt expansion joint is used for similar purpose. The second group includes fully resilient materials such as sponge rubber, cork granules molded with a resin binder and certain flexible cellular foams. The third group is utilized where the joint is expected to open wider than its original size and a typical product example is self-expanding cork.

Disadvantages of materials commonly used in the first group are (1) in the case of fiber expansion joint there is a tendency to break when cut into the long narrow strips usually required for application; (2) inability to conform to curved or irregular objects without breaking or cracking as in the installation of an expansion joint around a light pole; (3) high resistance to compression (e.g. 500–1000 p.s.i. which is normally required to compress the material to 50 percent of its original thickness) can cause spalling in the portion of the concrete slab adjacent to the joint by the reaction against a pebble or other small incompressible object which may become lodged in the joint; (4) a tendency to delaminate during service and consequently permits access of water into the structure causing formation of ice lenses and admission of water to the substrate. In addition, when the materials extrude from the joints due to the expansion of the concrete they have the tendency to remain extruded rather than to regain their original forms; this causes much of the objectionable thumping experienced by motorists on concrete roads.

During periods of dropping temperatures, when concrete slabs contract and open the joints, recovery of the commonly used joint fillers is often slow. Fiber glass is subject to most of the cited disadvantages and also tends to break apart in the joints and results in loss of effectiveness. Cork asphalt also has most of the disadvantages

of fiber expansion joints and, in addition, presents an even greater extrusion problem. The most common objections to the second group of joint fillers described above are their inordinately high costs and their strong tendency to "creep up" out of the joints. The third type of materials very frequently begin to expand before they are used making them unfit for application. From the foregoing it will be evident that although many materials have been tried and used as joint fillers in paving joint construction, these materials are lacking in one or more of the desired properties for the purpose and considerable improvement is indicated.

An object of the present invention is to provide an improved paving joint construction in which abutting concrete sections have positioned in a narrow space between the abutting concrete sections a new and novel traffic joint filler. Another object of the present invention is to provide an efficient paving joint construction composed of abutting concrete sections with an improved joint filler in the space between the abutting concrete sections which will permit the concrete sections to expand and contact while preventing entry of water in the space and the extrusion of filler above the surface of the concrete section. A further object of the present invention is to provide an economical joint filler of unitary construction which is eminently suitable for paving joint construction. Other objects and advantages will be apparent from the following description and accompanying drawing.

As described above, many materials have been tried and used as traffic joint fillers but because of the deficiencies of these materials there is a continuing search by numerous workers in the field for a new and improved traffic filler which will overcome the disadvantages of the fillers known in the art. Among the materials considered were conventional polyurethane foams which were used for other purposes. Superficially such polyurethane foams would appear to be an excellent material as an expansion joint filler in that these foams can be made of a closed-cell construction to prevent penetration of water, are light weight, are impervious to oils and hydrocarbons, are unitary in construction and can be manufactured at a relatively low cost. Unfortunately, on testing conventional urethane foam it was found that when the foam was subjected to compression (as would occur when such foam would be subjected to compression by abutting concrete sections) the cells would rupture destroying their water impermeability and permit ingress of water. Since one of the most important properties of expansion joint fillers is the retention of an integral watertight structure, a material in which the cells break is no longer water impervious and satisfactory in service. Ice lenses forming within the structure would have the effect of breaking of the material and could in time lead to the destruction of the joint. In addition, water passing through the joint filler (as it would if the joint were not impervious) would tend to scour the subgrade out from under the slab leading to consequent pumping of the slab and its ultimate fracture. Another important property of a joint filler is its availability to recovery after compression i.e. the availability of the filler to return to its orignnal shape when the concrete sections contract and to fill the increased space left by such construction. Indeed this recovery is the procedure prescribed in AASHO Specification M–153 which requires a minimum recovery of 65%. In conventional polyurethane foams as a result of the destruction of cell structure the recovery was relatively low.

In the manufacture of polyurethane cellular materials, it is well known to react a polyfunctional, active hydrogen containing polyester, polyesteramide or preferably a polyether with an organic polyisocyanate. Foamed products can be obtained by carrying out this reaction in the presence of a blowing agent e.g. carbon dioxide produced by the reaction of excess polyisocyanate with water or a halogen substituted alkane which is volatilized by the heat generated in the polymerization reaction.

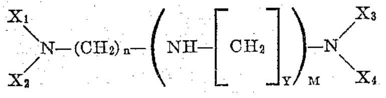
The polyethers are obtained by condensation of an alkylene oxide, such as ethylene oxide, propylene oxide, styrene oxide, or mixtures of these alkylene oxides with polyhydric alcohols and/or polyhydric phenols in the presence of suitable basic catalysts, such as trialkylamines, e.g. trimethylamine or inorganic bases, e.g. KOH. The polyols, that is polyhydric alcohols or polyhydric phenols, suitable for producing the preferred polyethers include for example glycerol, trimethylol propane, hexanetriol, fructose, hexitol, sobitol, maltose, sucrose, triphenylolethane, tetraphenylolethane, triphenylolpropane, resorcinol, pyrogallol, Bisphenol A, chlorinated diphenol, mixtures of the above compounds and mixtures of these compounds with water. (Polyethers corresponding to these types are described in U.S.P. 2,902,478; U.S.P. 2,927,918 and Belgian P. 584,738.)

The polyisocyanates employed for reaction with the polyol to produce the polyurethane foam have the general formula $R(NCO)_x$ wherein R is a hydrocarbon radical preferably an aromatic hydrocarbon and *x* represents a whole number of at least 2 generally 2–4. Illustrative examples of the polyisocyanates are m-phenylene diisocyanate, p-phenylene diisocyanate, 4,4′-diphenylmethane diisocyanate, 1,5-naphthalene diisocyanate, 1-chloro-3-methyl-benzene-4,6-diisocyanate and preferably tolylene diisocyante usually used as a mixture of 2,4 and 2,6 isomers.

In accordance with conventional practices for producing polyurethane forms the tolylene diisocyanate composition and polyether containing a plurality of hydroxyl groups are reacted in the presence of various additives, such as blowing agents, activators or catalysts, and dispersing agents or emulsifiers.

Examples of blowing agents for use in the present invention include carbon dioxide (produced by reaction of water and the diisocyanate) and fluorinated aliphatic saturated hydrocarbons as well as mixtures of these agents. The preferred blowing agent for the purposes of the present invention is one or can be a mixture of the group of compounds exemplified by the following particular members: monofluorotrichloromethane; dichlorodifluoromethane; monochlorotrifluoromethane; trichlorotrifluoroethane; dichlorotetrafluoroethane; tetrachlorodifluoroethane; 1,1 - difluoroethane; 1,1,1-chlorodifluoroethane. These fluorinated aliphatic blowing agents are characterized by being liquids or gases at normal temperatures and pressures, poor solvents for the organic polymer, and boiling at temperatures below that generated by the polyurethane formation reaction. They, preferably, have a significant solubility in the tolylene diisocyanate compositions and when in the gaseous state have a molecular size such that they do not readily diffuse through the interstices of the polyurethane molecules at ambient temperatures.

Examples of compounds for use as accelerators or catalysts include (1) conventional tertiary amine catalysts, such as triethylamine, N-methylmorpholine, triethylenediamine, N,N,N′,N′-tetramethyl-1,3-butanediamine; (2) tertiary amines containing hydroxyl groups and capable of crosslinking the polyurethane, that is compounds of the general formula

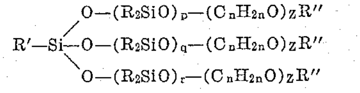


$$\begin{matrix} X_1 \\ \quad\diagdown \\ \end{matrix} N-(CH_2)_n-\left(NH-\left[CH_2\right]_Y\right)_M-N \begin{matrix} \diagup X_3 \\ \diagdown X_4 \end{matrix}$$

$$(X_1)(X_2)N-(CH_2)_n-\left(NH-\left[CH_2\right]_Y\right)_M-N(X_3)(X_4)$$

wherein X_1, X_2, X_3 and X_4 can be the same or different and are represented by the group H— ((O-alkylene)$_z$ in which *z* is from 1 to 4, alkylene means a divalent aliphatic saturated hydrocarbon radical containing from 1 to 10 C atoms, also one of X_1, X_2, X_3 and X_4 can be an alkyl group containing up to 20 C atoms; *n* is an integer from 1 to 10, preferably 2 or 3; M is 0 or an integer from 1 to 3; and Y is an integer from 1 to 10; such compounds include tetra(hydroxyethyl)ethylenediamine, tetra-(hydroxypropyl)ethylenediamine, condensation product of propylene oxide and di(ethylenediamine) and N-coco-N,N′,N′-tri(hydroxyethyl)ethylenediamine; and (3) organo-tin compounds such as tin hexanoate, tri-n-butyltin acetonate, bis(2-ethylhexyl)tin oxide, di-n-butyltin diacetate, di-n-butyltin dilaurate, di-n-butyltin dichloride and di-n-butyltin di(2-ethylhexanoate). These catalysts and/or accelerators can be used alone or mixtures of one or more of the three types can be utilized.

Examples of emulsifiers or dispersing agents include polyethylene phenol ethers, blends of polyalcohol carboxylic acid esters, oil soluble sulfonates and siloxane-oxyalkylene block copolymers. The preferred emulsifiers for the purposes of the present invention are the siloxane-oxyalkylene block copolymers of the general formula



$$R'-Si\begin{cases} O-(R_2SiO)_p-(C_nH_{2n}O)_ZR'' \\ O-(R_2SiO)_q-(C_nH_{2n}O)_ZR'' \\ O-(R_2SiO)_r-(C_nH_{2n}O)_ZR'' \end{cases}$$

wherein R, R′ and R″ are C_{1-8} alkyl radicals; *p*, *q* and *r* are each 2 to 15 and $-(C_nH_{2n}O)_Z-$ is a polyoxyalkylene block which is preferably a polyoxyethylene-polyoxypropylene block containing from 10 to 50 of each oxyalkylene unit; products of this type are covered in U.S.P. 2,834,748 and their use in polyurethane foam preparation is the subject of Belgian P. 582,362–3. Such siloxane-oxyalkylene block copolymers are commercially available; one of the commercial types is "Silicone L–520" marketed by Union Carbide Chemical Co., referred to in the examples as "silicone emulsifier," in which general formula above $R=CH_3$, $R'=C_2H_5$, $R''=C_4H_9$, $p=q=r=7$ and the block $-(C_nH_{2n}O)_Z-$ is a polyoxyethylene-polyoxypropylene block containing 50 oxyethylene and 50 oxypropylene units.

The rigid polyurethane foam compositions known in the art may and usually do contain in addition to the isocyanate active hydrogen containing components crosslinking agents, polymerization catalysts and emulsifying agents, fire retardant agents, auxiliary blowing agents, pigments and the like. Illustrative examples of these well-known agents are: Fire retardant agent, antimony oxide, bis-(2,3 - dibromopropyl)phosphate, tri - (chloroethyl)phosphate, chlorinated hydrocarbons; and pigments, copper phthalocyanine, hexadecachlor copper phthalocyanine, 1 mol tetrazotized o-anisidine coupled into 2 moles of acet-1,2,4-xylidide, Nigrosine Blacks and the like. The formulation curing and application treatments of such compositions are well known to those skilled in the art to which the specific compositions of this invention pertains and accordingly no extended discussion of these well-known collateral aspects of the invention is believed necessary.

Polyurethane foams are conventionally prepared by pouring the active ingredients namely polyisocyanate and polyether together with blowing agent and the usual additives such as catalyst and dispersing agent into a shallow trough or pan which for example has the dimensions of about 4–10 feet long, 2–4 feet wide and a height of about 6–12 inches. The polyisocyanate and polyol react to form a polyurethane foam having a length and width corresponding to that of the interior of the shallow pan and a height of several inches. After completion of the reaction this block of foam is removed from the pan and sliced horizontally to produce several boards of the desired thickness usually about ½ inch to 1 inch thickness. In the course of investigation of the problems concerning joint fillers and their application, and, more particularly, those of the polyurethane cellular board, it was found that such boards upon compression resulted in material destruction of the closed cell structure and low recovery. Because of the other desirable properties of polyurethane foam a further study of cellular polyurethane foam was continued to determine the cause of rupture of the cell and low recovery upon compression. Sections of cells in standard foam were taken and examined and it was found that the cells were not generally globular or spherical in shape but are more in the nature of an elliptical oval or egg-shaped with the longer axis being about 40–300% greater than the shorter axis of the cell. Merely as illustrative the cells would have an average diameter of shorter axis of about 10 mils and an average diameter of the longer axis of about 18 mils.

FIGURE 1 illustrates a section of foam cut across the short axis of the cells.

FIGURE 2 illustrates a section of foam taken across the longer axis.

FIGURE 3 illustrates the cell structure of a standard polyurethane cellular board.

FIGURE 4 illustrates a board in which the short axis is parallel to the forces of compression and the long axis perpendicular to the forces of compression.

FIGURE 5 is a vertical section of a paving joint construction.

FIGURE 6 is a perspective of a paving joint construction.

In the conventional cellular polyurethane board it was found that the long axis of the cells are parallel to the forces of compression to which a board would be subjected by expansion of abutting concrete.

As a result of the inherent cellular structure of standard polyurethane cellular board in which the long axis of the cell is parallel to the forces of compression applied to the side of the board as occurs upon expansion of abutting concrete there results rupture of a material portion of the cell structure and low recovery and greater absorption of water. Consequently conventional polyurethane cellular board was undesirable as traffic construction material. Upon further investigation it was found that the cells were elongated in the direction of foam rise during the production of the foam by reaction of a polyisocyanate with a polyol in the presence of a blowing agent. With this information the method of manufacture of cellular polyurethane board was altered. The active polyurethane foam forming constituents were introduced into a deep trough or pan i.e. a depth or height of at least 1 foot preferably about 2–4 feet and of the desired length and width generally about 5–15 feet long and about 2–4 feet wide. After the block of foam has formed it is removed from the pan and cut into panels or boards generally about ⅛ inch to about 4 inches, preferably about ¼ to 2 inches, thickness. It is most important that these panels be cut vertically i.e. parallel to foam rise to obtain a panel in which the long axis of the cells are perpendicular to the forces of compression as are obtained when applying pressure to the sides.

The joint filler of the present invention is a closed cell urethane foam panel or board having a thickness of about ⅛ inch to about 4 inches, preferably ¼ to 2 inches, a width and length at least several times the thickness, generally a width of about 1–4 feet and a length of about 5–15 feet, said cells having an elongated shape generally a three dimensional irregular polygon with the long axis of the cell appreciably greater than the short axis generally with the long axis about 40–300% greater than the short axis and with said cells arranged so that the long axes of the cells are perpendicular to thickness edge surface and parallel to the width edge surface, said panel being further characterized by having a density of about 1–4 preferably 1½ to 2½ lbs./cu. ft., a low requirement for compression to 50% original thickness of 20–45 lbs./sq. inch, and a recovery after compression to 50% original thickness of about 75–95%. The urethane joint filler of the present invention has a high order of flexibility. Strips of ½–1 inch thickness may be bent on curves of 6–10 inch radius without breaking. This quality lends itself very well to forming expansion joints between curved and/or irregular surfaces. Recovery from compression is between 75 and 95 percent of original thickness and extrusion is on the order of 1/10 inch. Unlike other moderately resilient joint fillers, recovery is virtually instantaneous, eliminating the possibility of open joints during periods of rapid contraction of the slab.

Because of its properties of indenting under low stress, the urethane joint filler will not spall adjacent concrete if small pebbles or other incompressibles fall into the joint. Other materials having a high resistance to point stresses will set up enough reaction force to break away corners of abutting slabs.

The urethane expansion joint is highly flexible and will make a perfect joint around curved or irregular objects. At the same time, any bowing which might take place when fresh concrete is poured on one side of the joint and then immediately on the other side after removal of the form as is common in sidewalk construction, readily corrects itself. Edging is easier with this material as there are in fibers to catch the tool. The light weight and ease in cutting the urethane joint filler make it much easier for contractors to handle, while its homogeneous structure is insurance against delamination during service in the joint. The urethane joint filler exceeds the specification requirements of AASHO M–153—Type III; Federal Specification HH–F–341—Type I, Class B; U.S. Army Corps of Engineers; and most State Highway, City and County specifications.

In paving joint construction the cellular joint filler is disposed intermediate between the sections of concrete that is to be poured and supported in the usual manner by dowels or other suitable means. Other concrete is then poured to fill the sections on both sides of the joint filler. The particular advantage of the urethane cellular filler is that on pouring of concrete it binds and forms a strong union with the concrete.

FIGURE 5 illustrates a paving joint construction with two abutting concrete slabs designated 1 and 2 between which is disposed the joint filler 3 which extends a short distance below the top surface of the concrete slabs. The space above the joint filler may be filled with a conventional mastic 4 termed in the art joint sealer, although if desired the joint filler may be extended almost flush with the top surface of the concrete and the joint sealer dispensed with.

FIGURE 6 is a perspective of a paving joint construction with abutting concrete slabs 1 and 2 and disposed therebetween joint filler 3. Joint sealer not shown in FIGURE 6 may then be applied to the top surface of joint filler 3.

The following example illustrates the present invention. The formulation for producing the foam is as follows:

	Pounds
Polyether triol	900
Trichloromonofluoromethane	316
Tetra(hydroxypropyl)ethylene diamine	84
Dibutyltindilaurate	2
Silicone emulsifier	8
Tolylene diisocyanate	770
	2080

All of the chemicals except the tolylene diisocyanate are carefully measured into 150 gallon mixing tank and are thoroughly mixed and cooled to a temperature of about 60° F. The tolylene diisocyanate is charged to a 40 gallon tank and is cooled to about 60° F. The contents of these two tanks are carefully metered through positive displacement pumps into a mixing head. The mold box is basically a plywood box 16 inches wide by 100 inches long by 40 inches deep with the sides hinged so that they can be dropped down to remove the finished cake. Into the mold box is introduced from the mixing head the foam formulation which issues as a liquid and is distributed over the bottom of the mold box in about one minute. As soon as the liquids are mixed in the head a chemical reaction starts. As the liquid lies in the bottom of the mold box this reaction continues, heat is evolved and when the liquid reaches the temperature at which the trichloromonofluoromethane boils (77° F.), the trichloromonofluoromethane is vaporized and the whole mass becomes a foam. The time while the liquid lies in the box and before it starts to foam is the "cream" time or induction time and normally varies between about 30–90 seconds. The foam rises up and fills the box in a period of about 2–3 minutes. The foam cakes are removed from the mold box after about 10 minutes set time. At this point the cake is firm enough to handle but still somewhat plastic and should be stored on a relatively flat surface for a period of about 24 hours to permit final curing. After curing the cake is transferred to a hot wire cutting machine. The cake is placed on a moving belt and is moved through a grid of Nichrome wires heated electrically to a dull heat, and thereby divided into boards or panels of 1 inch thickness. It is important that cutting be done vertically i.e. in the direction of the foam rise in order to obtain the proper alignment of cell structure to provide the desired compressive recovery.

In the table below are given the properties of the resultant panels. These properties meet or exceed specification requirements of AASHO M—153—Type III.

Properties

Compression:	
Load required to compress specimen to 50% original thickness	25–40 p.s.i.
Recovery:	
Percent of original thickness after three applications of loading to compress to 50% original thickness	75–90%.
Extrusion:	
Extrusion of free edge when compressed to 50% thickness with three edges restrained	1/16″–1/8″.
Accelerated weathering and freeze-thaw:	
Artifically aged at 165° F. for 3 days 10 cycles of freeze-thaw (−4° F. freeze, 75° F. thaw in water)	No effect.
Percent closed cells	90%.
Moisture vapor transmisison	1–2 perms/inch.
Water absorption	None, except in broken surface cells.
Density	1.8–2.0 lbs./cu.ft.

Although certain preferred embodiments of the invention have been disclosed for purpose of illustration, it will be evident that various changes and modifications may be made therein without departing from the scope and spirit of the invention.

I claim:

1. A paving joint construction in which abutting concrete sections are spaced apart with a joint filler positioned in the space between the abutting concrete sections, said joint filler consisting of a closed cell urethane foam panel having a thickness of about 1/8 to about 4 inches, a width and length at least several times the thickness, said cells in the panel having an elongated shape with the major axes of the cells about 40 to 300% greater than the short axes, and with said cells arranged so that the major axes of the cells are perpendicular to the thickness edge surface and parallel to the width edge surface, said panel being further characterized by having a density of about 1–4 lbs./cu.ft., a low requirement for compression to 50% original thickness of 20–45 lbs./sq. inch, a recovery after compression to 50% original thickness to about 75–95%, and a flexibility to permit bending on curves of 6–10 inch radius without breaking.

2. A paving joint construction in which abutting concrete sections are spaced apart with a joint filler positioned in the space between the abutting concrete sections, said joint filler consisting of a closed cell urethane foam panel having a thickness of about 1/4 inch to about 2 inches, a width of about 1 to 4 feet and a length of about 5 to 15 feet, said cells in the panel having an elongated shape with the major axes of the cells about 40–300% greater than the short axes, and with said cells arranged so that the major axes of the cells are perpendicular to the thickness edge surface and parallel to the width edge surface, said panel being further characterized by having a density of about 1½ to 2½ lbs./cu.ft., a low requirement for compression to 50% original thickness of 20–45 lbs./sq. inch, a recovery after compression to 50% original thickness to about 75–95%, and a flexibility to permit bending on curves of 6–10 inch radius without breaking.

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