Gap-Graded Cold Asphalt Concrete: Benefits of Polymer-Modified Asphalt Cement and Fibers

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Currently in France, the cold asphalt concrete market is growing, with microsurfacing increasingly replacing and giving better results than chip seal surface dressings. As part of the promotion of cold asphalt concrete in France, one contractor recently developed the first gap-graded cold mix. The use of polymer-modified asphalt emulsions and synthetic fibers made this practical. The binder is a cationic, ethylene vinyl acetate modified asphalt emulsion specially formulated to have controlled slow-setting characteristics. Both long- and short-term benefits are derived from the addition of fibers. The fibers initially increase the viscosity of the emulsion, so that gap-graded formulations can be placed without segregation. After curing, the fiber network reinforces the cold gap-graded asphalt concrete, increasing the shear strength and wear resistance. To date more than 500,000 m^2 of gap-graded fibrated asphalt concrete have been successfully laid.

Slurry seal technology was imported from the United States to France more than 25 years ago. Initial success led to the laying of 5 million m^2 of slurry seal in 1965. Unfortunately, the technique was abandoned a few years later, when skid resistance problems occurred.

In the early 1980s, with the advent of improved mixing and laying equipment, there was a renewed interest in cold asphalt concrete. Conventional slurry seals were normally designed with natural sand (about 50 percent) and small aggregates (less than 3 mm). The new specially adapted spreading machines allowed the replacement of natural sand with crushed sand from hard rock, and the use of 0/4, 0/6, or 0/10 graded aggregates.

Cold asphalt concrete may be defined as an asphalt emulsion (with or without polymer modification) mixed with continuous or gap-graded 0/4, 0/6, or 1/10 aggregate containing 100 percent crushed sand. Its market is currently growing as it replaces chip seal surface dressings. This improved technique has resulted in fewer broken windshields, a longer construction season, smoother riding surfaces, noise reduction, and very few failures.

To promote cold asphalt concrete in France and improve road safety through coarser and more durable pavement surfaces, a contractor recently developed the first gap-graded cold asphalt concrete. An integral part of this system is the use of polymer-modified asphalt emulsion in conjunction with synthetic fibers.

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GAP-GRADED FIBRATED COLD ASPHALT CONCRETE

In this process gap-graded aggregate containing synthetic fibers is mixed with a polymer-modified asphalt emulsion.

Aggregates

The aggregates consist of crushed hard rock meeting French specifications for asphalt concrete wearing courses. They are gap-graded, usually from 0/6 to 0/10 mm. Two typical grading curves are shown in Figure 1 (0/10 and 0/6 mm).

Fibers

Extra-fine synthetic organic fibers are used. These relatively long (typically 4 mm by 1.6 decitex) polyacrylonitrile fibers are surface treated to facilitate dispersion in aqueous media.

The fiber content of the asphalt concrete is very low (0.1 to 0.2 percent based on dry aggregate weight). However, because the fibers are extremely fine, there are a large number of fibers per unit area, yielding a very dense fiber network. For example, a 0/10 fibrated gap-graded mix with 0.15 percent fiber (3 decitex, 6 mm in length) spread at a rate of about 20 kg/m^2 will be reinforced by 15 million fibers/m^2. The fibers form a discontinuous chain, close to 100 km in length.

Binder

The binder is a polymer-modified asphalt cationic emulsion specially formulated to have controlled slow setting characteristics. Cationic emulsions perform well in French climatic conditions and allow the use of many aggregates, including unaltered extrusive igneous materials (granite, diorite, andesite, and basalt) and metamorphic rocks (gneiss, quartzite, and amphibolite).

The modification by ethylene vinyl acetate (EVA) copolymer simultaneously improves four essential properties of the binder: cohesion, temperature susceptibility, rheological behavior, and adhesion. The Vialit ram pendulum test demonstrates cohesion improvement by measuring the energy absorbed by the fracture of a binder film under a given impact. The binder to be tested is used to adhere a grooved steel cube to a grooved steel stand. A ram pendulum is released to knock

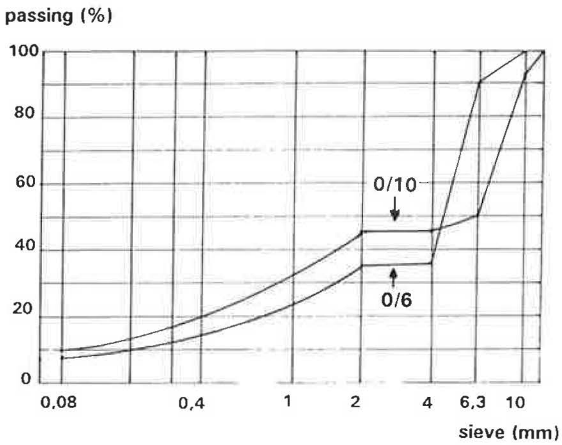

FIGURE 1 Grading curves of gap-graded aggregates used for fibrated cold asphalt concrete.

the cube off the stand, causing a cohesive failure of the binder. The cohesion is quantified by the difference between the energy needed to dislodge the cube and the energy needed to dislodge a blank—the cube without the binder. The test is run at a series of temperatures (−30°C to +60°C), and a cohesion versus temperature curve is generated. Figure 2 shows the curves of neat and EVA-modified asphalt cement. It shows that addition of 3 percent polymer increases the maximum cohesion at a given temperature as well as broadens the range of temperatures of high cohesive strength.

MIXING AND LAYING PROCEDURES

The mix is designed using a cohesiometer (modified manual cohesion tester—ISSA Technical Bulletin 139 and ASTM D 3910-80A) and a wet track abrasion tester (WTAT; ISSA Technical Bulletin 100 and ASTM 3910-80A). The cohesiometer determines the rate of set as well as the rate of development of wet cohesive strength of cold mixes, and the wet track abrasion tester measures resistance to wear.

The equipment used for mixing and laying the fibrated gap-graded cold asphalt concrete is identical to that commonly used for microsurfacing. The fibers are added volumetrically in proportion to the aggregates. Because the fibers are very fine, extremely small quantities (not exceeding a few grams per square meter) are involved. To ensure reliable and accurate addition, a special device to distribute the fibers into the aggregate was developed. An important advantage of this patented device is the dry addition of the fiber, which is more convenient than wet processes. The dry addition allows better control of the mixture moisture content, a critical laying parameter.

Typical application rates of the wet material are 12 to 15 kg/m^2 for 0/6 mm gap-graded (2/4) material and 20 to 23 kg/m^2 for 0/10 mm gap-graded (4/6) material. For example, a 0/6 mm gap-graded (35 percent of 0/2 and 65 percent of 4/6) cold asphalt concrete was laid at a rate of 13 kg/m^2 on a high-traffic highway in western France 2 years ago with excellent results. It should be noted that 0/10 cold asphalt concrete is used in rare cases where very high skid resistance is needed.

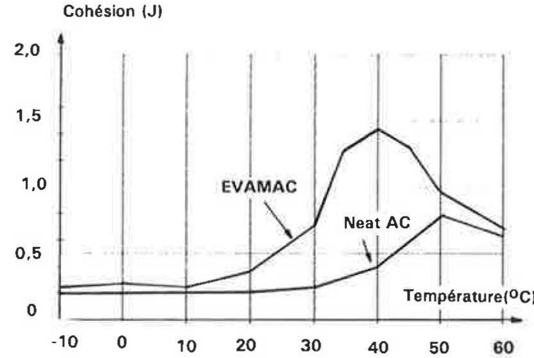

FIGURE 2 Effect of EVA on the cohesiveness curve of an asphalt cement.

Generally, a 0/6 cold asphalt cement surface is preferred even for roads carrying heavy traffic.

BENEFITS OF FIBER ADDITION

Benefits During and Immediately After Construction

The addition of fibers greatly increases the apparent viscosity of the asphalt emulsion and significantly modifies its rheological behavior, resulting in a thixotropic mixture. A Contraves TV viscometer with MS2 spindle was used to study the effect of fibers on the emulsion viscosity. This viscometer is capable of measuring 40 to 700 mPa.s. Figure 3 shows the increase in viscosity of the asphalt emulsion. Here the addition of 0.2 percent fiber increases the apparent viscosity of the emulsion by a factor of ten.

The higher emulsion viscosity and the modification of its rheological behavior (especially the very high viscosity at low shear) cause a concomitant change in the rheology of the mix, providing it with exceptional homogeneity. The French standard method slump test (NF 18 452) measures the time that a given amount of material needs to fill a given volume. Figure 4 shows the effect of fibers on the flow time versus moisture content. For a given water content, the flow time of the fibrated mix is about 3 sec longer than that of the mix without fibers.

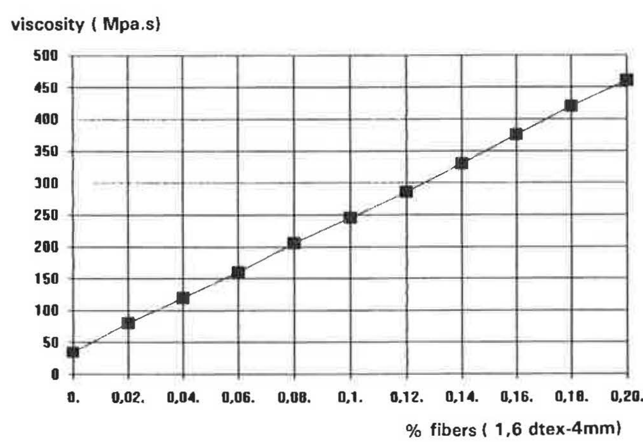

FIGURE 3 Effect of fibers on emulsion viscosity.

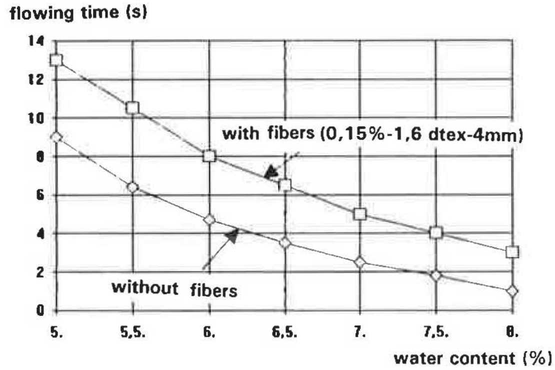

FIGURE 4 Modification of mix rheology by fibers (NF 18 452 slump test).

Because the consistency of the mix is substantially improved to a thixotropic pastelike material, gap-graded formulations can be used without risk of segregation. For the same reason, a gap-graded fibrated mix can be applied in very wide passes with results uniform across the whole pavement. In addition, there is no loss of aggregate due to traffic after reopening of the road. The fibers increase the shear strength of the mix even before the setting process is complete.

Long-Term Benefits

After curing, the cold gap-graded asphalt concrete is reinforced by the fiber network, which substantially increases the shear strength. Figure 5 is a diagram of the device used to test the shear strength. At 30°C, a beam of cured cold asphalt concrete (20 by 5 by 1 cm), fixed for 10 cm at one end, is uniformly loaded at 2.4 g/cm². The deformation at the end of the beam is measured as a function of time. Figure 6 shows that the shear resistance of the fiber-reinforced cold mix is roughly two times that of the control cold mix without fibers.

Similarly, the wear resistance of the fibrated mix in the presence of water is noticeably improved over that of the nonfibrated mix. In Figure 6 the wear resistances of two 0/10 mm cold mixes, one of which contains 0.15 percent fibers (3.3 decitex; 8 mm in length), were measured by the wet track abrasion test. This test measures the mass loss of immersed samples subjected to friction by a rubber pad. To accelerate the wear, the samples were conditioned before the test for 16 hr at a temperature of 18°C and 60 percent humidity (conditions different from those of American specifications).

Figure 7 clearly shows that the resistance to wear of the fibrated cold mix is much better than that of the unmodified mixture.

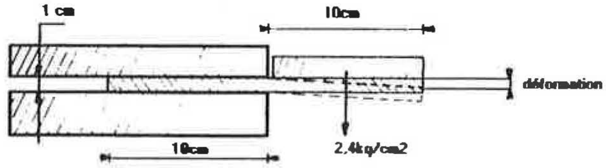

FIGURE 5 Device used to measure the shear strength of cold asphalt mixes.

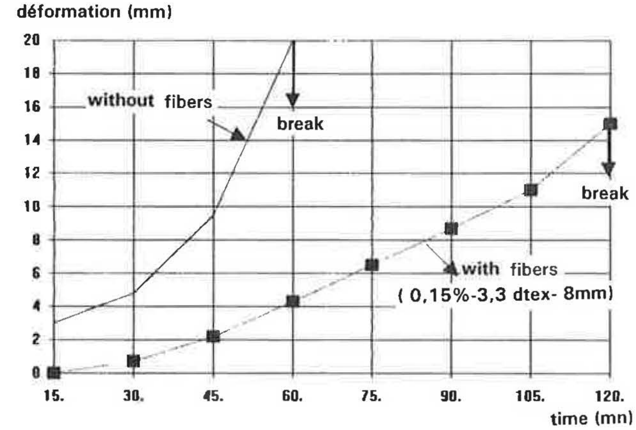

FIGURE 6 Creep of a beam of cold asphalt concrete with and without fibers.

The gap-graded aggregate ensures a granular surface texture, reducing glare and providing better drainage when it rains and, most important, imparting good skid resistance even for high-speed traffic. The skid resistance was measured with the R4E skidding resistance trailer built by the network of French Public Works Laboratories (LPC). This device measures the longitudinal coefficient of friction (LCF) of pavements and runways. A passenger car–type wheel with constant vertical load is towed at constant speed by a vehicle that also sprays the pavement with water. The wheel is locked for lengths of about 20 m, and the mean torque of the resistant rotational forces is measured. The test may be run at speeds from 40 to 140 km/hr, and measurements can be made in traffic. Figure 8 shows that gap grading ensures good skid resistance. LCF values greater than 0.45 at 80 km/hr measured on 0/10 gap-graded cold mixes bear evidence to safe surface courses even for high-speed driving.

CONCLUSIONS

The fibrated gap-graded cold asphalt concrete with polymer-modified asphalt emulsion is suitable for any type of traffic

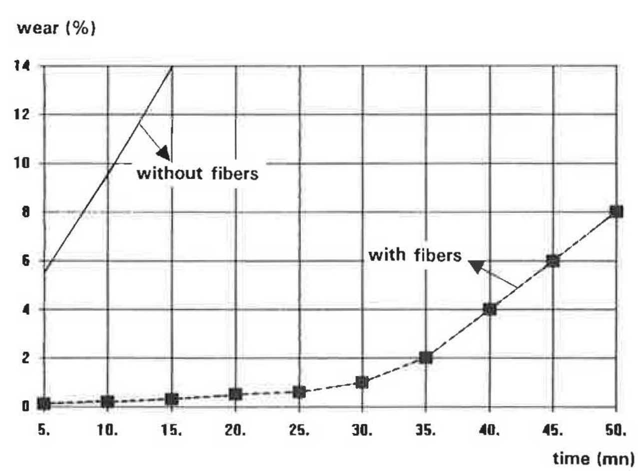

FIGURE 7 Wet track abrasion test results for two cold mixes.

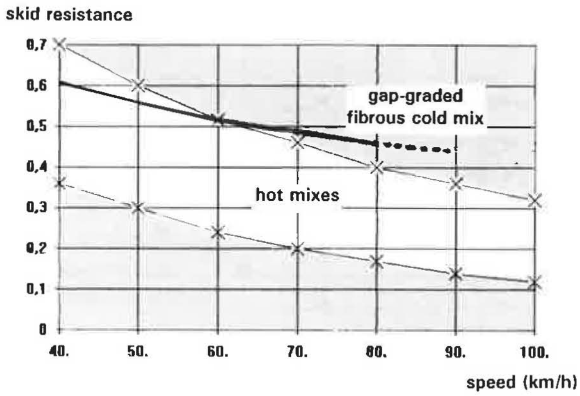

FIGURE 8 Skid resistance of gap-graded cold asphalt mix compared with conventional hot mix (white area corresponds to the LCF envelope of French roads).

(including high-volume roads) for maintenance of all types of pavements, as well as for new construction.

A maximum aggregate size of 6, 10, or, in rare cases, 14 mm, is selected depending on the degree of surface texture desired, the traffic type or level, and the admissible noise level under the given traffic conditions. A 0/10 grading will thus be selected for very heavy or rapid traffic in the open country, whereas the less noisy 0/6 material will be used in urban or heavily populated areas.

To date more than 500,000 m^2 of gap-graded fibrated asphalt concrete have been laid in various locations, some of which are heavily trafficked sections of major highways with constantly accelerating accident rates (called black points in France). The first jobs, dating back to 1986, are still performing well, particularly in reducing the number of accidents and maintaining consistent surface texture.

For example, a control section has been monitored on a very high-traffic road (more than 1,000 heavy trucks per day). After 5 years the skid resistance measured with the LPC R4E skidding resistance trailer remains very good, as indicated in Table 1.

TABLE 1 LPC R4E SKIDDING RESISTANCE TRAILER LCF RESULTS FOR A COLD ASPHALT CONCRETE AFTER 5 YEARS

Speed (kph)	LCF
40	0.47
60	0.44
80	0.36

The cost depends greatly on the area and type of laying machine used. In France, a 0/6 mm cold asphalt mix surface (10 000 m^2/day, 15 kg/m^2) costs roughly 15 FF/m^2 (less than \$3.00/m^2). The additional cost of the fibers is estimated to be about 4 percent.

The use of gap-graded cold mix should therefore continue to develop, further contributing to the revival of cold asphalt concrete in France.

Publication of this paper sponsored by Committee on Characteristics of Bituminous Materials.