Performance of Open-Graded Asphaltic Concrete Friction Courses in Arizona

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There has been a growing emphasis, particularly in the past seven to eight years, on the placement of what have become known as open-graded asphaltic concrete friction courses (ACFCs). Such placement is as a final, or wearing, course for asphaltic concrete pavements and is used not only for highways but for airport runways as well. It was reported in July 1976 that 47 states have now tried some type of open-graded mix and that 20 or 25 states are continuing this type of surfacing on a regular basis. The following performance aspects of proper ACFC design, construction, and maintenance, based on observations made over the past 25 years, are discussed: (a) Although the film coatings on particles in an open-graded ACFC are larger than those in dense-graded designs, a planned maintenance program that requires a fog seal of rejuvenators and/or combined asphalt rejuvenators every two or three years is essential (service life is affected by the lack of such a program); (b) an open-graded ACFC has the ability to hide surface reflective cracking, and it also provides space for subsequent fog seals of rejuvenating agents to retard cracking; (c) since an open-graded ACFC is sensitive to bitumen quantity, temperatures, and hauling distances, consideration should be given to control of the construction season; (d) adequate sealing of the existing pavement surface prior to placement of an open-graded ACFC is essential; and (e) under high traffic volumes and speeds, an open-graded ACFC facilitates the handling of traffic during construction and reduces the splashing effects of surface water.

To the motoring public, the only important component of the entire pavement structure is the surface course. The public is concerned that this surface is pleasing in appearance, promotes a smooth ride with directional stability, and provides adequate frictional characteristics for both vehicle acceleration and subsequent braking. In search of this "ultimate surfacing", varied combinations and gradations of asphalts and aggregates have been used over the past several years.

Particularly within the past seven to eight years, there has been a growing emphasis on the placement of what has become known as the open-graded asphaltic concrete friction course (ACFC). Such placement is as a final, or wearing, course for asphaltic concrete pavements and is used not only for highways but for airport runways as well. It was reported in July 1976 that 47 states have now tried some type of open-graded mix and that 20 or 25 states are continuing this type of surfacing on a regular basis (1). Although it is true that the sudden interest has been generated primarily from a safety standpoint--that is, higher frictional characteristics--this type of surfacing has many other benefits.

The following benefits are generally cited but not necessarily in the order given here (1,2):

1. Improved skid resistance at high speeds during wet weather,
2. Minimization of hydroplaning effects during wet weather,
3. Improved surface smoothness (present serviceability index),
4. Minimization of splash and spray during wet weather,
5. Improved visibility of painted traffic markings,
6. Improved night visibility during wet weather (less glare),
7. Lower tire noise levels,
8. Retardation of ice formation on the surface,
9. Tough and durable wearing surface,
10. Most economical use of high-quality skid-resistance aggregates, and
11. The fact that traffic can use the surface almost immediately after placement.

Notwithstanding this long list of attributes, there are also legitimate concerns and problems, which can be summarized as follows:

1. The use of chemicals for ice control is increased,
2. Spills of petroleum products cause deterioration,
3. Patching is more difficult,
4. Early preventive maintenance is necessary,
5. Handwork in placement creates a different surface texture, and
6. Provision must be made in the shoulder area to allow free flow of water collected in the open-graded mix.

There may be other problems, but these are the ones most often cited. These problems should not be considered completely insurmountable. For instance, spills of petroleum products at intersections can be minimized by densification of the mixture, by sand applications, or by flush applications of coal-tar products.

Successful patching can be accomplished by use of a chip-emulsion technique. As more experience with this technique is gained, problems of patching can be minimized.

SERVICE LIFE

At this point in the program, it is probably too early to determine a national life expectancy for friction courses, since only a few states had used this type of design prior to encouragement by the Federal Highway Administration (FHWA) through their Notice of May 28, 1973 (3). Current estimates of the service life of such courses range from 7 to 20 years.

It is quite obvious that the extent of service rendered by such friction courses depends on several things. The quality of the materials and the construction methods used are certainly prime factors in performance; of equal importance, however, is the attention given the material after placement. This is to say that preventive maintenance plays a big role in prolonging the life and capability of a friction course. All too often, a surfacing is placed with the assumption that it comes with a 10-year warranty and is then neglected to the degree that the only remedy is extensive patching or total removal and replacement. There are current maintenance sequences for periodic applications of rejuvenating agents or extender oils (every two or three years) that will indeed help to sustain these pavements for 20 years or more. Products are also available today that not only provide rejuvenating qualities but also add asphalt cement to the ACFC at the same time. This eliminates the need to apply dual fog seals (one to add bitumen and one to rejuvenate). It is expected that, depending on the level of maintenance rendered by any particular agency, service life, as reported nationally, will vary considerably.

ARIZONA EXPERIENCE

In Arizona, we look back at our experience with the use of the ACFC with some pride. ACFCs were first used in Arizona in 1954. These early finishing courses, called plant-mix seal coats, used an open-graded 1-cm (3/8 in) aggregate with 20-25 percent maximum passing the 2-mm (no. 10) sieve. Plant-mix seals were tried in a search for higher-quality seals that would provide a better friction surface and overcome the weaknesses of a chip seal.

To indicate the evolution in design from the first application attempts in 1954, the following table compares the original grading requirements with those finally approved in 1972 and in use today (4,5). It should be noted that the current grading is identical to that recommended by FHWA (1 mm = 0.039 in):

Item	Percentage Passing 1954	Percentage Passing 1976
Sieve size (mm)		
9.5	100	100
6.3	65-100	
4.75		30-60
2.36		7-15
2.00	10-25	
0.425	0-10	
0.075	0-3	0-4
Paving asphalt		
150-200 penetration	5.0	
AR 2000 or AR 4000		6.5

Design Considerations

Levels of Traffic

The question often arises as to when to specify an ACFC or when to resort to another type of strategy, such as a chip seal, for the surface course. Needless to say, this is a difficult question to handle unless one knows the conditions peculiar to a given project, such as (a) the location and the need for plant setup, (b) local levels of performance with ACFCs and alternate strategies, and (c) the volume and type of traffic to be handled during and after construction.

Previous performance often overshadows other considerations, but it has generally been found advantageous to apply ACFCs when average daily traffic volumes exceed 5000. This results in coverage of the Interstate system and major primary projects with an ACFC. It must be emphasized that the decision may be influenced by local economic situations and other extenuating circumstances. Handling high volumes of traffic during construction is greatly aided by use of an ACFC; this is not meant to infer that other strategies could not be used--just that they would cause greater inconvenience to the traveling public.

Drainage

The theory behind porous open-graded friction courses is that they allow for drainage through the mix and, if the transverse geometrics are correct, this drainage will leave the traveling surface by transverse movement (see Figure 1). One can note the effectiveness of this drainage by observing traffic movements during periods of heavy rainfall. Dense mixtures will tend to cause extensive splashing or whipping of surface water off the roadway surface and onto traveling vehicles, whereas surfaces that are open will reduce this tendency considerably. After periods of rainfall, one can observe the continuation of drainage for extended periods of time.

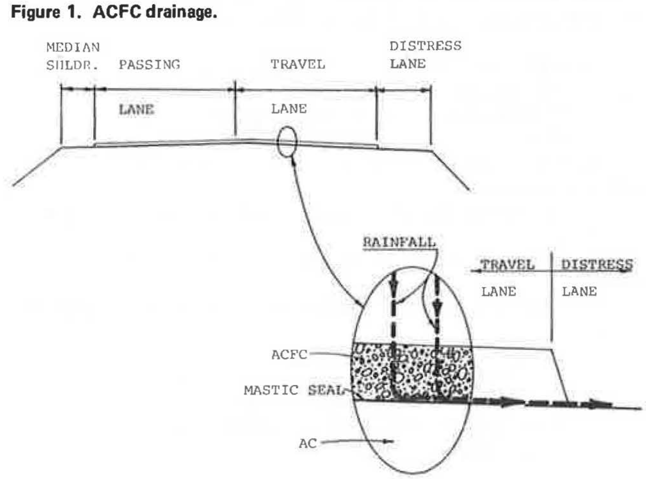
The importance of transverse geometrics cannot be overstated. The true effectiveness of an open-graded ACFC requires adequate movement of water off the roadway. When surface slopes are inadequate or subsequent densification of underlying pavement courses creates rutting, a collection basin can be formed that can create greater problems than the ones it was hoped the use of an open-graded ACFC would solve. In areas where temperatures reach freezing, the collection basin could become a hazard if the collected water freezes. It cannot be overemphasized that surface distortion and slope should be corrected by means other than the open-graded surface treatment. Consideration needs to be given to adequate cross slope and the minimal distances over which the water should be required to move. It would be better, for instance, to attempt to drain only half of an Interstate roadway by use of a crowned section than to attempt to drain the full width by cross-sloping.

Since realizing the complete benefits of an open-graded ACFC requires adequate drainage, it is imperative that consideration be given to optimizing all factors that influence drainage. Factors such as skid resistance and noise levels are also optimized by proper drainage.

Durability

Concern is often voiced over the inherent loss of mixture durability in open-graded ACFCs, since the openness of the mixtures is conducive to weathering, raveling, etc. When one considers the high asphalt contents used for these mixtures, it is apparent that the aggregate particles are being coated with films greater than those of routine dense mixtures. The greater film thicknesses help to retard the weathering of the mixture; however, planned preventive maintenance must be made a part of the total design strategy for these mixtures. A planned program for applying subsequent fog applications to add additional bitumen or rejuvenation materials should be considered before an open-graded ACFC is applied. By so doing, additional years of service life can be added and yearly performance greatly improved. If a planned maintenance program is not adhered to, a fog seal should be applied at the first indication of raveling. Experience has shown that, when open-graded mixtures ravel and no corrective action is taken, the result can be the development of rapid progressive failure by loss of the total surface. Once the failure has progressed to that point, patching is required and the loss of the desired surface texture is inevitable.

Figure 1. ACFC drainage.



Reflective Cracking

Recent national concerns have focused attention on the development of strategies for inhibiting cracking from reflecting through subsequent pavement courses. A study conducted in Arizona (6) indicated that test sections constructed with and without an open-graded ACFC perform quite differently. In effect, the open-graded ACFC, with its large, internal aggregate spacing, could easily "hide" the hairline crack at the surface and thus hide narrow cracks in an asphaltic concrete overlay (see Figure 2).

This ability to hide cracks must be viewed as an asset if one is primarily interested in roadway aesthetics. If one is interested in knowing that cracks do exist below the surface course, then it could be a disadvantage. At any rate, the use of open-graded ACFCs can be a means of inhibiting the appearance of reflective cracking. They also allow for subsequent fog-seal applications of rejuvenating agents to retard the growth of cracks.

Placement Considerations

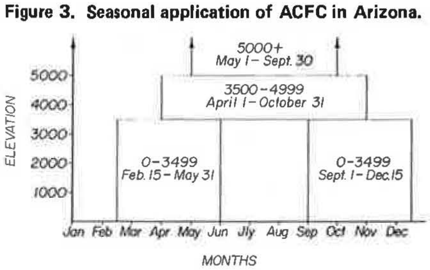
Time of Year

Due to the open grading and the thickness of the lift, the air and surface temperatures during placement of open-graded ACFCs are critical. The mixture needs to be compacted immediately after placement, especially during periods of less favorable environmental conditions. In fact, the considerations for placement of the mixture parallel closely the requirements for the satisfactory placement of a chip seal. In Arizona, constraints imposed on allowable construction time depend on project elevation (see Figure 3). Seal coats are only allowed to be placed during set time periods. The placement season for open-graded ACFCs is only slightly longer than that for chip seals for the same elevation levels.

Experience in Arizona has shown that the allowable times for placement have worked quite satisfactorily. When deviations from the allowable timing have been permitted, by change order, we have on occasion had second thoughts regarding that decision because of subsequent construction problems. The net effect of proper placement and compaction is the ability of the surface to carry routine traffic very soon after placement, whereas with emulsion-chip seals a cure period is necessary.

Figure 2. Ability of ACFC to hide cracks in known cracking area.

Figure 3. Seasonal application of ACFC in Arizona.



Sealing of Roadway

One of the most important placement considerations is that of providing an adequate seal to the existing pavement surface (7). The ACFC must provide for lateral drainage and must not be a collection basin for vertical movement of water into the existing pavement structure.

Unfortunately, all too often this important aspect of placement is overlooked and the result is deterioration of the underlying structure and flushing or bleeding in the ACFC. The tack coat applied prior to placement of the ACFC must be uniform and adequate to seal. Currently, Arizona specifies 0.27 L/m^2 (0.06 gal/yd^2) of asphalt cement for the tack coat. An emulsion tack can be applied as long as the residue effective for sealing is comparable to that required for an asphalt cement. Experience has shown a reluctance, however, to place an amount of emulsion tack coat that would be equivalent to the quantity of asphalt cement.

If the existing pavement cannot be adequately sealed, all of the other advantages sought from an ACFC may be overshadowed and it may be better to rely on a chip seal for the surface treatment.

Movement of Binder

Another problem encountered in Arizona with the placement of the mixture is the movement of the binder to the bottom of the transport vehicle due to haul distance and heat. The excess asphalt ends up in concentrated areas during placement, which results in flushing or bleeding. In an attempt to overcome this problem, projects have been contracted in which 1 percent of the design bitumen content was withheld and, after placement of the mixture, the 1 percent effective asphalt was added to the mixture by a surface flush of an emulsion. There have been varying opinions on the true worth of this approach. In Arizona, we are currently back to placing the total asphalt into the mixture at the time of mixing. The adoption of placement seasons may have helped to negate the need for the other technique. At any rate, we can suggest it as a workable technique for those attempting to place ACFCs that are open graded in conditions of (a) high plant temperatures that result in low mixing viscosities, (b) high ambient temperatures, and (c) long hauling distances.

As our use of recycling strategies increases, we may be looking for ways to place ACFCs by a cold process. This involves slurry applications, which have the advantage of sealing a roadway surface during placement by "walking" the slurry along the pavement surface. The problem of getting adequate binder to the roadway surface for sealing purposes is eliminated.

CONCLUSIONS

The following performance aspects of proper ACFC design, construction, and maintenance are based on observations made over the past 25 years:

1. An open-graded ACFC will not drain properly unless there are proper transverse geometries. Reducing the distance the water must travel should be considered.
2. Although the film coatings on particles in an open-graded ACFC are thicker than in dense-graded designs, a planned maintenance program that requires a fog seal of rejuvenators and/or combined asphalt rejuvenators every two or three years is essential. Service-life performance is affected by the lack of such a program.
3. An open-graded ACFC has the ability to hide surface reflective cracking. It also provides space for subsequent fog seals of rejuvenating agents to retard cracking.
4. Since an open-graded ACFC is sensitive to bitumen quantity, temperature, and hauling distance, consideration should be given to control of the construction season.
5. Adequate sealing of the existing pavement surface before placement of an open-graded ACFC is essential.
6. Under high traffic volumes and speeds, an open-graded ACFC facilitates the handling of traffic during construction and reduces the effects of the splashing of surface water.

It is apparent that, as the need for safe surfaces for the vast highway network increases, more consideration will be given to the strategy of placing open-graded ACFCs. As traffic volumes increase, additional justification may be found for spending a greater initial amount of funds for wearing surfaces than is now considered feasible. At any rate, technology and experience have advanced to the point that the construction of premium surface courses cannot be justified, and there should be an increase in the applications of open-graded ACFCs in the years ahead.

As the era of asphalt-pavement recycling commences, its inherent advantages with regard to saving materials and energy continue to be discovered. The conception of saving energy by cold processing has carried over into the placement of ACFCs in that ACFCs can also be placed by cold-slurry processes. This ability to cold process an ACFC surface course makes it possible to consider an energy-saving strategy of cold processing for all pavement strategies on a rehabilitation project--the point being that, if one desires an ACFC and experience has been only with "hot" processing, it is possible to obtain a similar material by a cold-processing strategy.

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The contents of this paper reflect our views, and we are responsible for the facts and the accuracy of the data presented. The contents do not necessarily reflect the official views or policies of the Arizona Department of Transportation.

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Performance Comparison Between a Conventional Overlay and a Heater-Scarification Overlay

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The heater-scarification technique has become one of the most commonly accepted forms of pavement surface recycling in use today. This has been due primarily to the record of successful performance exhibited by these projects over a relatively long period of time. The performance characteristics of a typical heater-scarification overlay project are analytically examined and compared with those of a conventional overlay. The comparison examines fatigue cracking caused by wheel loadings and thermal-fatigue cracking caused by daily temperature cycles. The results are presented for one combination of aged asphalt and recycling agent and one overlay type. The results show that for this combination the commonly held statement that a 19- to 25-mm (0.75- to 1.0-in) depth of heater scarification with 38 mm (1.5 in) of overlay will perform as well as 89 mm (3.5 in) of conventional overlay has some validity. The calculations illustrate the need for laboratory testing to select the best recycling agent for the particular asphalt being recycled and the need to tailor the characteristics of the recycled binder to produce the desired product.

Heater scarification, one of the oldest forms of surface recycling, is used primarily to correct surface distress in bituminous pavements. Surface distress includes a number of types, such as rutting, raveling, weathering, and corrugations. Mixture problems such as asphalt content, gradation, or asphalt properties can also be altered during the