Discussion

Written discussion (John Ferguson[1]*)*—This is a very appropriate paper at a time when there are many miles of highway to maintain and a trend towards reduced agency expenditures on highways exists. Some comments that I would like to make with regard to certain aspects of the paper follow.

Adhesion of Bitumen to Aggregate—Stickiness Versus Viscosity

Your paper mentions a minimum substrate temperature of 50°F (10°C) in respect to the effect of temperature on chip retention. It would be appropriate to relate the stickiness of the binder to the temperature by means of a minimum viscosity. There may be a bit of a misconception in the belief that because the emulsion rises up on the chip to the prescribed depth that the chip should be retained. However, the water phase of the emulsion is only the carrier; the bitumen component is the adhesive part. When the bitumen-aggregate interface is cold, (or when an application is made to a cold surface) the bitumen develops an extremely high viscosity and is no longer sticky.

Stickiness is related to viscosity. It has been proposed that adhesion to *clean* chip aggregate diminishes after the binder reaches a viscosity above 50,000 Pa.s (0.5×10^6 poise) as shown in Fig. D1. For dusty (high surface area) aggregate the maximum viscosity to attain adhesion is much lower. If the Tulsa emulsion (Table 4, probable viscosity of residue @60°C = 70 Pa.s) had been applied at 50°F (10°C), the binder viscosity when in contact with the pavement surface or with 10°C chip would be in the order of 1 million Pa.s—certainly not sticky. Bitumen viscosity at application temperatures can be estimated from ASTM D2493-95a Temperature Viscosity Chart. The use of this principle would assist in understanding the mechanism of bitumen adhesion to aggregate. It is noted that the apparent viscosity is not reported for any of the binders reported in this paper. Even in cases where adhesion has been achieved, low temperature induced high binder viscosity can impede the reorientation of the chips under traffic, with the result that there is insufficient binder depth for the aggregate. This can be the situation with seals applied at the end of the season.

Percentage Truck Traffic

There are no data on the percent truck traffic in the ADT. Truck tire pressure is approximately 120 psi, while cars are approximately 30 psi. This difference in tire pressure would impact the aggregate orientation. Truck volumes in excess of 15% of ADT may also effect the selection of the binder (lower penetration or higher viscosity).

The use of special nozzles to achieve different application rates across the seal appears to be an excellent concept. This provides for greater binder depth for chips in the section of the roadway that receives less compaction or reorientation by traffic.

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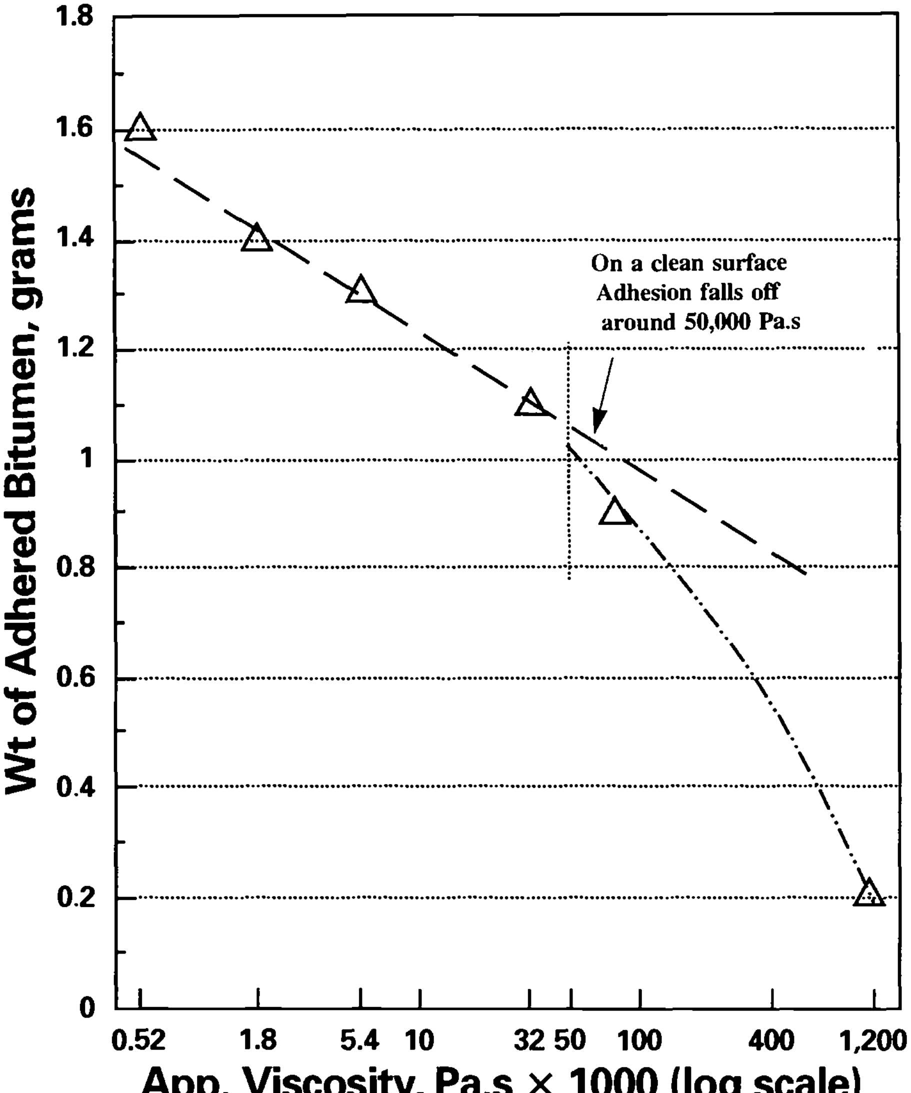

FIG. D1—*Viscosity of binder versus adhesion of binder to aggregate surface.*

Emulsion Viscosity—Saybolt Furol Seconds (SFS)

In Table 10, the Tazwell emulsions, a value of 69 SFS @ 50°C is reported, for CRS-2 Latex and it has been noted as a low value. It is expected that CRS-2 with this SFS viscosity would have suffered from run-off when applied, but there is no mention of this run-off in the report. At the application rate shown run-off may not have been a problem.

It is possible that the emulsion was actually thicker when applied, and that the reported value was determined on an aged sample in a laboratory some time later. In a true rapid setting emulsion there is a weak bond between the water phase and the contained bitumen.

This is as it should be, so that the bituminous phase quickly separates and adheres to the aggregate, and the water dissipates. This achieves rapid bonding of the aggregate and provides some protection against sudden rain showers during construction.

CRS emulsions that have those desirable construction characteristics have a tendency to agglomerate slightly with time, so that after few days (3 to 5) a decrease in SFS viscosity may have occurred. The results of a 1992 exchange program in Canada illustrate this concept in Fig. D2.

Although a true rapid set emulsion is indeed desirable for chip seals from the construction point of view, the supply of this product is impeded by laboratory procedures that fail to take into account the beneficial weak link between the water phase and the bitumen. Existing specifications, typically ASTM D2397, allow for sampled CRS emulsion to remain untested for up to 13 days (Section 3.1). The above figure illustrates that there may have been a considerable reduction in SFS Viscosity by that time period, compared with the viscosity at which the CRS was supplied.

Producers counteract the potential penalty associated with this phenomenon by increasing the strength of the bond between water and bitumen (more agent) which reduces the setting time during construction, making the product less acceptable. The emulsion industry needs to counteract this problem, preferably by having an industry agreement that for CRS-2 the SFS viscosity be determined at the point and time of delivery.

Seasonal Effects on Seal Coat

You mention ''Cool or Cold Weather Immediately after Construction'' as a problem in chip retention, which is true. It would be more appropriate for agencies to plan their maintenance program so that higher traffic volume roads were sealed when pavement temperatures are in the ''increasing'' part of their annual thermal cycle as shown in Fig. D3.

Seal coats applied while pavement temperatures are increasing (point A to point B) will have an opportunity to achieve proper embedment of the aggregate and increased adhesion as the summer progresses. Seals applied after the temperature begins to decline experience

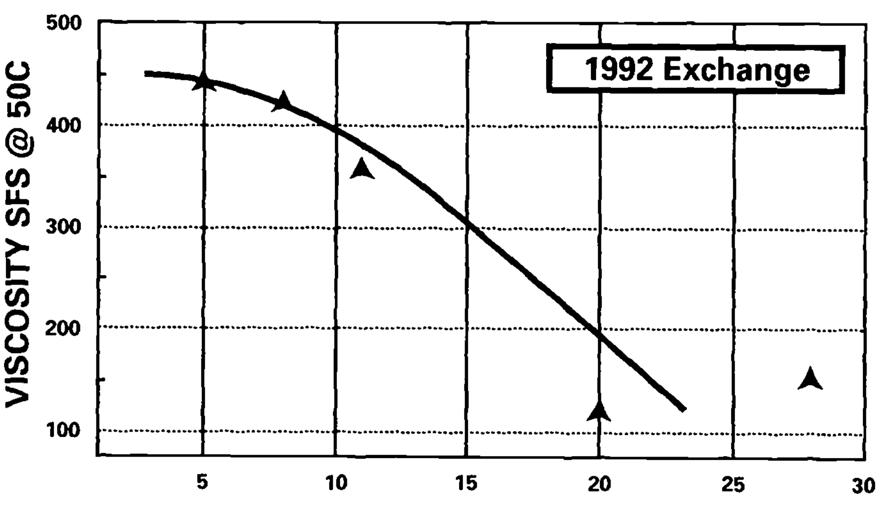

FIG. D2—*Effect of sample age on emulsion SFS viscosity for CRS emulsions.*

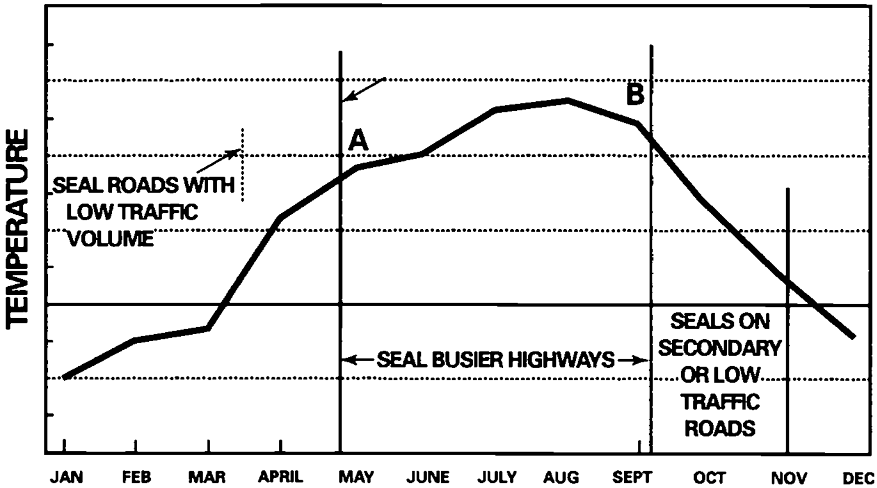

FIG. D3—*Recommended seal coat program based on annual thermal cycle.*

their best compaction and adhesion on the day they are placed. If conditions are not perfect on that day, there is little likelihood that there will be much improvement before cold weather or winter occurs.

Measurement of Surface Temperatures

No measurements of pavement surface temperatures were reported in this paper. Some measurements have been taken on sealed highway surfaces in Manitoba, where temperatures of light colored seal coat surfaces have been 5°C cooler than asphalt-rich highway surfaces, if measured when the highway surface temperatures were in the 32°C range. This might be a useful concept when considering binder selection under the SHRP system.

Public Relations

The aspect of public information or education with respect to seal coat application and their benefits is not mentioned in the paper. During discussion after the paper presentation, it was indicated that San Diego County did publish some information in advance to alert and educate the highway users, and that this activity was quite beneficial.

When the traveling public encounters a paving operation they are willing to tolerate a short delay because they interpret that operation as an improvement in the highway system. However, seal coat applications are generally not well understood by the traveling public, and are not interpreted in the same manner as hot mix paving. I believe the industry needs to undertake a campaign to educate the highway user regarding the benefits of the seal coat process prior to local applications.