DEVELOPMENT OF UK PROPIETARY ASPHALT SURFACING SKID RESISTANCE AND TEXTURE

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ABSTRACT

This paper considers the development of proprietary asphalt surfacing properties used in the United Kingdom due to trafficking. The project aimed to determine whether asphalt mixes made with lower PSV aggregate in smaller nominal sized asphalt mixes could provide adequate levels of in-situ performance compared to the traditional use of higher PSV aggregate and 14mm nominal sized mixes. It compared SCRIM and GripTester data from full-scale road trials with laboratory Wehner Schulze laboratory data measured using asphalt laid at the road trial. The proprietary mixes were 14mm, 10mm and 6mm maximum aggregate size made with porphyry and quartz granite aggregate. Based on their PSV these aggregate sources would typically not be used on heavily trafficked roads in the UK. Surface texture was monitored using laser sensor during SCRIM assessment. In-situ testing found good levels of skid resistance for all mixes over the last 4 years since installation. The optimum nominal mix size was 10mm. The 14mm mixes had a noticeable drop in texture depth whereas the smaller nominal size mixes remained relatively unchanged. The Wehner Schulze was found to rank the mixes similar to in-situ measurement in contrast to PSV which did not. A model was developed to predict in-situ skid resistance based on Wehner Schulze data.

INTRODUCTION

Proprietary asphalt surfacing systems have developed over the last 20 years in the UK. Originally based on German and French asphalt mixes, these have typically been designed to enhance specific properties such as wet skid resistance or reduced noise and spray characteristics. They are normally made with high quality materials such as aggregates with high PSV and modified bitumen. PSV is the laboratory measurement of aggregate skid resistance using the British and European polished stone value test method (BS EN 1097-8, 2009) However, the cost of high PSV aggregate and modified bitumen coupled with the need to look at more sustainable options or optimised mixes has led to this approach being further developed. Greater use of local materials is seen as a sustainable option. However, aggregates with high PSV typically do not occur where demand is greatest in the UK (Thompson et. al., 2004). This imposes greater carbon foot-print and cost on these products. Do et. al. (2007) found that asphalt surfacing mixes made with smaller nominal aggregate sizes had higher skid resistance. The use of smaller aggregates sizes in densely packed mixtures can also improve durability. These types of surfacing materials with small aggregates have a closer texture and lower internal air voids which limits the ingress of water and subsequent moisture damage problems such as stripping. However, smaller aggregates sizes can give lower texture depth which might affect higher speed skid resistance.

By adequate selection of local smaller aggregate sizes with adequate polishing resistance, it might be possible to provide safe skid resistance levels through the life of the asphalt surfacing while reducing the cost and increasing its durability, hence enhancing the sustainability profile of the product. A major UK collaborative research project focussed on skid resistance performance of smaller sized asphalt mixes (Roe et. al. 2008). Trial sites covering a range of trafficking conditions, nominal aggregates sizes and PSV were evaluated in terms of skid resistance and surface texture development.

This paper considers one of the trial sites reported by Roe et. al. (2008). The trial was laid by Aggregate Industries (AI) in 2006 on the slow lane of a heavily trafficked dual carriageway. Two aggregates, a porphyry and a quartz granite, were used in three proprietary asphalt surfacing mixes with maximum aggregate sizes of 6mm, 10mm and 14mm. The development of wet skid resistance and texture depth were measured using SCRIM and GripTester. Samples of the aggregate used and the 6 mixes were assessed using Wehner-Schulze (WS).

MATERIALS USED

Two igneous rock types were used i.e. a porphyry (PSV 60) and quartz granite (PSV 55). Igneous rocks would typically not be used in the UK for heavily trafficked roads because their PSV is lower than the PSV60+ normally specified. These were used as the aggregate in three proprietary surfacing materials i.e. 6mm Urbanpave, 10mm Superflex Carriageway and 14mm Hitex. These are typical of products developed by many asphalt companies in the UK.

The 6mm Urbanpave is gap-graded asphalt similar to SMA and uses polymer modified binder for improved performance. It has a uniform, smooth surface and typically used in urban areas. The 10mm Superflex Carriageway is continuously graded similar to asphalt concrete and has a polymer modified binder for enhanced flexibility and crack resistance. It is used when durability is an important requirement. Both Urbanpave and Superflex are practically impermeable with lower in-situ air voids compared to more common thin surfacing systems. The 14mm Hitex is a polymer modified asphalt thin surfacing designed for high speed, high volume roads. It provides noise and spray reduction combined with good resistance to permanent deformation.

THE TRIAL SITE

The trial was located on Lane 1 of the A14 eastbound between Junctions 15 and 16 near a town called Thrapston in Northamptonshire, UK. It consisted of 6 different surfacing mixtures each approximately 500m in length. They were laid between 21st and 23rd September 2006. The traffic levels are considered heavy with an estimated 3250 commercial vehicles per day.

IN-SITU MEASUREMENT OF SKID RESISTANCE AND TEXTURE

Wet skid resistance and laser sensor texture depth (SMTD) was measured in the inside wheel-path at 50km/h using the Sideway-force Coefficient Routine Investigation Machine (SCRIM) nine times between September 2006 to October 2009. The volumetric sand-patch technique was used to assess texture depth at time of construction (BS EN 13036-1, 2010). Four GripTester surveys were carried out during this time. Average SCRIM Coefficient (SC) values, based on individual data measurements averaged over 10m intervals, are plotted in Figure 1.

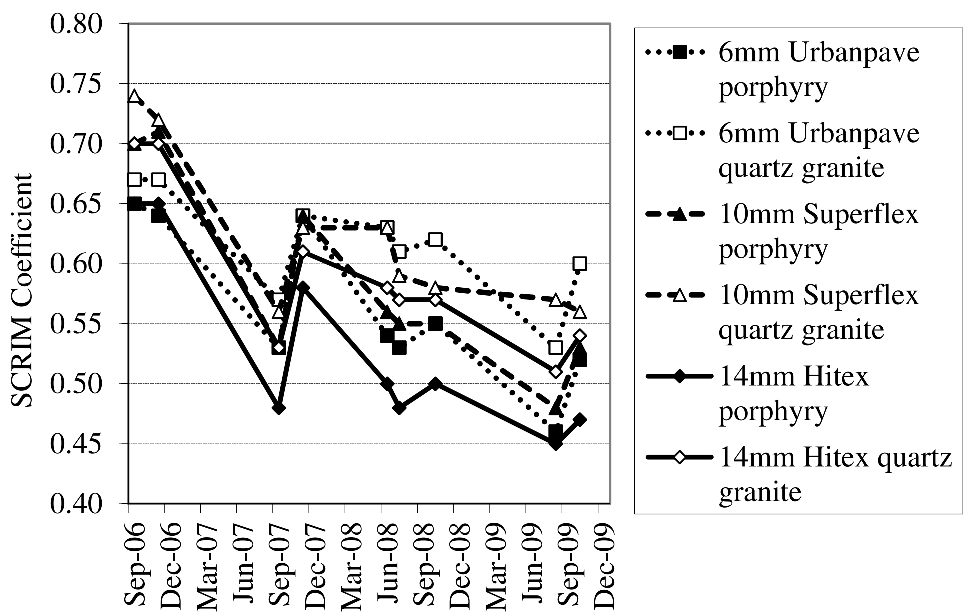

Figure 1. SCRIM data – all measurements

Initial SC values varied between 0.65 - 0.75 indicating high skid resistance. The SC data shows a general decrease as the aggregate becomes exposed and the asphalt mixes move towards equilibrium in relation to trafficking and environmental conditions. The data shows the effect of seasonal variation between lower values in the summer and higher values in the winter due to roughening of the surface (HD 28, 2004). The time for aggregate exposure takes about 6 months to happen, however this period can be much longer (Roe et. al., 2005).

Skid resistance measurements in the UK are normally taken during the summer months i.e. 1st May to 30th September when the skid resistance is expected to be at its lowest. Figure 2 plots only the summer month data to remove the influence of winter roughening. A simple log trend has been used to fit the data. It also removes the early life phenomena associated with some asphalt mixes as they develop towards their equilibrium.

This shows skid resistance to decrease over the first 12 month period tending towards equilibrium. The plots suggest equilibrium has not been reached. For the same rock-type, the plots show the 14mm mix to have less skid resistance than the 10mm and 6mm mixes. The 10mm mix performed marginally better than the 6mm mix. Despite having the lower PSV (55) the quartz granite had better skid resistance compared to the porphyry with PSV 60.

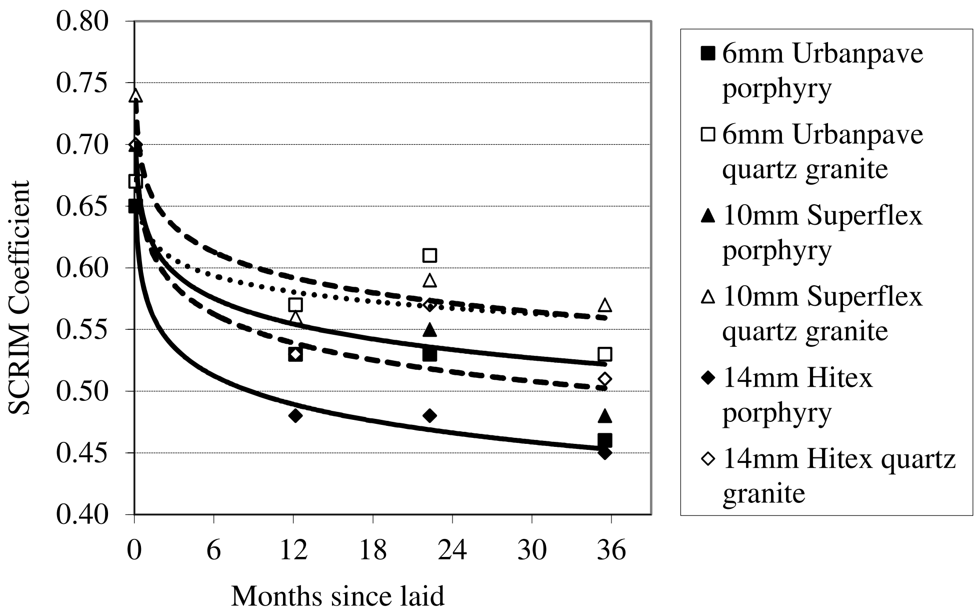

Figure 2. SCRIM data – summer month data only

The change in GripTester data is plotted in Figure 3 as Equivalent SC using the formula Equivalent SC = 0.89 x GripNumber (Dunford, 2010). A similar log reduction of skid resistance was found for all test sections. The 10mm mixes had higher Equivalent SC values compared to the 6mm and 14mm mixes. Again, the GripTester data found the quartz granite mixes made with lower PSV aggregate to have better values of skid resistance. Both the SCRIM and GripTester data suggest the PSV test under-predicts performance of the quartz-granite aggregate.

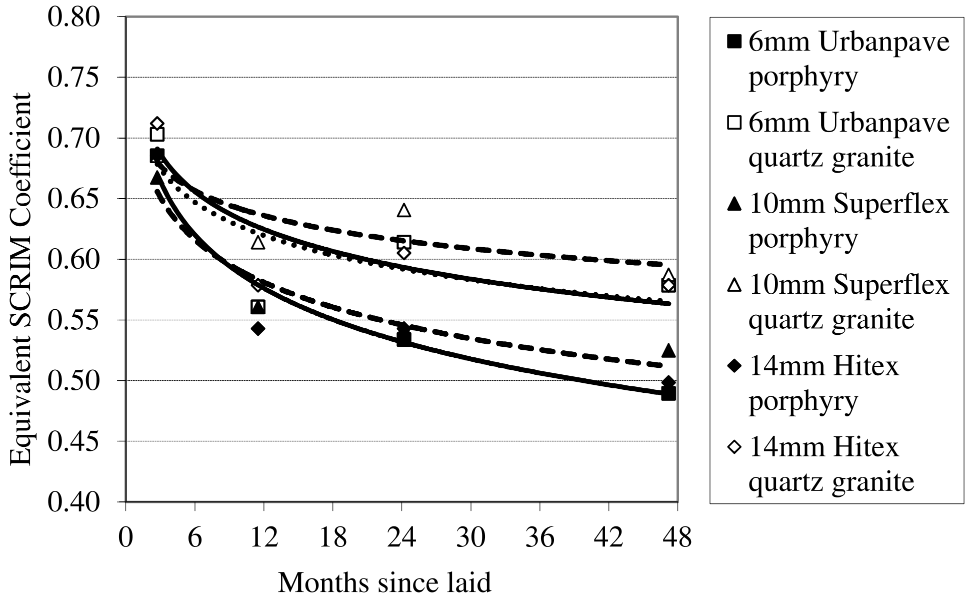

Figure 3. GripTester data expressed as Equivalent SCRIM Coefficient

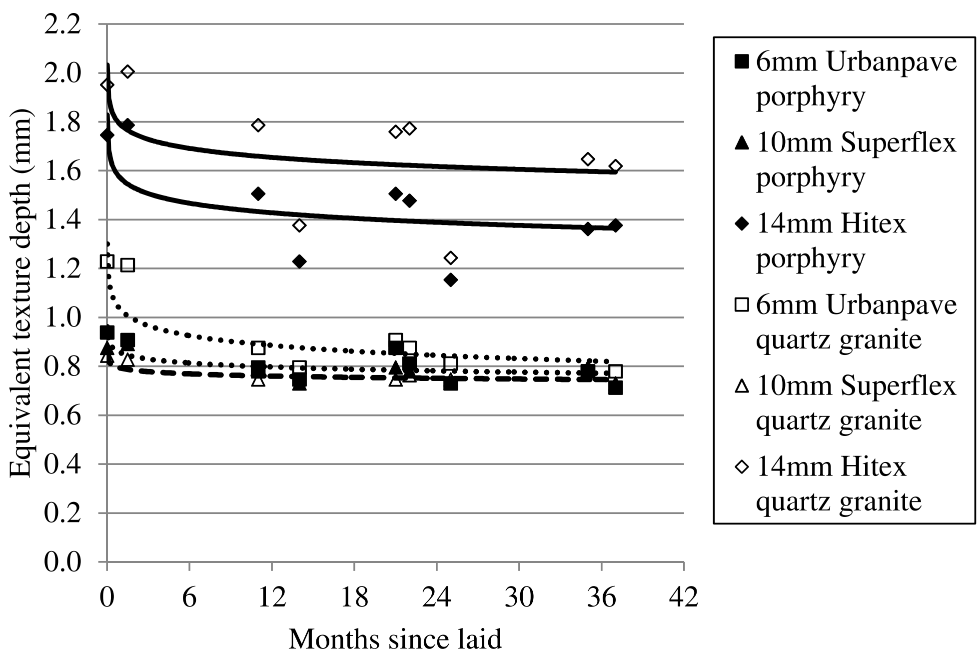

Figure 4. Development of texture depth (TD_{SMTD}) with time

The development of texture depth with time is plotted in Figure 4. This is based on laser texture measurements taken during SCRIM testing converted to Equivalent Texture Depth based on the sand patch method using the equation

$TD_{SMTD} = 1.67 \times SMTD^{0.84}$ ($R^2 = 0.93$). This shows texture to decrease with time towards an equilibrium level. The change in texture with time is more pronounced for mixes with higher initial textures. The two 14mm mixes show seasonal effects in the development of texture depth. The data shows that texture depth for both 10mm Superflex mixes i.e. with the lowest initial values, remained almost the same over the 3 year period. This suggests a relationship between degree of change and contact area between tyre and asphalt surface texture.

LABORATORY TESTING

Laboratory prediction of skid resistance development was carried out using the Wehner-Schulze (WS) test (Huschek, 2004). This method was developed in Germany over 30 years ago to assess the polishing properties of both aggregate and asphalt mixes. The equipment is now being considered as a European standard test method. The test is carried out on 225mm diameter test specimens made with either aggregate particles or cores taken from laid asphalt or laboratory compacted slabs. The latter was used in this investigation.

The test is in two stages. During the polishing stage, three rubber-covered conical rollers are forced onto the test surface at a pressure equivalent to the tyre pressure of a commercial vehicle. The roller head is rotated at 500rpm for 1 hour giving 30,000 revolutions or 90,000 roller passes. A friction measuring system consisting of a measuring head with three rubber sliders is accelerated to 3,000rpm, equivalent to a tangential velocity of a rubber slider at 100km/h.

Water is sprayed onto the surface to give a theoretical water film thickness of 0.5mm. The test head drops to make contact with the surface and decelerates as a result of friction to a stop. Torque transducers mounted in the measuring head measure the reaction force which is then used to determine friction coefficient. In the standard test, the friction at 60 km/h is used.

In this investigation material sampled at the asphalt plant was used to prepare 300 x 300 x 50 mm roller compacted slabs. Cores 225mm in diameter were taken from the slabs. The 6mm Urbanpave and 10mm Superflex were assessed at the Berlin Technical University. The results are plotted in Figure 5. This shows the development of friction measured at 60 km/h with increasing number of polishing cycles. The plots show initial removal of bitumen and polishing of aggregate micro-texture. Maximum friction occurred at approximately 10,000 polishing passes. After this friction coefficient decreased as the exposed aggregate started to polish. Equilibrium conditions had not been reached after 180,000 polishing cycles.

The 10mm Superflex with porphyry has higher friction than the 6mm Urbanpave with the same aggregate. Friction values for the 10mm Superflex and 6mm Urbanpave with the quartz granite aggregate are the same. This agrees with both the SCRIM and GripTester data not agreeing with PSV based prediction and suggests that the WS test is possibly better for predicting performance.

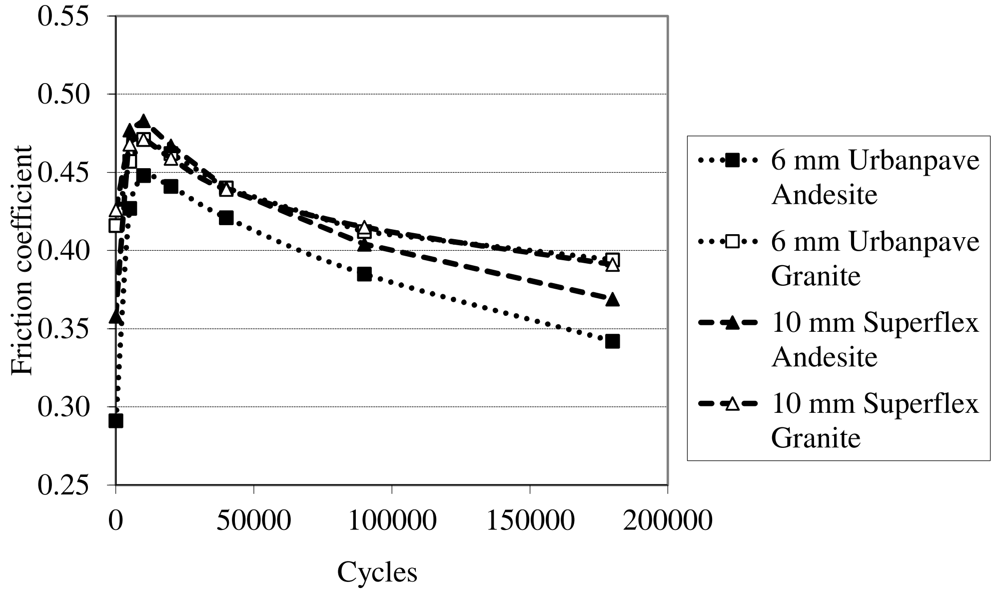

Figure 5. Development of Wehner Schulze data

PREDICTING SKID RESISTANCE DEVELOPMENT

The Wehner Schulze data was used to predict development of skid resistance for the asphalt mixes. The number of polishing cycles in the WS test was first converted to actual traffic counts. Tang (2007) proposed the following relationship between the polishing duration or number of cycles (N) in the WS machine and the cumulative number of commercial vehicles (T): $N = 0.024 \times T$.

For example, 180,000 polishing cycles represents 7.5 million commercial vehicles. The estimated number of commercial vehicles per day for the trial site is 3250. This corresponds to approximately 6½ years of trafficking. Huschek (2005) showed that the friction values obtained with the WS after 90,000 polishing cycles corresponds to a surface condition after 4 to 5 years of very heavy traffic. Thus, it could be speculated that 180,000 polishing cycles is equivalent to 8 - 10 years heavy trafficking.

The friction coefficient determined during the WS test was converted to a skid resistance measurement value determined on-site e.g. an equivalent SCRIM coefficient. Huschek (2005) proposed the following relationship between SC determined at 80km/h using the German SCRIM and friction coefficient (μ_{WS}) obtained using the WS test; SC (80km/h) = $0.96\mu_{WS} + 0.06$. This was based on testing cores in the WS taken from the wheel-path where German SCRIM measurements had been taken.

UK SC values measured at 50km/h were converted to SC values at 80km/h using the following relationship (HD28, 2004) SC (50km/h) = SC (80km/h) + (80 x 2.18 x10^{-3} - 0.109). The model proposed by Huschek (2050) was found to underestimate SC, most probably due to differences between the UK and German versions of SCRIM machine.

The values determined from the regression equations for both sets of data at the same traffic levels were used to obtain a relationship between SC at 50km/h and WS friction coefficient at 60km/h. This is plotted in Figure 6. This shows good correlation between the two methods with rock type more important than nominal aggregate size.

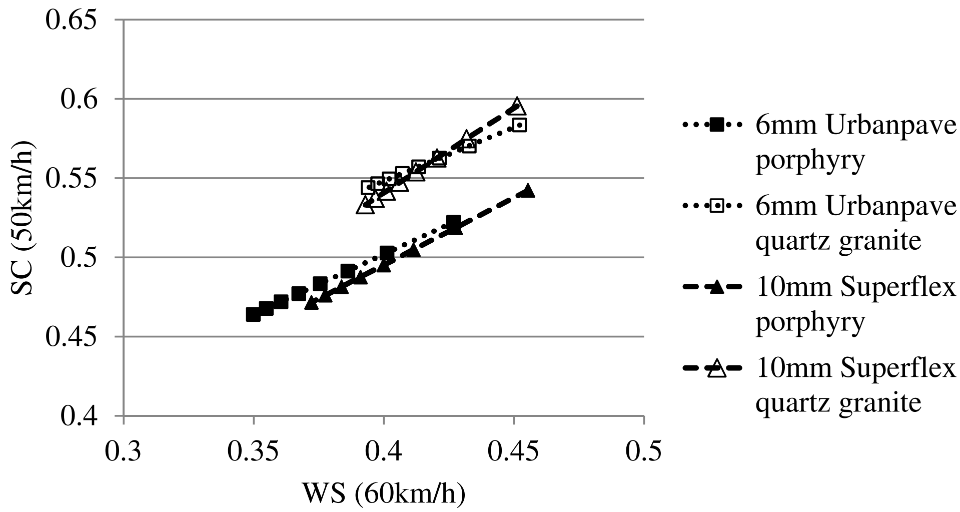

Figure 6. Wehner Schulze (60km/h) v. SCRIM Coefficient (50km/h)

CONCLUSIONS

This paper has considered the development of surfacing asphalt mix performance for three types of proprietary material made with two aggregates. SCRIM and GripTester assessment found that for the same rock type, the 14mm materials had lower wet skid resistance than the 10mm and 6mm mixtures measured using both SCRIM and GripTester at 50km/h. The 10mm mixes performed better than the 6mm mixes.

Despite having lower PSV, the quartz granite mixes (PSV 55) performed better than the porphyry mixes made with higher PSV 60 aggregate. This issue raises concern regarding the use of the PSV test to adequately predict in-service wet skid resistance for all aggregates types in all types of application. Having a higher PSV does not necessarily mean higher in-service performance. This highlights the need for methods such as the Wehner Schulze that tests the actual asphalt mix rather than just the 10mm size specified in the British Standard PSV method.

Wehner Schulze testing found that mixes made with the quartz granite aggregate (PSV = 55) had higher friction values than those produced with the porphyry with PSV 60. The same trend was found for in-service measurements using both SCRIM and GripTester. This suggests that the WS test is possibly better than PSV at predicting skid resistance of asphalt mixtures in the laboratory. Models were developed to predict SCRIM coefficient based on Wehner Schulze test data.

The texture depth of14mm Hitex was consistently greatest, followed by the 6mm Urbanpave and 10mm Superflex. The decrease in texture depth with time due to trafficking was greatest for the 14mm mixes with highest initial texture depth. The texture depth of the 10mm Superflex did not change during the first 3 years in-service.

The data presented in this paper considers development of in-service performance over for the first three years. The laboratory predictions are based on standard test conditions e.g. the 6 hour PSV test and the 180,000 cycles for the Wehner Schulze. The Wehner Schulze data shows that the materials have not reached equilibrium. This makes correlation between in-service measurement and laboratory difficult and continues to be an area of research in the UK.

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