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NOISE CONTROL FOR A BETTER ENVIRONMENT

About the reduction effect of tire/road noise of longitudinal groove rough surface hybrid pavement

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ABSTRACT

Longitudinal groove rough surface hybrid pavement is a unique construction method, which provides 1) the excellent drainage function close to the road surface with the single layer top surface mixtures and 2) the watertightness in the subsurface pavement which is comparable to the stone mastic asphalt mixtures.

Longitudinal groove rough surface hybrid pavement, which is a feature of this construction method, was made possible by an asphalt finisher with the improved compaction apparatus. Longitudinal groove rough surface possesses the durability, which is sustainable even in heavy traffic like highways, and also made it possible to reduce the tire/road noise if compared with the pavement whose road surface becomes dense with use. In addition to the reduction of tire/road noise, this construction method has more functions, one of which is adopting it as an accident countermeasure pavement due to the empirical performance in the reduction of highway's accident.

This paper describes about the functions and effects such as tire/road noise that is maintained by this longitudinal groove rough surface hybrid pavement.

Keywords: Longitudinal groove rough surface finishing, tire/road noise reduction, reduction of highway accidents

1. INTRODUCTION

Dense-graded asphalt pavement, which is widely utilized as general pavement, has advantages such as low cost, the swift opening to traffic after construction, as well as its ease of repair. At the same time, problems have become apparent relating to driving safety in rainy weather due to the buildup of water on the road surface, which causes hydroplaning and water spraying phenomena. In addition, there is concern about skidding accidents caused by the freezing in wintertime of the water that builds up on the pavement surface.

Drainage-related pavement has been popularized in Japan since the 1980s due to its resolution of the driving safety problems of dense-graded asphalt pavement described

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above, and for newly obtaining effects such as the reduction of tire/road noise. This drainage-related pavement is an effective pavement with regard to safety aspects which is mainly utilized as a surface layer on roads that are exclusively used by automobiles. However, over long-term use, deficiencies have also become apparent including the reduction of the drainage function due to blockage of pores, the occurrence of stripping from the surface of the lower layer caused by the permeation of moisture, and the necessity of replacing two layers when implementing repairs. Additionally, in cold and snowy regions cases have also become apparent of destruction from the pavement body caused by the freezing and expansion of moisture remaining inside the pavement body resulting from drops in temperature.

In order to improve these kinds of problem areas relating to drainage-related pavement, this company has developed longitudinal groove rough surface hybrid pavement [1)]. This pavement has a single surface layer which maintains both the same drainage function as drainage-related pavement in the area close to the road surface, and the same waterproofing function as crushed stone mastic asphalt mixture (known below as SMA) in its lower part. (Refer to Figure 1.) In addition, by implementing the road laying using a modified asphalt finisher as the compaction equipment, the pavement surface can be given a rough surface finish that includes longitudinal grooves. (Refer to Photograph 1.) Because the surface texture depth of this longitudinal groove rough surface is the same as in drainage-related pavement, it is possible to reduce tire/road noise and to inhibit the buildup of water on the road surface in rainy weather. In addition, various functions are added due to the combination of the longitudinal groove rough surface with the hybrid structure.

This paper describes about the functions and effects such as tire/road noise that is maintained by this longitudinal groove rough surface hybrid pavement.

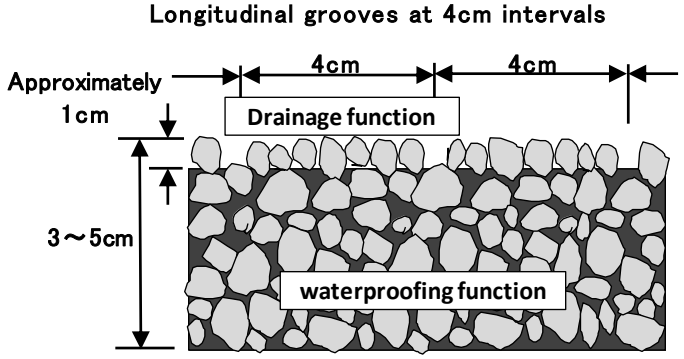

Figure 1 - Longitudinal groove rough surface hybrid pavement structure image

Photograph 1 - Example of longitudinal groove rough surface finishing

2. PROBLEM AREAS IN EXISTING CONSTRUCTION METHODS

As described above, although drainage-related pavement has been popularized in all the Japanese regions as pavement which realizes outstanding driving safety during rainy weather, various problem areas have also become apparent. As an indication of the main problem areas, the following points are cited.

1) With the longer use of roads, more pore blockages are occurring, which reduce the drainage and noise reducing functions.
2) In the road structure, moisture such as rainwater permeates into the surface layer of the drainage-related pavement and drains away while flowing across the base layer surface. This exposes the surface of the base layer to water, and the increase in occasions of water ponding will eventually cause stripping of asphalt from the base layer surface, destroying the base layer. The number of cases during repairs in which replacement down to the base layer part is required are increasing.
3) In order that aggregate scattering does not occur even in cold and snowy regions in particular, the binder used is the same as those used in drainage-related pavement.
4) In dense-graded asphalt pavement, the freezing prevention agents that are scattered in the wintertime as part of road surface administration remain only on the surface, and will flow off the road in a short period of time. This is due to influences including scattering caused by the wind pressure from passing traffic, and means that the effect of the agents will not continue for long. In comparison, the structure of drainage-related pavement causes the freezing prevention agents to permeate into the surface layer and easily flow away rather than remaining on the road surface. Therefore, the effect of the freezing prevention agents will not continue for long in this case either.

3. POINTS OF IMPROVEMENT FROM EXISTING CONSTRUCTION METHODS

In order to resolve the problem areas of existing pavement that were cited in the previous section, improvements were planned by giving consideration to the points described below when developing the new construction method. With regard to the mixtures and the target properties and conditions immediately following construction, consideration was also given to hybrid pavement structure surface layer mixtures used on expressways as well as considering drainage-related pavement and SMA. The target properties and conditions of the longitudinal groove rough surface hybrid pavement that was developed are shown in Table 1 and Table 2.

1) It was believed that the destruction from the inside of the surface layer and the stripping of the lower layer surface which occur in cold and snowy regions is caused by the structure in which the entire surface layer has a high porosity. Accordingly, longitudinal groove rough surface hybrid pavement (known below as hybrid pavement) was adopted as a structure in which the surface was given the same roughness (target drainage layer of approximately 10mm) as drainage-related pavement, while the lower part was given the same water-tightness as SMA. By employing this structure, it was also possible to limit the permeation of freezing prevention agents, which are scattered on road surfaces in wintertime, to the inside of the surface layer.
2) Although a hybrid pavement structure was adopted as described above to realize protection of the longitudinal groove rough surface hybrid pavement lower layer mixture, the coefficient of permeability of this mixture was set to a target of $K_{15}=1\times10^{-7}$cm/s or less, which is considered the same as being impermeable.
3) In order that aggregate scattering does not occur even in cold and snowy regions in particular, the binder used in the longitudinal groove rough surface hybrid pavement has the same properties and conditions as the binder used in drainage-related pavement in Japan.

4) The drainage function immediately after construction was given a target seepage water volume of 800mL/15s or greater, which is the indicator for drainage-related pavement in cold and snowy regions. However, because it was anticipated that the adoption of the hybrid pavement structure would reduce the drainage function compared to drainage-related pavement, the construction machines were improved to create a rough surface finish that improves the drainage function.

Table 1 - Target properties and conditions of mixtures

Item		Longitudinal groove rough surface hybrid pavement standard values	Reference values		
			Drainage-related pavement	SMA	High function pavement Type II*1
Marshall compaction count	(No. of times)	50 times on both surfaces	50 times on both surfaces	50 times on both surfaces	50 times on both surfaces
Marshall stability	(kN)	5.0 or more	3.43 or more	5.0 or more	6.0 or more
Residual stability	(%)	75 or more	75 or more	75 or more	75 or more
Cantabro loss amount (-20℃)	(%)	12 or less	20 or less	—	12 or less
Coefficient of permeability K_{15}	(cm/sec)	1.0×10^{-7} or less	1.0×10^{-2} or less	1.0×10^{-7} or less	1.0×10^{-7} or less
Dynamic stability (DS)	(Times/mm)	6,000 or more	3,000 or more	3,000 or more	3,000 or more

*1: Pavement with a hybrid pavement structure that is used in expressways

Table 2 - Target road surface properties and conditions values immediately after construction

Item		Longitudinal groove rough surface hybrid pavement standard values	Reference values		
			Drainage-related pavement	SMA	High function pavement Type II*1
Road surface texture depth (MPD)	(mm)	1.2 or more	—	—	1.2 or more
Water permeation amount	(mL/15sec)	800 or more※2	1,000 or more	—	—
Skid resistance value (BPN)	(BPN_{20})※3	60 or more	60 or more	60 or more	60 or more
Skid resistance value (DF tester)	(μ)	0.25 or more	0.25 or more	0.35 or more※4	0.25 or more※4

*1: Pavement with a hybrid pavement structure that is used in expressways
*2: Corresponding to the permeation content of permeable pavement that has a porosity of 17%
*3: Conversion value to the BPN values at a road surface temperature of 20°C
*4: Numerical value when used as a surface layer

4. INVESTIGATION OF CONSTRUCTION MACHINES

In construction work using general asphalt finishers (known below as AF), the road surface is laid so that it is flat, as shown in Photograph 2.

Because there was concern based on the results of the indoor testing using the wheel tracking test piece that the longitudinal groove rough surface hybrid pavement mixture developed this time could not satisfy the seepage water volume standard value of 800mL/15s or more, investigation was made into improving the water permeation function by modifying the construction method.

At this time, it was thought that a rough surface finishing method using rollers would be difficult. After searching for improvement methods using AF machines, it was possible to realize a rough surface finish including longitudinal grooves by improving the taper units. In addition to the tamper units, improvements have also been made to

the vibrator units, and it has been confirmed that a seepage water volume of around 1,000mL/15s can be secured in the finished road surface. (Refer to Photograph 3.)

Photograph 2 - Example of road-laying using a general AF

Photograph 3 - Example of road-laying using a longitudinal groove rough surface hybrid pavement -dedicated AF

5. TIRE/ROAD NOISE REDUCTION EFFECT

Because the thickness of the drainage layer which maintains the pores is thinner in longitudinal groove rough surface hybrid pavement than in drainage-related pavement, the noise absorbing function will be slightly degraded compared to drainage-related pavement. However, longitudinal groove rough surface hybrid pavement still maintains a tire/road noise reducing function that is greater than functional SMA with an appropriate texture depth and dense-graded asphalt pavement.(Refer to Table 3 and Figure 2.) In particular, because the frequencies between 1,000-10,000Hz have become lower for longitudinal groove rough surface hybrid pavement than dense-graded asphalt pavement or functional SMA, it can be said that the air pumping noise (the noise generated by the compression and expansion of the air between the road surface and the tire tread grooves) is reduced compared to these pavements.

As a result of this function, it will be possible to reduce the effect of noise on the surrounding environment, and according to a two-year follow-up survey it was confirmed that an effect similar to that of drainage-related pavement can also be maintained by this function. (Refer to Figure 3) Regarding this tire/road noise, it has been confirmed that the same trends are found on expressways, and the noise reducing effect can be maintained even on heavy traffic roads.

Table 3 - Tire/road noise measurement results from a simple measuring car

	Immediately after construction (AP values)			
Frequency (Hz)	Longitudinal Groove Rough Surface Hybrid Pavement	Drainage-related pavement	Functional SMA	Dense-graded asphalt pavement
"A" characteristics	92.0	90.4	93.2	96.2
Top Size	13mm	13mm	13mm	13mm

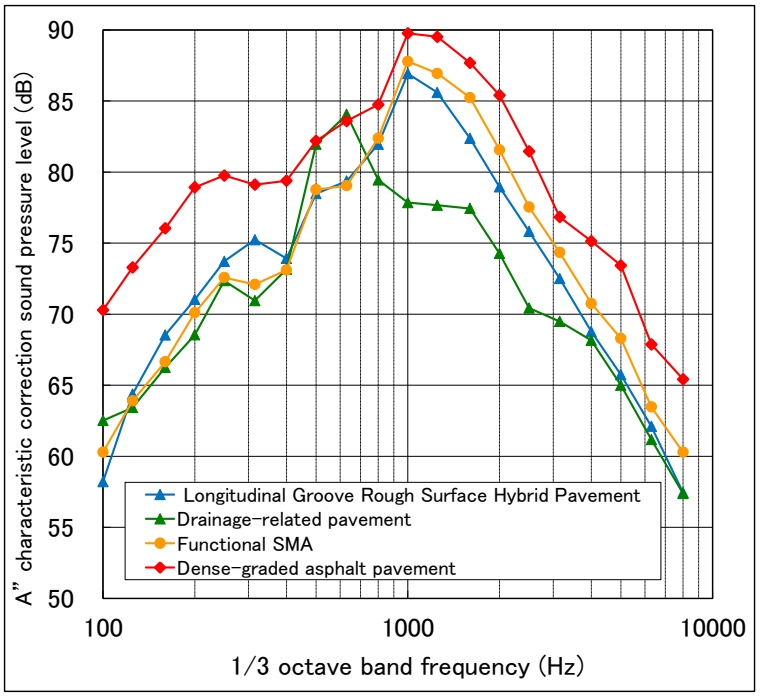

Figure 2 - Tire/road noise frequency characteristics

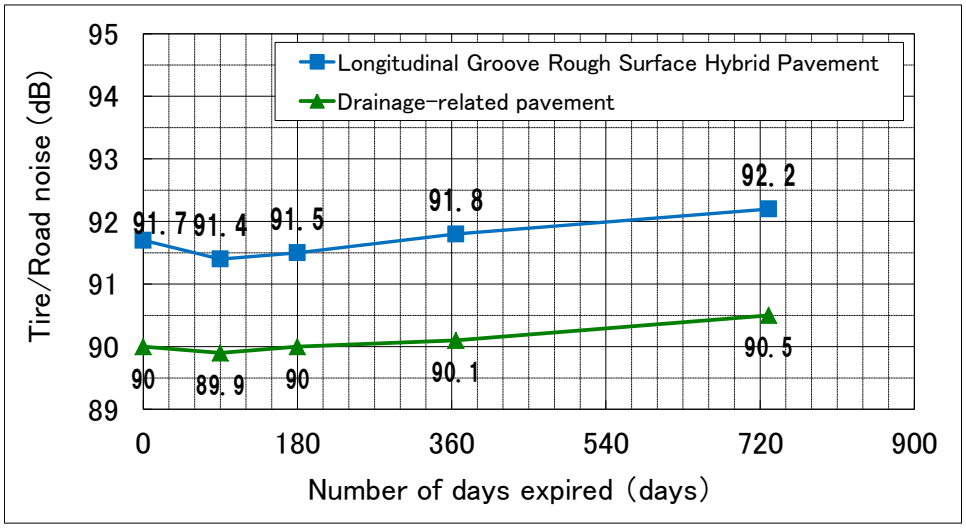

Figure 3 - Tire/road noise tracking survey results

For example, Table 4 and Figure 4 show the results of measuring the tire/road noise of the adjacent longitudinal groove rough surface hybrid pavement and dense-graded asphalt pavement in the prefectural road. From the measurement results, it is confirmed that the tire/road surface noise can be reduced compared to the dense-graded pavement

because the tire/road surface noise of the longitudinal groove rough surface hybrid pavement is lower than the dense-graded pavement did it.

Table 4 - Tire/road noise measurement results from a simple measuring car

	Tire/road noise (AP values)	
Frequency (Hz)	Longitudinal Groove Rough Surface Hybrid Pavement	Dense-graded asphalt pavement
"A" characteristics	91.8	96.5
Measurement timing	Immediately after construction	Existing pavement

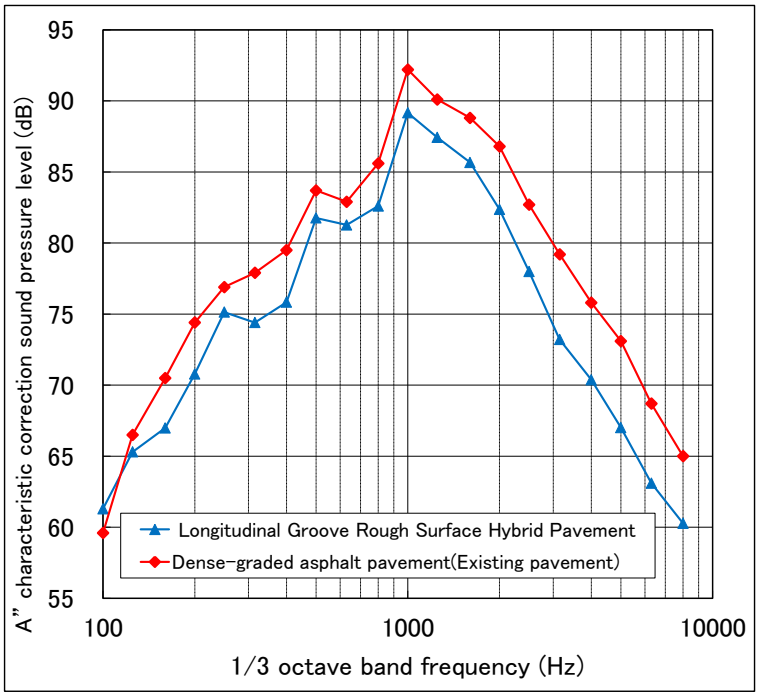

Figure 4 - Tire/road noise frequency characteristics

In addition, drainage pavement may be clogged with voids and drainage function may decrease. Compared to drainage-related pavement with such exiting pavement, we have confirmed cases where tire/road noise of longitudinal groove rough surface hybrid pavement is low. (Refer to Table 5 and Figure 5.)

Table 5 - Tire/road noise measurement results from a simple measuring car

	Tire/road noise (AP values)	
Frequency (Hz)	Longitudinal Groove Rough Surface Hybrid Pavement	Drainage-related pavement
"A" characteristics	91.9	93.1
Measurement timing	Immediately after construction	Existing pavement

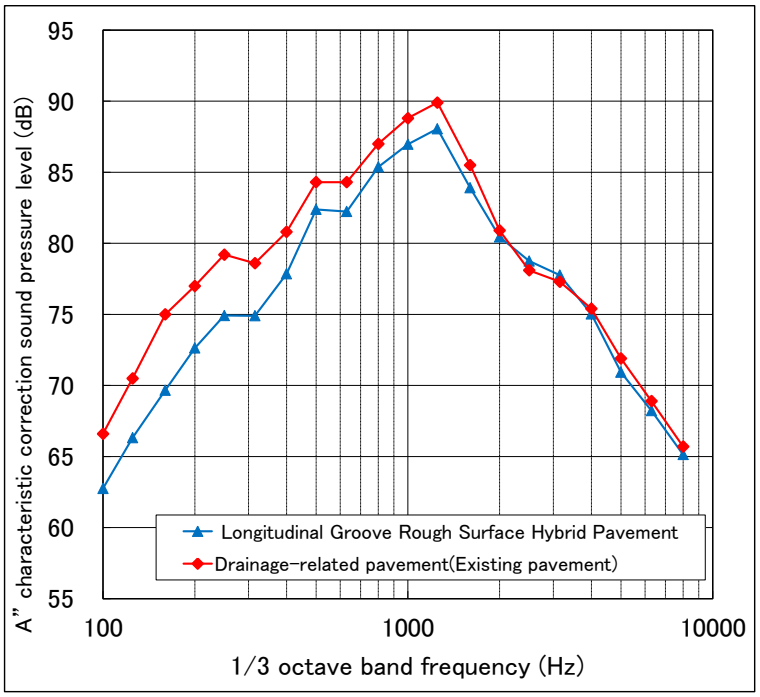

Figure 5 - Tire/road noise frequency characteristics

6. OTHER EFFECTS THAT CAN BE EXPECTED DUE TO USE OF LONGITUDINAL GROOVE ROUGH SURFACE HYBRID PAVEMENT

6.1 Improvement of visibility while driving

In longitudinal groove rough surface hybrid pavement, the longitudinal grooves on the surface can limit the diffuse reflection of light such as from sunlight. Photograph 4 shows the situation of a road surface of an expressway. Compared to the hybrid pavement (Name when used for expressways: High function pavement II type) shown on the right side, it can be confirmed that the longitudinal groove rough surface hybrid pavement on the left side realizes less diffuse reflection of the sunlight. From this it is believed that it will be easier for drivers to confirm the road surface while driving, improving the driving safety.

Photograph 4– Example of improving visibility by limiting the diffuse reflection of sunlight

6.2 Reduction of traffic accidents caused by skidding

Because the longitudinal groove surface has a high lateral slip friction coefficient, a reduction in accidents can be expected[3] in locations where a high skid resistance is required, particularly on roads which have tight curves[4].

Figure 6 and Figure 7 show the results of measuring the skid resistance on the expressway indicated in 6.1. Although the braking force coefficient is the same for both pavements as shown in Figure 6, the longitudinal groove rough surface hybrid pavement obtains a high sideway force coefficient result as shown in Figure 7. From this result, it is believed that the longitudinal groove rough surface hybrid pavement limits vehicle skidding.

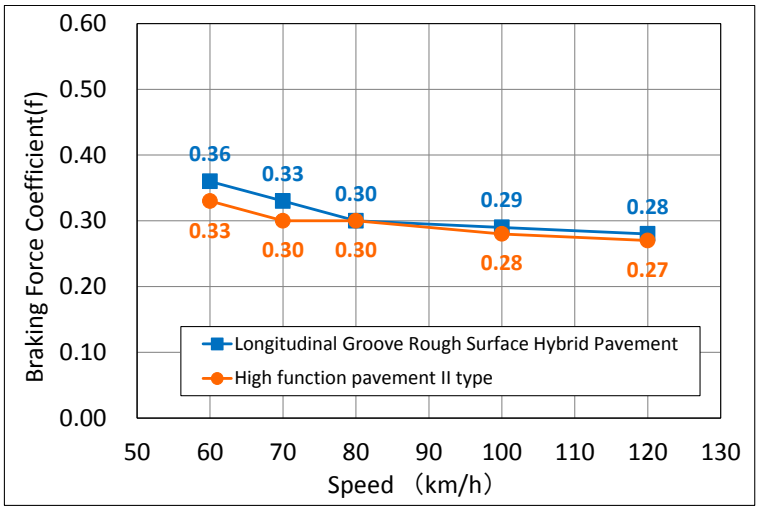

Figure 6- Result of measuring braking force coefficient

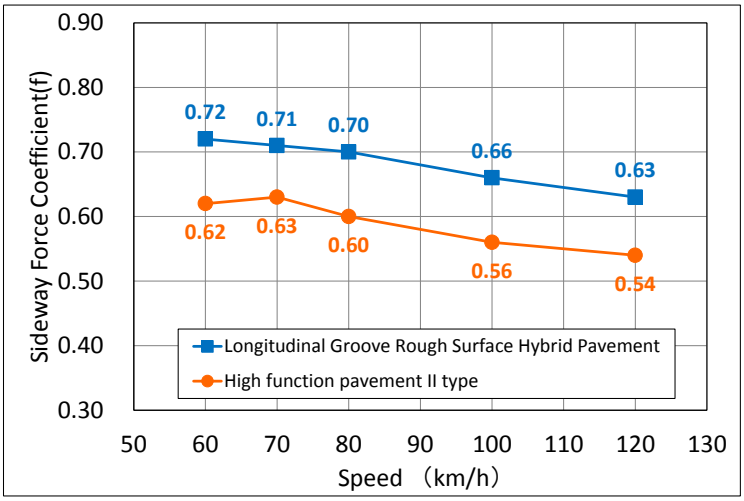

Figure 7 - Result of measuring sideway force coefficient (Steering angle 15°)

It has been confirmed that the numbers of accidents are actually reduced due to the use of longitudinal groove rough surface hybrid pavement. Table 6 shows the number of accidents at a location with a series of tight curves known by the nickname of the "Omega Curve" on the Meihan National Route at the National Route No. 25 bypass. Although 30 accidents occurred in the approximately one-year period before the construction of the longitudinal groove rough surface hybrid pavement, a large reduction to one tenth of the number of previous accidents was apparent in the 12-month period following the longitudinal groove rough surface hybrid pavement construction. For this reason, the application of longitudinal groove rough surface hybrid pavement is increasing as an accident countermeasure.

As the causes of the skidding limitation, in addition to the high sideway force coefficient it is thought that one reason is the fact that the longitudinal groove rough surface is ensured and skid resistance can be maintained even on heavy traffic roads as shown in Table 7. However, it is planned to verify the cause and effect relationship between the accident limitation and the longitudinal groove rough surface together with third party institutions going forward.

Table 6 -Number of traffic accident occurrences on the R25 Meihan Expressway (Osaka direction)

KP	Before longitudinal groove rough surface hybrid pavement construction January to November 2015	After longitudinal groove rough surface hybrid pavement construction January 2016 to December 2016
90.9	1	0
91.0	17	1
91.1	9	1
91.2	3	1
Section totals	30	3

Table 7 -Results of road surface properties and conditions test follow-up survey (at the Maitani Curve on the R25)

	Water permeation amount (mL/15sec)	Skid resistance value (BPN_{20})
Immediately after construction	1,224	79
One year after construction	923	85
Target road surface properties and conditions values of longitudinal groove rough surface hybrid pavement (Immediately after construction)	800 or more	60 or more

7. SUMMARY

Drainage-related pavement, which maintains effects such as a high drainage function and noise reduction ability, provides a high driving safety in conditions such as rainy weather. However, deficiencies have become apparent including damage caused to the base layer and the durability in cold and snowy regions. In response, Longitudinal groove rough surface hybrid pavement has been developed, which is able to resolve these problem areas while continuing to maintain the advantages of drainage-related pavement. In the functions maintained by this longitudinal groove rough surface hybrid pavement, the following points can be summarized regarding the effects on the environment. In the functions maintained by this longitudinal groove rough surface hybrid pavement, the effects on the vehicle ride are summarized below.

1）By implementing construction of the longitudinal groove rough surface hybrid pavement using a modified dedicated asphalt finisher as the compacting equipment, the road is given a longitudinal groove rough surface finish. Because this longitudinal groove rough surface has a drainage layer of approximately 10mm close to the surface which has a noise absorbing function, tire/road noise is reduced compared to dense-

graded type pavement. Due to this, it has become possible to reduce the effect of noise on the surrounding environment.

2）The longitudinal groove rough surface can limit the diffuse reflection of light including sunshine to improve the visibility when driving.

3）The lateral slip friction coefficient is high, and the surface has realized certain results in greatly reducing the number of accidents in locations having consecutive tight curves. This means that application of longitudinal groove rough surface hybrid pavement can be expected as a type of pavement that will reduce the number of accidents in locations which require a high skidding resistance.

8. CONCLUSIONS

Longitudinal groove rough surface hybrid pavement can reduce tire/road noise due to its longitudinal groove rough surface, and is a pavement that allows the addition of effects including improvement in visibility through limiting the diffuse reflection of light including sunlight and the reduction of accidents. However, because the results of testing on actual roads only extend for around seven years, some items relating to long-term durability and skidding accident prevention causes cannot yet be fully explained.

Therefore, in addition to conducting verification by continuing to implement follow-up surveys relating to long-term durability going forward, this company intends to join together with third party institutions to conduct verification with regard to the causes of skidding accident prevention such as by measuring slip friction coefficients. It is also intended to proceed with investigations with regard to the further added values of longitudinal groove rough surfaces to verify the superiority of longitudinal groove rough surface hybrid pavement over other types of pavement.

9. REFERENCES

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