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Comparisons of structural behavior between level and cant area of asphalt concrete track

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HIGHLIGHTS

- The behaviors of asphalt concrete level track and cant track were investigated.
- The asphalt tracks were constructed with gauge system.
- Full-scale tests were performed to simulate train movements on the rail tracks.
- There are certain differences between the outer and inner sides of cant track.
- Level track and cant track are applicable in long-life service.

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ABSTRACT

This study compares the behaviors of asphalt concrete level track and cant track under static and dynamic loadings. The asphalt tracks were constructed with attached and embedded gauges for measuring earth pressure, settlement of the structure, and strain at the bottom of asphalt layer. Full-scale tests were performed to simulate train movements on the rail tracks. According to the measurement results, there are certain differences in the earth pressure, settlement, and strain between level track and cant track, and between the outer and inner sides of cant track. Both level track and cant track are applicable in long-life service.

1. Introduction

Ballast track is ongoing maintenance due to scattering and plastic deformation of pebbles or gravel by the train load; however, maintenance manpower and time are absolutely lacking. To solve this problem, a ballastless track with a trackbed of concrete or asphalt concrete instead of gravels has been introduced from around the world in the 1960s [1]. Asphalt layer directly paved beneath sleepers is capable of performing as an elastic layer under the railway instead of open-graded unbound ballast layer [2]. In South Korea, it has been actively applied to tunnel sections and subways, and recently applied to the high-speed railway KTX.

In addition, the asphalt concrete track, which is known as a kind of martial track, has no research and development results in Korea, but the research and development and application results are showing increasing trend mainly in Germany, Europe, and the USA; especially in Germany, since 1990, it has been operated under the operating performance certification from the German Federal Railway Authority (EBA), including ATD (Asphalt supporting layer for Track Direct support), SATO (Smart Automatic Train Operation), GETRAC®, and Walter system [3]. Meanwhile, most of the asphalt track, the sleepers are laid directly on the asphalt trackbed, In Japan, however, the slab tracks type RA, proposed in 1968, have been installed on the asphalt concrete slabs [4,5].

Asphalt track combines advantages of gravel track (construction costs) and the concrete track (safety). A new concept track system that can overcome construction costs of maintaining disadvantage of a gravel ballast track, repair costs for the concrete track by natural disasters' loss, and fractures during quick maintenance due to

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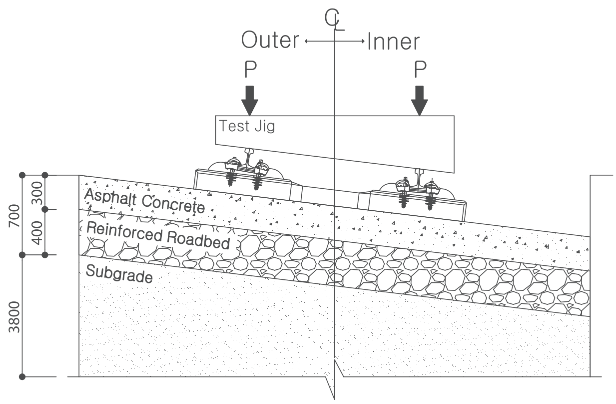

Fig. 1. Schematic diagram of test track constructed with cant (unit: mm).

the derailment, and possibly, the carbon dioxide emissions, noise and vibration reduction compared to concrete track is excellent. In particular, the construction productivity relative joints are not needed by the viscoelastic properties of asphalt concrete and can be quickly attached to the track in any season, compared to the concrete track. On the other hand, it is possible to apply the asphalt track with a high gradient (cant = 180 mm) since molding ability is good and can be a variety of cross-sectional shape and high precision (±2 mm) construction due to asphalt concrete's high internal friction [3,6]. Rose [7] suggested that rutting of the asphalt mixture is not a concern in the asphalt track since the pressures are applied over a wide area; therefore, the asphalt content could be 0.5% higher than that considered optimum for highway applications with air-voids of 1–3% for a strong and impermeable mat. Visco-elastic strength and modulus of asphalt concrete can make it better suited for the requirements of high-speed railway substructures and there is also no indication of any damages or cracks of the asphalt after many years of heavy traffic under widely varying conditions [8,9]. Lee [10] performed full-scale tests to evaluate the performance of an asphalt track system with static loading. Measurements of earth pressure, strain, and displacement indicate that a thickness of approximately 30 cm is appropriate for an asphalt trackbed subjected to train loadings.

In this paper, the behaviors of level track and cant track, in the curve of the asphalt concrete track, developed by Korea Railroad Research Institute (KRRI) was compared. An experimental construction of asphalt track with asphalt concrete trackbed, soil subgrade, and reinforced roadbed materials, and a trajectory taking into account the cant of 180 mm; followed by the analyses of earth pressure, settlement of the structure, and strain at the bottom of asphalt layer. The construction and instrumentation for the cant track were implemented as those for the test track of level track described by Lee [10] in the previous study.

2. Experimental construction

2.1. The construction of subgrade and reinforced roadbed

It is well known that the mechanical properties of asphalt mixtures are greatly influenced by temperature and loading time.

Table 2
Gradation of subgrade.

Sieve size (mm)	Percent passing (%)
4.75	75.5
2	62.5
0.85	44.2
0.425	31.7
0.25	23.6
0.11	16.5
0.075	11.1

Table 3
Properties of reinforced roadbed.

	Water content (%)	Dry density, γ_{dmax} (kN/m^3)	Specific gravity	Absorption (%)	Wear rate (%)	Plasticity index
Standard	–	–	≥2.45	≤3.0	≤35	N.P
Roadbed	7.2	21.69	2.68	0.9	30.3	N.P

Table 4
Gradation of reinforced roadbed.

Sieve size (mm)	Standard	Percent passing (%)
53	100	100
37.5	95–100	95.2
26.5	–	90.3
19	60–90	76
9.5	–	62.8
4.74	30–65	50.4
2.36	20–50	37.5
0.425	10–30	11.9
0.075	2–10	5.4

Table 5
Rheological properties of CRM and SBS -modified asphalt binders.

Aging states	Asphalt properties	CRM	SBS
Unaged binder	Viscosity at 135 °C (cPs)	1000	400
	$G^*/\sin\delta \geq 1.0$ kPa		
	64	8.25	1.31
	70	4.67	0.66
	76	2.36	0.34
RTFO aged residue	$G^*/\sin\delta \geq 2.2$ kPa		
	64	12.79	2.86
	70	6.46	1.44
	76	3.59	0.73
RTFO + PAV aged residue	$G^*/\sin\delta \leq 5000$ kPa		
	25	–	3540
	31	1820	–
	Stiffness at −12 °C ≤ 300 MPa	170	160
	m-value at −12 °C ≥ 0.3	0.33	0.35
PG grade		PG76-22	PG64-22

Therefore, since the modulus of elasticity of asphalt concrete changes with temperature, the temperature of the point 5 cm below the surface of asphalt concrete was kept at 40 °C during

Table 1
Properties of subgrade.

	Water content (%)	Dry density, γ_{dmax} (kN/m^3)	Maximum particle size (mm)	Modified CBR	No.4 passing (%)	No. 200 passing (%)	Plasticity index
Standard	–	20.0	≤100	≥10	25–100	0–25	≤10
Subgrade	7.3	20.98	19	19.5	75.7	11.1	N.P