严寒地区高速铁路设计

Design of High Speed Railway in Severely Cold Region

CRDC 中国铁设

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PART ONE

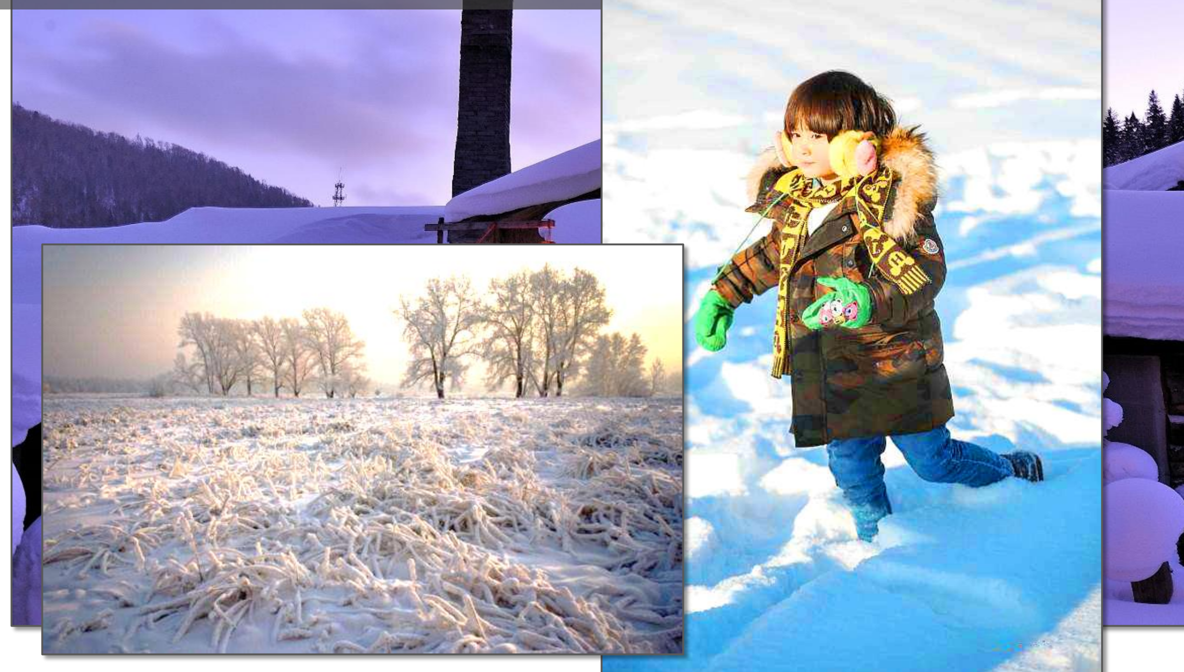
Technical Difficulties of HSR in Severely Cold Region

严寒地区高速铁路面临主要问题

1. Technical Difficulties of HSR in Severely Cold Region

Northeast China spans 40o-47o North Latitude, most regions of which are severely cold. Duration of freezing ice and snow last up to 5-6 months, and the minimum temperature reaches minus 40℃ or below, the temperature difference 80℃. Soil frozen depth remains 165cm-272cm. The maximum thickness of snow cover is more than 40cm.

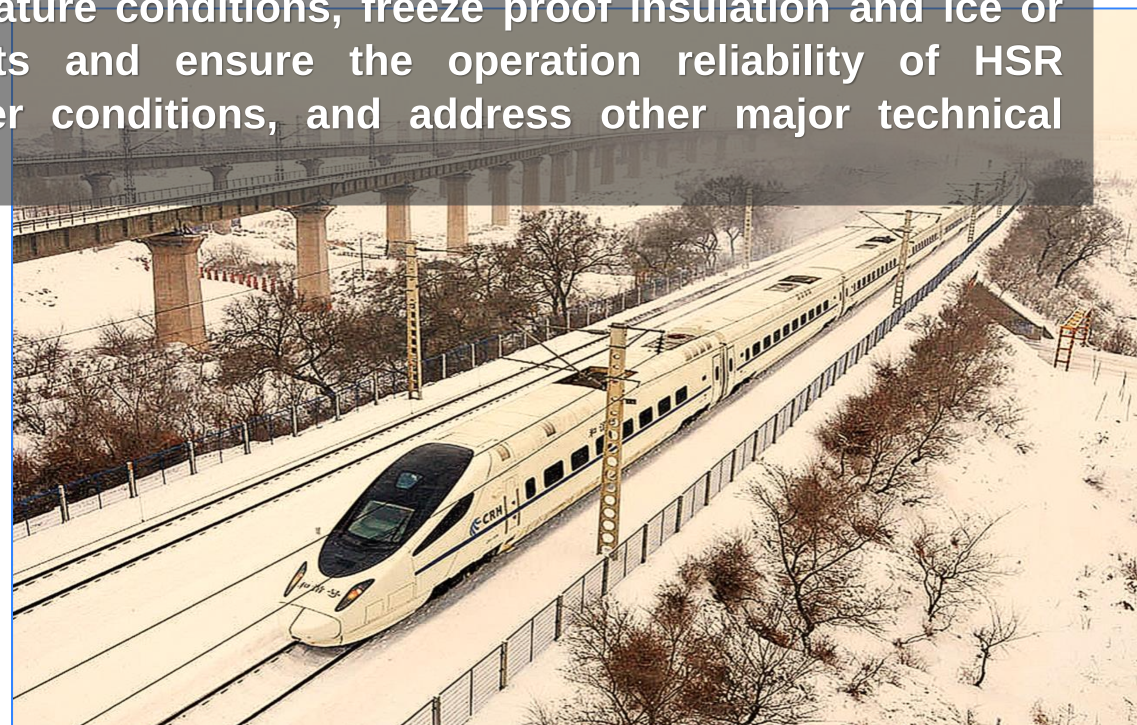
北纬40度到47度的中国东北地区，大部分区域属于严寒地区，严寒冰雪气候长达5～6个月，最低温度超过零下40摄氏度，温差超过80摄氏度，土壤冻结深度在165~272cm之间，最大积雪厚度超过40cm。



1. Technical Difficulties of HSR in Severely Cold Region

To meet the requirements of running performance, stability and stiffness uniformity of HSR track system in severe cold regions and operation reliability of the HSR devices and equipments, it is essentially required have control over frost heave deformation for embankments, bridges and other structures, construction quality control in low temperature conditions, freeze proof insulation and ice or snow melting of equipments and ensure the operation reliability of HSR equipments in harsh weather conditions, and address other major technical difficulties.

为满足严寒地区高速铁路轨道系统的平顺性、稳定性、刚度均匀性以及设备运行的可靠性要求，需解决路基、桥涵等构筑物冻胀变形控制，冬季低温条件下施工质量控制，构筑物、设备保温防冻和融冰除雪以及恶劣气候条件下保障高铁设备运行可靠性等重大技术难题。



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PART TWO

Engineering Measures for HSR in Severely Cold Region

严寒地区高速铁路设计采取的措施

2. Engineering Measures for HSR in Severely Cold Region

With regard to the difficulties confronted in the severely cold region, the designers and engineers have over past years conducted a number of scientific and technological researches on the basis of experiences of Harbin – Dalian HSR and Harbin-Qiqihar HSR constructions, and have made breakthroughs in terms of frost heave deformation control of seasonal frozen soil embankment, ice-melting and snow-eliminating of equipments, operation safety and reliability and other major technical difficulties. A complete series of HSR design technologies in severely cold region have been formulated.

针对严寒地区高速铁路面临的问题，以哈大、哈齐等高速铁路建设为依托，设计人员历时数年开展了大量科技攻关，攻克了季节性冻土路基冻胀形变控制、设备融冰除雪、运营安全保障等重大技术难题，形成了严寒地区高速铁路成套设计技术。

Civil Works
土建工程

The control technology and integrated monitoring technology system of the freeze-thaw embankment have been built up. Mono-block slab track, filling layer and new materials of bridge bearing grouting have also been developed. The anti-freeze technology of tunnel has been renovated to overcome the civil engineering difficulties of HSR infrastructure in severely cold region.

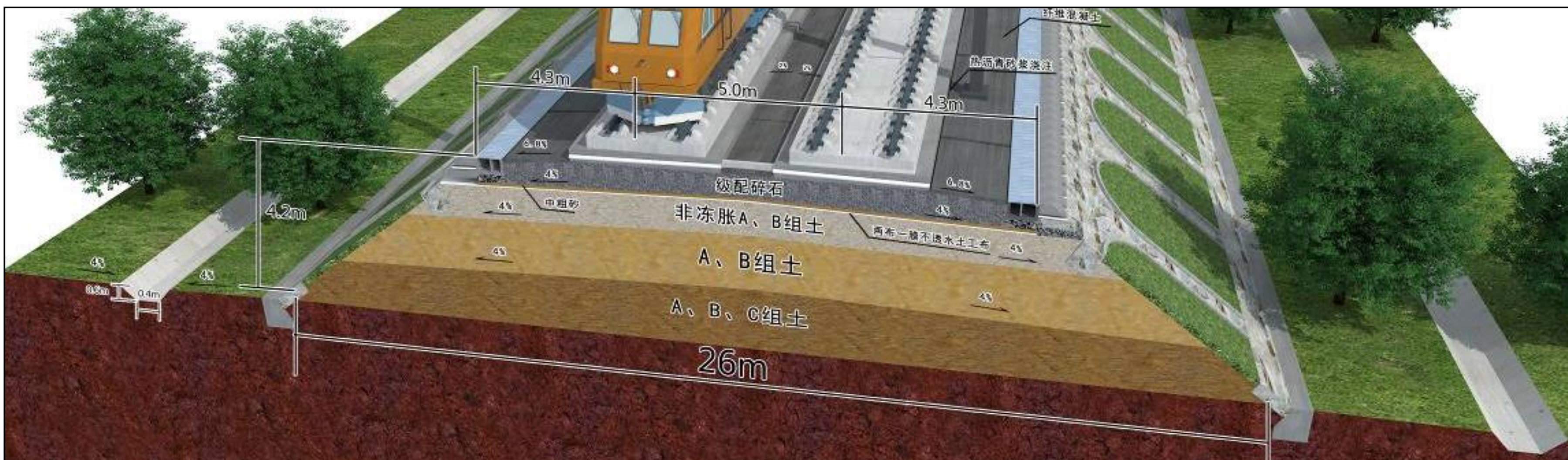
构建了冻融路基冻胀控制技术和综合监测技术体系，研发了单元板式无砟轨道及填充层和桥梁支座灌浆新材料，创新了隧道抗冻防冻技术，攻克了严寒地区高铁基础设施土建工程技术难题。



Embankment Frost Heave Deformation Control Technology 路基冻胀变形控制技术

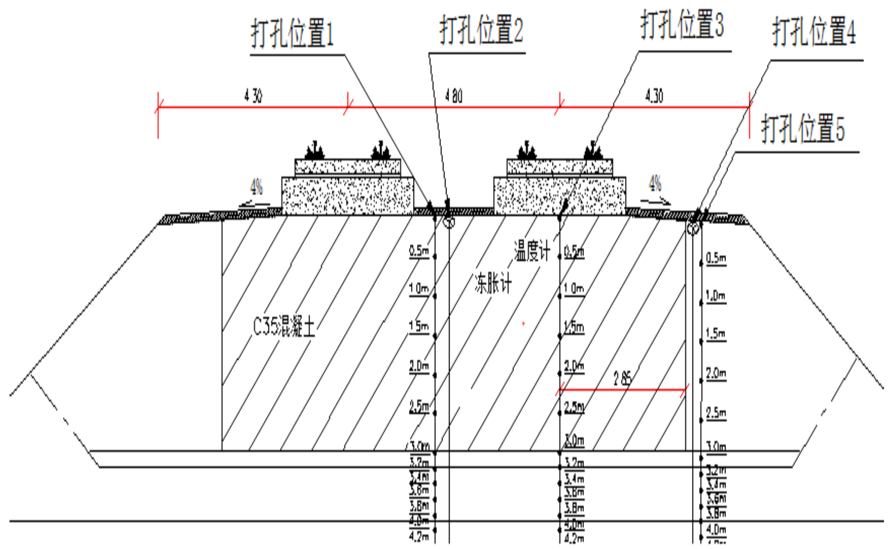
The anti-frost heave theory of HSR embankment prevention and control system in severely cold region is systematically established and put forward, and a complete set of design technologies based on the control of moisture and packing frost heave within the embankment protection depth.

系统提出了严寒地区高速铁路路基防排疏渗系统防冻胀理论，构建了基于路基防护深度范围内控制水分和填料冻胀性的成套设计技术；



Embankment Frost Heave Deformation Control Technology 路基冻胀变形控制技术

The frost heaving test method and device of HSR embankment coarse fillings are developed. The calculation method of roadbed foundation frost heaving degree on the basis of unfavorable condition is produced. The anti-frost-heaving embankment structure with high permeability, low water-conservation capacity, weak frost-heaving filler and special concrete foundation is renovated. Anti-frost-healing of embankment in severely cold region has been successfully resolved.



研发了高速铁路路基粗粒填料冻胀试验方法及装置，提出了基于不利条件填料冻胀率的基床冻胀计算方法，创新了高渗透性、低持水性、弱冻胀性填料路基和特殊条件下混凝土基床等防冻胀路基结构，解决了严寒地区路基防冻胀世界性难题。

Integrated Monitor Technology of Embankment Frost Heave Deformation 路基冻胀变形综合监测技术

The comprehensive monitoring and analysis system are established of HSR embankment in severely cold region, revealing the nature of the spatial and temporal development and distribution of the embankment frost heave deformation.

建立了严寒地区高速铁路路基冻胀综合监测分析系统，揭示了路基冻胀变形时空发展和分布规律；

The influence factors about frost heaving of slab track embankment are studied and determined.

研究确定了无砟轨道路基冻胀关键影响因素，建立了路基冻胀演变模型；

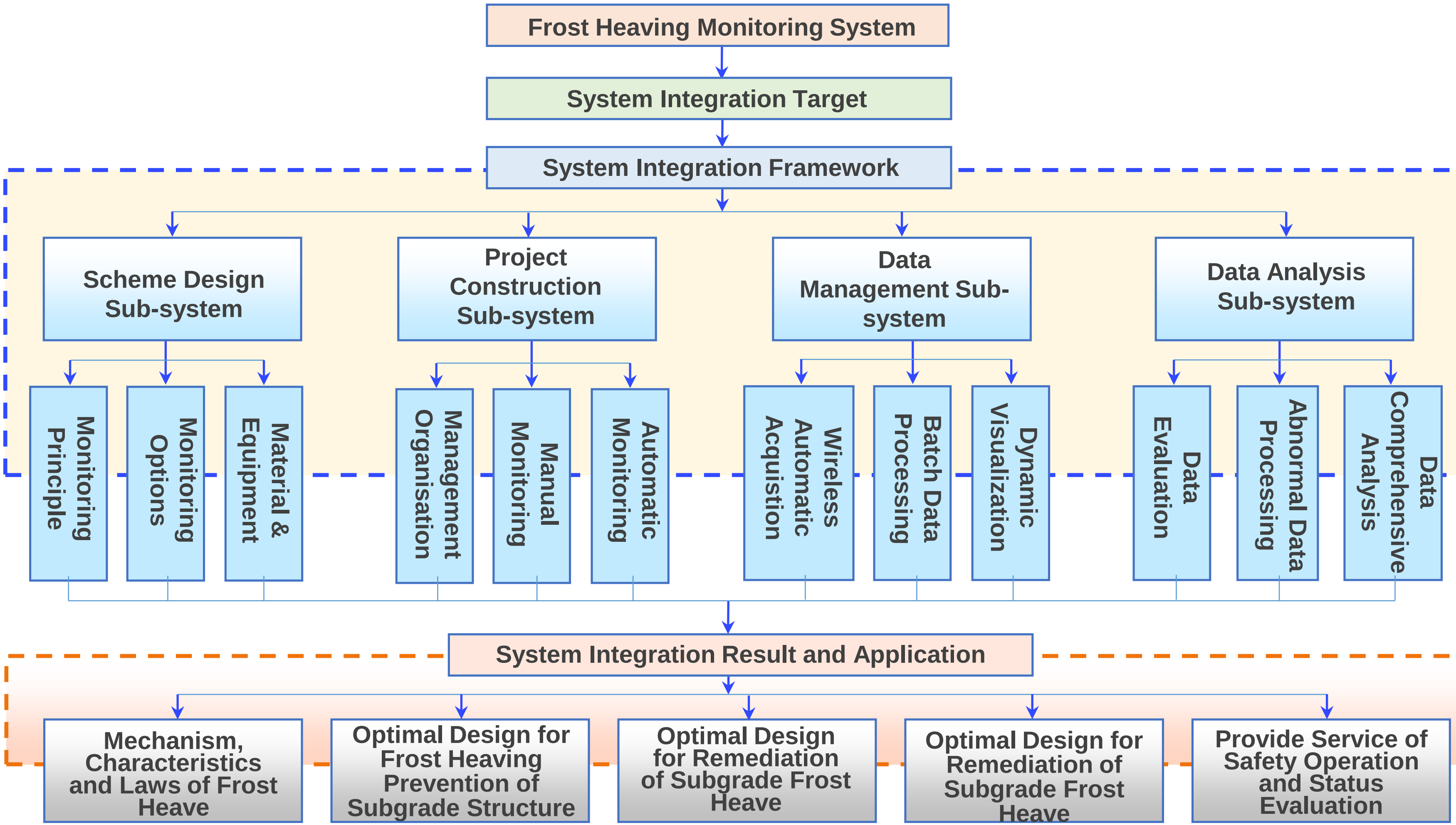
Evolution model of frost heave expansion is built up.

阐明了路基冻胀与冻结指数、结构层位、填料细粒含量等因素的关系；

The correlations between frost heave and freezing index, structure horizon and fine fillings content are elaborated. The dynamic smoothing technology of HSR in winter and summer is also put forward, so as to control the impact of embankment frost heave on operation and reduce the maintenance workload, and ensure the safety of HSR operation.

提出了严寒地区高速铁路路基兼顾冬夏的动态平顺处理技术，控制了路基冻胀对运营的影响，降低了维护工作量，保障了高速铁路的安全运营。

Integrated Monitor Technology of Embankment Frost Heave Deformation 路基冻胀变形综合监测技术



Bridge Construction Technology at Low Temperature in Winter 桥梁冬季低温施工技术

In order to meet the needs of construction in winter, winter negative temperature pipeline grouting material is researched and developed, and the performance testing standard for grouting material of post-tensioned pre-stressed pipe in severely cold region is formulated, so as to resolve the problem of pipe grouting construction in cold region in winter.

为满足寒冬期施工需要，研制了冬季负温管道压浆材料，制定了严寒地区冬季施工后张法预应力管道压浆材料性能检验标准，解决了寒区冬季管道压浆施工的难题。

Bridge Construction Technology at Low Temperature in Winter 桥梁冬季低温施工技术

The contradiction is solved between flow performance and retention of grouting material and setting time with the construction technology of grouting materials established, which is suitable for grouting materials of the bridge bearing under 0 ~ -5 ℃ and -5 ℃ ~ -10 ℃ temperatures. Material quality assessment methods are produced.

研制出适用于0～-5℃、-5℃～-10℃温度条件下桥梁支座灌浆材料，解决了灌浆材料流动性能及保持性与凝结时间之间的矛盾问题，建立了灌浆材料施工工艺及材料的质量评定方法。

Anti-freeze Design for Tunnels

隧道防寒防冻设计

Under low temperature circumstance, once water seepage occurs in tunnel, the frozen ice would undermine HSR equipments and operation safety. With comprehensive measures of protection, drainage and interception adopted, water protection and drainage technology of tunnel is renovated.

严寒隧道渗漏水后结冰危及高速铁路设备和行车安全，通过采用防、排、堵综合技术措施，创新了隧道防寒保温防排水技术。

Anti-freeze Design for Tunnels

隧道防寒防冻设计

The cold-proof, heat-insulation and water drainage technology at both interior and exterior of HSR tunnel with the maintaina bility conditions have been ren ovated, so as to solve the prob lem of ant-frost, heat-insulatio n and drainage of HSR tunnel structure in cold region, and a complete set of anti-freeze and drainage system takes shape.

提出了寒区高速铁路隧道抗冻防冻技术，创新了具备可维护性条件的洞内、外防寒保温排水技术，解决了寒区高速铁路隧道结构抗冻及保温排水难题，形成一整套完善的防寒、抗冻的隧道排水系统；

Anti-freeze Design for Tunnels

隧道防寒防冻设计

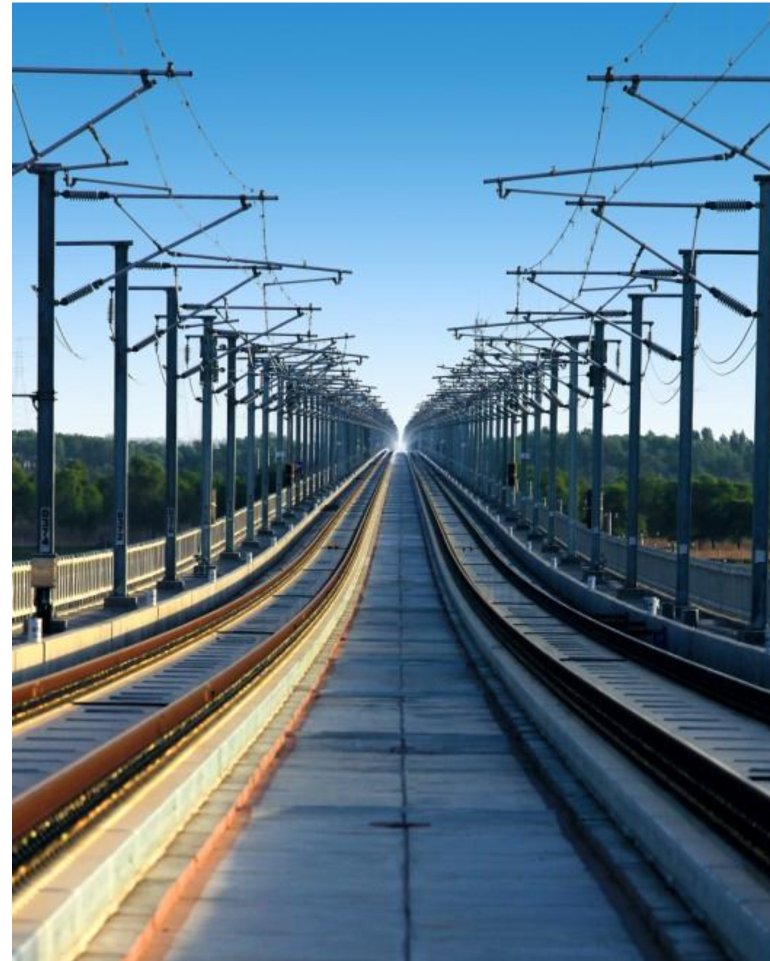
In respect to tunnel portal, it is to take radial grouting and reinforce surrounding rock and cut off water, and build the secondary lining with reinforced concrete and use backfill at the back of lining, so as to strengthen tunnel structure itself and the frost resistance of surrounding rock.

针对隧道洞口采取了径向注浆加固围岩并堵水、二次衬砌采用钢筋混凝土加强以及衬砌背后采用回填注浆等技术措施，加强了隧道结构自身及周边围岩的抗冻能力。

Ballastless Track Technology in Severely Cold Region 严寒地区无砟轨道技术

In the severely cold region, once the ballastless track slab cracks, he ice-snow circulation will expand the crack due to the freezing-thawing cycle. It will impair the service life of track slab Therefore, the CRTSⅢ ballastless track slab structure is developed, which adopts the biaxial prestressed track slab to avoid the occurrence of cracks on the track slab’s surface, by doing this, unfavorable influence of frost heave on the track structure can be effectively reduced.

严寒地区无砟轨道结构产生裂缝后，在冰雪循环冻融作用下裂缝不断扩展，将影响轨道板使用寿命。CRTSⅢ型板式无砟轨道结构，采用双向先张预应力轨道板，避免了轨道板表面裂缝的产生，从而有效降低冰雪冻胀对轨道结构的不利影响。



Ballastless Track Technology in Severely Cold Region 严寒地区无砟轨道技术

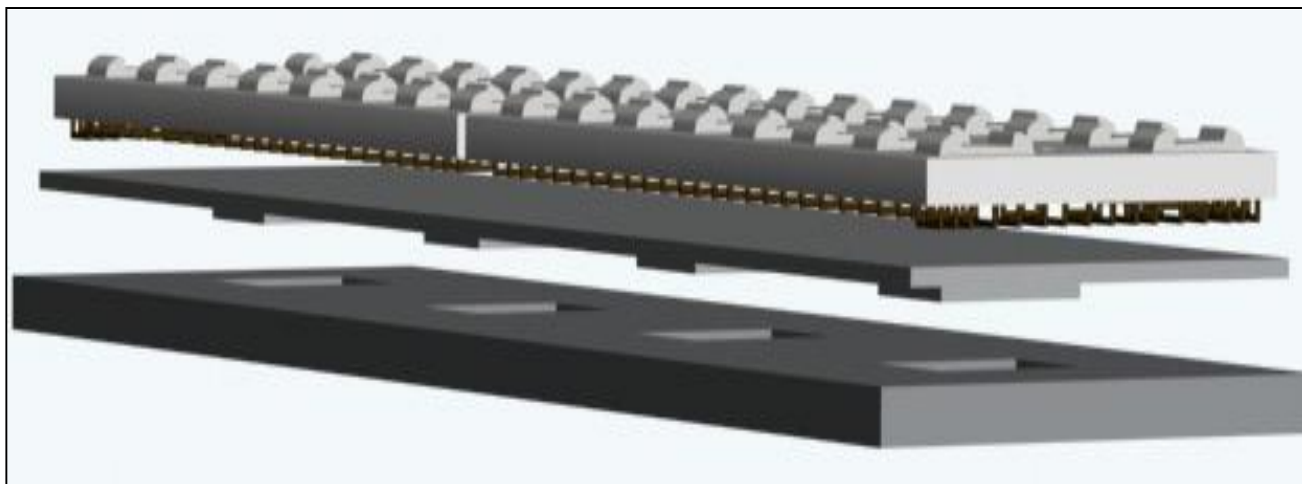
Taking into account the frost resistance, rail platform is provided at the fastener fulcrum position to reduce the snow and ice impact on the fastener system. The adoption of ‘composite board’ structure, made of self-compacting concrete and track slab, improves the durability of the track structure.

同时考虑了抗冻性能，在扣件支点位置设置承轨台从而降低冰雪长时间冻结对扣件系统影响。板下采用自密实混凝土与轨道板形成“复合板”结构，提高了轨道结构的耐久性。

Ballastless Track Technology in Severely Cold Region 严寒地区无砟轨道技术

In design, it takes full consideration of frost resistance of reinforced concrete base. In the subgrade, bridge and other open-line sections, transverse expansion joints are set every 1 to 2 rail slab of the base, which forms a unit structure. Standard of filling material between the expansion joints in ballastless track structure is developed.

设计上充分考虑了钢筋混凝土底座的抗冻性能。在路基及桥梁等明线地段的底座每隔1~2块轨道板设置横向伸缩缝，形成单元结构。研发并制定了适用于严寒地区无砟轨道结构间伸缩缝的嵌缝材料标准。



Ballastless Track Technology in Severely Cold Region 严寒地区无砟轨道技术

Targeting the drainage problem between lines in subgrade section, the horizontal drainage channel is set between the bases, which reduce bad influence of drainage facilities on subgrade and durability of track structure.

针对路基地段线间排水问题，在底座间设置横向排水通道，减少了排水设施对路基本体和轨道结构耐久性的不利影响。针对严寒地区大跨度桥梁普遍存在的梁端扣件间距超限问题，采取梁端底座悬出与设置异型轨道板相结合的设计措施，解决了严寒地区大跨度连续梁梁端扣件间距超限的难题。

Ballastless Track Technology in Severely Cold Region 严寒地区无砟轨道技术

Aiming at over-limitation fastening gap at the end of the beam commonly seen in bridges with big spans in severely cold regions, proper design measures are adopted, as combined bedplate hanging at the bottom of the beam and setting abnormal track slab. Therefore, the problems can be solved.

针对严寒地区大跨度桥梁普遍存在的梁端扣件间距超限问题，采取梁端底座悬出与设置异型轨道板相结合的设计措施，解决了严寒地区大跨度连续梁梁端扣件间距超限的难题。

E&M System

四电系统

Key technology on anti-icing, ice melting of OCS and snow melting of turnout in HSR are innovated. Outdoor equipment in severely old regions can rely on application technology to ensure that E&M equipment can operate functionally in the winter under special weather conditions.

创新了高速铁路接触网导线防冰融冰、道岔融雪等关键技术，严寒地区室外设备可靠应用技术，保证了四电设备在冬季特殊气候条件下可靠运行。

Ice Melting Technology of OCS
接触网融冰技术

During the season changes from winter to spring or from autumn to winter, the OCS is liable to encounter ice coverage phenomenon in the maintenance skylight time, which would affect the normal power supply. By establishing the theoretical model of anti-icing theory of OCS and simulation model of the traction power supply system under the condition of anti-ice melting, the calculation theory of anti- ice melting ice is put forward; and technical equipment of anti–icing and anti-ice melting is developed. Therefore, the technical problem of stability of pantograph current-collection of EMU train in severely cold region is solved.

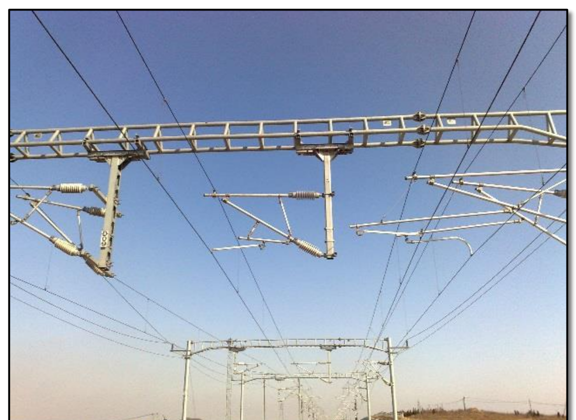
冬春、秋冬季节变化时段，维修天窗时间接触网易出现覆冰现象，影响列车正常受电。通过建立接触网防覆冰特性理论模型和接触网防融冰状态下牵引供电系统仿真模型，提出了防冰融冰计算理论，研发了接触网防冰融冰技术装备，解决了严寒地区动车组弓网受流稳定性技术难题。

Cantilever Condition Monitoring System of OCS

接触网腕臂状态监测系统

A set of techniques is innovated including cantilever’s calculation, pre-assembly, installation and monitoring. On-line monitoring software and equipment for the cantilever of OCS is developed, which solves the problem of monitoring the system under extreme temperature.

创新了严寒地区高速铁路接触网腕臂计算、预配、安装及监测成套技术，研发了接触网腕臂状态在线监测软件及设备，解决了系统极端温度下监测难题。

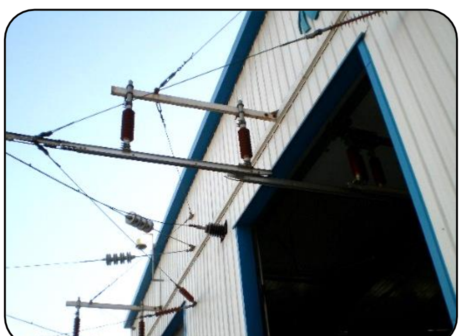


Mobile OCS Technology in EMU Serving Workshop

动车整备库移动接触网技术

In winter, the EMUs running in and out of the servicing workshop influence greatly on the internal temperature, which would affect the operating environment and maintenance efficiency. By adopting mobile OCS technology at the entrance of serving workshop, once the EMU trains enter the workshop, the door will be closed immediately, so that the internal temperature will remain constant.

在冬季，动车组出入运用所整备库对库内温度影响较大，影响库内作业环境和整备检修效率。在整备库大门处采用移动接触网技术，动车组进出整备库后即密闭库门，保证动车整备库温度。



Snow Melting System of Turnout

道岔融雪系统

Switch are easily to be buried under the snow in the winter time, which would lead to the snow to be squeezed into ice flake, therefore, hard to switch and affect the operation. According to the characteristics of severely cold region, based on the electric heating method, adopting additional external locking heating device and other measures to improve the snow melting on switch rail and top iron parts, to solve problems such as: geometric changes of switch rail caused by snow-melting device in severely cold region; bad conversion of turnout caused by heating blind spots.

道岔在冬季容易被积雪掩埋，道岔转换时易造成积雪被挤压成冰片状，引起道岔转换的卡阻而影响运营。根据严寒地区特点，在电加热道岔融雪技术基础上，采用增加外锁闭加热装置、改进道岔融雪加热条功率等措施，改善了道岔尖轨和顶铁部位的融雪效果，使道岔尖轨保持密贴，解决了严寒地区融雪设备可能引起道岔尖轨几何尺寸变化及加热盲区造成道岔转换不良的难题。

Reliable Application Technology of Outdoor Equipment 室外设备可靠应用技术

Whole set technology of direct control and drive OCS isolation switch centralized monitoring technology is innovated, solving the problem of electronic devices' instability in severely cold regions; outdoor unattended room adopts technical measures to take control of the heat leakage rate and low temperature starting technology to ensure the normal use of outdoor equipment under severely cold conditions.

创新了电缆直控式接触网隔离开关集中监控成套技术，解决了严寒地区电子器件不稳定的难题；对室外无人值守机房采取了控制漏热率的技术措施及低温启动技术，确保严寒条件下室外设备的正常运用。

Operation and Safety Facilities

运营及安全保障设施

Ice melting equipment for EMU is researched and developed, fault detection system of EMU train operation and cantilever condition monitoring system are innovated, disaster prevention and security monitoring system is improved, an efficient operation and security system of high-speed EMU in severely cold region is formed.

研发了动车组融冰除雪设备，创新了动车组运行故障检测系统、接触网腕臂状态监测系统，完善了防灾安全监控系统，构建了严寒地区高速动车组高效运营和安全保障系统。

Ice Melting and Snow Removal Technology of EMU

动车组融冰除雪技术

By building the analysis model of snow-covered ice at the bottom of the EMU, the simulation results determine the air supply temperature, velocity, outlet angle, height to the train set and other control parameters, so that directional snow blowing by hot air is realized. It solves the technical problem of snow removal and ice melting at the bottom of the train set, which improves the operation efficiency of the EMU.

通过构建动车组车底附雪结冰分析模型、模拟计算仿真，确定系统的送风温度、速度、出风角度、距车体高度等控制参数，实现了热风智能定向吹雪，解决了动车组底部除雪融冰技术难题，提高了动车组整备运用效率。

On-line Monitoring of Snow and Ice on EMU

动车组积雪结冰在线监测

In the hub station, fault image detection system of high-speed EMU operation is set up. The EMU online operation detection network system is built by integrating high-speed camera, automatic image recognition, image transmission and processing accelerator technology to automatically monitor the on-line bogie, equipment cabin, snow, ice at the bottom of the train set and technical conditions, to achieve risk warning, so that safety impact of ice and snow on EMU operation is effectively controlled.

在枢纽站设置了高速动车组运行故障图像检测系统，通过集成高速摄像、图像自动识别、图像传输及处理加速器技术，构建了动车组在线运行状态检测网络系统，可自动监测在线运行动车组转向架、设备舱、车底积雪结冰及技术状态，实现风险预警，有效控制积雪结冰对动车组行车安全的影响。

Anti-strike Technology for Balise and Other Outdoor Equipment 应答器等室外设备防击打技术

For the case that frazil ice on EMUs in severe cold region striking signal device, the Front Protective Pad Block technology is originated and overcomes the crux of the balise and other wayside equipment struck and damaged by ice fallen off the EMUs, which improves the adaptability of wayside signal equipment to the icy and snowy environment in severely cold regions.

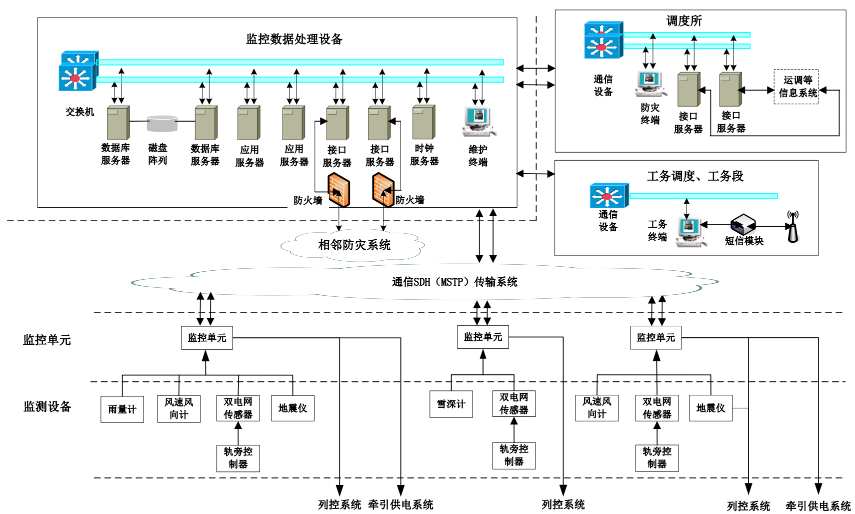
根据严寒地区动车组挂冰凌击打信号设备的情况，首创“绕前加装防护垫块”防护技术，攻克了应答器等轨旁设备受动车脱落冰块击打损坏的难题，提高了轨旁信号设备对严寒冰雪环境的适应性。

Disaster Prevention and Safety Monitoring System

防灾安全监控系统

The disaster prevention and safety monitoring establishes a subsystem for rainfall depth monitoring, which is organically integrated with the monitoring systems of strong wind, precipitation, foreign object intrusion and seism, effectively lowers or reduces the impact of snow on HSR by real-time monitoring of snow depth data, thus ensuring the operation safety.

防灾安全监控建立雪深监测子系统，并与大风、雨量、异物侵限及地震等监测系统有机集成，实时监测积雪深度数据，有效降低或减少雪灾对高速铁路影响，确保运营安全。



03

PART THREE

Operation Practices of HSR in Severely Cold Region

严寒地区高速铁路运营实践

3. Operation Practices of HSR in Severely Cold Region

Relying on the above technology, presently, eight HSR lines have been constructed in the northeastern region, of which, the operating kilometrage reaching 2,659 km, while the HSR under construction will reach up to about 2,572 km.

依托上述技术，目前东北地区已建成8条高速铁路，运营里程2659公里，正在建设高速铁路约2572公里。

3. Operation Practices of HSR in Severely Cold Region

Of Harbin-Dalian HSR, put into operation in 2012, the experimental maximum speed reached 385km/h while the operation speed 300km/h, creating the world record for HSR lines operated irn the severely cold regions. Within the past five complete freeze-thaw cycles, the continuous monitoring shows that the under-track foundation has been in good condition. The equipment that has undergone various unfavorable conditions such as cold blizzard, including traction power supply, communication and signal, has fully verifies the reliability and safety of the technology.

2012年开通的哈大高速铁路实验最高速度385km/h，开通运营最高速度300km/h，开创了世界严寒高铁商业运营速度之最。在过去5个完整的冻融循环期内，经连续监测，线下基础设施状态良好，牵引供电及通信、信号等设备经历了严寒暴雪等各种不利工况的考验，充分验证了各项技术设备的可靠性和安全性。

3. Operation Practices of HSR in Severely Cold Region

HSRs under operation

Name of HSR	Operation Kilometrage(km)	Design Speed(km/h)	Time of Opening to Traffic
Qinhuangdao-Shenyang HSR	400	250	October, 2003
Changchun-Jilin HSR	111	250	January, 2011
Harbin-Dalian HSR	921	350	December, 2012
Panjin-Yingkou HSR	89	350	September, 2013
Harbin-Qiqihar HSR	281	250	August, 2015
Shenyang-Dandong HSR	206	250	August, 2015
Jilin-Tumen-Huichun HSR	359	250	September, 2015
Dandong-Dalian HSR	292	200	December, 2015

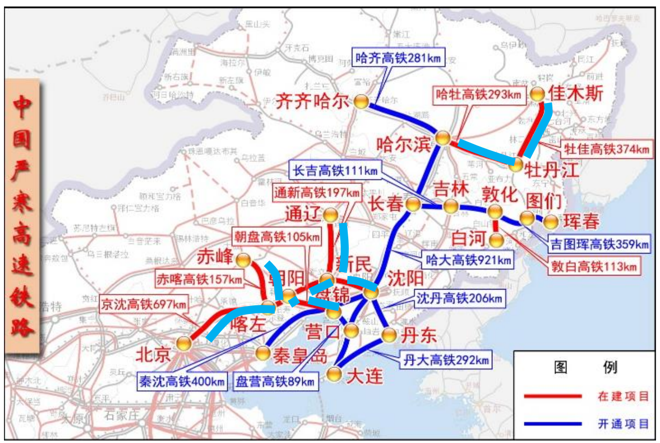
开通的高速铁路

项目名称	运营里程（km）	设计速度km/h	开通时间
秦皇岛至沈阳高速铁路	400	250	2003年10月
长春至吉林高速铁路	111	250	2011年1月
哈尔滨至大连高速铁路	921	350	2012年12月
盘锦至营口高速铁路	89	350	2013年9月
哈尔滨至齐齐哈尔高速铁路	281	250	2015年8月
沈阳至丹东高速铁路	206	250	2015年8月
吉林至图们至珲春高速铁路	359	250	2015年9月
丹东至大连高速铁路	292	200	2015年12月

3. Operation Practices of HSR in Severely Cold Region

HSRs under construction

Name of HSR	Length (km)	Design Speed(km/h)
Harbin-Mudanjiang HSR	293	250
Beijing-Shenyang HSR	697	350
Chaoyang-Panjin HSR	105	350
Chifeng-Kazuo HSR	157	250
Tongliao-Xinmingao HSR	197	250
Shenyang-Jiamusi HSR	1123	250~350



在建高速铁路

项目名称	全长（km）	设计速度km/h
哈尔滨至牡丹江高速铁路	293	250
北京至沈阳高速铁路	697	350
朝阳至盘锦高速铁路	105	350
赤峰至喀左高速铁路	157	250
通辽至新民高速铁路	197	250
沈阳至佳木斯高速铁路	1123	250~350


THANKS!
CRH