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Impact Analysis of Tunnel Cross Section Shape on Tunnel Temperature Field Calculation

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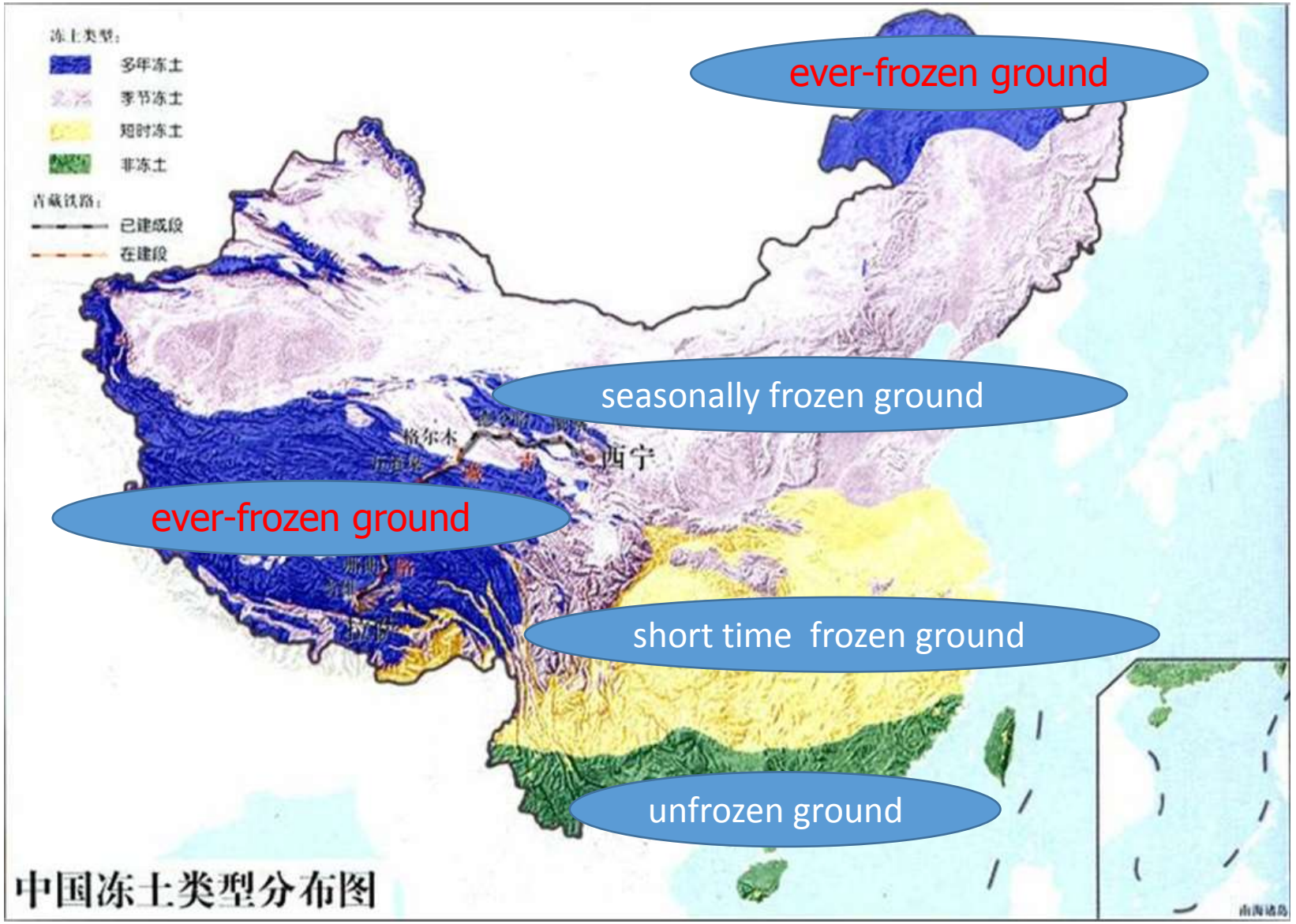
Outline

- **1、Impact analysis of tunnel cross section shape on tunnel temperature field calculation**

  道断面形状对隧道温度场的影响
- **2、Finite difference calculation model of tunnel temperature field under ventilation with circular section**

  考虑通风作用的隧道温度场有限差分计算模型(圆形断面）
- **3、Temperature field analysis of an actual cold region railway tunnel**

  寒区铁路隧道温度实测研究



Frozen soil type distribution of China

中国冻土类型分布图

The Necessity of Research

- Research on cold region tunnel design is becoming urgent because of the vast infrastructure construction projects being undertaken for railways and highways in cold regions. The prediction of temperature fields, which are used as references for relevant cold-proofing measures, is an important factor in cold region tunnel engineering design.
- Most traffic tunnels have horseshoe shape or side wall shape cross sections. Calculation formulae of temperature field for circular cross section tunnel model were studied by many scholars. It is necessary to find out the difference of temperature distribution between circular cross section tunnel model and actual horseshoe shape cross section tunnel model.

Calculation model

CFD-FLUENT Model.

Tunnel legth of 1000m.

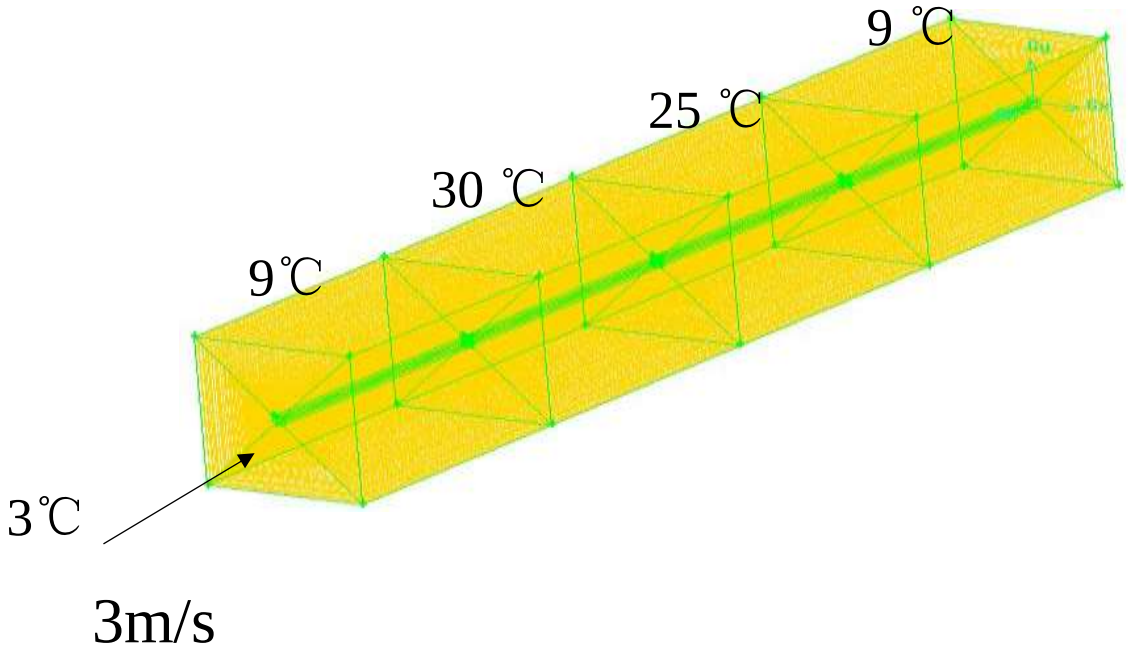
Original rock temperature of 9℃、30 ℃ 、25 ℃ 、9 ℃ degree centigrade of each 250m.

Entrance airflow temperature of 3℃.

Airflow speed of 3m/s.

Exit air pressure is standard atmospheric pressure.

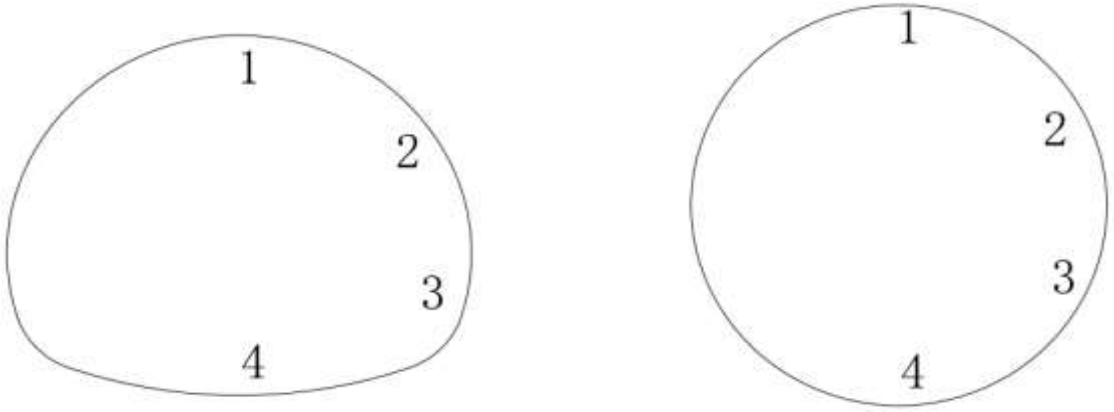
CFD软件FLUENT计算对比，1000m隧道模型，原始岩温9℃、30 ℃ 、25 ℃ 、9 ℃。隧道入口设置风温边界条件3℃恒温和速度入口边界条件3m/s；隧道出口设置为压力出口边界条件，并给定出口压力为大气压。



Three-dimensional computational grid partitioning schemes

CFD软件1000m隧道三维计算网格划分示意图

The same section area



layout of temperature test points
隧道断面内温度测点分布图

Table 1 Parameters of materials

Materials 介质 材料	Density 密度 kg/m^3	Specific heat capacity at constant pressure 比热容 $J/(kg\cdot ^oC)$	Thermal conductivity 导热系数 $W/(m\cdot ^oC)$
surrounding rock 围岩	2200	850	2.5
airflow 空气	1.2	1005	0.0242

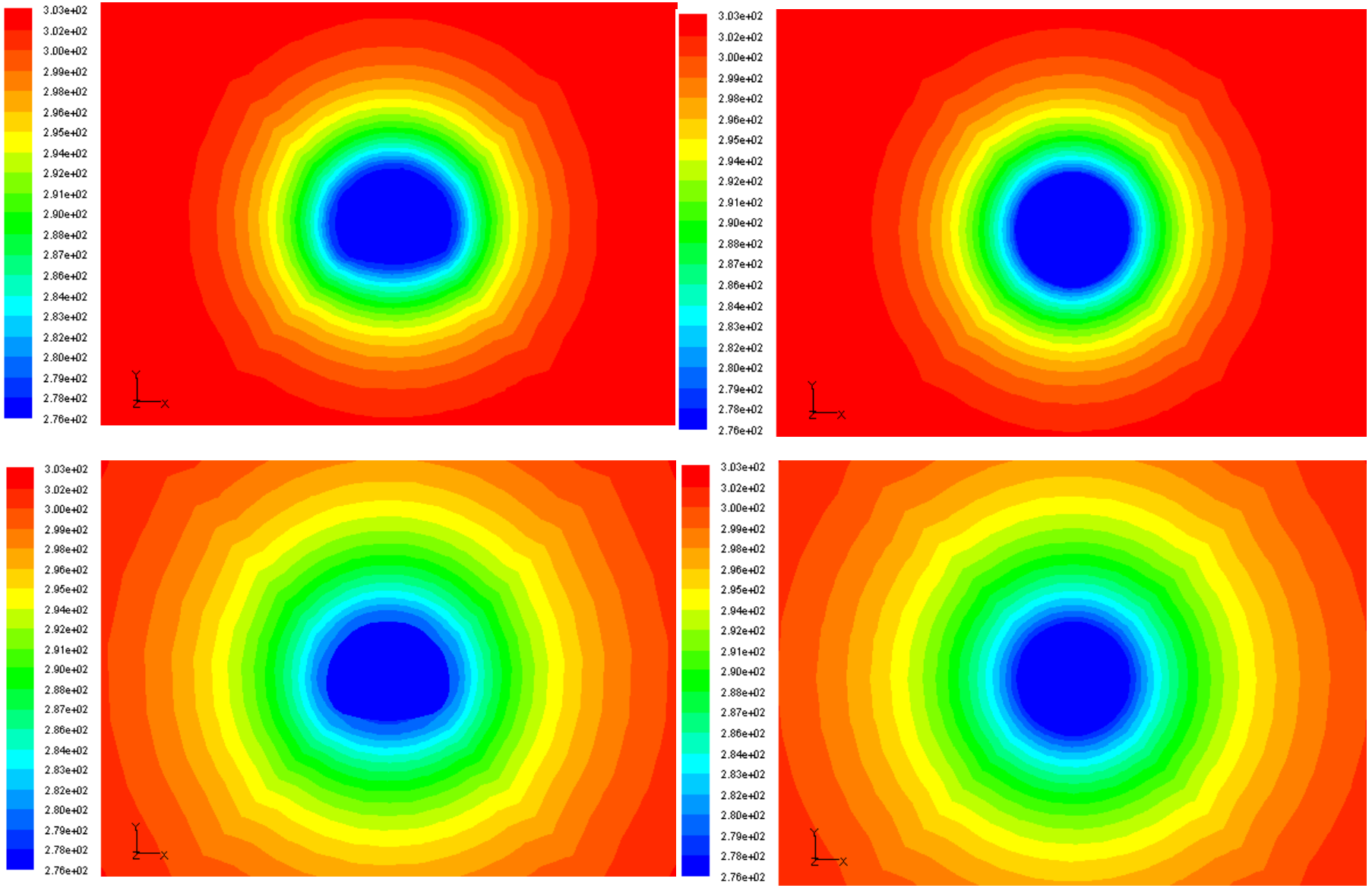
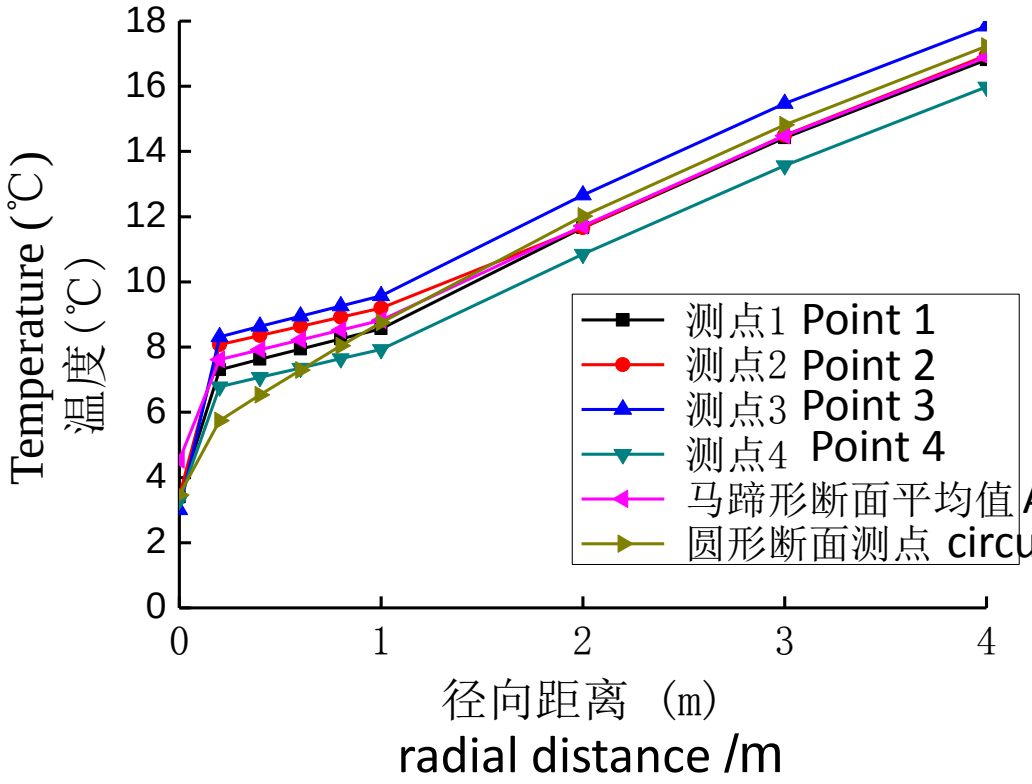
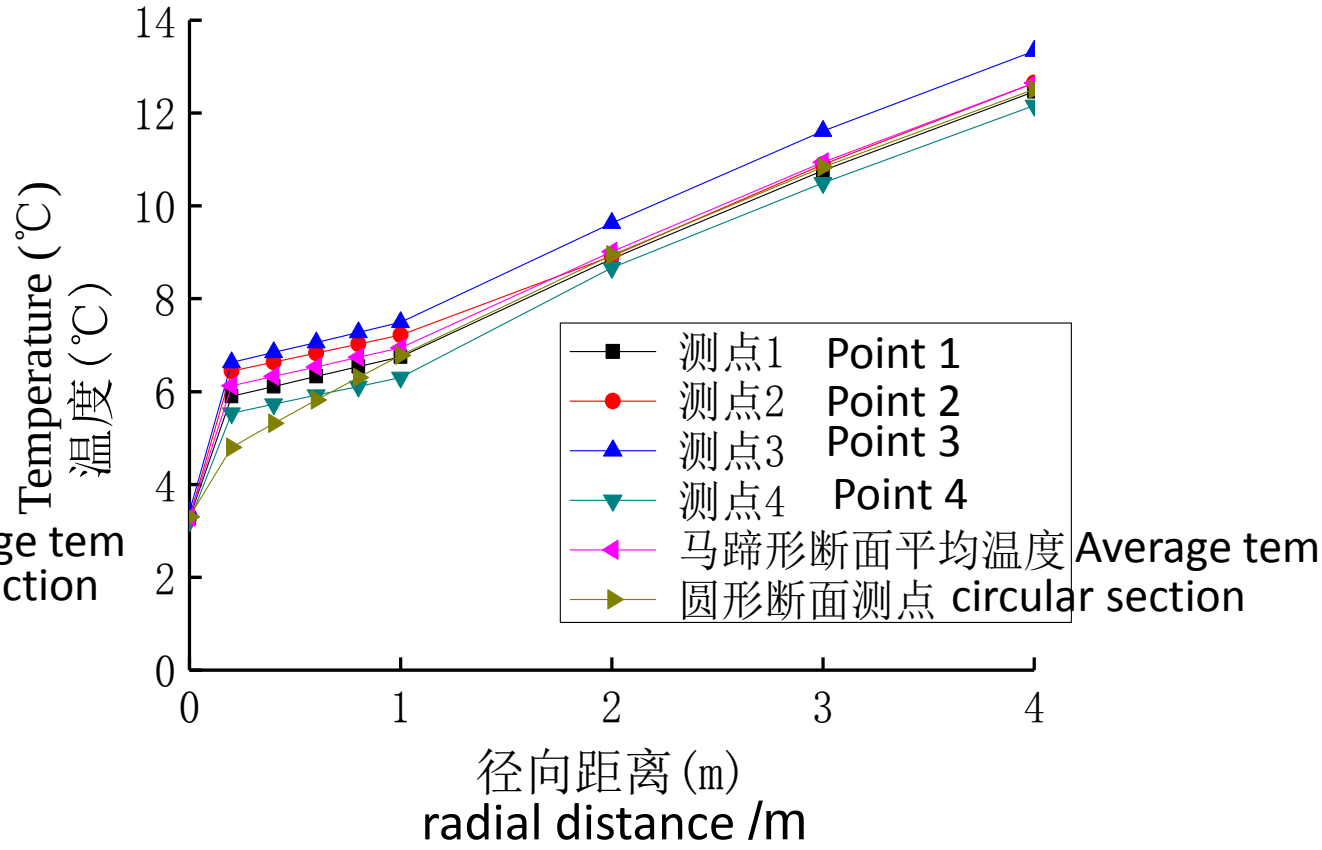


Figure 1. Radial temperature graph after calculated for 5 years (400m away from entrance section)

Calculation results



Radial temperature distribution when calculated 1 year
(400m away from entrance section)
计算1年马蹄形（测点1～4）和圆形断面内各点温度
（距入口400m断面）



Radial temperature distribution when calculated 5 years
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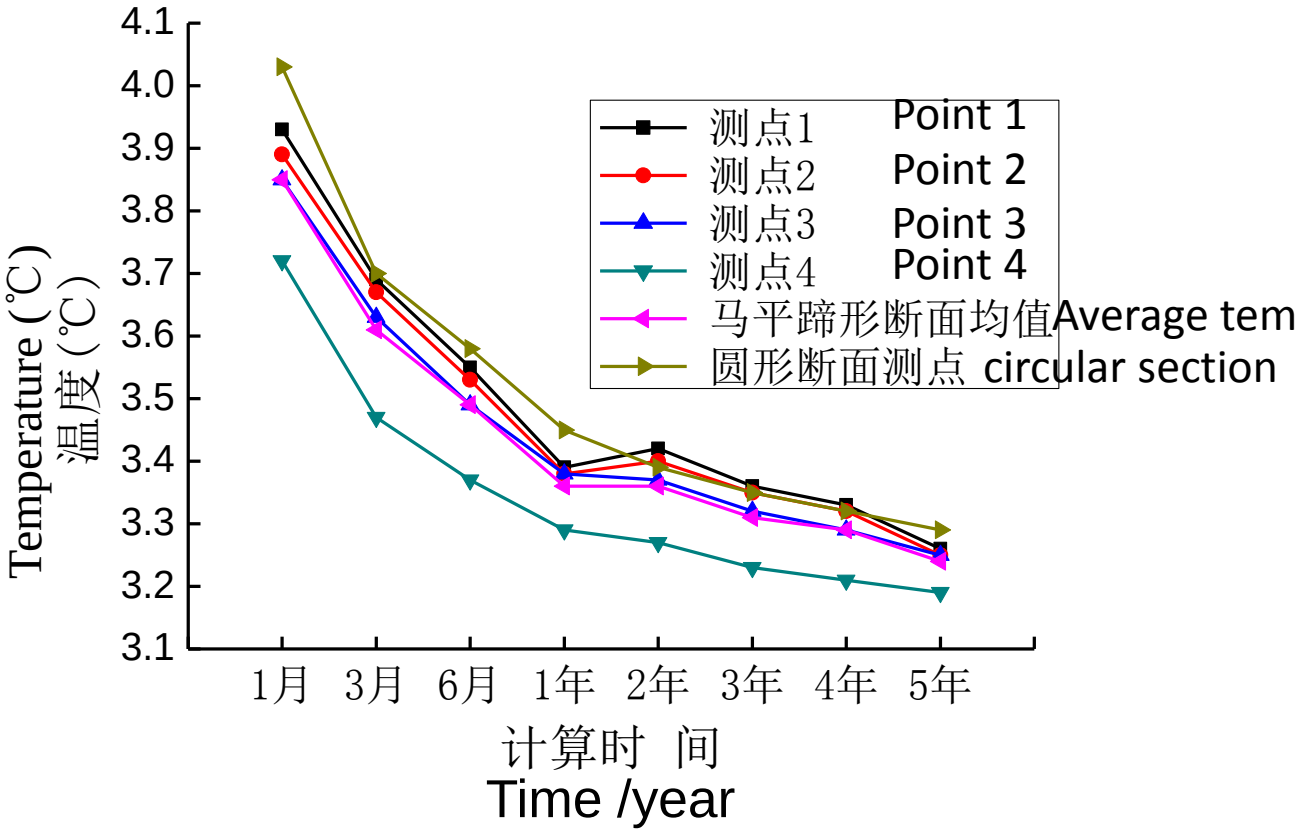
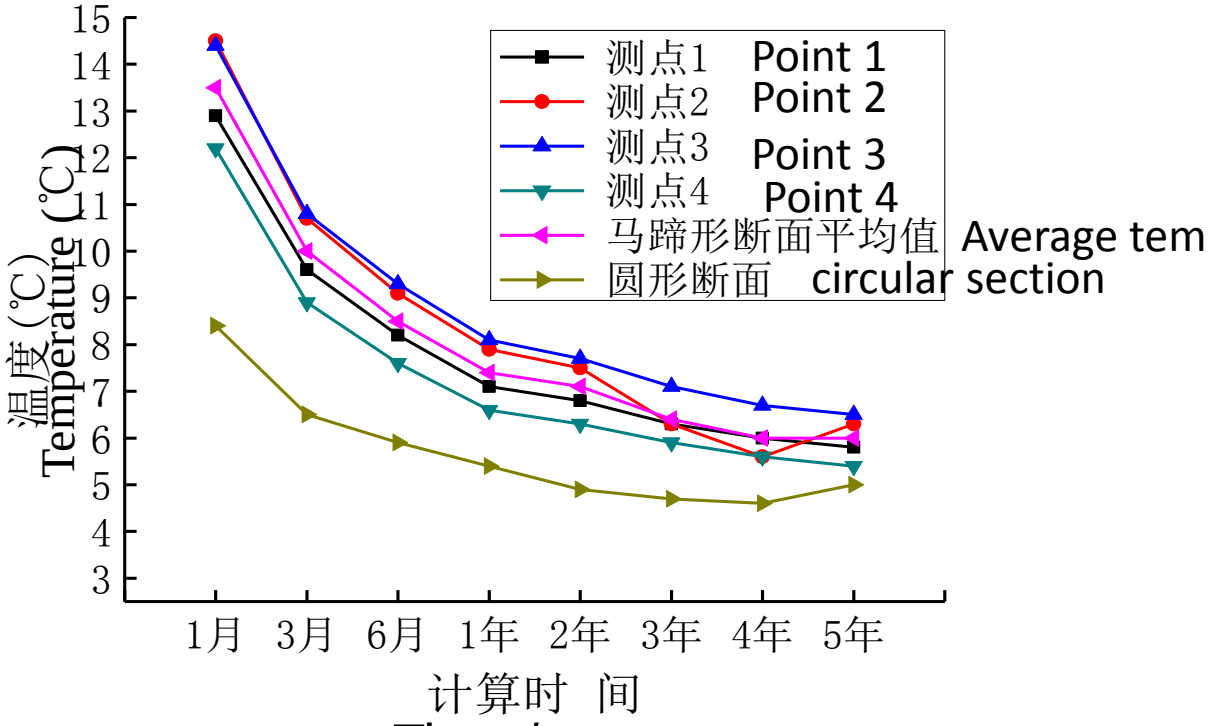
Calculation results



Convective boundary temperature distribution of horseshoe shape and circular tunnels (400m away from entrance section)

马蹄形和圆形断面洞壁温度随时间变化图（距入口400m断面）



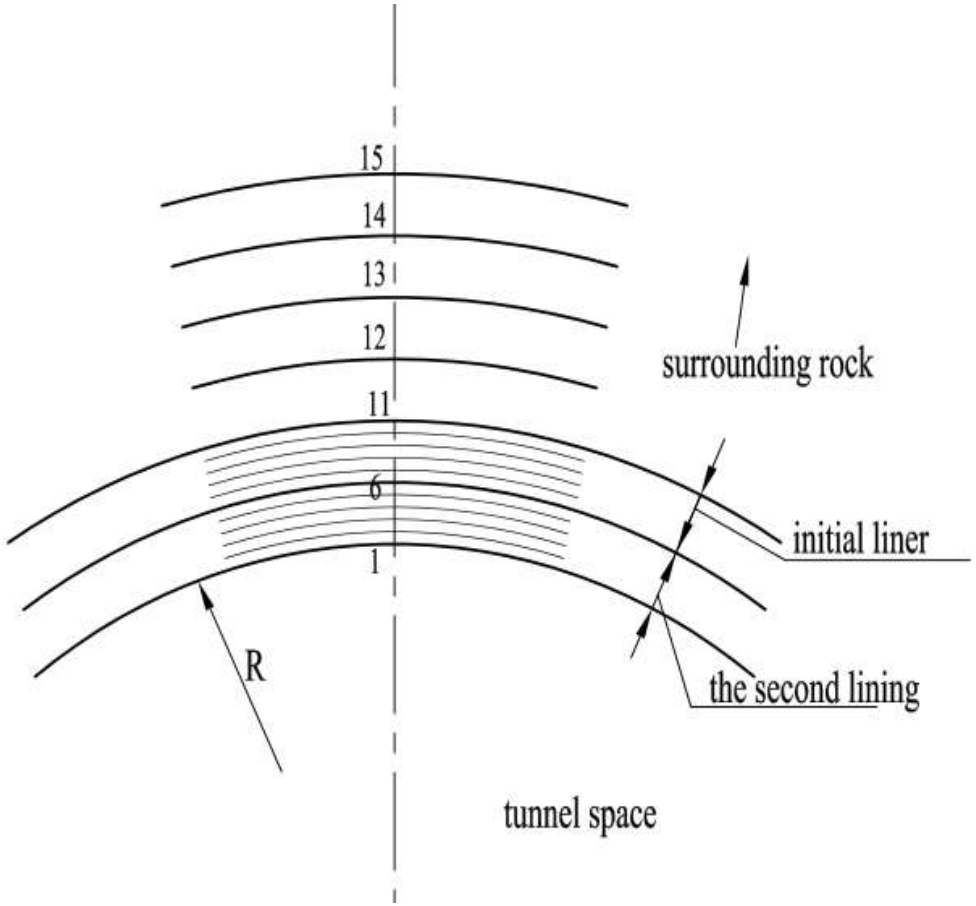
Surrounding rock(0.1m) temperature distribution of horseshoe shape and circular tunnels (400m away from entrance section)

距进口400m两种形状断面围岩温度随时间变化图（径向0. 1m）

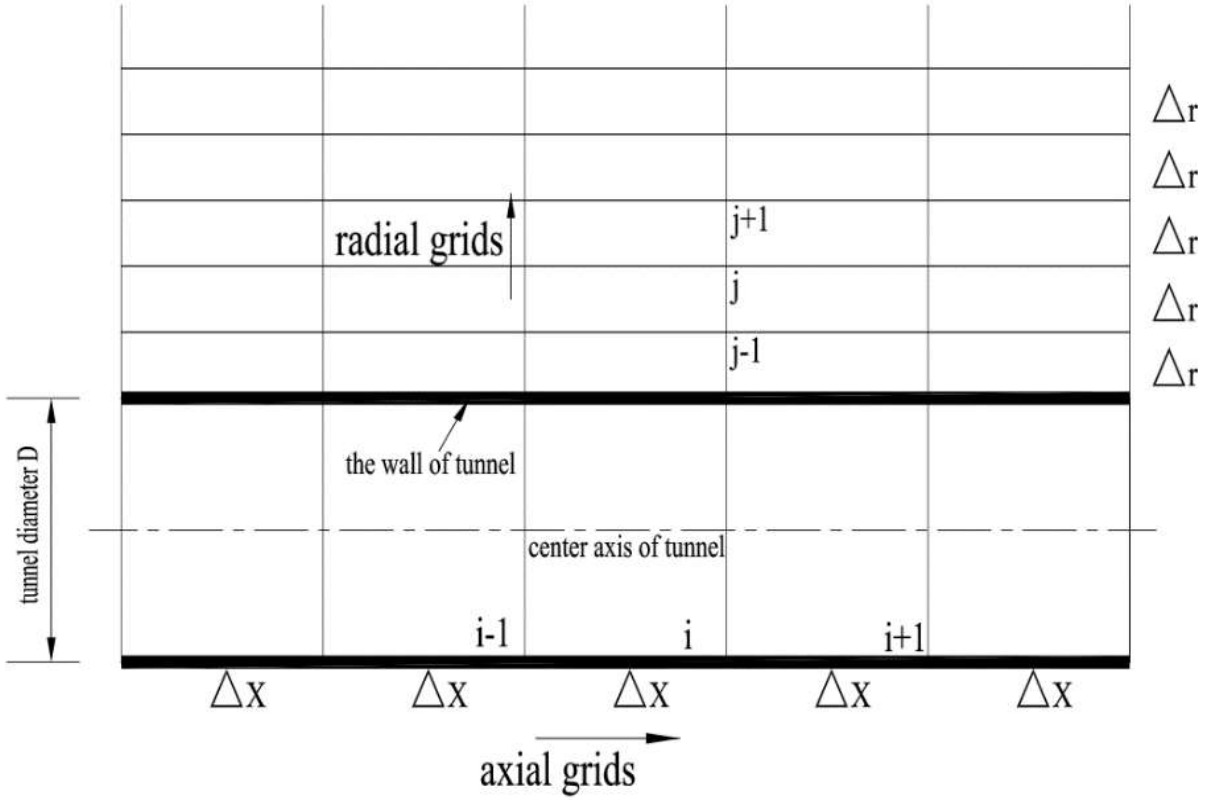
The calculation results show that as the calculation time goes, the temperature difference of surrounding rock for horseshoe shape tunnel and the corresponding equivalent diameter circular tunnel is becoming smaller and smaller. It can reach the requirement of engineering design.

马蹄形断面和等效直径圆形断面隧道模型温度场有细微差异，随着时间的增长，差异逐渐减小。圆形断面计算模型能够满足工程应用使用要求。

Finite differencing calculation model



The partition schematic of the calculated tunnel cross-section, with the computing nodes numbered in the cross-section



The distribution of the internal nodes of the axial direction in the tunnel

The approximation formula for the temperature of the internal grid node is

围岩内部节点的温度 $T_{i,j}^{n+1}$ 的近似表达公式：

$$t_{i,j}^{n+1}=T_{i,j}^{n}(1-2F_0-\frac{2a\Delta\tau}{(\Delta x)^2})+t_{i,j+1}^{n}(F_0+\frac{a\Delta\tau}{2r_j(\Delta r)})+t_{i,j-1}^{n}(F_0-\frac{a\Delta\tau}{2r_j(\Delta r)})+\frac{a\Delta\tau}{(\Delta x)^2}(t_{i+1,j}^{n}+t_{i-1,j}^{n})$$

The approximation formula of the temperature of the convection boundary node is

对流边界节点1的温度 $T_{j,n+1}$ 的近似表达公式：

$$T_{i,1}^{n+1}=2F_0(1+\frac{\Delta r}{4R+\Delta r})T_{i,2}^{n}+\frac{a\Delta\tau}{(\Delta x)^2}\left(T_{i-1,1}^{n}+T_{i+1,1}^{n}\right)+\frac{8hR\Delta\tau}{c_p\rho\Delta r\left(4R+\Delta r\right)}T_{fi}^{n}+\left[1-\left(F_0R+\frac{a\Delta\tau}{2\Delta r}\right)\frac{8}{4R+\Delta r}-\frac{2a\Delta\tau}{(\Delta x)^2}-\frac{8hR\Delta\tau}{c_p\rho\Delta r\left(4R+\Delta r\right)}\right]T_{i,1}^{n}$$

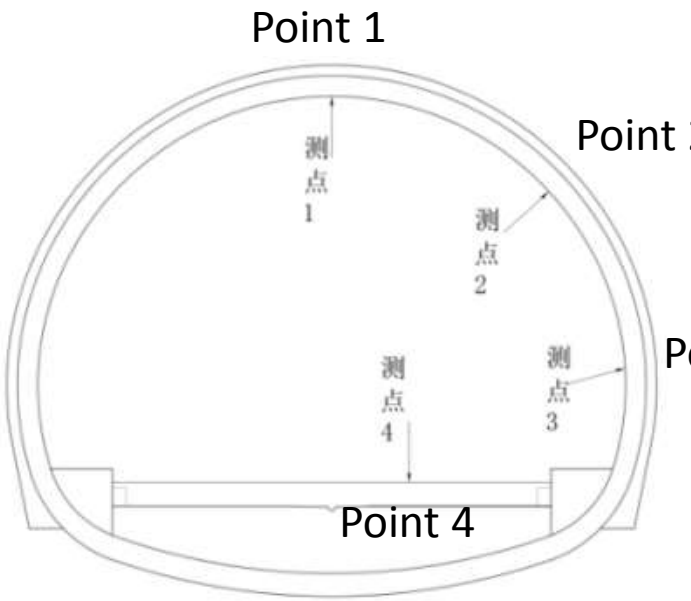
The longitudinal approximation formulas for the airflow temperature in the tunnel is

隧道纵向风流近似温度 t_{fi}^{n+1} 的表达式：

$$T_{fi}^{n+1}=(\frac{hU(t_{i,1}^{n}+t_{i,1}^{n+1})}{2\rho Ac_p}+\frac{q_s}{\rho Ac_p}-v\frac{t_{fi+1}^{n}-t_{fi-1}^{n}}{2\Delta x}+\frac{t_{fi}^{n}}{\Delta\tau}-\frac{hUt_{fi}^{n}}{2\rho Ac_p})/(\frac{1}{\Delta\tau}+\frac{hU}{2\rho Ac_p})$$

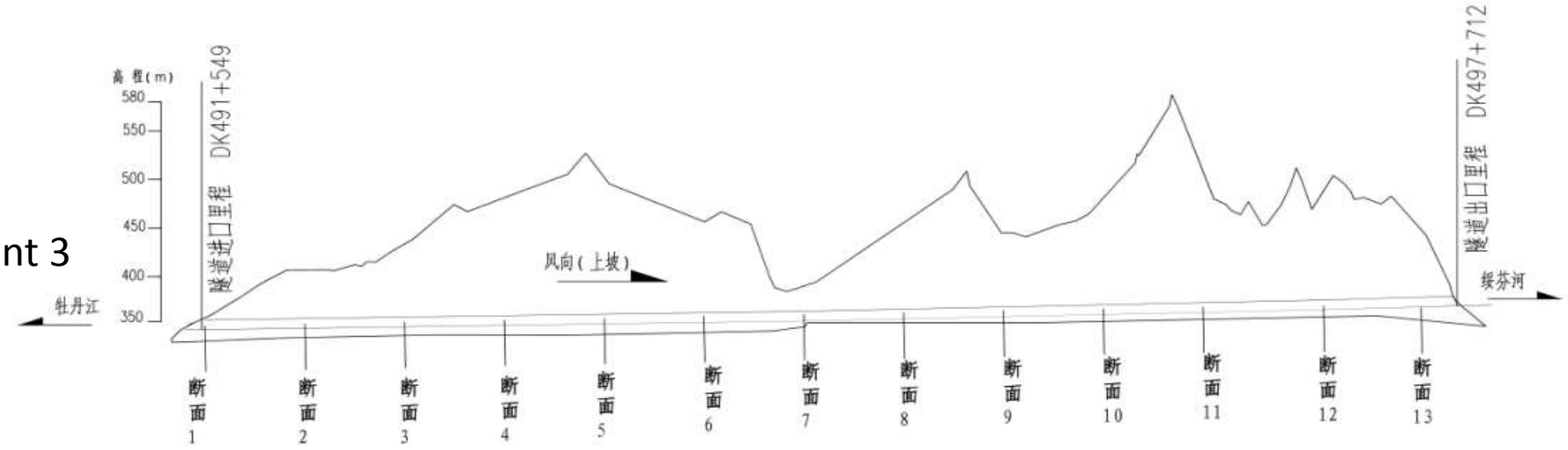
Temperature field investigation of cold region railway tunnel

寒区铁路隧道温度实测研究



Measuring points distribution in tunnel section

隧道温度测试横断面内测点分布图



Topographical sketch and temperature measuring points of Sui Yang tunnel

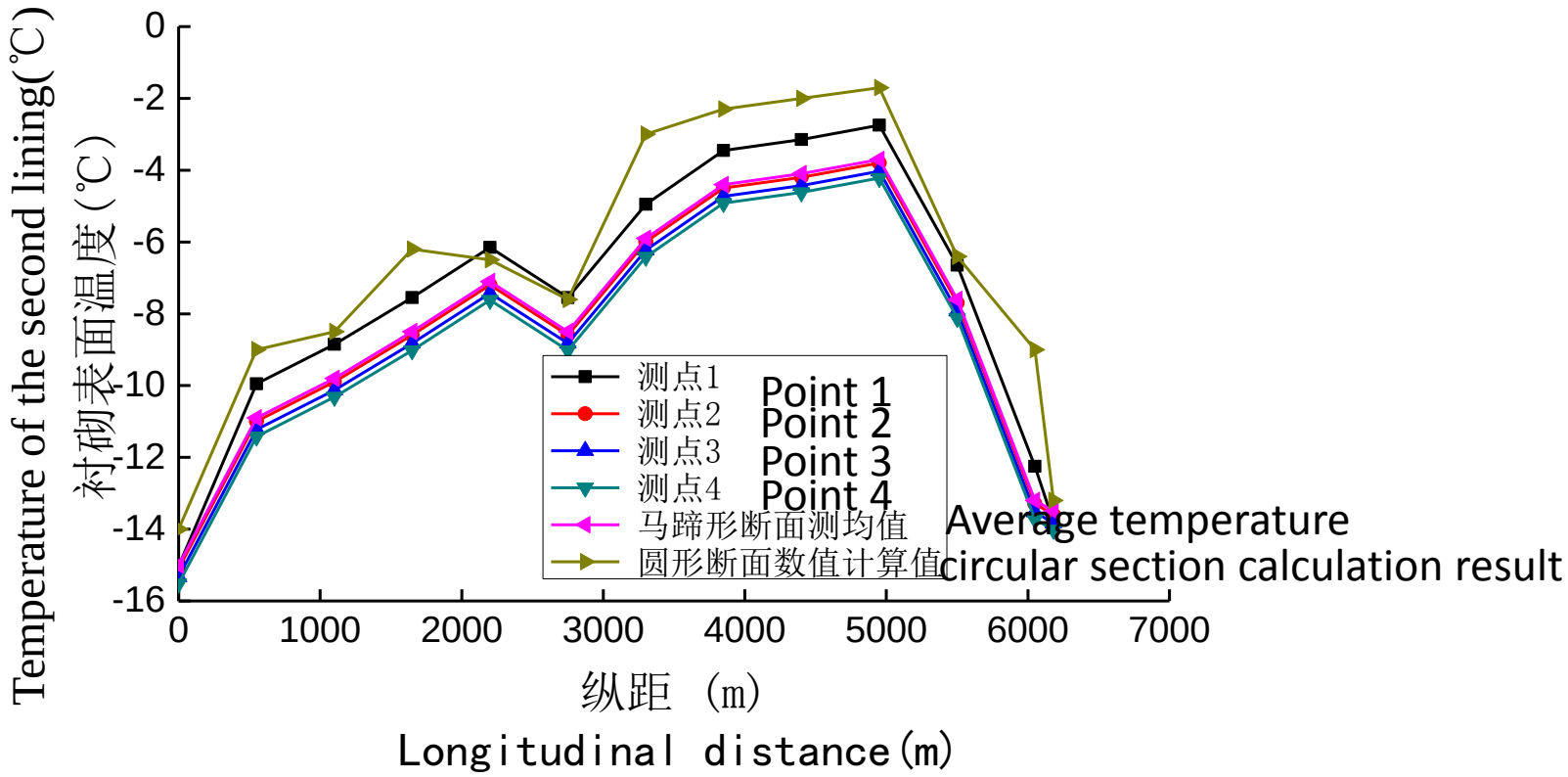
绥阳隧道温度测试断面随纵向分布示意图

于2015年1月对东北牡绥线铁路改造工程在建长度6170m的绥阳隧道进行温度实测，绥阳隧道于2013年9月贯通。

diameter of 10 m当量直径为10m，
investigated airflow speed of 3.8m/s.实测洞内平均自然风速为3.8m/s。

Airflow temperature of tunnel entrance 入口风温：

$T_f = 2.5 + 18.5 \times \sin(2 \times 3.1415 \times i / 365)$ ℃

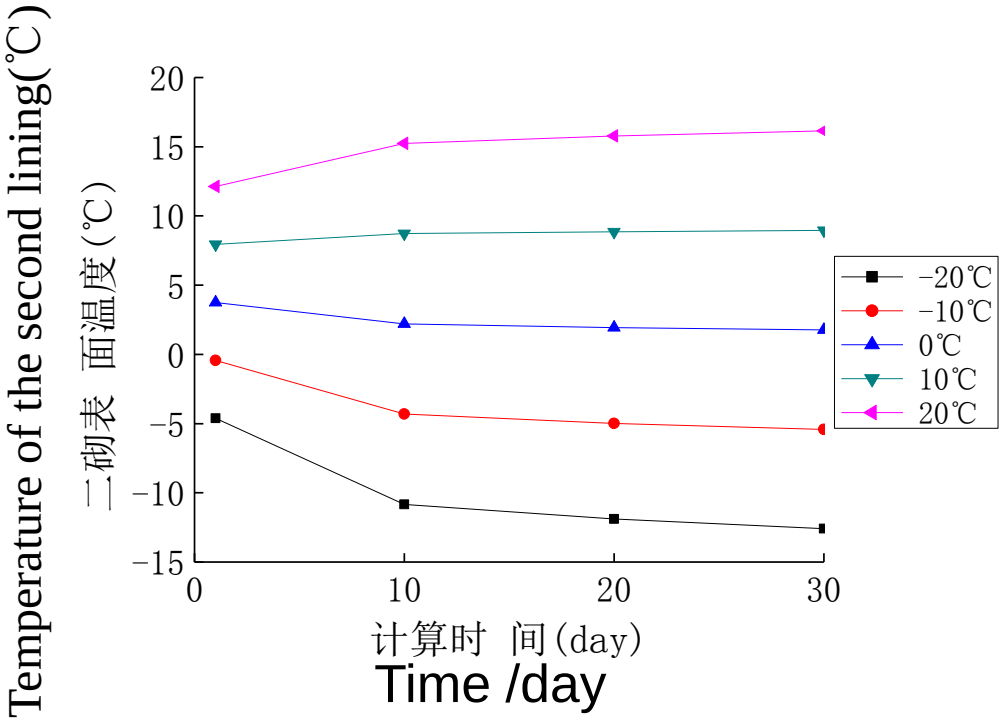


The meassured temperature and the calculated temperature of the surface of the lining

绥阳隧道衬砌表面温度实测值和圆形断面模型计算值

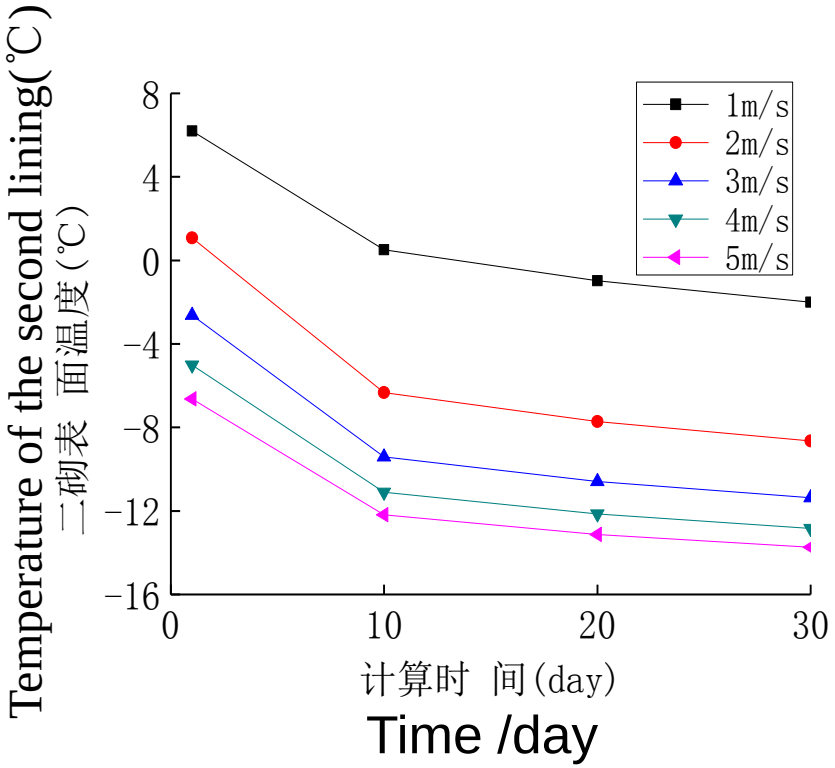
The investigated average temperature is closer to point 3(the arch waist).

Calculation resultes has the same law with the meassuring temperature with little difference.



Temperature of lining under different airflow temperature

不同风流温度时绥阳隧道衬砌表面温度（DK493+529）



Temperature of lining under different airflow speed

不同洞内风速条件下绥阳隧道衬砌表面温度（DK493+529）

The entrance airflow temperature and airflow speed influence the temperature field of tunnels greatly.

The circular section finite-difference model can be used to guide the design of insulation design for cold-region tunnels, thereby overcoming the difficulties encountered because of the complexity of modeling and stringent hardware requirements of general finite element software. The entrance airflow temperature and airflow speed influence the temperature field greatly of tunnels. The influence of the mechanical ventilation and train-induced wind on the temperature field distribution can be studied in this way.

对比寒区隧道温度场有限差分计算结果和温度测试结果可知，两者随隧道纵向分布趋势一致且差值较小。圆形断面模型有限差分计算方法克服了通用有限元软件同时考察对流换热和传热困难、建模复杂、对硬件要求高的弊端，在隧道温度场的长期分布规律的预测计算中易于使用。可以用于研究隧道内机械通风和列车活塞风等对隧道温度场的影响。

Thank you !

谢谢大家!