联合荣大

中国成都
Chengdu. China
10/2024

高炉内衬耐材发展方向探讨

Discussion on the Trend of Refractory Lining for Blast Furnace

Dr. Perry Zhang 章荣会 博士

Allied Rongda Enterprises Group

Tel:13801066625@139.com

perry@rongda.com.cn






Catalogue

联合荣大
ALLIED RONGDA

1.1 不定形耐火材料发展过程
The Development of Monolithic Refractory Materials

联合荣大 ALLIED RONGDA

- **不定形耐火材料施工方法发展过程**
  Development of refractory construction:
  捣打到喷注+人力施工到机械施工
  Ramming to shotcrete + By mannual to by machine

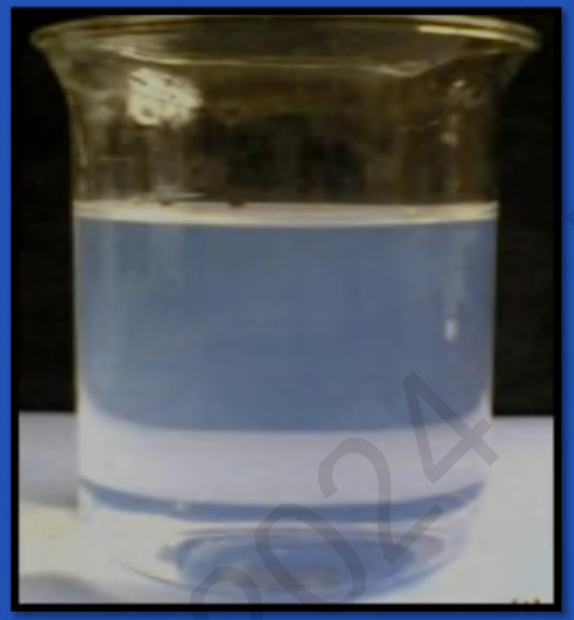
捣打	浇注/预制	喷涂	喷注
Ramming	Castable/Preshaped	Guning	Shotcreting

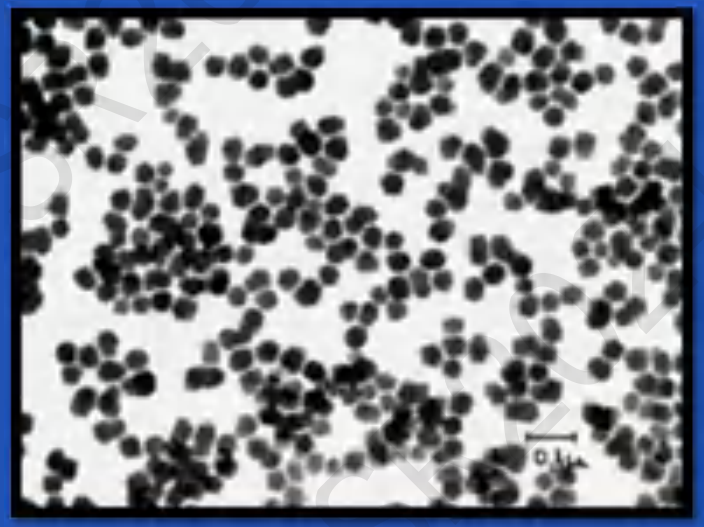
不定形耐火材料结合剂的发展
Development of bindings for monolithic Refractory

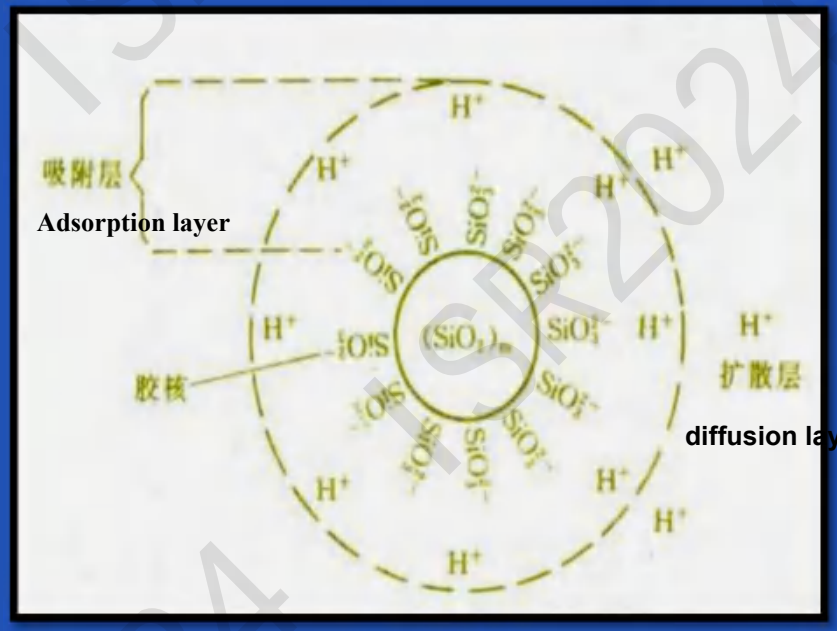
硅酸盐水泥portland cement 磷酸盐 Phosphate 水玻璃 water glass	铝酸盐水泥 Aluminate cement	微粉结合/超低水泥结合 Micro powder technology Ultra-low cement	纳米溶胶结合/无水泥 Nano-sol binders, etc No cement

硅溶胶的优势
Advantage of Silica Sol-Material

联合荣大 ALLIED RONGDA







- 防爆，因为不存在结合剂迁移，不会堵塞毛细管通道，只有水蒸气的挥发。

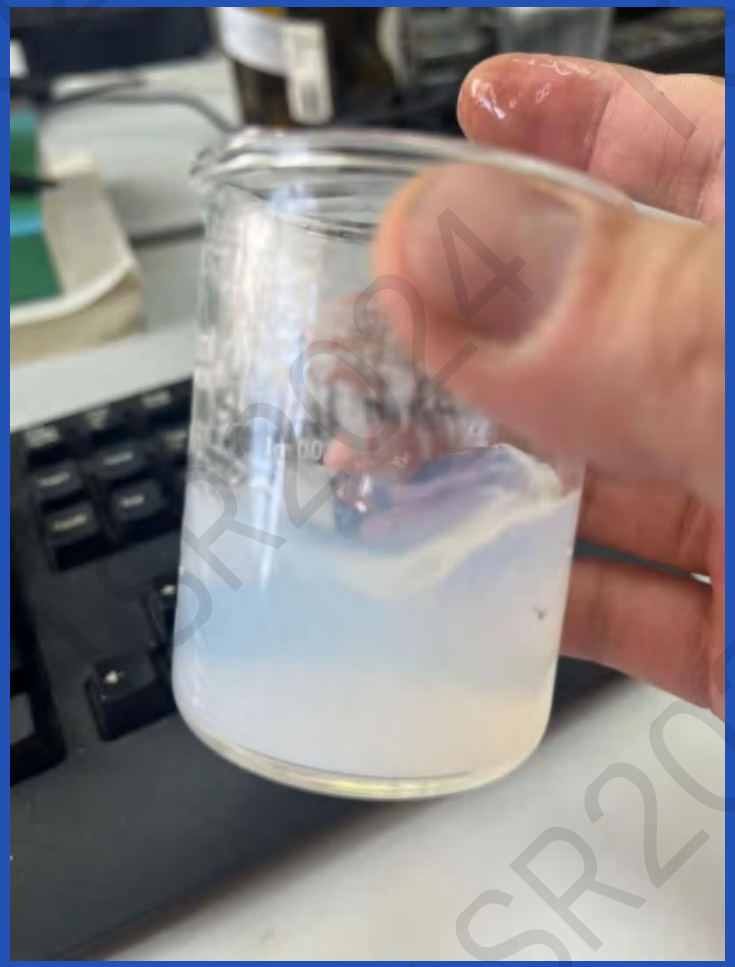
Resistant to heatup explosion, due to no migration of binders to stuck of capilary pores, and only water vapaourated.

- 低温烧结陶瓷结合中温强度高。Lower temperature sintering to ceramic binding.
- 引入杂质少。Inlet less impurities.

高质量硅溶胶
High Quality Silica Sol

联合荣大
ALLIED RONGDA

溶胶沉淀
Precipitation of silica sol



均匀固化/失透
Uniform hardening

国产硅溶胶
（30, 40，50%）

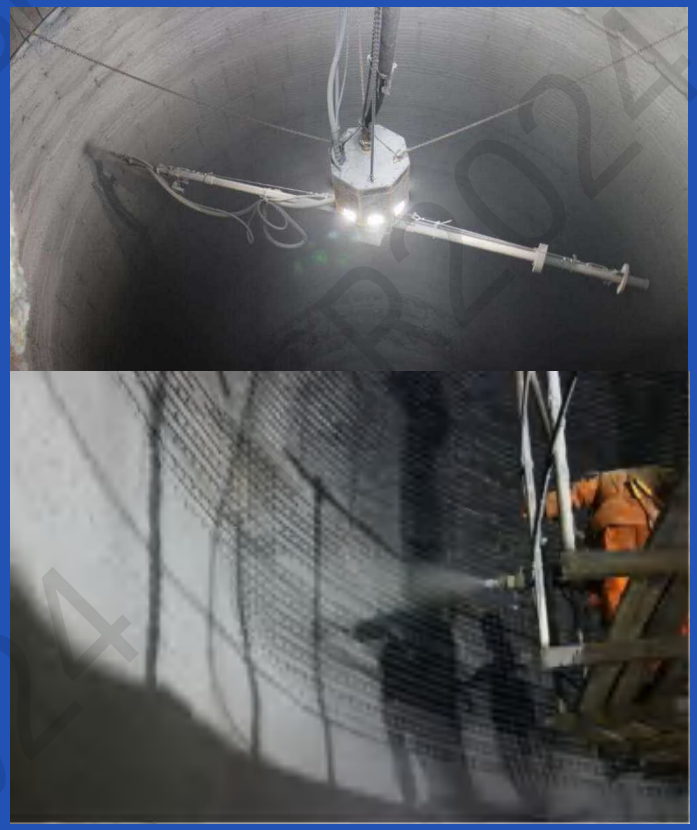
Now we have
30, 40, and 50%
solid content
sol silica
domestic product.

1.2 高炉内衬耐材演变Evolution of Blast Furnace Lining

联合荣大 ALLIED RONGDA

全炉砌砖
Whole furnace masonry:
including special-shaped bricks
at the air outlet and iron mouth

半干法喷涂修补，反弹量极高。
Semi dry spraying:
Rebound by more than 15%;
Low strength, short lifespan

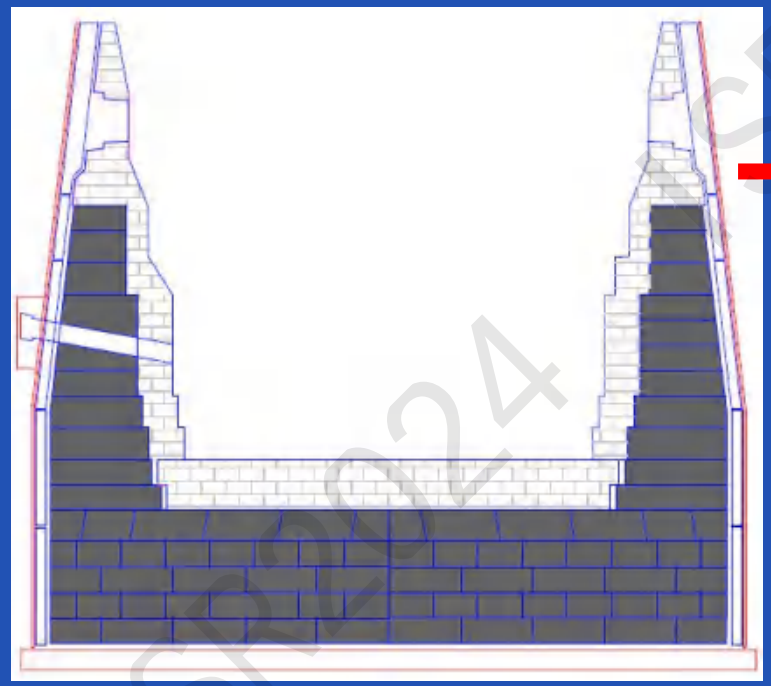


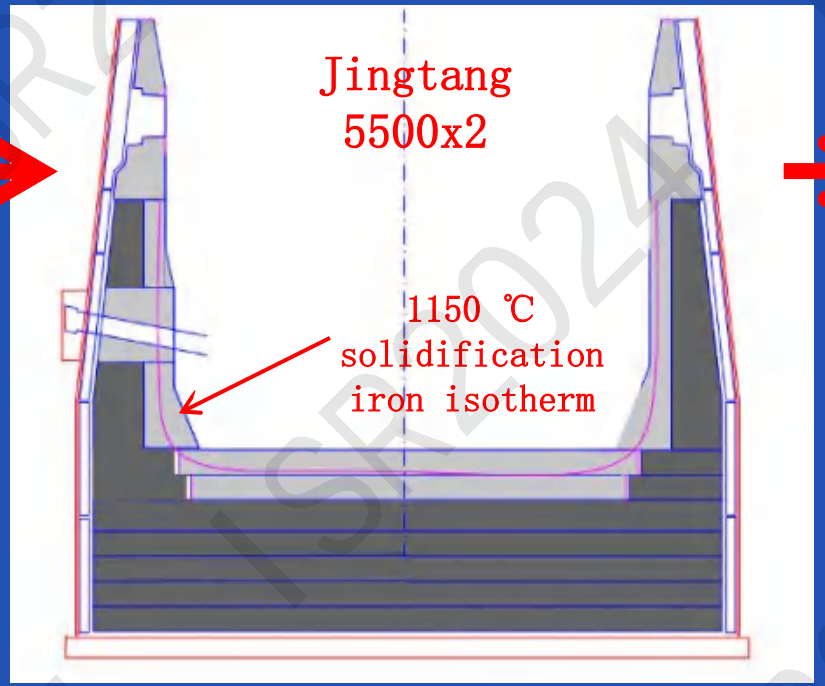
喷注
Up part shorcrete
High strength, wear-resistant, and
long-lasting, simple and fast

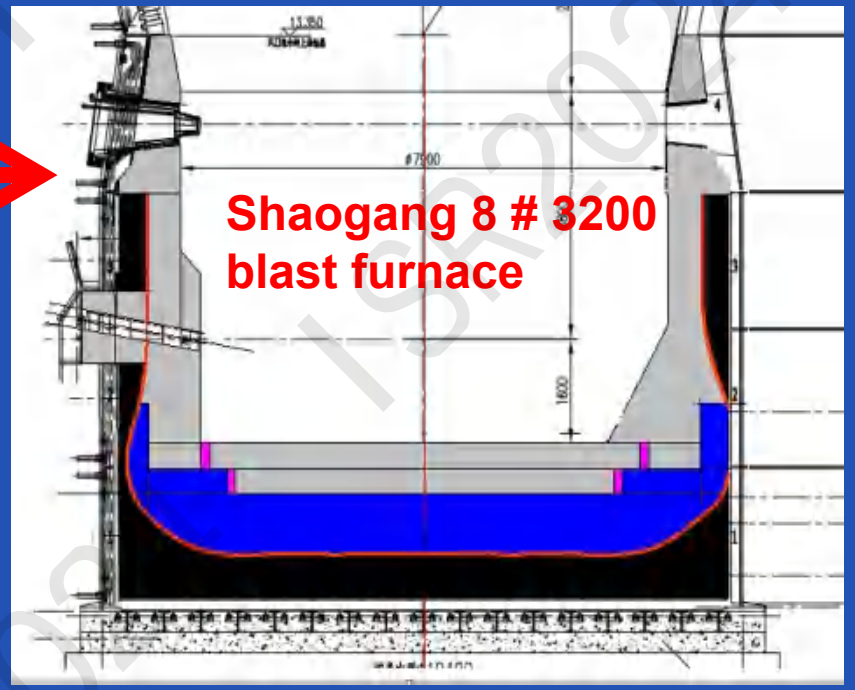
联合荣大使命：高效率帮助客户解决问题！

高炉炉缸维修的演变
Evolution of blast furnace hearth maintenance

联合荣大 ALLIED RONGDA







恢复设计
碳砖+陶瓷杯砌筑
Restore Design
Carbon brick+ceramic cup

碳砖+整体浇注陶瓷杯
Carbon bricks
+ Monolithic ceramic cup

残砖利用+炉缸整体浇注
Residual carbon brick
+Integral casted working layer

联合荣大使命：高效率帮助客户解决问题！

2 高炉内衬典型不定形耐材技术
Typical Unshaped Refractory Technology for the Inner Lining of Blast Furnace

联合荣大 ALLIED RONGDA

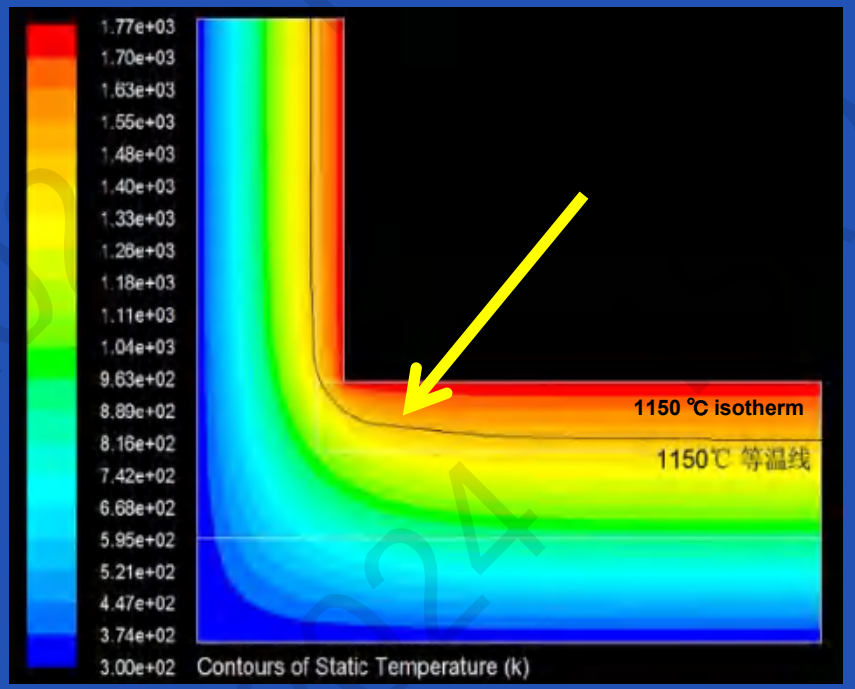
炉缸整体浇注
Monolithic hearth casting of BF

冷却壁预挂渣皮
Precasted SIFC cermet layer on cooling staves as prehanging slag crust

高炉内衬喷注修复
Shotcrete lining for blast furnace relining

2.1 传统结构高炉炉缸碳砖侵蚀机理
Erosion mechanism of carbon bricks in the hearth of traditional structure blast furnace

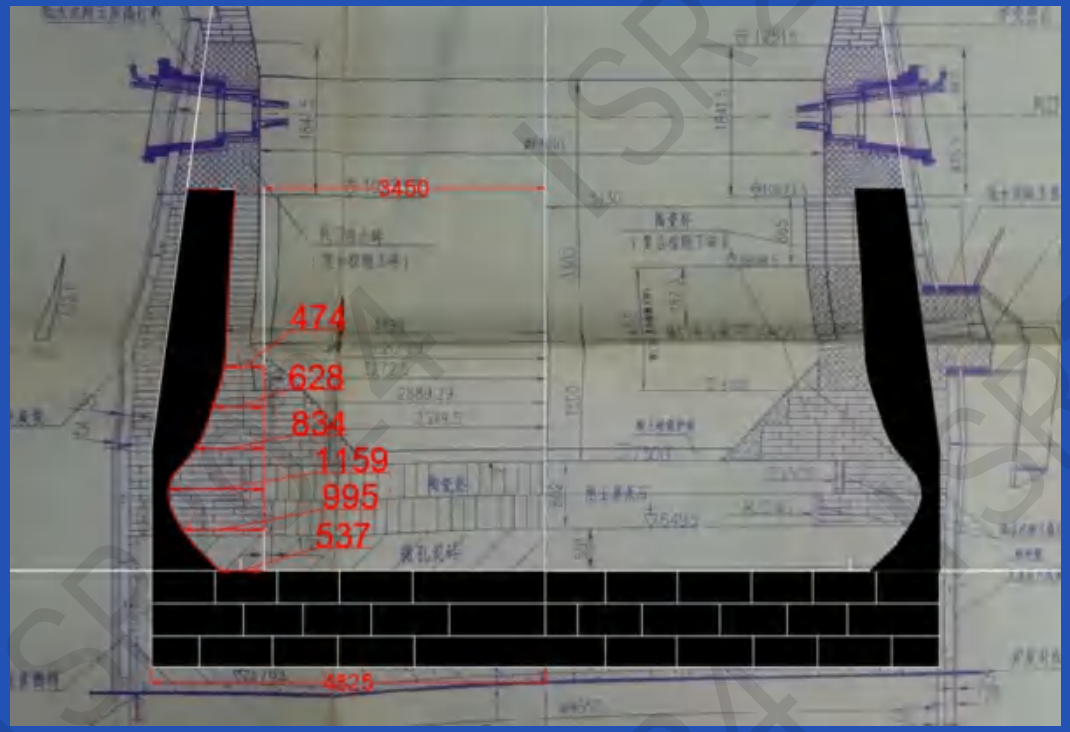
联合荣大 ALLIED RONGDA



传统结构炉缸砌筑结构Masonry structure of traditional hearth

高炉炉缸侵蚀机理
The erosion mechanism of the blast furnace hearth

联合荣大 ALLIED RONGDA



象脚侵蚀

Elephant foot erosion

炉底锅底形侵蚀

Corrosion of BF hearth bottom

炉缸铁水温度波动造成炉缸碳砖溶解侵蚀
Temperature fluctuations causes fluctuations of C Concentration in molten Iron which leads to disolution of carbon brick

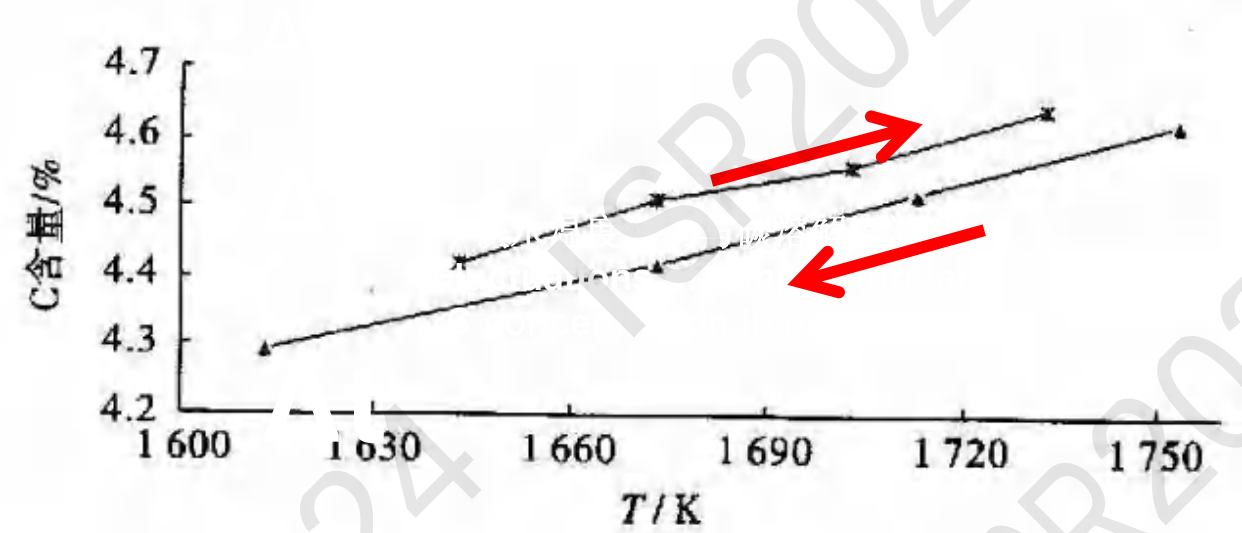


图4 铁水碳饱和溶解度与温度的关系

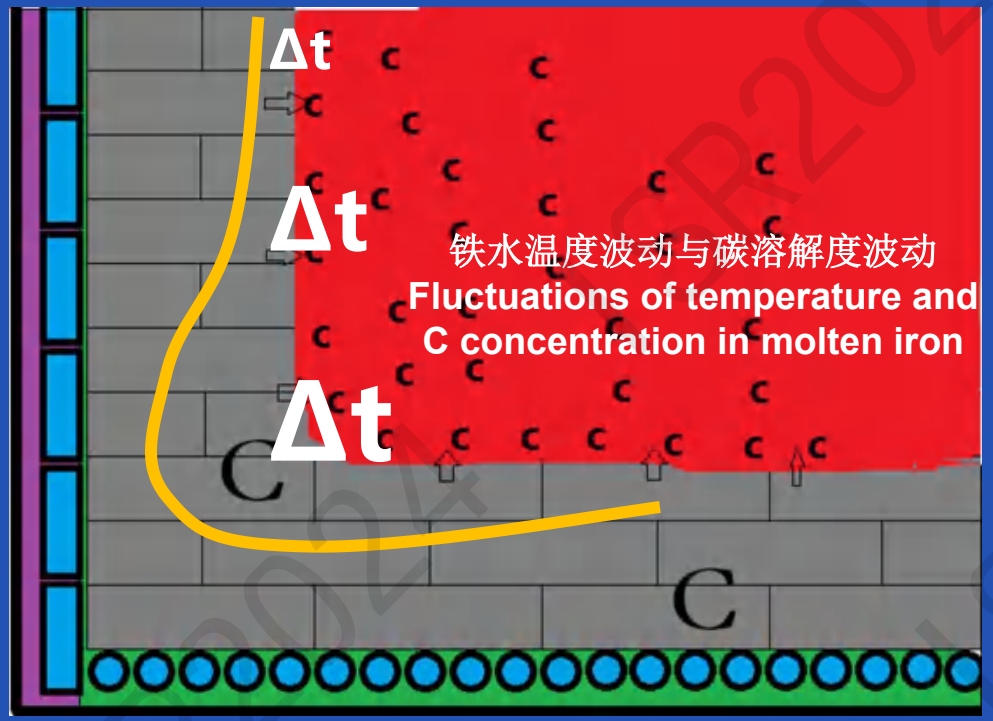
Fig.4 The relationship between saturated carbon content in hot metal and temperature

铁水中的C的溶解度随温度变化而变化。铁水温度降低则C析出漂浮（不会长回碳砖），铁水温度升高则要溶解吸收更多的 C（比如来自侧壁碳砖）。

The solubility of carbon (C) in molten iron changes with temperature. When the temperature of molten iron decreases, carbon precipitates and floats (and will not grow back to carbon bricks). When the temperature of molten iron increases, more carbon needs to be dissolved and absorbed (for example, from the sidewall carbon bricks).

炉缸铁水温度波动造成炉缸碳砖溶解侵蚀

The temperature fluctuation of molten iron in the hearth causes dissolution and erosion of carbon bricks in the hearth.



铁口周期性出铁，铁口以下死铁层内铁水温度是周期性升降的。周期性温差越大，这种吸收与析出就会越剧烈。

炉缸内炉缸底部立面与底面拐角处是双面冷却，此处铁水温度升降的幅度最大，最容易发碳的溶解与析出漂浮。

铁水流经越多的区域，碳更容易被带走，对应出铁口两侧下部区域，既是温度波动幅度最大的区域也是铁水流经的的区域，因此就变成了“象脚侵蚀区”，这里最容易发生象脚侵蚀。

The taphole discharges iron periodically. The temperature of the molten iron in the dead iron layer below the taphole rises and falls periodically. The larger the periodic temperature difference, the more intense this absorption and precipitation will be. At the corner where the vertical surface and the bottom surface of the hearth bottom are double-sided cooled. At this point, the amplitude of temperature rise and fall of the molten iron is the largest, and carbon is most likely to dissolve, precipitate and float. In areas where molten iron flows through more, carbon is more easily carried away. Corresponding to the lower areas on both sides of the taphole, this is not only an area with the largest temperature fluctuation amplitude but also an area where molten iron flows through. Therefore, it has become the "elephant foot erosion area", where elephant foot erosion is most likely to occur.

炉缸浇注料研发过程
Research and Development Process of Hearth Castable

联合荣大
ALLIED RONGDA

尝试研发不溶于铁水且抗渣侵蚀的耐火材料
Try to develop refractory materials that are insoluble in molten iron and resistant to slag erosion.

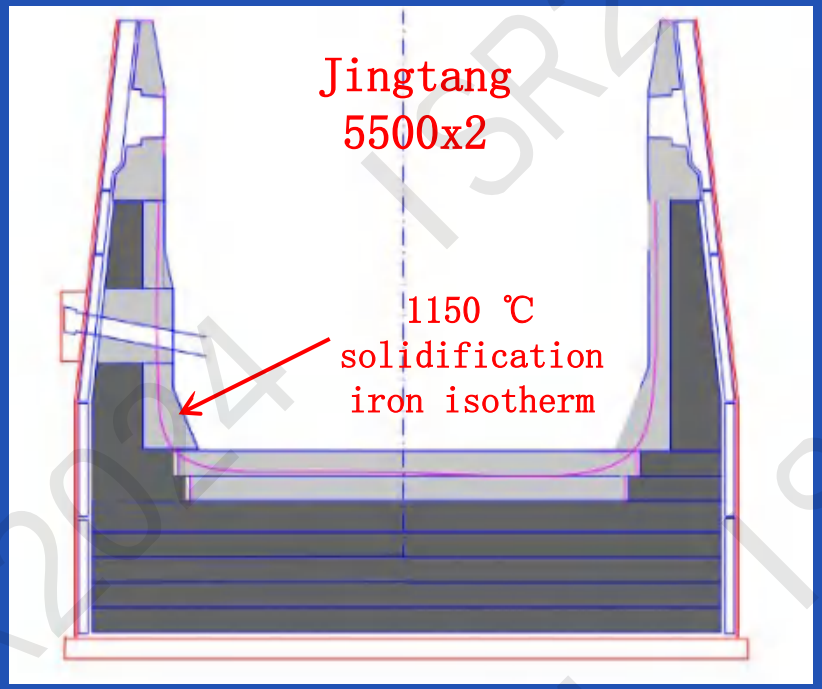
Cooperate with Shougang Jingtang Company and Shougang Technology Research Institute to conduct simulated hearth casting tests in the factory.
Take samples and comprehensively evaluate the properties of materials such as erosion resistance, explosion resistance and thermal shock resistance.
Later, it is applied in the hearth casting of three 5500 cubic meters blast furnaces in Jingtang.

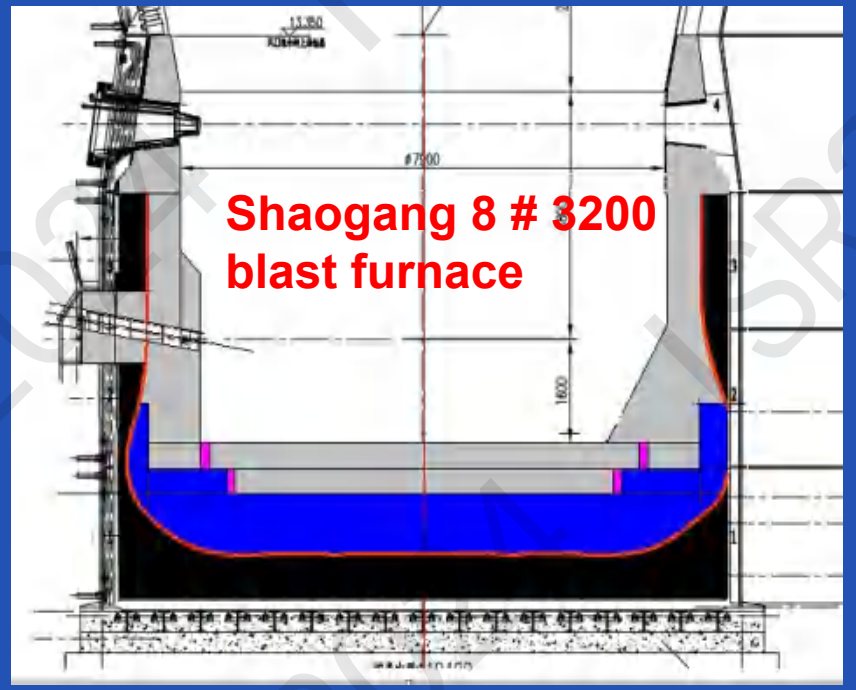
与首钢京唐公司和首钢技术研究院合作，在工厂内做模拟炉缸浇注试验；
取样，对材料抗侵蚀、防爆、抗热震等性能综合评判，后在京唐三座5500m³高炉炉缸浇注应用。

联合荣大使命：高效率帮助客户解决问题！

高炉炉缸维修的新模式
Novel Modes of Blast Furnace Hearth Maintenance

联合荣大 ALLIED RONGDA





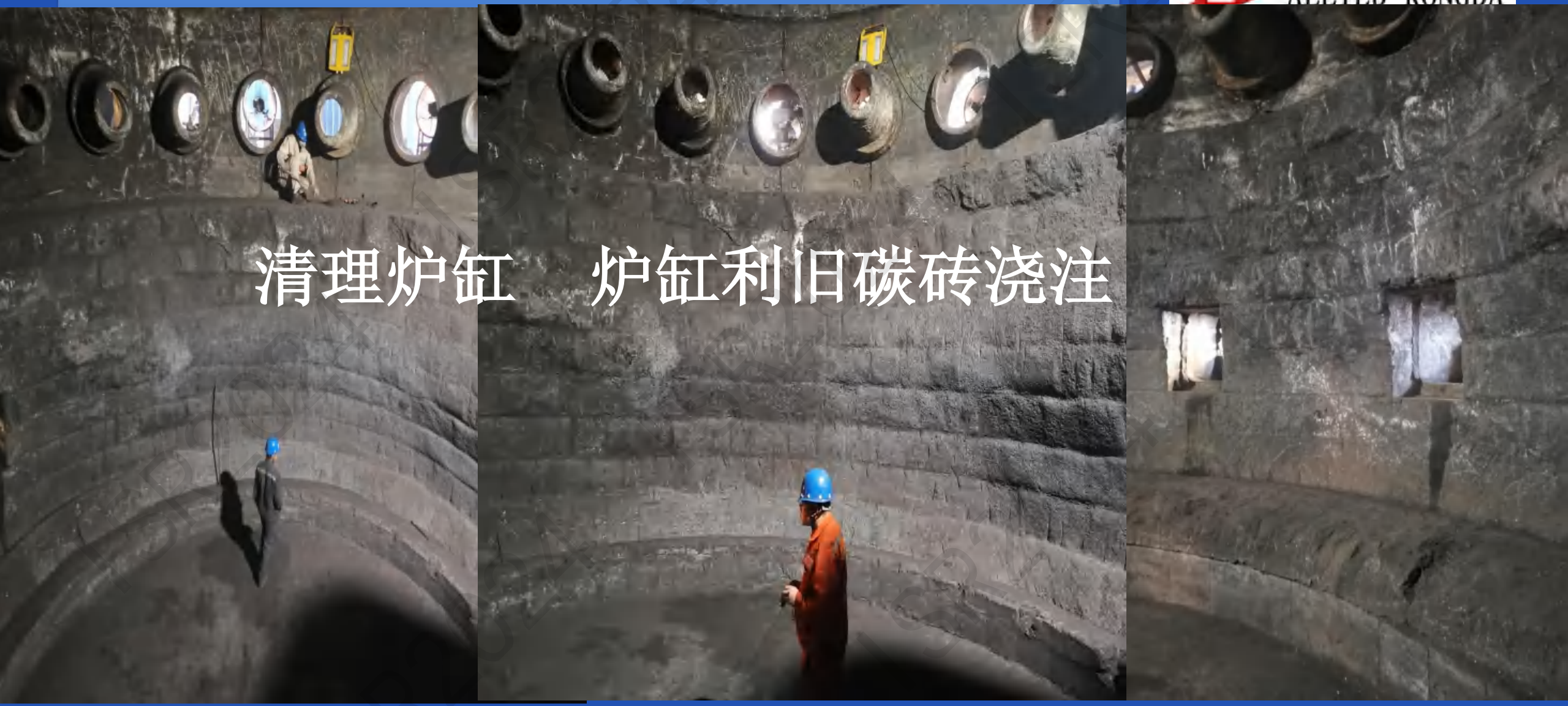
碳砖+整体浇注陶瓷杯
Carbon bricks
+ Monolithic ceramic cup

残砖利用+炉缸整体浇注
Residual carbon brick
+Integral casted working layer

联合荣大使命：高效率帮助客户解决问题！

Clean the Hearth for Recasting on the Residual Carbon Bricks

联合荣大
ALLIED RONGDA

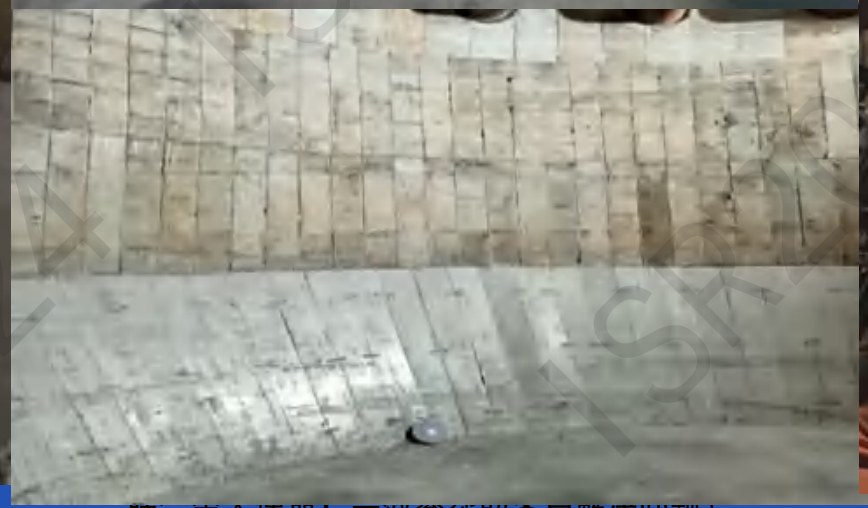


炉缸浇注Furnace Casting

联合荣大
ALLIED RONGDA

炉缸整体浇注效果

The overall casting effect of the hearth



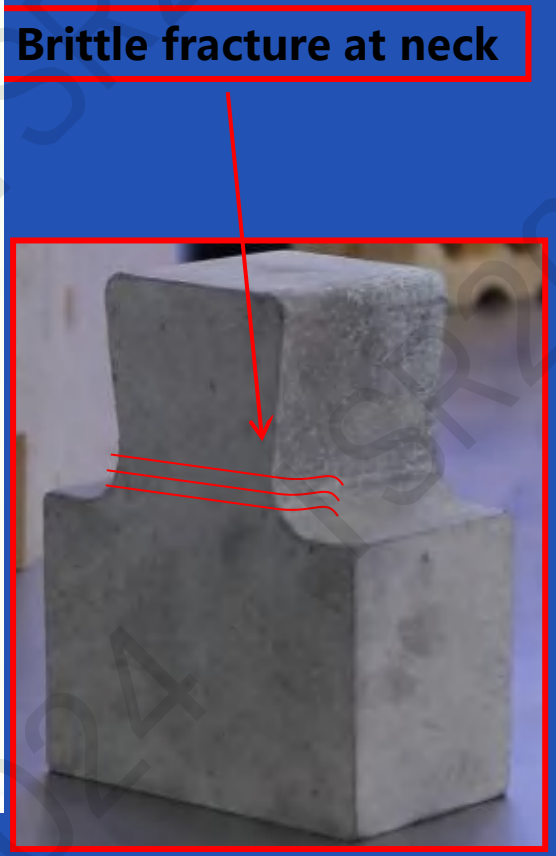
2.2 预挂渣皮技术
SIFC Cermet Pre - slag Crust Hanging Technology

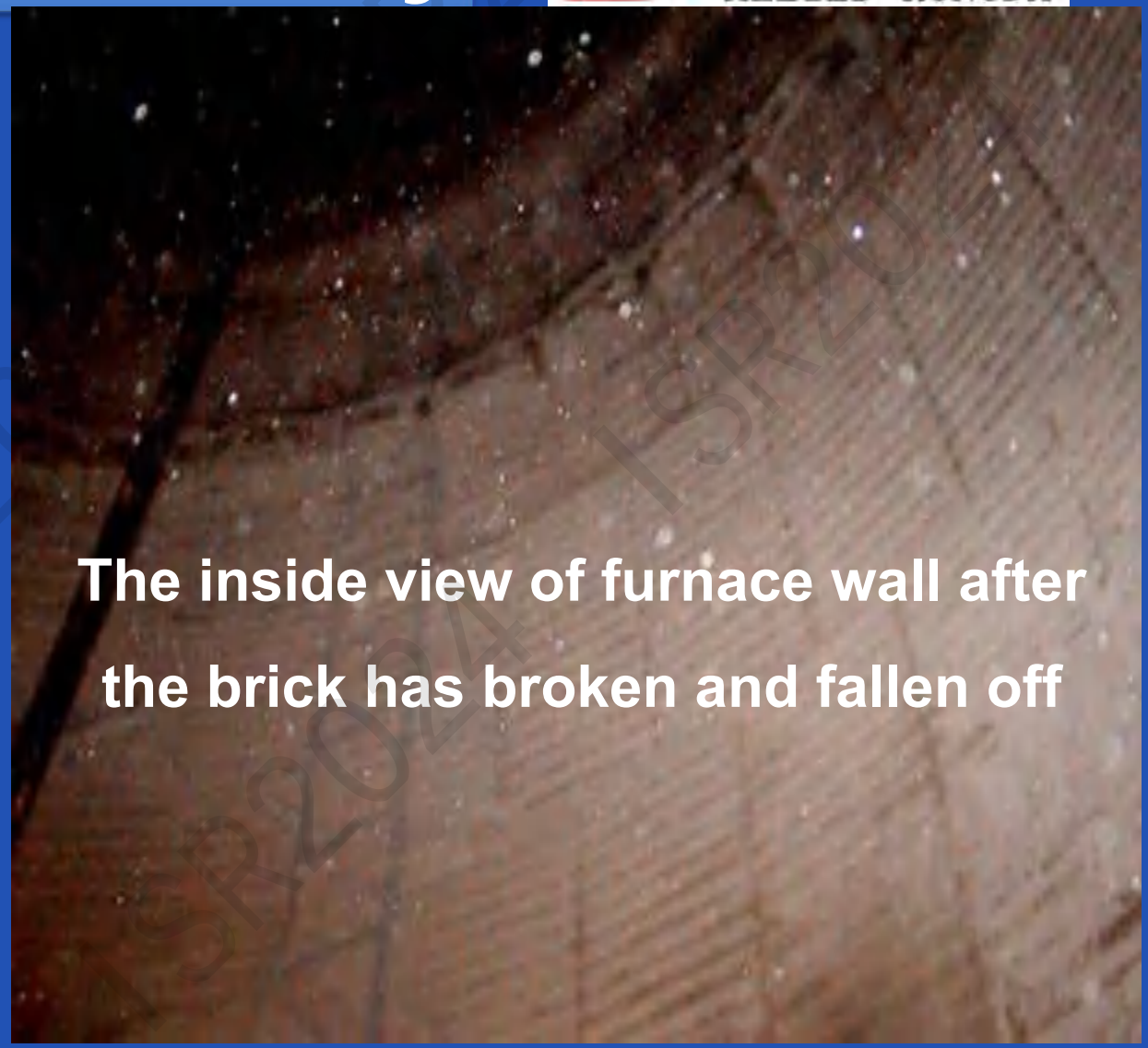
联合荣大
ALLIED RONGDA

传统镶砖的颈部脆断
Brittle fracture at the neck of traditional brick lining

联合荣大 ALLIED RONGDA

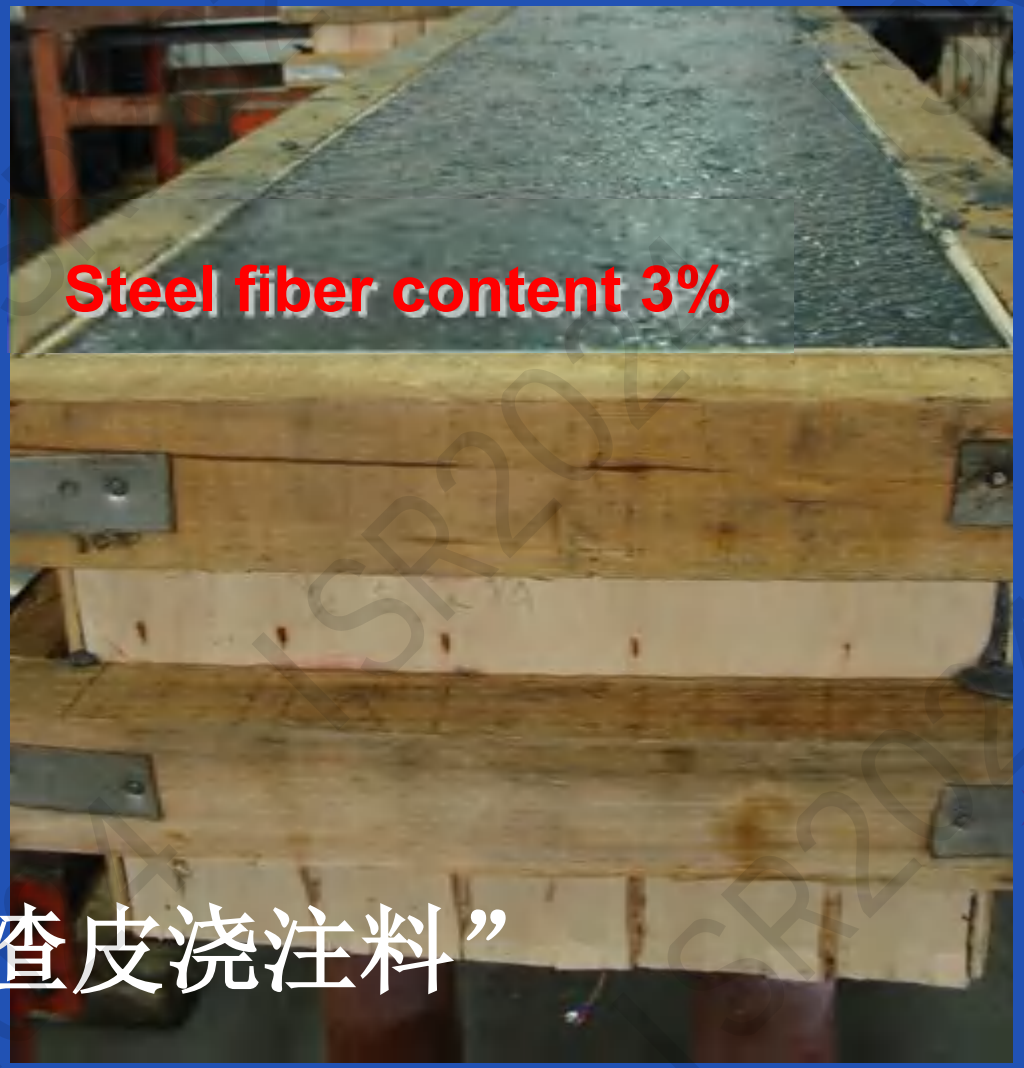
Cooling Stave





Early 'pre hung slag skin castable'

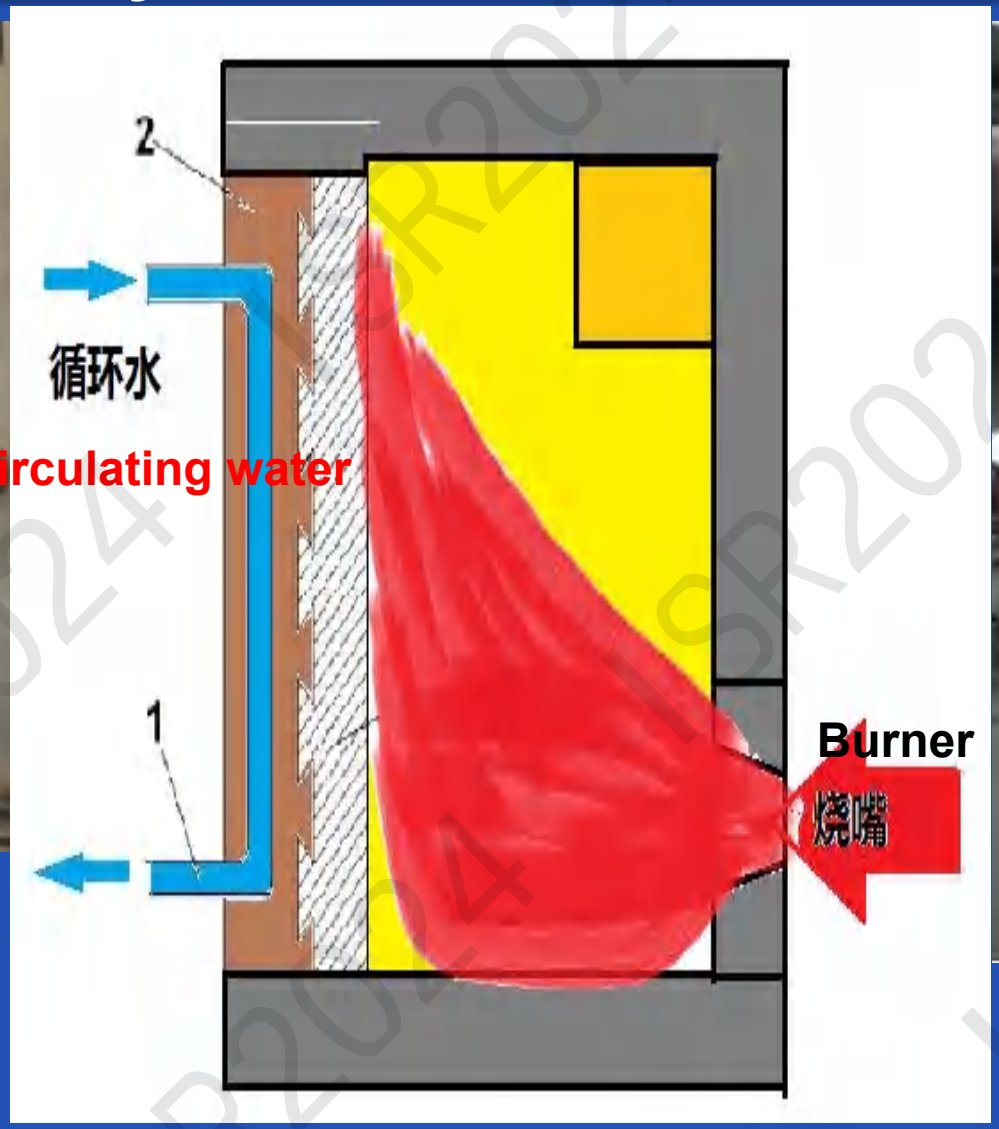
联合荣大
ALLIED RONGDA



早期的“预挂渣皮浇注料”

Experimental verification of ordinary steel fiber reinforced castables

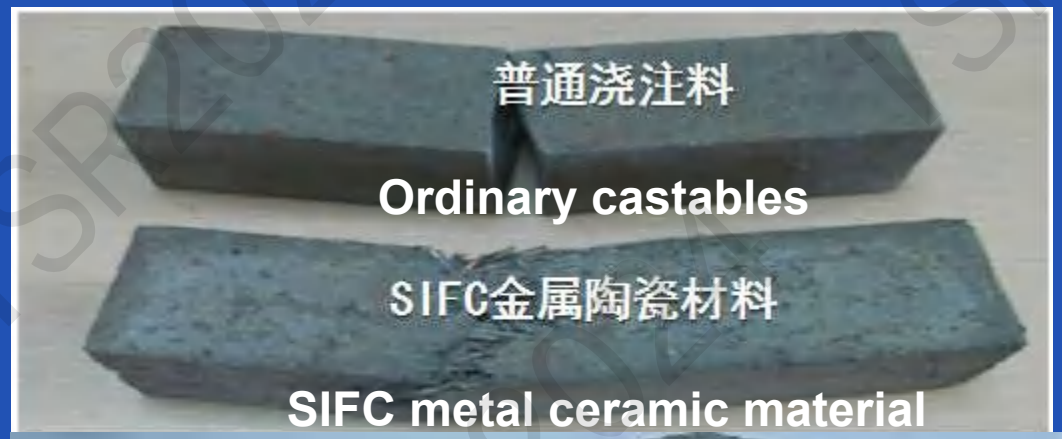
联合荣大 ALLIED RONGDA

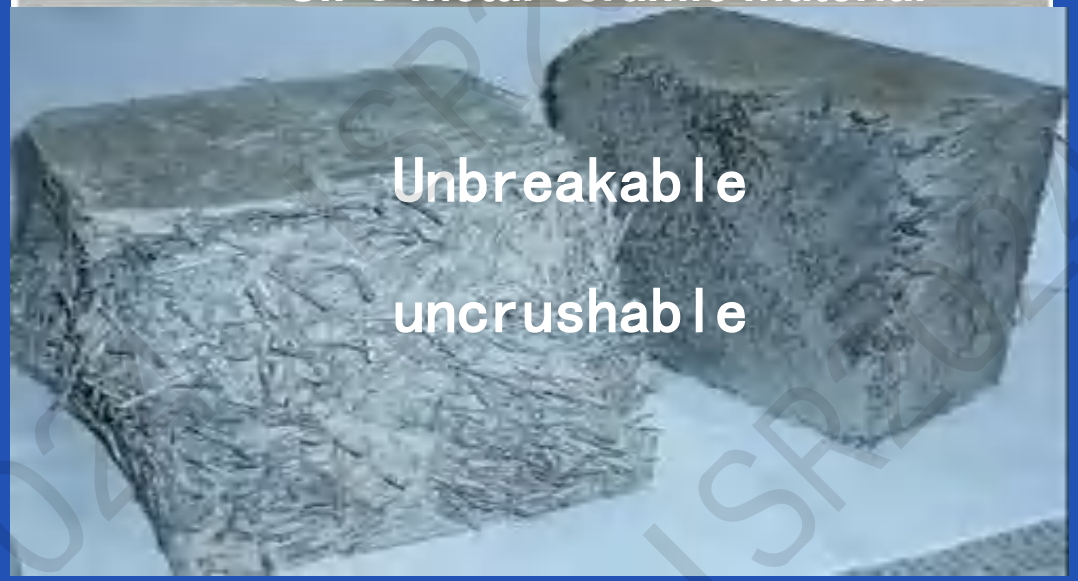


实验验证普通钢纤维浇注料

SIFC金属陶瓷预挂渣皮材料特点
Characteristics of SIFC Cermet

联合荣大 ALLIED RONGDA





- High steel fiber content of 20-30wt%
- High flexural strength (50-80MPa)
- High toughness (high bending/compression ratio, 1:2)
- High temperature resistance
- Wear resistance
- Self repairing

Steel fiber content 1-5%

High Thermal Conductivity

联合荣大
ALLIED RONGDA

Table 1 Thermal conductivity of SIFC at different temperatures

表 1 不同温度下 SIFC 的导热系数

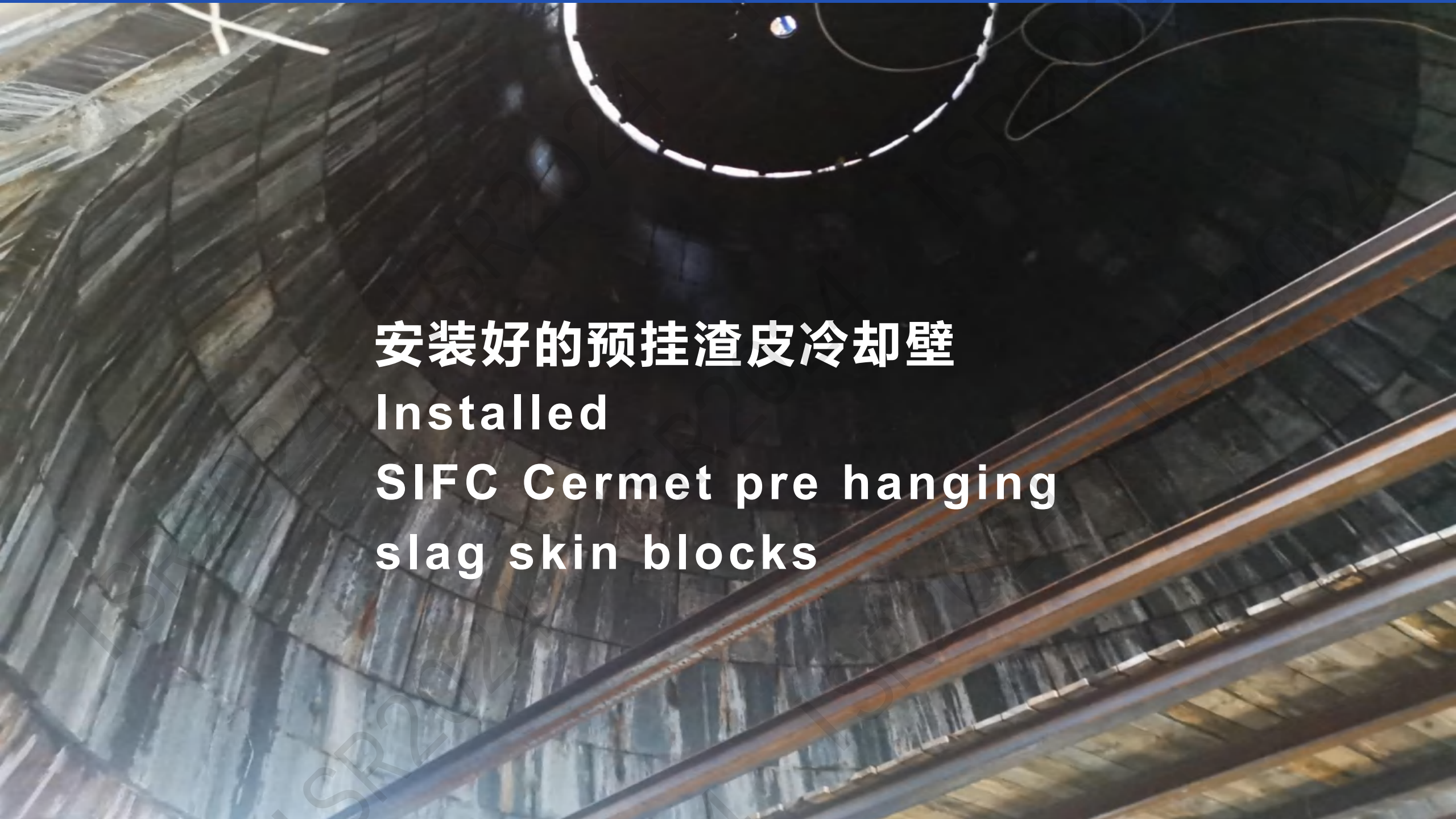
	温度		导热系数
	摄氏温度(℃)	开氏温度(K)	W/(m · K)
计算值	0	273	7.99
	40	313	8.31
	60	333	8.47
	80	353	8.64
	100	373	8.81
试验值	300	573	10.82
	600	873	14.63
	800	1073	18.58
	1000	1273	23.01
计算值	1200	1473	29.01
	1300	1573	32.58
	1400	1673	36.61

SIFC高导热特点

At high temperatures, the thermal conductivity of the material can reach over 20W/(m · K), ensuring efficient heat transfer;

Refractory base material ensures the material's resistance to slag and iron erosion.

Applicaation



安装好的预挂渣皮冷却壁

Installed

SIFC Cermet pre hanging

slag skin blocks

After three years of use

联合荣大
ALLIED RONGDA

➢ 某高炉使用三年后渣皮

2.3 Lining by Shotcreting in Blast Furnace.

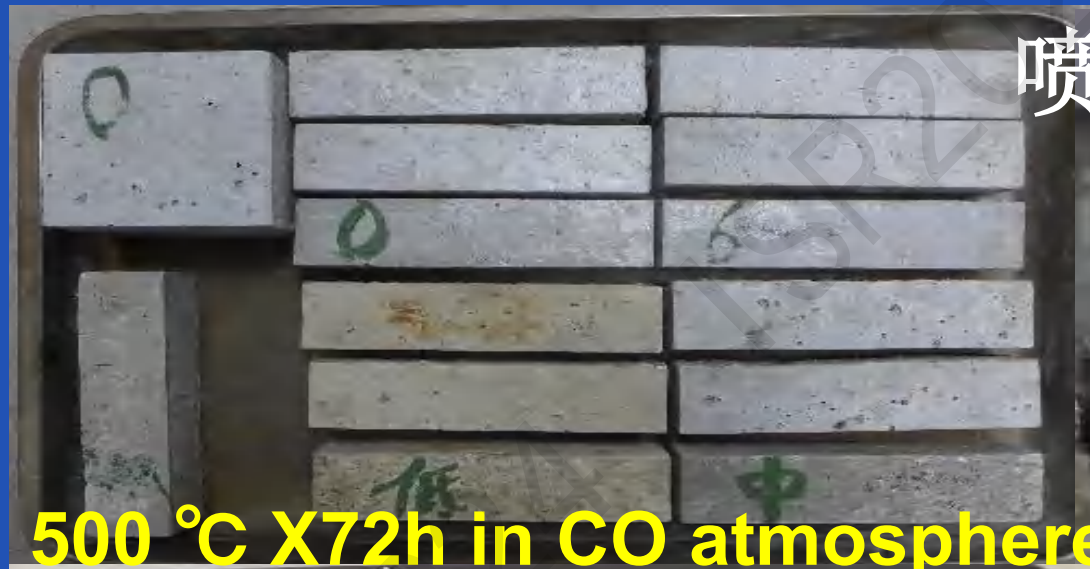
联合荣大
ALLIED RONGDA

高炉喷注造衬

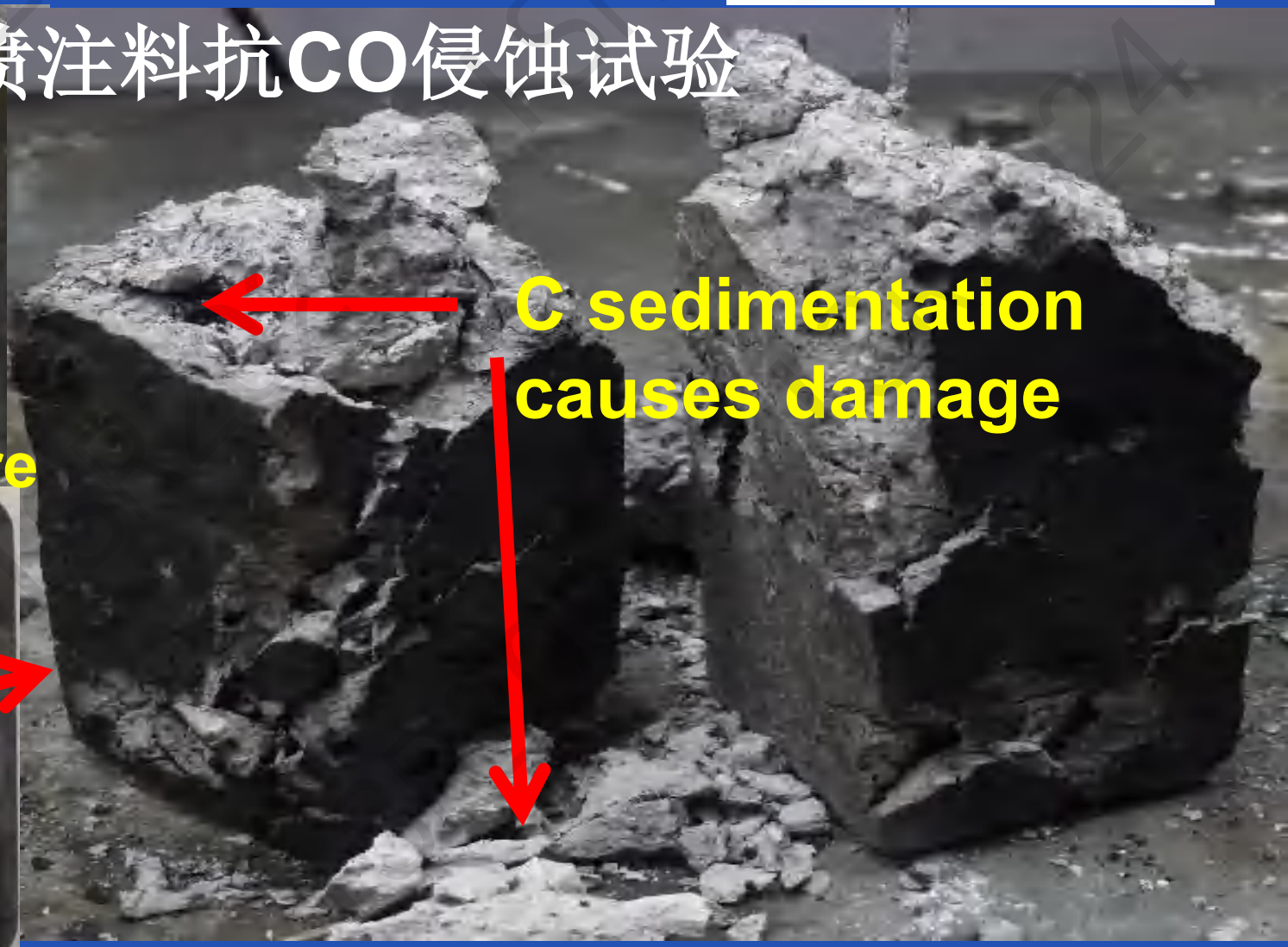
Test on the Resistance to CO Erosion of Shotcreting Materials

联合荣大 ALLIED RONGDA

喷注料抗CO侵蚀试验



500 ℃ X72h in CO atmosphere



C sedimentation causes damage

Research and development of large-scale and efficient shotcreting equipment

联合荣大
ALLIED RONGDA

大型高效喷注装备的研发

大喷量可伸缩
Large spraying volume and retractable

沙钢5800高炉

Shotcreting linning
Shagang 5800 blast furnace
The largest domestic and world's second largest giant blast furnace
by Allied Rongda team

4038 giant blast furnace
Ansteel Bayuquan
鞍钢鲅鱼圈4038立方高炉

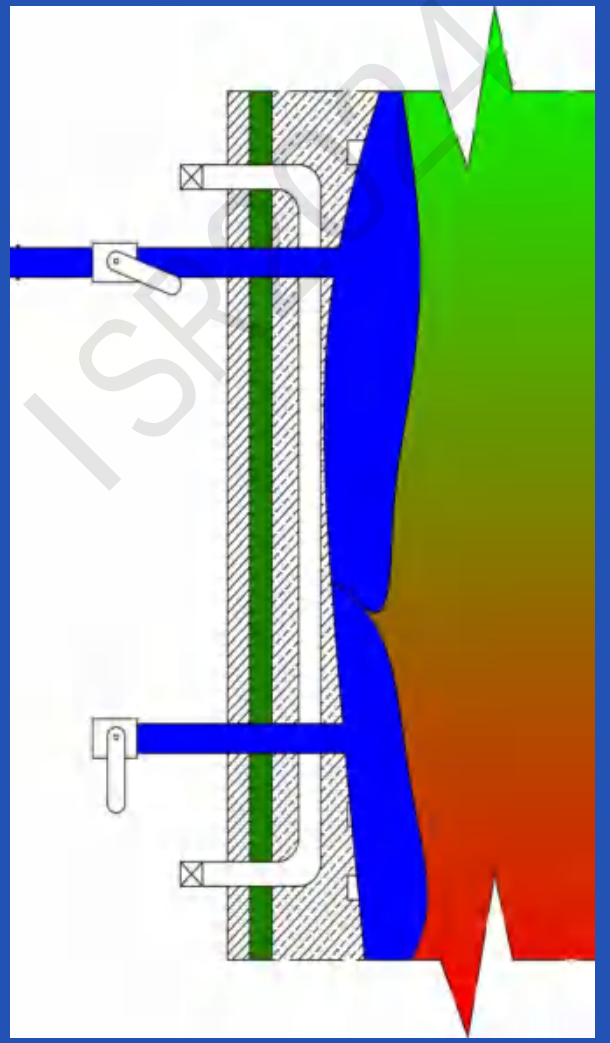
Highest record of spraying volume
22 t/hr
total amount over 400tons

Shougang Jingtang 2 # 3 # 5500BF

首钢京唐

联合采天使命：高效率帮助客户解决问题！

热态修补Hot state repair technology



3高炉内衬耐材技术趋势
Trends of refractory Tech for BF lining

联合荣大
ALLIED RONGDA

个人观点Personal Opinions

1 使用复合材料替代传统的碳砖Less carbon brick for hearth but more composite material replaced.

2 更多的不定形材料替代定形制品More unshaped material.

3 喷注与压入技术的应用，包括热态施工Shotcrete and injection, cold and hot online.

4 基于快速恢复生产的高炉维修总维修General contractor for blast furnace rapid repair and maintenance

高炉停炉清理效率进步情况

联合荣大
ALLIED RONGDA

大连特钢
1260m³高炉
2018年
清理13天

宝钢韶钢
1080m³高炉
2019年施工
清理11天

陕钢龙钢
1880m³高炉
2020年施工
清理10天

宝钢韶钢
3200m³高炉
2020年施工
清理15天

津西特钢
1080m³高炉
2020年施工
清理10天

鞍钢
2580m³高炉
2021年施工
清理7天

唐山中厚板
1800m³高炉
2022年施工
清理5天

阳春新钢铁
1250m³
2023年
清理2.5天

4 高炉快修检修工程总包

工程总包资质

联合荣大
ALLIED RONGDA

正在取得冶金工程
总承包二级资质

建筑业企业资质证书

企业名称：[redacted]程材料股份有限公司

详细地址：[redacted]房镇经纬工业区龙云路9号

统一社会信用代码：9111011660042534 4D 法定代表人：章荣会

注册资本：6815.8996万元人民币 经济性质：股份有限公司(非上市、自然人投资或控股)

证书编号：D311163044 有效期：2023年12月31日

资质类别及等级：
冶金工程施工总承包叁级 2016/05/04; ******

资质类别及等级：
冶金工程施工总承包叁级

本使用件仅用于：工程施工、日常使用

使用期限：2023-03-17至2023-06-16

企业最新信息
可通过扫描二维码查询

发证机关：北京市住房和城乡建设委员会行政审批服务专用章(1)
2022年06月10日

建筑业企业资质证书

企业名称：北京联合荣大工程材料股份有限公司

详细地址：北京市怀柔区北房镇经纬工业区龙云路9号

统一社会信用代码：9111011660042534 4D 法定代表人：章荣会

注册资本：6815.8996万元人民币 经济性质：股份有限公司(非上市、自然人投资或控股)

证书编号：D211160493 有效期：2023年12月31日

资质类别及等级：
建筑装修装饰工程专业承包贰级 2011/10/12; ******

资质类别及等级：
建筑装修装饰工程专业承包贰级

本使用件仅用于：工程施工、日常使用

使用期限：2023-03-17至2023-06-16

企业最新信息
可通过扫描二维码查询

发证机关：北京市住房和城乡建设委员会行政审批服务专用章(1)
2022年06月10日

专业高效的施工团队

联合荣大
ALLIED RONGDA

炉底找平和炉底砖砌筑

专业科学的工程实施方案

目录

专业项目部全程24小时作业

通过项目前期精心准备、科学制定施工方案以及高效的施工组织，计划60天的施工工期大幅度提前，剔除停工等待其他工序环节，大修项目用时51天（含7天烘炉）。

高炉快修检修工程总包

联合荣大
ALLIED RONGDA

前期侵蚀诊断 | 停炉降料线 | 开孔放残铁 | 炉料炉缸清理 | 冷却壁更换镶砖 | 扒渣门修复 | 炉缸整体浇注 | 炉缸砌筑 | 高炉内衬喷注 | 高炉压浆 | 烘烤、投产 | 诊断平台、操作维护





联合荣大使命：高效率帮助客户解决问题！

责任·尊严·创新·卓越

联合荣大

www.alliedrongda.com.cn