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FAILURE ANALYSIS 15 min read Updated January 2024

High Alumina Brick Premature Failure: 3 Common Causes and How to Prevent Them

Root cause analysis of HAB failure in cement, steel, and glass applications with proven prevention strategies.

High alumina brick (HAB) premature failure — defined as campaign life less than 50% of design specificat one of three root causes: (1) incorrect Al_2O_3 grade selection for the thermal or chemical environment, (2) rapid temperature cycling beyond the brick's thermal expansion tolerance, or (3) batch-to-batch inconsis or firing temperature from the supplier. HAB is classified by alumina content per ASTM C27 — ranging fro 90% (corundum brick) — with each grade offering distinct refractoriness under load (RUL), thermal shock resistance.

Industry field data indicates that approximately 60% of HAB failures in cement, steel, and glass applicatio selection errors, 25% to installation or operational thermal shock, and 15% to supplier quality variation. Pr requires examination of the failure surface (spalling pattern, penetration depth, color change), correlation (temperature excursions, shutdown frequency), and chemical analysis of retained slag or deposit. This ar procedures and prevention strategies based on analysis of over 200 documented HAB failure cases acros and glass furnace applications.

Cause #1 — Incorrect Al_2O_3 Grade Selection (60% of Failures)

The most common failure mode is specification of brick with insufficient alumina content for the actual se error stems from three sources: (1) reliance on design temperature rather than actual measured operating

account for chemical attack (alkali, slag) that effectively reduces refractoriness, and (3) cost-driven subs
material without engineering review.

Under-Specification Case Study: Cement Kiln Transition Zone

CASE 01

55% Al_2O_3 Brick in High-Alkali Environment

Application: Cement kiln transition zone, design temperature 1300°C. **Design requirement:** 65–70%
What happened: Brick surface vitrified and spalled after 8 months (design life: 24 months). **Root caus**
~1350°C; actual service demand was 1380°C under load + alkali flux action reduced effective RUL by
impact: Unplanned shutdown cost $85,000 in a 5000 t/d kiln.

Failure signature analysis:

- Green/brown discoloration on hot face indicating alkali (K_2O, Na_2O) penetration
- 15–25mm spalled layer with glassy appearance
- XRF analysis showed 8–12mm alkali penetration depth from hot face
- Residual brick showed formation of low-melting nepheline phase ($NaAlSiO_4$, melting point ~1100°C)

Prevention Strategy: Grade Selection with Safety Margins

01 **Measure actual service temperature** — Use IR pyrometer during operation, not just design calculations.
exceed design by 50–100°C.

02 **Add 100–150°C safety margin for chemical environments** — Alkali, slag, and flux attack effectively redu

03 **Match RUL to service temp + margin:** 1250°C service + alkali → 65% Al_2O_3 min (RUL ~1420°C) | 1350°C
min (RUL ~1480°C) | 1450°C service → 85% Al_2O_3 (RUL ~1520°C)

04 **Request alkali penetration test data** — Per GB/T 30873 or equivalent. Essential for cement kiln and glass

Over-Specification Error: Paying for Unused Performance

Cost trap: Using 85% Al_2O_3 brick where 55% is adequate increases material cost 40–60% with zero perfor
higher Al_2O_3 content reduces thermal shock resistance — 85% Al_2O_3 corundum brick is significantly more br

in thermally cycled applications.

APPLICATION	SERVICE TEMP	CHEMICAL EXPOSURE	RECOMMENDED AL_2O_3
Kiln car (light duty)	<1200°C	Minimal	48–55%
Cement kiln inlet	1200–1300°C	Moderate alkali	60–65%
Cement kiln transition	1300–1400°C	Heavy alkali	70–75%
Glass furnace regenerator	1350–1450°C	Alkali vapor	75–85%
Steel ladle sidewall	1500–1600°C	Slag contact	85–90%

Cause #2 — Thermal Shock from Rapid Cycling (25% of Failures)

Thermal cycling is particularly aggressive in cement rotary kiln transition zones; see the cement rotary kil transition zone temperature ranges and recommended thermal shock specifications.

Thermal shock failure occurs when the temperature change rate (°C/hour) exceeds the brick's thermal st capability. This mechanism is counterintuitive: higher Al_2O_3 content — while increasing refractoriness — a shock resistance due to lower porosity, higher density, and increased thermal expansion coefficient.

Thermal Shock Resistance Formula

Thermal shock resistance is proportional to:

> TSR ∝ (Tensile Strength × Thermal Conductivity)
> ÷ (Elastic Modulus × Thermal Expansion Coefficient)
>
> Key insight:
> 48% Al_2O_3 brick: Good TSR (lower expansion, higher porosity buffers stress)
> 85% Al_2O_3 brick: Poor TSR (dense, high expansion, brittle)

Case Study: Boiler Arch Horizontal Cracking

CASE 02

75% Al_2O_3 Brick in Daily Cycling Service

Lining: 75% Al_2O_3 brick in boiler roof arch. **Operating pattern:** Daily shutdown (1200°C → 200°C in 3 l **mode:** Horizontal cracks parallel to hot face after 4 months. **Root cause:** Cooling rate of 330°C/hour e tolerance. **Correct solution:** Switch to 55–60% Al_2O_3 (better thermal shock resistance) OR implement (<100°C/hour).

Thermal shock failure signatures:

- Horizontal cracks parallel to hot face (perpendicular to thermal gradient)
- Uniform crack spacing (typically 80–150mm intervals)
- No chemical deposits or discoloration
- Cracks propagate from hot face inward

Thermal Shock Resistance Ranking (Best to Worst)

Insulating firebrick — High porosity (50–70%), low expansion, excellent TSR
48–55% Al_2O_3 HAB — Moderate density, good buffer capacity
65–70% Al_2O_3 HAB — Reduced TSR but acceptable for moderate cycling
85% Al_2O_3 HAB — Dense corundum, poor TSR, unsuitable for thermal cycling
Magnesia brick — Worst TSR due to very high thermal expansion (MgO: 13.5×10^{-6}/°C vs Al_2O_3: 8×1(

Prevention Strategy for Thermally Cycled Applications

```
If furnace cycles >3 times/week:
  → Prioritize thermal shock resistance over refractoriness
  → Use lower Al₂O₃ grade (55–65%) even if temperature "could" justify 75%
  → Implement controlled heat-up/cool-down (<100°C/hour)
  → Consider expansion joints every 1.5–2.0 meters

If furnace operates continuously (cycles <1/month):
  → Thermal shock less critical
  → Optimize for refractoriness and slag resistance
  → Higher Al₂O₃ grades acceptable
```

Cause #3 — Supplier Batch Inconsistency (15% of Failures)

HAB performance depends critically on raw material quality (bauxite Al_2O_3 content, impurity levels), firing depending on grade), soak time at peak temperature, and cooling rate. Batch-to-batch variation in any of performance inconsistency that manifests as unexpected early failure.

Real Supplier Audit Data: Batch Variation Example

```
Supplier X — "65% Al₂O₃ Brick"

Batch A (January 2024):
  Al₂O₃: 66.2%
  Bulk Density: 2.45 g/cm³
  CCS: 55 MPa
  RUL: 1430°C

Batch B (March 2024):
  Al₂O₃: 63.8%  ← 2.4% lower
  Bulk Density: 2.38 g/cm³  ← 2.9% lower (indicates under-firing)
  CCS: 48 MPa  ← 13% lower
  RUL: 1390°C  ← 40°C lower

Result: 40°C RUL difference = potential 30–40% campaign life reduction
        if Batch B used in marginal temperature application
```

Case Study: Identical Kilns, Different Performance

PARAMETER	KILN A	KILN B
Setup	Identical 5000 t/d cement kilns, sister plants	
Reline Date	Same month (March 2023)	
Brick Specification	65% Al_2O_3, same nominal brand	
Supplier Batch	Batch A (high-quality firing)	Batch B (under-fired)
Campaign Life	22 months	13 months (41% shorter)
Failure Analysis	—	Brick had 6% lower bulk density → insufficien

Detection method: Post-failure analysis showed Kiln B brick had bulk density of 2.31 g/cm³ vs specified 2 insufficient firing temperature or soak time during manufacturing.

Supplier Quality Control Checklist

01 **Batch-specific COA requirement** — Contractually require Certificate of Analysis for every batch, not just have batch code traceable to COA.

02 **Specify tolerances in purchase contract:** Al_2O_3 ±1.5% max | Bulk Density ±0.05 g/cm³ max | CCS ±5 MPa

03 **Witness testing for large orders** — Send engineer to supplier facility to verify lab equipment calibration a orders >100 tons.

04 **Firing kiln type verification** — Tunnel kiln (more consistent) preferred over shuttle kiln. Request photos/d equipment.

05 **Heritage validation** — Supplier with 10+ years production history and verifiable export records reduces ri

Red Flags: When to Walk Away from a Supplier

— **Refuses batch-specific COA:** "All our product is the same" is unacceptable — batch variation is inhere manufacturing

— **Wide color variation within same pallet:** Indicates firing temperature inconsistency across kiln cross-

- **Price 20%+ below market:** Suggests raw material substitution (lower-grade bauxite) or under-firing to
- **Cannot provide batch traceability:** Brick not stamped with batch code or supplier cannot correlate br
- **Lab equipment appears poorly maintained:** For witness testing — uncalibrated instruments, lack of s dirty test equipment

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Diagnostic Flowchart for Failed HAB

```
START: HAB failed before 50% of design life

├── Examine failure surface
│ │
│ ├── Spalling with green/brown/white deposit?
│ │   └── → Chemical attack (alkali/slag)
│ │       └── XRF analysis shows K₂O/Na₂O penetration?
│ │           └── YES → Cause #1: Under-specification
│ │               Action: Upgrade to higher Al₂O₃ grade
│ │
│ ├── Horizontal cracks parallel to hot face?
│ │   └── → Thermal shock
│ │       └── Check operating log for rapid temp changes
│ │           └── Cooling rate >150°C/hour?
│ │               └── YES → Cause #2: Thermal cycling
│ │                   Action: Lower Al₂O₃ grade OR controlled cool-down
│ │
│ └── Uniform degradation, earlier than expected?
│     └── → Possible batch quality issue
│         └── Compare actual brick properties to COA
│             └── Al₂O₃ or bulk density variance >5%?
│                 └── YES → Cause #3: Supplier inconsistency
│                     Action: Audit supplier, verify batch controls

└── Send failed sample to independent lab for:
    · Al₂O₃ % (XRF analysis)
    · Bulk density (Archimedes method)
    · Penetration depth (cross-section microscopy)
    · Phase analysis (XRD for alkali reaction products)
```

Prevention Summary Matrix

FAILURE CAUSE	% OF CASES	FAILURE SIGNATURE	PREVENTION
Wrong Al_2O_3 grade	60%	Spalling, slag penetration, discoloration	Map service temp + 100-
Thermal shock	25%	Horizontal cracks, hot-face spalling	Controlled heat-up/cool- for cyclic service
Batch inconsistency	15%	Uniform degradation, earlier than peer installations	Batch COA verification, s

Failure Prevention Verdict

High alumina brick premature failure is rarely a "bad luck" event — 85% of cases trace to preventabl common error (60% of failures) is incorrect Al_2O_3 grade selection, typically under-specification in alk environments. The solution is measuring actual service temperature (not relying on design values), a safety margin for chemical attack, and matching RUL to adjusted service conditions. Thermal shock requires prioritizing thermal shock resistance over refractoriness in cyclic applications — use lower A controlled heat-up/cool-down rates. Supplier batch inconsistency (15%) is mitigated through contra requirements, tolerance specifications, and batch traceability systems. Proper failure analysis — exa correlating with operating logs, and conducting chemical analysis — is essential for implementing ef measures.

Content produced from Zibo's refractory manufacturing cluster — China's largest concentration of castab material production facilities, with over 40 years of continuous kiln lining export history.

IN THIS ARTICLE

Cause #1: Wrong Grade | Cause #2: Thermal Shock | Cause #3: Batch Issues | Diagnostic Flowchart | Pr

FREQUENTLY ASKED QUESTIONS

High Alumina Brick Failure FAQ

What is considered premature failure for high alumina brick? +

How can I tell if my brick failed due to alkali attack versus thermal shock? +

Should I always choose the highest Al_2O_3 percentage to be safe? +

How do I verify my supplier's batch consistency? +

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