KINGSFORM METALWORKS

ENGINEERING TOOLKIT

CARBON STEEL GUIDE

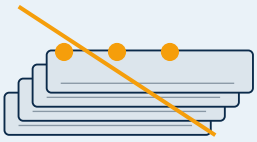
Grade selection, product form, fabrication, welding, corrosion protection and procurement

SELECT THE STEEL

235 355 550

Match strength, ductility, weldability, formability and product form to the function.

CONTROL FABRICATION



Manage edge quality, grain direction, heat input, restraint, scale and dimensional variation.

PROTECT THE SURFACE

Design the coating system, preparation, drainage, handling and inspection as one package.

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KFR-019	1.0	2026-07-18	English
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01 PURPOSE AND SELECTION WORKFLOW

Select carbon steel from function, process and environment together

A familiar grade name is not enough. Product form, thickness, delivery condition, heat treatment, surface condition and certification can change both performance and manufacturability.

CORE PRINCIPLE

Release the material as a complete purchase specification: governing standard, grade, product form, dimensions and tolerances, delivery condition, surface state, testing, traceability, welding requirements and corrosion protection.

1 Function

Load, stiffness, fatigue, impact, wear, temperature, life and safety classification.

2 Product form

Sheet, plate, bar, section, mechanical tube, structural tube, wire, casting or forging.

3 Fabrication

Laser, punching, bending, drawing, machining, welding, heat treatment and coating.

4 Environment

Indoor, outdoor, wet, chloride, chemical, soil, abrasion, cleaning and maintenance.

5 Verification

MTC, dimensions, weld qualification, coating tests, NDT and first-article checks.

THE THREE QUESTIONS THAT PREVENT MOST MATERIAL ERRORS

IS THE GRADE STRONG ENOUGH?

Check yield, tensile, elongation, toughness, fatigue, thickness effect and temperature - not only a catalogue minimum.

CAN IT BE MADE REPEATABLY?

Confirm bendability, weldability, tool wear, heat treatment, edge quality, springback and production tolerances.

WILL THE SURFACE LAST?

Choose preparation and coating for the actual corrosion category, geometry, handling, repair and maintenance plan.

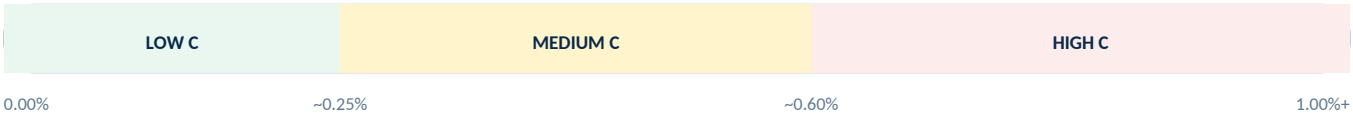
DO NOT BUY BY A TRADE NAME ALONE

Names such as mild steel, black steel, cold rolled, galvanized, Q235, S355 or A36 describe different aspects and systems. State the controlling standard and required properties.

02 CARBON STEEL FAMILIES

Carbon content influences hardness, ductility and welding risk

The boundaries below are conventional screening ranges, not universal legal definitions. Alloying, microalloying, heat treatment and processing can dominate the final behavior.



Group	Typical carbon screen	General behavior	Fabrication focus	Common fabricated uses
Low-carbon / mild	Typically up to about 0.25% C	High ductility, low hardness, broad weldability	Scale, surface, bend direction, coating and dimensional control	Brackets, frames, enclosures, tubes, general structures
Medium-carbon	About 0.25-0.60% C	Higher strength/hardness; lower ductility	Preheat, heat treatment, machinability and cracking risk	Shafts, pins, wear parts, forged/machined components
High-carbon	About 0.60% C and above	High hardness and wear potential after heat treatment	Forming is limited; welding often special or avoided	Springs, blades, high-strength strip and wear elements
HSLA / microalloyed	Low carbon plus Nb/V/Ti or other strengthening	Higher yield at useful ductility; thinner sections possible	HAZ softening/hardening, bend radius, filler and forming capacity	Structural plate, sheet, chassis, lifting and transport parts
Weathering steel	Alloyed for improved atmospheric resistance	Forms a protective patina only in suitable exposure	Detail drainage, wet-dry cycles, welding consumable and runoff staining	Exposed structures, architectural and transport applications

LOW CARBON DOES NOT MEAN LOW STRENGTH

DENSITY
about 7.85 g/cm3
Weight estimates

ELASTIC MODULUS
about 200 GPa
Stiffness is similar across many grades

THERMAL EXPANSION
about 12 um/m-K
Temperature movement

MAGNETIC
generally magnetic
Not a grade identification method

03 GRADES AND STANDARD SYSTEMS

Use comparisons only as screening - not substitution approval

Chinese GB, European EN, ASTM/SAE and ISO systems use different product scopes, chemistry limits, toughness classes, thickness rules and supplementary options.

System example	Nominal strength idea	Product / use	Important caution
Q235B (GB/T)	General structural, around 235 MPa class	Plate, sections and general welded fabrication	Impact quality, thickness and product standard matter
S235JR (EN)	General structural, 235 MPa class	Hot-rolled structural products	JR/J0/J2 refer to impact test conditions - not cosmetic grade
ASTM A36	General carbon structural steel	Shapes, plates and bars for welded/bolted construction	Yield requirement varies with product and thickness; not sheet specification
Q355B / S355JR/J2	Higher-yield structural classes	Plate, sections, frames and load-bearing fabrication	Not direct equivalents; compare chemistry, toughness and delivery condition
ASTM A572 Grade 50	HSLA structural steel, 345 MPa class	Shapes, plates, bars and structural work	Confirm grade, thickness, notch toughness and welding code
SAE 1008/1010 type	Low-carbon chemistry family	Cold-rolled sheet, wire or tubing feedstock depending product standard	Chemistry designation alone does not define sheet properties or tolerances

EQUIVALENT IS AN ENGINEERING DECISION

A substitute must meet the same functional requirements: chemical composition, mechanical properties, impact toughness, thickness range, weldability, product tolerances, delivery condition, surface and certification.

1 STANDARD SCOPE

2 CHEMISTRY

3 MECHANICALS

4 TOUGHNESS

5 PRODUCT / CONDITION

6 FABRICATION / COATING

04 STRENGTH, TOUGHNESS AND WELDABILITY

Read the whole property set - not yield strength alone

Higher strength can reduce section size, but it can also increase springback, forming load, notch sensitivity, weld procedure control and inspection requirements.

Property	What it controls	Common design mistake
Yield strength	Onset of permanent deformation and many static sizing checks	Assuming the minimum is the same at every thickness and product form
Tensile strength	Maximum engineering stress before fracture in a tensile test	Using it as the only measure of joint or fatigue performance
Elongation	Ductility under the specified test geometry	Comparing values from different gauge lengths or thicknesses
Charpy impact	Notch toughness at a specified temperature	Ignoring service temperature, thickness and weld HAZ toughness
Hardness	Local resistance to indentation; can screen heat treatment or HAZ	Treating hardness as a direct substitute for full mechanical testing
Fatigue strength	Life under cyclic stress and stress concentration	Using static yield margin while ignoring weld detail and surface notch
Through-thickness ductility	Resistance to lamellar tearing in restrained welded joints	Omitting Z-quality or joint redesign where through-thickness strain is high

CARBON EQUIVALENT - A WELDABILITY SCREEN, NOT A PROCEDURE

IIW CEV

CEV = C + Mn/6 + (Cr+Mo+V)/5 + (Ni+Cu)/15

Useful for many structural steels. The applicable code may use a different formula, limit or product value.

PREHEAT DEPENDS ON MORE THAN CEV

- Combined thickness and heat sink
- Hydrogen level and consumable control
- Joint restraint and stress concentration
- Heat input, interpass and cooling rate
- Required hardness, toughness and code

05 HOT-ROLLED, COLD-ROLLED AND COATED FLAT PRODUCT

Surface state and production route affect formability, appearance and coating

Do not use hot rolled, cold rolled, pickled or galvanized as if they were grade names. Each is a supply condition that still requires a material specification.

Supply condition	Surface / tolerance	Forming and welding	Typical selection reason
Hot rolled (HR)	Mill scale possible; wider gauge/flatness variation than CR	Good general fabrication; scale affects laser, weld and coating prep	Cost-effective structural parts, thicker sheet and plate
Hot rolled pickled and oiled (HRPO)	Scale removed; oiled surface	Cleaner laser/weld/paint route; oil must be removed before coating	Fabricated brackets, frames, stamped and welded parts
Cold rolled (CR)	Smooth, clean appearance; tighter thickness and shape control	Good for precision forming; work-hardening and temper matter	Enclosures, cosmetic panels, appliance and formed components
Continuous galvanized sheet	Factory-applied zinc on coil sheet	Cut edges and welding fumes need control; coating changes bend/weld behavior	High-volume sheet parts with built-in sacrificial protection
Electrogalvanized sheet	Thin, uniform zinc; smooth appearance	Good paint base in some systems; lower zinc mass than many HDG products	Automotive, enclosures and precision coated sheet
Pre-painted / organic coated	Finished coil coating before fabrication	Cut edge, scratch, bend radius and heat damage become critical	High-volume panels and architectural products

COIL DIRECTION MATTERS

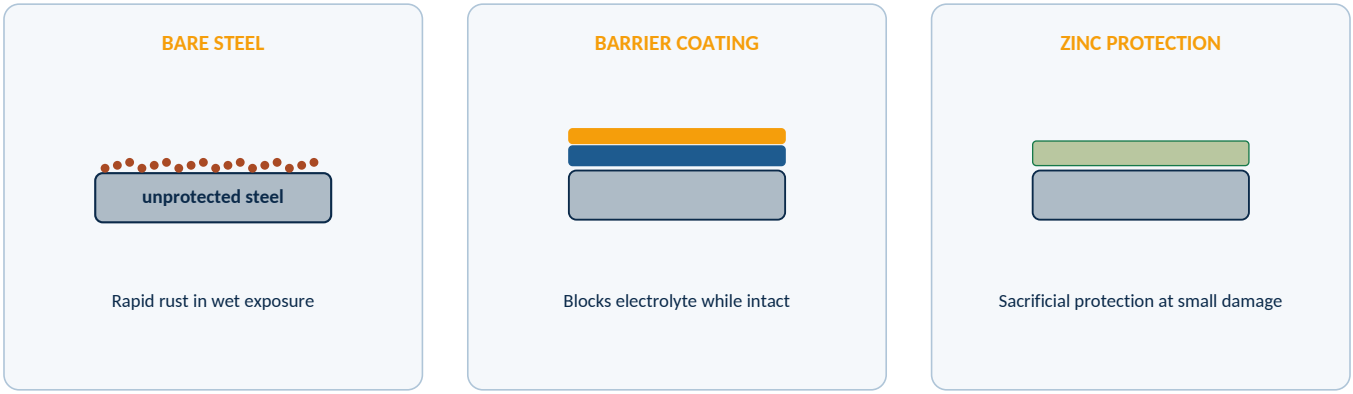
Rolling direction can affect bend cracking, springback, earing, surface texture and flatness. Show grain direction on drawings when function or appearance depends on it.

06 CORROSION AND PROTECTION SYSTEMS

Bare carbon steel needs an intentional exposure strategy

Corrosion performance depends on environment, preparation, coating type, film thickness, edges, crevices, damage, drainage, maintenance and compatibility with the substrate.

Protection route	Strengths	Key limits / design controls	Typical verification
Paint / liquid coating	Flexible system build; field repair possible	Surface preparation, edge stripe coat, cure, film thickness and environment	Preparation grade, DFT, adhesion, holiday and appearance
Powder coating	Durable appearance; efficient shop process	Pretreatment, sharp edges, Faraday areas, cure and UV class	Cure record, film thickness, adhesion, color/gloss sample
E-coat	Good recess coverage on suitable assemblies	Tank size, drain holes, pretreatment, sealing and topcoat needs	Coating weight/DFT, coverage, adhesion, corrosion test
Electroplated zinc / zinc-nickel	Thin, controlled finish for small parts	Hydrogen embrittlement risk, thread allowance, rack marks and passivation	Thickness, adhesion, corrosion test and bake record if applicable
Hot-dip galvanizing after fabrication	Thick sacrificial coating and edge coverage	Vent/drain, distortion, fit, appearance, threads and alloy reactivity	ISO 1461 coating thickness/appearance and repair plan
Continuous galvanized sheet	Integrated coil protection and high throughput	Cut edges, weld damage, forming cracks and local repairs	Coating mass, surface condition and fabrication inspection
Phosphate / black oxide	Conversion or cosmetic treatment; good paint/oil base	Limited standalone outdoor corrosion life	Bath control, appearance, coating mass or oil retention



SALT SPRAY IS NOT A UNIVERSAL LIFE PREDICTOR

Use cyclic or service-relevant tests when appropriate. Neutral salt spray is primarily a comparative process-control test for a defined coating system and defect condition.

07 CUTTING, FORMING AND MACHINING

Protect edge quality and local ductility through the process chain

Material grade, thickness, rolling condition, edge damage, tool radius, grain direction and work hardening determine whether a part bends cleanly and holds size.

Process	Primary design variables	Failure risks	Release controls
Laser / plasma	Thickness, grade, coating, kerf, HAZ, assist gas, piercing	Dross, taper, hard HAZ, nitrided edge, coating fumes	Cut standard/sample, burr side, edge cleanup and critical hole method
Shear / blank / punch	Clearance, tool condition, grain direction, hole size and edge distance	Burr, rollover, fracture zone, distortion and edge cracking	Burr direction/limit, die clearance study and forming sequence
Press-brake bending	Inside radius, V opening, grain, tensile/yield ratio and springback	Cracks, excessive thinning, angle drift and tool marks	Trial bend, minimum radius by supplier, surface protection and angle method
Deep draw / stamping	r-value, n-value, blank shape, lubrication, draw ratio and beads	Tearing, wrinkling, earing and split flange	Material designation for drawing, forming simulation and prototype validation
Machining	Hardness, scale, inclusion rating, tool geometry and coolant	Tool wear, built-up edge, distortion and decarburized skin	Machining allowance, condition/hardness and datum after stress relief
Heat treatment	Grade chemistry, section, quench route and target properties	Distortion, cracking, scale, decarburization and mixed hardness	Qualified cycle, coupons, hardness map and post-HT machining plan

BEND RADIUS IS NOT A SINGLE MATERIAL CONSTANT

A safe radius depends on grade, thickness, temper, grain direction, edge quality, bend method, tool opening, cosmetic requirement and production variation. Confirm with the fabricator and a representative trial.

BENDING CHECK

rain direction + edge + radius + springback

DFM QUESTIONS

- Can the feature be made before or after forming?
- Is the cut edge in tension during the bend?
- Will coating or scale damage the tool or surface?
- Where is the final inspection datum?

08 WELDING CARBON AND HSLA STEELS

Control hydrogen, hardness, heat input and restraint

Low-carbon steel is generally weldable, but thickness, carbon equivalent, microalloying, cold work, joint restraint and service toughness can make a routine-looking weld high risk.

1 BASE METAL

Grade, product, thickness, CEV/Pcm, heat treatment and traceability.

2 JOINT

Load path, access, root, fit-up, restraint, backing and lamellar-tear risk.

3 PROCESS

WPS, filler, polarity, shielding, heat input, preheat and interpass.

4 EXECUTION

Cleanliness, tack sequence, consumable storage, run-off and distortion plan.

5 VERIFY

VT/NDT, hardness/toughness if required, dimensions and coating repair.

Risk	What raises it	Design / process response
Hydrogen cracking	Higher hardenability, thick section, high restraint, hydrogen and rapid cooling	Low-hydrogen system, clean/dry joint, preheat/interpass and qualified WPS
HAZ hardening	High CEV/Pcm, low heat input, fast cooling and cold ambient	Control heat input and cooling; verify hardness where code/service requires
HAZ softening	Some TMCP, quenched/tempered or advanced sheet grades	Use grade-specific welding limits, filler choice and qualification testing
Lamellar tearing	Through-thickness strain, inclusions and highly restrained T-joints	Redesign joint, reduce restraint, buttering, Z-quality plate if justified
Distortion	High weld volume, unbalanced sequence, thin sheet and poor fit-up	Reduce weld size/length, balance sequence, fixtures, presets and intermittent welds where allowed
Toughness loss	Excessive heat input, wrong consumable, coarse HAZ or low-temperature service	Specify impact requirement and qualify WPS at governing thickness/temperature

MATCHING STRENGTH IS NOT ALWAYS THE ONLY FILLER RULE

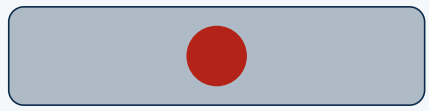
Filler selection also considers toughness, hydrogen level, dilution, heat treatment, joint restraint, fatigue, code approval and service environment. Follow the governing welding code and qualified WPS.

09 DESIGN FOR GALVANIZING AND COATING

Geometry determines coverage, drainage, distortion and repair

The same assembly can coat well or fail repeatedly depending on venting, drainage, crevices, edge radius, weld continuity, trapped chemicals, rack points and handling.

SEALED VS VENTED HOLLOW SECTION



TRAPPED AIR / LIQUID

VENT + DRAIN AT HIGH / LOW POINTS

DESIGN RULES TO CONFIRM WITH THE COATER

- Provide vent and drain paths for every enclosed volume and overlapping plate cavity.
- Avoid narrow acid traps, sealed lap joints and inaccessible crevices.
- Round sharp edges or stripe coat them so specified film builds at the edge.
- Allow for zinc/coating thickness on holes, slots, threads, bearings and mating faces.
- Place lifting/rack points where marks are acceptable and drainage is effective.
- Review asymmetric weldments and thin sheet for thermal distortion.
- Specify masking, thread chasing, touch-up method and maximum repair area.

Before coating	During process	After coating
Remove scale, rust, oil, weld spatter, sharp burrs and silicone contamination.	Control blast profile / pretreatment, bath carryover, film build, cure and grounding.	Inspect DFT, coverage, adhesion, holidays, color/gloss, threads and transport damage.
Define edge radius, weld continuity, drain paths, cosmetic class and masked areas.	Keep parts oriented so liquids drain and powder/paint reaches recesses.	Repair only by approved method; document area, preparation and final thickness.

GALVANIZING IS A HIGH-TEMPERATURE IMMERSION PROCESS

Confirm venting, material suitability, distortion risk, coating appearance and fit with the galvanizer before releasing a complex welded assembly. ISO 14713-2 provides design guidance; ISO 1461 covers fabricated articles.

10 PRODUCT FORM AND PROCUREMENT

Specify the product standard that actually supplies the part

Plate, sheet, structural tube and mechanical tube can share a chemistry family but have different tolerances, testing, weld seam conditions and intended uses.

PLATE / STRUCTURAL SHAPES

Standard + grade + thickness/size + impact class + delivery condition + surface + UT/through-thickness options.

HOT / COLD ROLLED SHEET

Sheet standard + commercial/drawing/structural designation + thickness tolerance + temper + surface + oil/film.

STRUCTURAL HOLLOW SECTION

Structural tube standard + grade + shape + outside dimensions + wall + seam + corner radius + straightness/twist.

MECHANICAL TUBING

Mechanical tube standard/type + OD/section + wall + condition + seam treatment + surface + dimensional tolerances.

BAR / SHAFT STOCK

Chemistry/mechanical grade + hot/cold drawn + heat treatment + size/straightness + decarb + machining allowance.

FASTENERS / WIRE / SPRING

Specific product and property-class standard + heat treatment + coating + hydrogen controls + certification.

Purchase-order field	Minimum definition
Material identity	Governing standard, grade/designation, product form and required edition
Dimensions	Nominal size, thickness class, tolerances, flatness/straightness, edge/corner and length
Delivery condition	As-rolled, normalized, TMCP, quenched/tempered, annealed, cold-drawn or specified temper
Mechanical / toughness	Required yield/tensile/elongation, impact temperature/class, hardness or other product tests
Surface state	Mill scale, pickled/oiled, cold-rolled finish, galvanized coating, rust preventive oil or blast condition
Welding / forming	CEV/Pcm limits if contractual, bend direction/radius, weldability and repair restrictions
Certification	Heat/lot traceability, inspection certificate, marking, test reports and retention period

DO NOT REPLACE STRUCTURAL TUBE WITH MECHANICAL TUBE - OR VICE VERSA - WITHOUT REVIEW

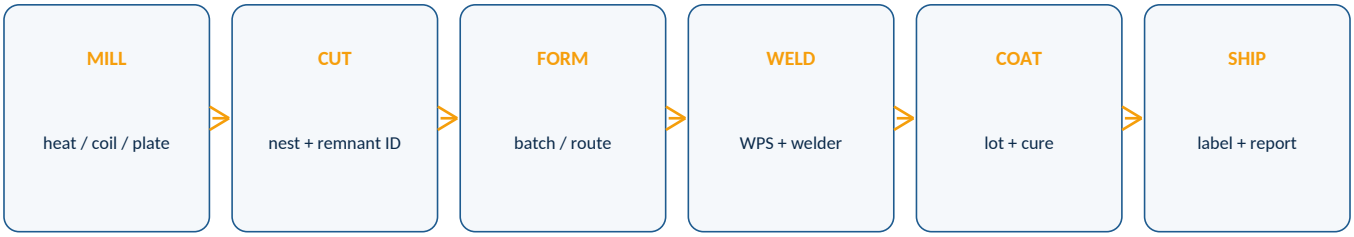
The intended use, mechanical tests, dimensional tolerances, weld seam condition and certification can differ even when dimensions look identical.

11 INSPECTION, CERTIFICATION AND TRACEABILITY

Verify identity, properties, dimensions, welds and coating separately

A correct heat certificate does not prove the fabricated part is correct; a good dimensional report does not prove material identity. Link each verification to a controlled requirement.

Verification	Confirms	Limit / caution
MTC / inspection certificate	Heat chemistry, specified properties and supply condition	Traceability must survive cutting, nesting, subcontracting and rework
Marking / heat transfer	Links part or batch to source material	Method must not damage fatigue, sealing or cosmetic surfaces
PMI by XRF / OES	Elemental identity depending instrument	Handheld XRF generally cannot measure carbon; OES may be needed for carbon grades
Tensile / Charpy / hardness	Specified mechanical behavior on defined specimens	Sampling direction, thickness, temperature and heat treatment must match the standard
Dimensional inspection	Size, flatness, straightness, twist, hole and assembly geometry	Use agreed datums, temperature and calibrated methods
Weld inspection / NDT	Workmanship and discontinuities to the selected code/level	NDT extent and acceptance must be specified before production
Coating inspection	Preparation, DFT, adhesion, coverage and appearance	Coating tests do not replace base-metal or weld verification



TRACEABILITY LEVEL SHOULD MATCH RISK

Full piece-level traceability is not necessary for every bracket, but safety-critical, pressure, lifting, fatigue or regulated work may require heat-to-part records, controlled remnants and positive transfer.

12 COMMON FAILURES AND CORRECTIVE ACTIONS

Diagnose the process chain, not only the visible defect

The final defect often originates earlier: wrong sheet condition, damaged edge, uncontrolled heat input, poor drainage, incomplete preparation or lost traceability.

Observed problem	Likely contributors	Corrective action
Bend cracks at edge	Too-tight radius, hard/HSLA grade, burr in tension, poor edge or wrong grain direction	Verify material/condition; improve cut edge; rotate grain; increase radius; trial representative lots
Weld toe cracks / delayed cracking	Hydrogen, high CEV, thick/restrained joint, low preheat or arc strike	Stop and investigate; qualified repair; control consumables, preheat, restraint and WPS
Frame is out of square	Unbalanced weld sequence, poor fit-up, excessive weld size, weak fixture	Rebalance sequence, reduce weld volume, use datums/fixtures, preset and intermediate checks
Coating peels or blisters	Oil/salt/scale, weak pretreatment, under-cure, moisture or incompatible system	Identify contamination; rework preparation; validate cure and coating stack
Rust starts at edges / welds	Thin film at sharp edge, missed stripe coat, weld spatter, crevice or damaged zinc	Round/clean edges; stripe coat; seal detail; repair zinc/coating by approved method
Threads bind after coating	No allowance/masking, coating buildup, damaged thread or wrong chase method	Define mask/oversize/tap-after; inspect gauge after coating; protect repaired surface
Material mix-up	Lost heat tags, uncontrolled remnants, similar appearance or vague purchase order	Quarantine; verify by records/OES as needed; restore controlled transfer and labeling
Unexpected brittle performance	Wrong grade/condition, low-temperature service, thick section or poor HAZ toughness	Review standard and toughness class; test; redesign or replace material/WPS

REWORK CAN CHANGE THE MATERIAL SYSTEM

Flame straightening, weld repair, grinding, re-galvanizing, thread chasing and local heating can alter hardness, residual stress, thickness, coating and traceability. Approve and record rework before shipment.

13 DESIGN RELEASE CHECKLIST AND REFERENCES

Release the material, fabrication and corrosion plan together

Use the checklist across design, procurement, fabrication, welding, coating and quality. Delete only items proven not applicable.

- [ ] 1. Governing material standard, grade and product form are specified.
- [ ] 2. Strength, ductility, toughness and temperature requirements are defined.
- [ ] 3. Thickness/size effects and delivery condition have been checked.
- [ ] 4. Local substitute or cross-standard grade has written engineering approval.
- [ ] 5. Sheet condition (HR, HRPO, CR, coated) is stated - not implied.
- [ ] 6. Rolling/grain direction is shown where forming or appearance depends on it.
- [ ] 7. Bend radius, edge quality, burr direction and springback are validated.
- [ ] 8. Laser/punch/thermal-cut edge requirements are specified.
- [ ] 9. Machining hardness, allowance and stress-relief plan are defined.
- [ ] 10. Welding code, WPS, filler, preheat/interpass and hydrogen controls are set.
- [ ] 11. CEV/Pcm or grade-specific weldability limits are reviewed where relevant.
- [ ] 12. Impact, HAZ hardness, lamellar-tear and fatigue risks are addressed.
- [ ] 13. Weld size/length and sequence minimize distortion and unnecessary cost.
- [ ] 14. Final assembly datums and inspection stage are defined.
- [ ] 15. Corrosion category, exposure and maintenance plan are documented.
- [ ] 16. Surface preparation and coating system are contractually specified.
- [ ] 17. Edges, crevices, drainage, rack points and masking are designed for coating.
- [ ] 18. Galvanized hollow sections have approved vent and drain details.
- [ ] 19. Thread/hole allowances for zinc, paint or powder are included.
- [ ] 20. MTC, heat/lot traceability and marking method match project risk.
- [ ] 21. PMI/OES method and limitations are defined where mix-up risk exists.
- [ ] 22. NDT, dimensional, mechanical and coating acceptance criteria are explicit.
- [ ] 23. Packaging prevents water traps, coating damage and uncontrolled corrosion.
- [ ] 24. Deviations, repairs and material substitutions require written approval.

CORE REFERENCES - STATUS CHECKED 18 JULY 2026

- ISO 630-1:2021 and ISO 630-2:2021 - structural steels.
- ISO 3574:2012 - cold-reduced carbon steel sheet for commercial/drawing use.
- ISO 4995:2014 - hot-rolled structural-quality steel sheet.
- ISO 5952:2019 - weather-resistant structural-quality hot-rolled sheet.
- ASTM A36/A36M - carbon structural steel; verify active edition.
- ASTM A1008/A1008M-26 and A1011/A1011M-25 - cold/hot-rolled sheet.
- ASTM A500/A500M - structural tubing; ASTM A513/A513M-25 - mechanical tubing.
- AWS D1.1/D1.1M:2025-AMD1 - Structural Welding Code - Steel.
- ISO 5817:2023 and ISO 15614-1:2017/Amd 1:2019 - weld quality / WPS.
- ISO 8501-1:2007 - visual surface preparation grades (revision underway).
- ISO 12944-5:2019 - protective paint systems (revision underway).
- ISO 1461:2022 and ISO 14713-1:2017 / 14713-2:2019 - zinc protection.

Use licensed standards and the project contract as the controlling source. Official publishers: iso.org, astm.org and aws.org.