

WHITE PAPER 10 · CAMEROON STEEL

SAFER BUILDINGS NEED REBAR THAT MEETS ITS DECLARED GRADE

Reinforcing steel standards, testing and certification in Cameroon, and why certified production with traceable quality control, enforced at the point of sale and on site, is the fastest way to raise the floor.

DOCUMENT CONTROL

Reference	CS-WP-10
Edition	10 October 2026
Status	First edition
Classification	Public
Prepared by	Cameroon Steel
Series	Cameroon Steel public white papers, 10 of 10
Scope	Reinforcing bar (rebar) quality: structural role, metallurgy, international and Cameroonian standards, quality infrastructure, mill testing, site acceptance, durability in a humid coastal climate, wire rod, mesh and sections, recommendations
Evidence cut-off	10 October 2026
Sources	Annex C lists every source cited with an [S-id] marker; Annex D gives the data behind every chart
Standards cited	Requirements quoted from standards are summaries for orientation. The current edition of each standard governs; users should obtain it from the publisher.
Languages	English (full text), French (full text), Chinese (summary)

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What this paper is not. It is not a design code, a product specification, a certification document, an offer or a commitment. Structural design and acceptance decisions remain the responsibility of qualified engineers applying the standards in force. The paper refers to Cameroon Steel's planned plant at Mboro only as a public-record example of a producer that has set certified products as an objective.

Statement of interest. This paper is published by Cameroon Steel, which is developing a steelworks at Kribi. It is written to inform public debate; its analysis is independent of any commercial offer, and every figure is sourced or labelled with its status.

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EXECUTIVE SUMMARY: SAFER BUILDINGS START WITH BARS THAT MEET THEIR GRADE

Building safety in Cameroon depends on reinforcing steel that actually has the strength, cross-section, ductility and bond its label declares. The national rebar standard is mandatory and the State has shown it will enforce it, but the evidence from building sites and from neighbouring markets suggests that a material share of the bars sampled on sites fall short, and that unmarked bars are the worst. Certified domestic production with traceable quality control, combined with enforcement at the point of sale and simple acceptance checks on site, is the most effective and least costly way to raise the floor.

19 %

more paid per kilogram of steel when an 11 mm bar is sold at the price of a 12 mm bar (derived)

16 %

less steel in a 12 mm bar rolled one millimetre undersize (derived)

23 %

shortfall against the design force for an 11 mm grade 400 bar sold as 12 mm Fe500 (derived)

2022

year the NC 236 rebar standard became mandatory (order of 20 April) [S04]

89 %

mean annual relative humidity at Kribi, 1991 to 2020 (modelled) [S50]

Ten findings

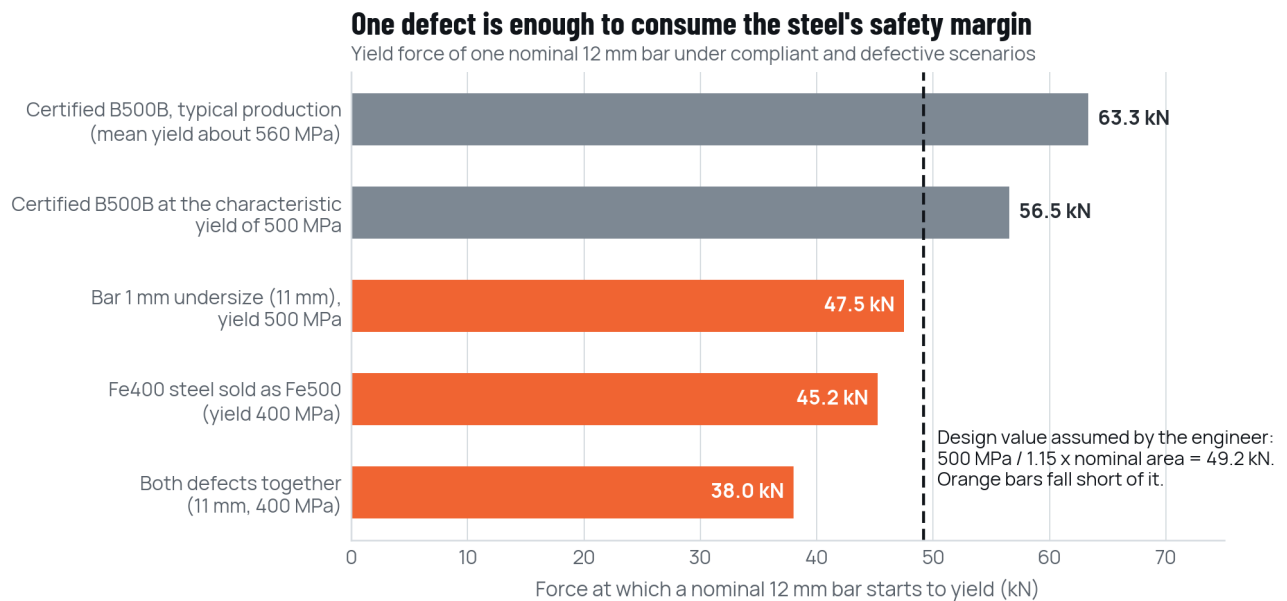
- 01 Rebar quality has become a public-safety question in Cameroon.** Building collapses in Douala in July 2023 (33 to about 40 deaths reported) and July 2026 (six deaths) had several reported causes, including the absence of a building permit and a building already declared unsafe [S20][S21][S22]. Practitioners have linked collapses to poor bars [S10], and when the Government refused in January 2026 to revise the rebar standard, the press reported that it cited deadly collapses linked to substandard materials [S06][S08]. This paper attributes no collapse to steel, but treats rebar as the one cause that can be verified cheaply before construction.
- 02 A grade is a bundle of four properties, and the market discusses only one.** "Fe500" promises a yield strength, but a design also assumes a cross-section (checked by mass per metre), ductility (strain at maximum force A_{gt} and strength ratio R_m/R_e) and bond (rib geometry). Ductility and section are the properties most often missing and least visible to the buyer.
- 03 One defect is enough to consume the steel's safety margin.** A nominal 12 mm grade 500 bar is designed to carry 49.2 kN at yield. Rolled one millimetre undersize it yields at 47.5 kN; made of grade 400 steel at 45.2 kN; with both defects at 38.0 kN, 23% below the design value (derived, Figure ES.1). These bars show no distress in everyday use; they remove the reserve that covers overloads, poor concrete and the extra floors owners often add.
- 04 Good rebar is made by an honest route that can be audited.** Grade 500 within the weldability limit (carbon equivalent of 0.50% or less) is reached by quenching and self-tempering the bar or by microalloying, in

a melt shop that refines each heat and analyses it by spectrometer [S31][S48]. Bars made strong by excess carbon, or re-rolled from scrap of unknown composition, are brittle, weld badly and vary from bundle to bundle.

-
- 05 The main standards agree on strength but differ on ductility, bond and proof.** European-family grades (B500B under BS 4449 or NF A 35-080-1, Eurocode 2 class B) guarantee Agt of at least 5% and Rm/Re of at least 1.08, cap overstrength and are normally proven by third-party certification [S30][S31][S38]. ASTM A615 Grade 60 guarantees a lower yield, elongation after fracture and no carbon-equivalent limit [S34][S35]. Specifiers should name "NC 236 Fe500 with class B ductility", the weldability limit and the proof required, never "Fe500" alone.
-
- 06 Cameroon's legal chain is complete and has been enforced.** Law 96/11 (1996), ANOR (2009), the PECAE import-conformity programme (2015, operational 2016), the rebar import ban (2016, reaffirmed 2023) and the mandatory NC 236 standard (2022) form a coherent system [S04][S12][S13][S14][S15]. ANOR withdrew a certificate and recalled bars of a grade absent from the standard in October 2024, and the Government refused to revise the standard in January 2026 [S04][S05][S06][S07].
-
- 07 Pricing per bar rewards light bars.** Homologated prices are set per bar, taken here as the standard commercial length of 12 m (assumed): about 600 to 650 FCFA per kg at nominal mass in October 2023 [S11]. A bar at the edge of the 4.5% tolerance costs the buyer 4.7% more per kilogram; a bar one size light, 19% more (derived). Pricing and payment per tonne would remove the incentive to roll light without changing price levels.
-
- 08 The regional evidence points to unmarked and uncontrolled bars.** In a 2023 study of 24 bars sampled on building sites in Bamenda, Douala, Maroua and Yaoundé, 11 had yield stresses below 400 MPa (the study reports 52%; its own counts give 46%; sampling years are not stated), and bars without a manufacturer's mark failed every test [S19]. Nigeria's standards body sealed 13 plants in 2020 after most samples failed diameter and mass per metre [S25]; an Ethiopian market study found yield scatter two to three times that of controlled production [S28][S29].
-
- 09 Five site checks catch most defective bars before they reach a column.** Checking paperwork, reading the rolled-in mark, weighing three bars per diameter, measuring ribs and bending a sample cold take less than an hour per delivery. Bars without a legible mill mark should not be used in structural members. Laboratory tests settle the remaining doubts, especially on strength.
-
- 10 On the coast, cover and concrete decide durability.** Kribi and Douala stay above 80% relative humidity in every month [S50]. Eurocode 2 recommends at least 35 mm of cover for durability against airborne salt and 45 mm in splash zones, plus a 10 mm execution allowance, with dense concrete [S36][S37]. Spacers, low water/cement ratios and curing protect bars more than any coating.
-

A defective bar looks exactly like a good one once it is cast

The central quantitative point of this paper is shown in Figure ES.1. The engineer designs on the assumption that a grade 500 bar of 12 mm yields at no less than 435 MPa over its nominal area, after the partial factor of 1.15 that Eurocode 2 applies to reinforcing steel [S36]. A certified bar from a well-controlled mill typically yields well above that, because good production carries a mean yield around two standard deviations above the characteristic value [S29]. A defective bar does not.



DERIVED **Figure ES.1.** One defect is enough to consume the steel's safety margin. A certified B500B bar yields 15% to 29% above the design value; a bar one millimetre undersize, a grade 400 bar sold as grade 500, or both, yield below it.

Source: Cameroon Steel calculation; partial factor from EN 1992-1-1 [S36]; mean yield of controlled production from the JCSS Probabilistic Model Code [S29]. Method in Annex A.

None of these defects would be visible to the owner of a building under normal use, because service stresses in reinforcement are kept well below yield [S36]. That is precisely why they matter: they consume the reserve that is meant for the unexpected, and ductility defects remove the warning that a well-designed building gives before it fails.

Domestic certified production is the lever, because domestic production is the market

Since imports of rebar were suspended in 2016, the bars in Cameroonian buildings have been made almost entirely in Cameroon [S13][S52]. Whatever view one takes of the ban, it settles where quality must be won: in Cameroonian melt shops and rolling mills, and in the distribution chain that connects them to building sites. Three features of domestic production make it the most effective place to raise the floor.

First, **quality can be built in only at the mill**. Chemistry, quench, rolling and testing decide the properties of a bar; no merchant or site can add them later. A melt shop with a ladle furnace and a spectrometer, a controlled quench and a laboratory that tests every heat is the only reliable source of bars that meet their grade.

Second, **traceability starts at the mill**. Heat numbers, rolled-in marks, bundle tags and type 3.1 inspection certificates link every bar to its chemistry and its tests, and make recalls possible. Certification by ANOR, and by independent schemes where producers seek them, turns a producer's own testing into a guarantee that buyers can check.

Third, **enforcement works best on identifiable producers**. With imports closed, surveillance means checking the products of a limited number of domestic mills and their distribution. Unmarked or untraceable bars are, by definition, outside the certified system and can simply be refused.

What the evidence does not show matters as much. It does not show that domestic bars are generally poor, nor that any producer mentioned in the press made unsafe bars. It shows that bars of unknown origin and quality circulate, that enforcement has worked when it was applied, and that the market lacks the information and the price signals that would let compliant producers win on quality.

What should change, and who should act

The paper's recommendations (Chapter 10) are designed to make good bars easy to recognise and bad bars risky to sell, without relaxing the standard or creating new institutions.

For ANOR and the Ministry of Commerce. Publish the essential requirements of NC 236 and a register of certified producers with their rolled-in marks; strengthen certification with surveillance audits, independent sampling and statistical evaluation; sample bars at merchants in the main cities and publish the results by brand and diameter; homologate prices per tonne and require the nominal mass of each bar to be displayed; and report annually on conformity and enforcement.

For the Ministry of Public Contracts and contracting authorities. Put a standard clause in every public works contract requiring certified NC 236 bars with class B ductility, type 3.1 inspection certificates tied to heat numbers and site acceptance checks, and pay only for accepted steel measured by mass. With 2,026.3 billion FCFA of public investment budgeted in 2026 [S80], public procurement can shift the whole market.

For the Ministry of Housing and Urban Development and municipalities. Link building permits for multi-storey and public buildings to certified steel, delivery acceptance records and inspection of reinforcement before concrete is poured; publish durability guidance for coastal construction.

For engineers and contractors. Specify the full grade, read the mill certificate in six checks before unloading, weigh and bend on delivery, refuse unmarked bars, never heat a bar to bend it, and enforce cover with spacers.

For producers. Roll every bar with a legible mill mark, aim at nominal mass, report ductility and carbon equivalent on every certificate, invite independent sampling and support training of masons and foremen.

PUBLIC-RECORD EXAMPLE

Cameroon Steel is developing a steel complex at Mboro, in the Kribi industrial-port zone, designed for 1 Mtpa at full development; the foundation stone was laid on 30 December 2024 [S01][S02][S03]. Its first phase is an electric arc furnace melt shop that makes billets, with output flexible between rolled products (wire rod and reinforcing bar) and merchant billets for existing re-rollers, which today import about 60% of their charge; billet imports were about 161 kt in 2023 [S52][S53]. Because installed rebar capacity is several times domestic demand [S53], the project would not close a rebar shortage: its tonnage is aimed at replacing imported billets and wire rod and at exports within CEMAC (White papers 04 and 09), and its relevance to this paper is quality. Cameroon Steel's objective, stated in this paper, is to place on the market only bars certified by ANOR to NC 236 and by an independent body to a recognised international reference, with heat-number traceability from melt to bundle. This is an objective of a project under development, not a claim about existing production.

How the paper is built

The paper follows the life of a bar. Chapter 1 explains why rebar quality decides how a concrete building behaves when it is overloaded, and sets recent collapses in the region in context without attributing causes. Chapter 2 explains the metallurgy of rebar: chemistry, the routes to grade 500, quenching and self-tempering, and the carbon equivalent. Chapter 3 compares the European, American, international and Cameroonian standards property by property, with tables of bar masses, tolerances and bond requirements. Chapter 4 maps Cameroon's quality infrastructure, from the 1996 standardisation law to price homologation. Chapter 5 describes how a mill proves quality through testing, statistics and traceability. Chapter 6 catalogues what goes wrong and how a site can detect it. Chapter 7 proposes specification clauses and acceptance practice for designers, contractors and public buyers. Chapter 8 addresses corrosion and durability in the humid coastal climate. Chapter 9 extends the argument to wire rod, mesh and sections. Chapter 10 sets out ten recommendations with an indicative calendar, and Chapter 11 lists the evidence gaps that remain.

The evidence base combines four kinds of source: the standards themselves and certificates that summarise them; official Cameroonian sources, notably ANOR's published programme documents and communiqués; peer-reviewed studies of rebar bought on markets or sampled on sites in Cameroon, Nigeria and Ethiopia; and press reports of regulatory decisions and building collapses, which are cited for the facts they report and attributed in the text. Where press reports are the only public record, as for the 2024 certificate withdrawal and the 2026 refusal to revise the standard, the paper relies on more than one outlet. The paper uses only public information about Cameroon Steel's project and describes its quality commitments as objectives.

Every number carries its source in Annex C, and every derived number is explained in Annex A. Standards are summarised for orientation only; their current editions govern. Where the public record is silent, notably on the full technical content of NC 236, on official findings into recent collapses and on the testing capacity of Cameroonian laboratories, the paper says so rather than filling the gap.

HOLD THE STANDARD, MAKE CERTIFICATION VISIBLE, PRICE BY THE TONNE AND CHECK EVERY DELIVERY.

The paper's argument in one line

Statement of interest. This paper is published by Cameroon Steel, which is developing a steelworks at Kribi. It is written to inform public debate; its analysis is independent of any commercial offer, and every figure is sourced or labelled with its status.

CHAPTER 1

REBAR QUALITY DECIDES WHETHER A CONCRETE BUILDING WARNS BEFORE IT FAILS

Reinforced concrete is a partnership: concrete resists compression, steel resists tension, holds cracks closed and supplies the ductility that turns an overload into visible distress rather than sudden collapse. Every structural calculation assumes that the bar on site has its declared yield strength, its declared cross-section, enough ductility and adequate bond. When one of these is missing, the safety margin is consumed silently, and the failure, if it comes, comes with little warning.

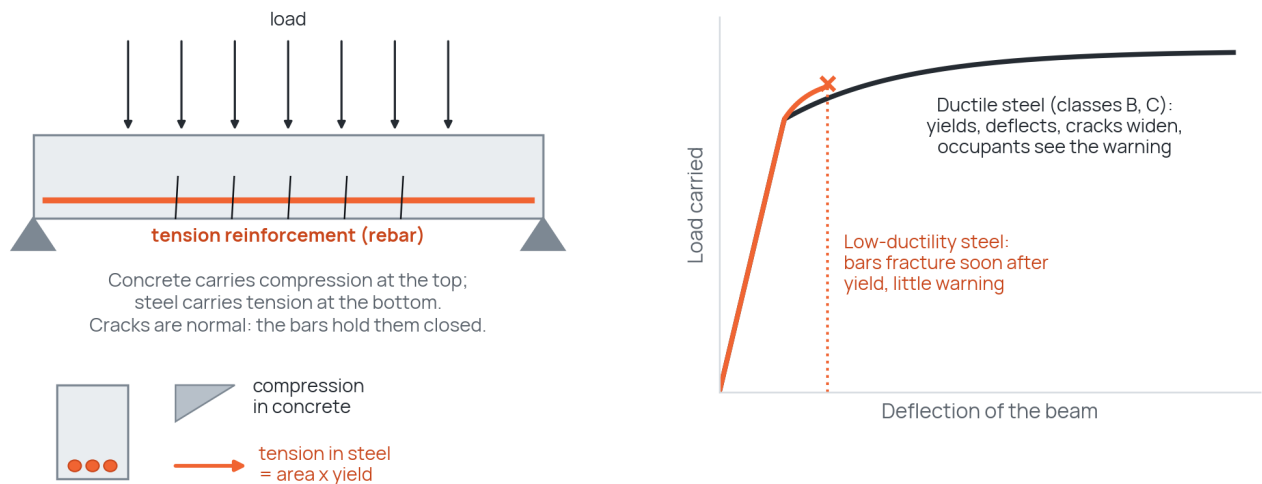
1.1 Steel carries the tension that concrete cannot

Concrete is strong in compression and weak in tension. A beam or slab under load bends: its top fibres shorten and its bottom fibres lengthen. The bottom of the section cracks almost as soon as the building is loaded, and from that moment the only thing holding the two faces of each crack together is the reinforcing bar crossing it. The bar is therefore not an accessory. In a beam it is the tension chord of the internal lever arm; in a column the longitudinal bars share the axial load and the links (stirrups) confine the concrete core and stop the bars from buckling; in a slab the bars spread load and control cracking; at every joint the bars must be anchored and lapped so that force passes from one member to the next.

Design codes translate this role into a single number the engineer can use. Under Eurocode 2 (EN 1992-1-1), the design strength of reinforcement is its characteristic yield strength divided by a partial factor of 1.15 for persistent and transient situations [S36]. For a grade 500 bar the engineer therefore works with $500 / 1.15 = 435$ MPa (derived). The partial factor exists to cover the normal statistical scatter of a controlled steel population and small geometric deviations. It was never intended to absorb a grade 400 bar sold as grade 500, or a bar that is one size lighter than its label.

Ductile steel turns an overload into a visible warning

How a reinforced concrete beam works, and how its response depends on the ductility of the bars (schematic)



ILLUSTRATIVE Figure 1.1. A reinforced concrete beam relies on its bars to carry tension and to give warning. With ductile reinforcement the beam yields, deflects and cracks visibly before it fails; with low-ductility bars the same beam can fail soon after first yield, with little warning.

Source: Cameroon Steel schematic based on the design principles of EN 1992-1-1 [S36]. Not test data.

The same logic applies to the concrete itself, which carries its own partial factor of 1.5 [S36]. But concrete quality is at least partly visible on site: a mason can see a weak, honeycombed or badly compacted pour. A rebar defect is invisible once the bar is tied into a cage and covered. That is why the quality of reinforcing steel has to be proven before it is built in, and why the burden of proof should sit with the producer, the merchant and the site, in that order.

1.2 Four properties make up the promise of a grade

When a merchant sells a bar marked "Fe500" or "B500B", the label is a promise about four properties. Each has a distinct structural role, and each can fail independently.

Strength. The yield strength (symbol R_e or f_y) is the stress at which the steel stops behaving elastically. It sets the force a bar can carry before it stretches permanently. Standards specify a characteristic yield strength, the value that at least 95% of production must exceed, and many also cap the maximum, because a bar that is much stronger than declared changes the way a structure fails [S31][S38].

Section. The force a bar carries is its yield strength multiplied by its cross-sectional area. Because bars are not perfectly round (they carry ribs), standards define the area through the mass per metre: a 12 mm bar must weigh 0.888 kg/m within a tolerance of 4.5% [S31][S32]. A bar that is lighter than allowed has less steel in it, whatever its label says.

Ductility. Ductility is the ability to stretch well beyond yield before breaking. It is measured by the total elongation at maximum force (A_{gt}) and by the ratio of tensile strength to yield strength (R_m/R_e), which shows how much the steel hardens as it stretches. These two numbers define the ductility classes A, B and C of Eurocode 2 [S30][S36].

Bond. A bar works only if it cannot slip through the concrete. Bond comes mainly from the transverse ribs rolled onto the surface, and is specified through rib geometry and a parameter called the relative rib area, f_R [S36].

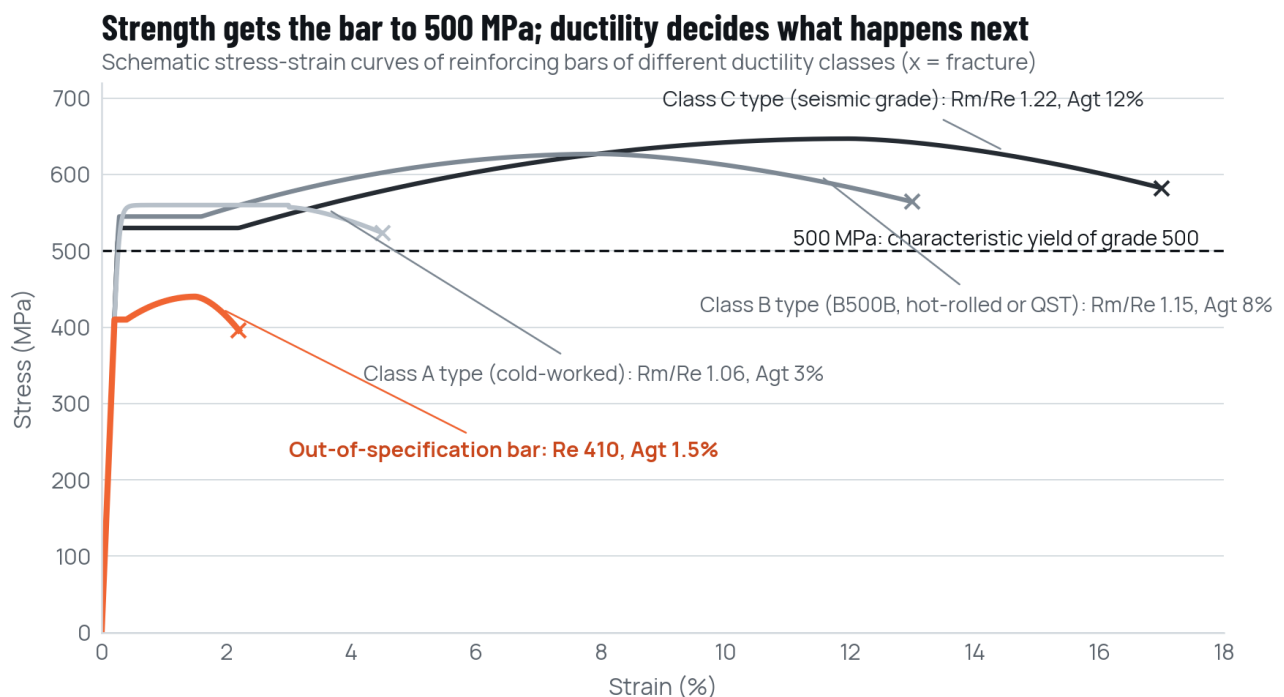
Behind these four sit three further properties that matter on real sites: **bendability** (a bar must bend to a hook or a link without cracking, and in some cases be straightened again), **weldability** (controlled by chemistry, summarised in the carbon equivalent) and, for bridges and industrial floors, **fatigue resistance** [S31][S38]. The

chapters that follow treat each in turn. The essential point here is that a grade is a bundle of properties, and that the market tends to talk about only one of them, strength, while ductility and section are the properties most often missing.

1.3 Ductility is what gives occupants time to leave

Most reinforced concrete buildings are designed so that, if they are ever overloaded, the steel yields before the concrete crushes. Yielding steel stretches; the beam sags; cracks open wide enough to see; plaster falls; doors jam. These are warnings. A building that gives them can be evacuated and propped. That behaviour depends entirely on the steel being able to stretch, which is what A_{gt} and R_m/Re measure.

Eurocode 2 makes this explicit in two ways. First, its Annex C defines three classes of reinforcing steel: class A with R_m/Re of at least 1.05 and A_{gt} of at least 2.5%, class B with at least 1.08 and 5.0%, and class C with R_m/Re between 1.15 and 1.35 and A_{gt} of at least 7.5% [S30][S36]. Second, the code ties the designer's freedom to the class of steel: the redistribution of bending moments in continuous beams and slabs is limited more tightly for class A than for classes B and C, and plastic methods of analysis assume class B or C [S36]. In other words, a design prepared for class B steel quietly assumes that the bars can rotate and redistribute load. If class A or worse is delivered, that assumption fails.



ILLUSTRATIVE Figure 1.2. Strength gets a bar to 500 MPa; ductility decides what happens next. Classes B and C keep hardening over several per cent of strain; an out-of-specification bar may reach a similar stress and then fracture at 2% strain.

Source: Cameroon Steel schematic. Class limits from EN 1992-1-1 Annex C [S30][S36]; curve shapes are indicative.

Ductility also underpins robustness: the capacity of a building to survive the loss of a column, a gas explosion, a vehicle impact or a local overload without progressive collapse. Robustness rules rely on continuous ties that can stretch and hang the damaged part of the structure from the undamaged part. A tie made of brittle bars, or of bars that crack at their bends, cannot do this. In seismic regions this is the decisive property, which is why seismic codes demand class C or equivalent steel; Cameroon is not a high-seismicity country, but the same argument applies to accidental actions, poor construction and the extra floors that owners frequently add.

A BAR THAT IS ONE SIZE LIGHT OR ONE GRADE WEAK LOOKS EXACTLY LIKE A GOOD ONE ONCE IT IS INSIDE THE CONCRETE.

The case for proving quality before the pour

1.4 Collapses in the region show what is at stake, not a single cause

Building collapses in Douala, Yaoundé, Lagos and other West and Central African cities are reported every year. Their causes are almost always multiple: no building permit, floors added without design, weak concrete, poor detailing, inadequate supervision, heavy rain on structures already damaged, and sometimes substandard reinforcement. Official investigations are rarely published in full, and the paper does not attribute any particular collapse to steel quality. The table below lists cases for which an official statement or an investigation finding has been reported by credible media, to show the setting in which rebar quality is discussed.

Table 1.1 Selected building collapses in Cameroon and Nigeria with officially reported facts (neutral summary)

Date	Place	Building	Reported toll	Official statement or finding	Source
2016	Douala	Building collapse	5 deaths	Local authorities had identified 500 buildings in danger of collapse in Douala in June 2016	[S20]
12 Sep 2014	Lagos, Nigeria	Six-storey church guesthouse	116 deaths	Coroner attributed the collapse to structural failures; the building had no planning permission	[S24]
1 Nov 2021	Ikoyi, Lagos	21-storey tower under construction	At least 44 deaths	Investigative tribunal: collapse rooted in an "erosion of professional ethics and due diligence"	[S23]
23 Jul 2023	North Douala	Four-storey residential block, fell on a neighbouring house	33 reported on 24 Jul; about 40 provisional	Minister of Housing and Urban Development: no building permit; residents reported cracks and exposed, rusted reinforcing rods; presidential order for an investigation	[S20] [S21]
10 to 11 Jul 2026	Bonamoussadi, Douala	Two-storey building	6 deaths, 4 injured	Building had been declared at risk of ruin, evacuated and sealed by the urban community, then reoccupied; heavy rain	[S22]

Source: as listed; tolls as reported at the time. No public technical finding on the cause of the July 2023 Douala collapse was found (see the evidence-gaps chapter).

Two features of the Cameroonian debate stand out. First, practitioners link collapses to steel quality explicitly: in April 2023, after the import ban was reaffirmed, an engineer quoted in the Cameroonian press attributed "several building collapses" to the "approximate quality" of some locally produced bars and to the use of informally collected scrap [S10]. Producers rejected the charge, and one stated that it held ISO 9001 certification and met international standards [S10]. Second, the Government itself invoked collapses when it refused, in January 2026, an industry request to revise the national rebar standard; the press reported that the refusal referred to deadly collapses linked to substandard construction materials and to the State's effort to clean up and structure the sector [S06][S08].

Neither statement proves that steel caused a particular failure. Together they show that the question of rebar quality is now a public-safety question in Cameroon, and that the policy answer chosen so far is to hold the standard, not to relax it.

FINDING

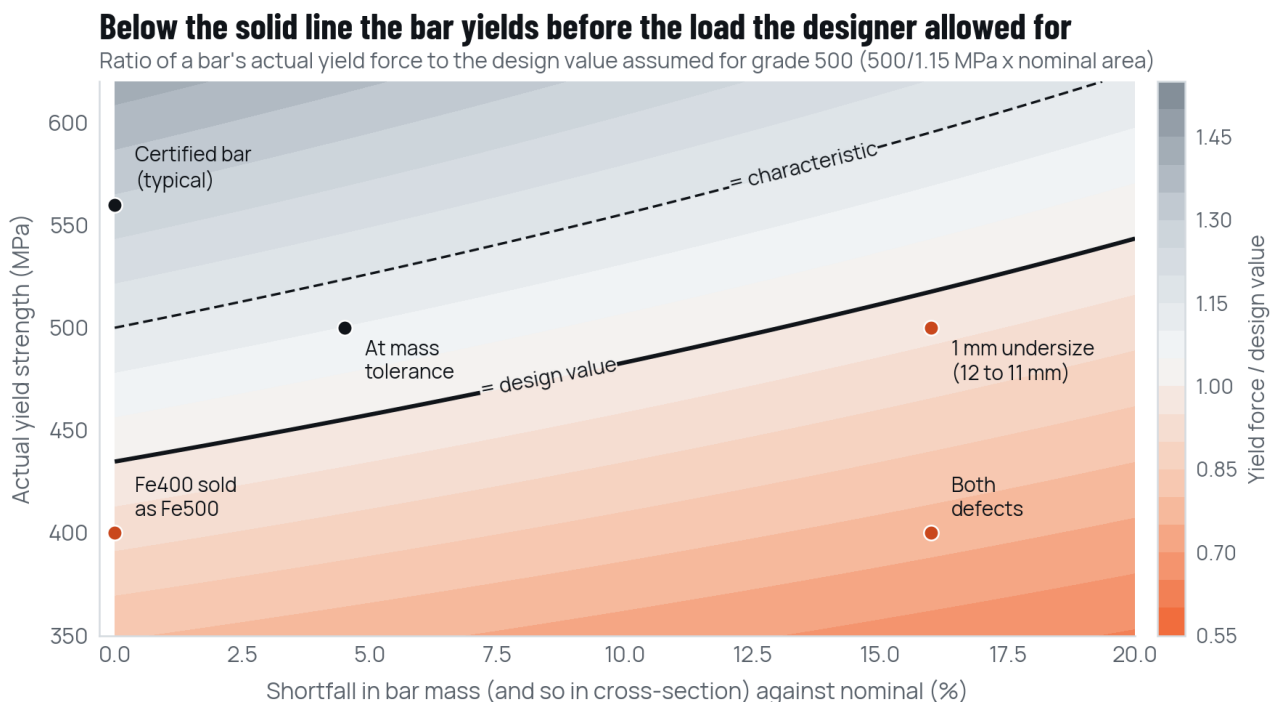
The evidence does not allow any collapse in the region to be blamed on reinforcing steel alone, and this paper does not do so. It does show that rebar quality is one of the few causes that can be verified cheaply, before construction, with a scale, a tape, a bend test and a certificate.

1.5 A light or weak bar consumes the safety margin silently

How much does a defective bar matter? The arithmetic is simple and is shown in full in Annex A. Take a 12 mm grade 500 bar. Its nominal area is 113.1 mm². At the characteristic yield of 500 MPa it starts to yield at 56.5 kN; the designer counts on 435 MPa, or 49.2 kN; and a typical bar from a controlled mill, with a mean yield around 560 MPa (the mean of a well-controlled population is about two standard deviations of 30 MPa above the nominal value [S29]), yields at about 63.3 kN (all derived).

Now take three common defects:

- **One size light.** A "12 mm" bar that is in fact 11 mm has 16% less area. Even at 500 MPa it yields at 47.5 kN, 3% below the design value.
- **One grade weak.** A grade 400 bar sold as grade 500 yields at 45.2 kN, 8% below the design value.
- **Both.** An 11 mm bar of grade 400 yields at 38.0 kN, 23% below what the engineer assumed.



DERIVED Figure 1.3. Below the solid line a bar yields before the load the designer allowed for. A bar may be at most 4.5% light and still sit comfortably above the line if its strength is right; a bar one millimetre undersize or one grade weak falls below it.

Source: Cameroon Steel calculation; partial factor from EN 1992-1-1 [S36]; mass tolerance from EN 10080 / NF A 35-080-1 [S31][S32]. Method in Annex A.

None of these bars will show distress in a building under its everyday loads. Eurocode 2 limits the steel stress under the characteristic load combination to 80% of the characteristic yield strength [S36], so even a sub-standard bar is usually far from yield in service. The danger is in the reserve. The margin that was meant to cover an unforeseen overload, a section of poorly compacted concrete, a missing link, a column cast slightly out of plumb, or the third floor that the owner adds five years later, has already been spent at the hardware merchant's counter. Errors that would each be harmless on their own then combine.

The ductility defect is worse, because it removes the warning as well as the margin. A brittle bar may meet its yield strength in a tensile test and still crack when the mason bends it into a link, leaving a fractured hook hidden in a column. It may fracture at small strain in a structure that is redistributing load after damage. Of the four properties, ductility is the one least visible to the buyer and least discussed in the market, and the one that most separates a structure that bends from one that breaks.

1.6 Quality failures compound, so the cheapest control comes first

The practical consequence is about sequence. In the chain of decisions that produces a building, the reinforcing bar is the component whose quality is cheapest to verify and most expensive to correct. A mill can test every cast for chemistry and every lot for tensile properties at a cost that is small against the value of the steel. A merchant can weigh a bar. A site can bend a sample and check a certificate. Once concrete has been poured, the only ways to know what is inside are destructive coring, scanning and load testing, at many times the cost.

This paper therefore argues for raising the floor of rebar quality in Cameroon through three layers of control that reinforce each other:

1. **At the mill**, certified production with traceable quality control, so that every bundle can be linked to a heat number, a chemical analysis and a set of mechanical tests (chapters on metallurgy and testing).
2. **At the point of sale**, enforcement of the mandatory national standard through market surveillance, visible marking and pricing by weight, so that a light or unmarked bar cannot compete with a compliant one on price (chapters on the quality infrastructure and on defects).
3. **On site**, simple acceptance checks by contractors and supervising engineers, backed by laboratory testing when in doubt and by public procurement rules that make certified steel a condition of payment (chapters on specification and acceptance, and on recommendations).

Each layer is imperfect alone. Together they make the substandard bar both risky to sell and likely to be caught. The following chapters set out the metallurgy that makes good rebar, the standards that define it, the Cameroonian institutions that police it, and the practical checks that any site can apply.



**THE BAR IS THE ONE COMPONENT OF A BUILDING
WHOSE QUALITY CAN BE PROVEN BEFORE IT
DISAPPEARS INTO THE CONCRETE.**

Illustrative view. Generated image of workers assembling reinforcement cages on a building site; not a photograph of any project, place or person.

CHAPTER 2

GOOD REBAR IS DESIGNED IN THE MELT SHOP AND FIXED IN THE ROLLING MILL

Reinforcing bar is a plain carbon-manganese steel whose properties are decided in two places: the chemistry set in the melt shop and the thermal path imposed in the rolling mill. Modern mills reach grade 500 either by quenching and self-tempering the bar as it leaves the last stand or by adding small amounts of vanadium or niobium; both routes keep carbon and the carbon equivalent low enough for bending and welding. The routes that reach strength by adding carbon, or that re-roll scrap of unknown composition, are the ones that produce brittle and erratic bars.

2.1 Rebar is a simple steel with strict limits on what it must not contain

A reinforcing bar is about 98% iron. The rest is a short list of deliberate additions and a longer list of elements that arrive uninvited, mostly from scrap. The European reference for weldable reinforcing steel, EN 10080, and the national standards built on it (BS 4449 in the United Kingdom, NF A 35-080-1 in France) set maximum contents on the cast analysis: carbon 0.22%, phosphorus 0.050%, sulphur 0.050%, nitrogen 0.012%, copper 0.80%, and a carbon equivalent of 0.50% [S31][S32][S38][S39]. A slightly higher carbon content, up to 0.25%, is tolerated in some national versions if the carbon equivalent is held at 0.48% or lower [S32].

These are not arbitrary numbers. Each limit protects one of the properties described in the previous chapter.

Table 2.1 What each element does in a reinforcing bar, and the limits of the European reference standards (cast analysis)

Element	Why it is there	Limit (EN 10080 family)	What goes wrong if it is out of control
Carbon (C)	Main strengthening element; forms pearlite and, on quenching, martensite	0.22% max (0.25% allowed in some versions if $Ceq \leq 0.48\%$)	Above the limit: brittle welds and heat-affected zones, cracking at bends, lower ductility
Manganese (Mn)	Strengthens ferrite, ties up sulphur, controls hardenability for quenching	No general cap; enters the carbon equivalent (some national versions cap at 1.60%)	Too little: soft bars and hot shortness from sulphur; too much: high Ceq , hard spots
Silicon (Si)	Deoxidiser added in the ladle	No general cap (0.60% in some versions)	Poor deoxidation: porosity and inclusions in the billet
Phosphorus (P)	Impurity from scrap and ore	0.050% max	Embrittlement, poor bend and rebend performance, especially in cold conditions
Sulphur (S)	Impurity from scrap and fuels	0.050% max	Sulphide inclusions, cracking during hot rolling, laps and seams
Nitrogen (N)	Picked up in the electric arc furnace	0.012% max (higher if bound by vanadium or aluminium)	Strain-ageing: steel loses ductility after bending, fails the rebend test

Element	Why it is there	Limit (EN 10080 family)	What goes wrong if it is out of control
Copper (Cu) and other residuals (Ni, Cr, Mo, Sn)	Arrive with scrap; cannot be removed in the furnace	Cu 0.80% max; Cr, Mo, V, Ni, Cu enter the carbon equivalent	Surface cracking during rolling (copper), higher Ceq, erratic hardenability in the quench
Vanadium (V), niobium (Nb)	Deliberate micro-additions, typically a few hundredths of a per cent	Not capped; enter the carbon equivalent	Correct use: fine grain and precipitation strength without extra carbon
Carbon equivalent (Ceq)	Summary index of hardenability and weldability	0.50% max	Above the limit: welds harden and crack; tack-welded cages become brittle

Source: limits from the AFCAB certificate summary of NF A 35-080-1 [S31] and the Ferriere Nord specification summarising EN 10080 and national versions [S32]; element roles are standard metallurgy. Product-analysis limits are slightly higher than cast limits [S38].

Two features of this list matter for Cameroon. First, residual elements such as copper, tin, nickel and chromium cannot be removed in an electric arc furnace once they are in the scrap; they can only be diluted with clean feed such as direct reduced iron (DRI) or pig iron, or avoided by sorting. A mill that relies on mixed, informally collected scrap carries a structural risk of rising residuals unless it measures every heat. Second, phosphorus and sulphur are removed only by a refining slag. An electric arc furnace with a ladle furnace can do this; a simple induction furnace that only melts, without a refining step, largely keeps whatever phosphorus and sulphur the scrap contains. That is one reason why the route by which a bar was made tells a buyer something about the risk it carries.

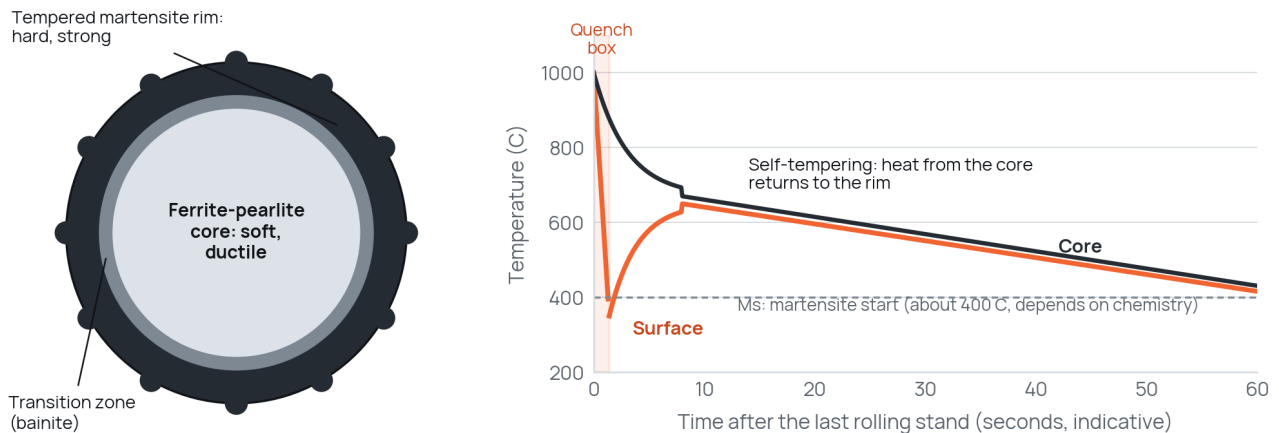
2.2 There are three honest routes to 500 MPa, and one dishonest one

A plain carbon steel with 0.20% carbon, rolled and left to cool in air, has a yield strength well below 500 MPa. To reach grade 500 without breaking the carbon limit, mills use one of three routes.

Quenching and self-tempering (QST). The most widespread modern route was developed at the Belgian research centre CRM and published in the early 1980s under the name Tempcore [S48]. As the hot bar leaves the last rolling stand, it passes through a short, intense water-cooling line. The outer layer cools fast enough to transform into martensite, a very hard phase, while the core stays hot. When the bar leaves the water, heat flowing out of the core reheats ("self-temper") the martensitic rim, restoring some toughness. On the cooling bed the core then transforms slowly into soft, ductile ferrite and pearlite. The finished bar is a composite: a strong tempered-martensite rim around a ductile core, made from a low-carbon, readily weldable chemistry.

Quenching gives strength from the rim, ductility from the core

Cross-section of a quenched and self-tempered (QST, Tempcore-type) bar and the temperature history behind it (schematic)



ILLUSTRATIVE Figure 2.1. Quenching gives strength from the rim and ductility from the core. The temperature history of the surface and the core after the last stand explains the three zones visible on an etched cross-section.

Source: Cameroon Steel schematic after the Tempcore principle [S48]. Temperatures and times are indicative only and vary with bar size, rolling speed and water flow.

QST is economical because it uses no alloying additions, but it is demanding. The depth of the martensitic rim, and therefore the yield strength, depends on the finishing temperature, the rolling speed, the bar diameter and the water flow and pressure in the quench box. If any of these drifts, properties drift with them, sometimes along the length of a single bar. A well-run QST mill measures these parameters continuously; a poorly run one produces bars whose strength varies from one bundle to the next. Research has also examined how the hard rim behaves when bars corrode or are cycled under load, which is one reason why some specifiers distinguish QST bars from microalloyed ones in demanding applications [S49].

Microalloying. Small additions of vanadium (often with nitrogen) or niobium refine the grain and form fine precipitates that strengthen the steel without extra carbon. Microalloyed bars have uniform properties through the section, tolerate welding and hot bending well, and are commonly used for large diameters, for coils and for class C (seismic) grades. Their cost is the alloy addition.

Cold working. Stretching or twisting a bar, or cold-rolling ribs onto wire rod, raises its yield strength at the expense of ductility. Cold-worked products typically fall into ductility class A and are mainly used in welded mesh and small diameters [S33].

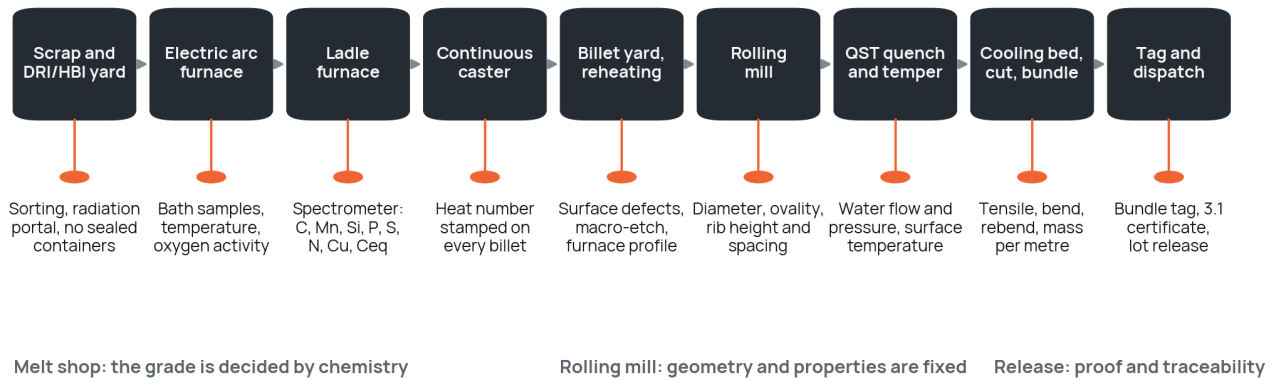
The fourth route is the one this paper is about. It consists of reaching an apparent grade by **raising carbon and manganese** well beyond the limits, or simply by **labelling** a bar with a grade it does not have. High-carbon bars can show a high yield strength in a test, but they bend poorly, weld badly and break at low strain. Re-rolled bars, made by reheating and rolling down old rails, plate offcuts or scrap bars without remelting them, inherit whatever chemistry and internal defects the feed contained. Neither can be made consistent, because nothing in the process measures or controls what goes in.

2.3 Nine control points turn a recipe into a guaranteed product

Making rebar in an electric arc furnace mini-mill is a sequence of nine steps, and each one has a quality control point. The melt shop decides the grade by chemistry; the rolling mill fixes the geometry and the mechanical properties; release testing and tagging make the result provable.

Quality is built in at nine control points, not inspected in at the end

Route of a reinforcing bar through an electric arc furnace mini-mill, with the main quality control points (orange)



ILLUSTRATIVE Figure 2.2. Quality is built in at nine control points, not inspected in at the end. Chemistry is measured in the ladle; the heat number follows every billet; diameter, rib geometry and quench conditions are measured in the mill; tensile, bend and mass tests release each lot.

Source: Cameroon Steel schematic of a scrap and DRI based electric arc furnace route; control points reflect common factory production control practice under certification schemes [S31][S38].

Three of these points deserve emphasis because they are the ones most often missing in small mills.

The spectrometer. An optical emission spectrometer analyses a sample from each heat in a few minutes and reports carbon, manganese, silicon, phosphorus, sulphur, nitrogen, copper and the other residuals. Without it, a melt shop does not know its carbon equivalent, cannot correct a heat before casting, and cannot write a truthful certificate.

The heat number. Every cast receives a unique number that follows its billets through reheating and rolling and appears on the bundle tag and the inspection certificate. This is the backbone of traceability: when a bar fails a test on site, the heat number leads back to the chemistry, the casting date and every other bundle made from the same steel.

The quench line. In a QST mill, water flow, pressure and the bar's surface temperature after quenching should be logged for every bar size and speed. These records explain variations in yield strength long before they produce a failed test.



ILLUSTRATIVE Illustrative view. Generated image of a hot bar on a rolling-mill roller table; not a photograph of any project, place or person.

2.4 Billets and rolling decide surface quality, dimensions and mass

A bar is only as sound as the billet it was rolled from. Continuous casting can leave porosity and segregation of carbon and sulphur along the axis of the billet, surface cracks and deep oscillation marks; rolled down, these become internal discontinuities, laps and seams that open when the bar is bent. Mills therefore inspect billets visually, cut and etch sample cross-sections to reveal internal soundness, and reject or condition defective billets before reheating. A re-roller that buys billets on the open market should demand the same evidence from its supplier, heat by heat.

Reheating sets the temperature at which rolling starts. Too cold, and mill loads rise while the finishing temperature, which drives the result of the quench, falls; too hot or too long, and the billet loses metal to thick scale and its grain coarsens. Scale that is not removed by descaling is rolled into the surface as pits and scabs.

The rolling mill then reduces the billet through a sequence of passes to the finished diameter. Two properties that a buyer can later measure are decided here: the **diameter and ovality** of the bar, which together set its mass per metre, and the **rib geometry**, which is cut into the finishing rolls. Both drift as rolls wear. A mill that redresses or changes its finishing rolls on schedule, and measures mass per metre and rib height at every roll change and every shift, holds its product near nominal; a mill that runs its rolls until they are visibly worn produces bars that become progressively lighter and less ribbed. Mass is also money: a mill that is paid per bar gains from every gram it does not roll, which is why the price regime discussed in the chapter on the quality infrastructure matters for quality.

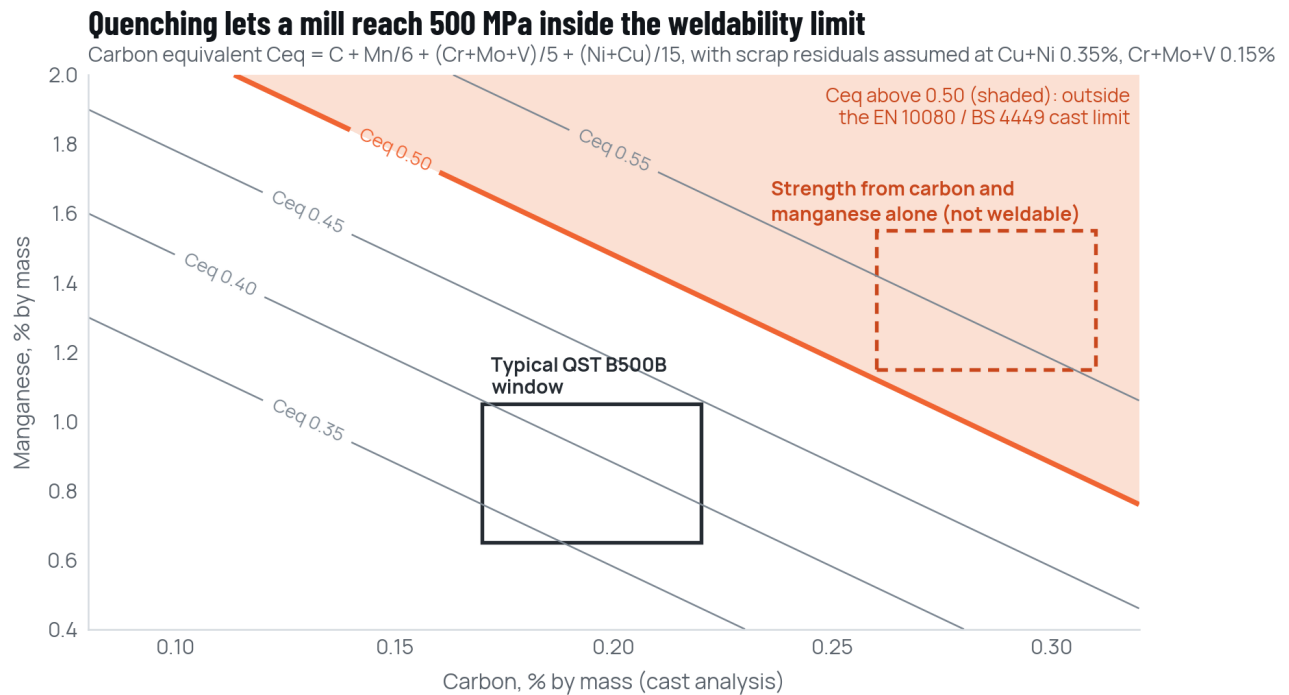
Finally, bars are cooled on the cooling bed, straightened, cut to length (usually 12 m in Cameroon) and bundled, and each bundle receives a tag carrying the heat number, grade, diameter and date. This is the point at which traceability is preserved or lost. Bundles that mix bars from different heats, or tags printed without reference to a heat, break the chain that links a bar to its test results.

2.5 The carbon equivalent is the single best predictor of weldability

On Cameroonian sites, reinforcement cages are often tack-welded for convenience, and bars are sometimes lap-welded or welded to embedded plates. Whether this is safe depends on the steel's hardenability, summarised by the carbon equivalent. The formula used by the European standards, derived from the International Institute of Welding expression, is:

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

with all contents in per cent by mass [S31]. A Ceq of 0.50% or lower on the cast analysis is the condition for a reinforcing steel to be declared weldable under EN 10080 and its national versions [S31][S32][S38]. The American standard for weldable bars, ASTM A706, uses a different formula and caps the carbon equivalent at 0.55% [S41], while the general-purpose American bar standard, ASTM A615, sets no carbon-equivalent limit at all, which is why A615 bars are not assumed to be weldable without specific procedures [S40][S41]. Welding of reinforcing steel is itself governed by its own standard, EN ISO 17660-1, which assumes a weldable steel to begin with [S71].



DERIVED **Figure 2.3.** Quenching lets a mill reach 500 MPa inside the weldability limit. The QST window (box, solid) sits well inside Ceq 0.50; a bar made strong by carbon and manganese alone (box, dashed) falls outside it.

Source: Cameroon Steel calculation of the Ceq formula [S31] with assumed scrap residuals ($Cu + Ni$ 0.35%, $Cr + Mo + V$ 0.15%); limit from [S31] [S32]. Windows are indicative.

The figure makes the trade-off visible. With typical scrap residuals, a QST bar at 0.17% to 0.22% carbon and 0.65% to 1.05% manganese sits between Ceq 0.35 and 0.47. A mill that tries to reach the same strength by air cooling alone needs much more carbon and manganese, and ends up above 0.55. Its bars may pass a tensile test and still produce brittle, cracked tack welds and heat-affected zones. For a buyer, the Ceq printed on an inspection certificate is therefore not a technicality: it says whether the bar was made by an honest route.

2.6 A small-mill industry is only as good as its scrap and its laboratory

Cameroon's steel industry is a cluster of re-rollers and small melt shops, mostly in Douala, that convert imported billets and local scrap into rebar, wire rod, light sections and wire; installed rebar capacity was reported at 627 kt per year against domestic demand of about 180 kt [S53]. This structure has two consequences for quality.

First, the quality of a bar made from purchased billets depends on the billet supplier's chemistry and on the re-roller's reheating, rolling and cooling control. A re-roller that does not test incoming billets, or that mixes billets of different heats in one rolling campaign, loses traceability at the first step.

Second, mills that melt local scrap depend on its sorting. Mixed scrap brings copper wire, tinned cans, galvanised sheet, alloy steels and non-metallic contamination. Without sorting at the yard, a radiation portal and a spectrometer on every heat, residuals drift and the carbon equivalent with them. Cameroonian engineers have publicly linked poor bars to the use of informally collected scrap [S10]; whatever the merits of that claim for any individual producer, the metallurgical risk it describes is real and measurable.

The remedy is not exotic. It is a ladle furnace to refine and adjust each heat, a spectrometer to prove it, clean metallics such as DRI or hot briquetted iron to dilute residuals, a controlled quench line or microalloying practice, and a laboratory able to test every lot. These are the elements that certification schemes audit, as the chapter on testing describes.

PUBLIC-RECORD EXAMPLE

Cameroon Steel's planned first phase at Mboro, in the Kribi industrial-port zone, centres on an electric arc furnace melt shop with a ladle furnace, within a complex designed for 1 Mtpa at full development [S01][S02][S03]. Its billets can be rolled on site into reinforcing bar and wire rod or sold to the re-rollers described above, which today import about 60% of their charge [S53]. With rebar capacity already well above demand, what such a plant can add to the market is traceable, refined steel rather than more rebar capacity. Cameroon Steel's objective, stated in this paper, is to place on the market only bars certified to the mandatory Cameroonian standard and to a recognised international reference, with heat-number traceability from melt to bundle. This is an objective, not a claim about existing production.

2.7 Five questions reveal how a bar was made

A buyer cannot audit a melt shop, but five questions, put to a merchant or producer and answered with documents, reveal most of what matters about the route by which a bar was made:

1. **How was the steel melted and refined?** An electric arc furnace followed by a ladle furnace can remove phosphorus and sulphur and adjust each heat; a furnace that only melts cannot. Re-rolled bars were not melted at all.
2. **Is every heat analysed, and is the carbon equivalent reported?** A certificate that gives a full cast analysis and a Ceq for each heat shows that a spectrometer is in use; a certificate without chemistry shows nothing.
3. **How is grade 500 reached?** Quenching and self-tempering or microalloying are honest routes; a carbon content above 0.22% combined with a high manganese content is not.
4. **Where do the billets come from?** A re-roller should name its billet suppliers and hold their certificates by heat; billets of unknown origin make every downstream test less meaningful.
5. **Can a bundle be traced to its heat?** A tag with a heat number that appears on a certificate, and a rolled-in mark on every bar, show that traceability is maintained to the end.

A producer who can answer all five with documents is running a controlled process. One who cannot answer the first three is asking the buyer to trust a label. The chapter on specification and acceptance turns these questions into contract clauses.

CHAPTER 3

THE MAIN STANDARDS AGREE ON STRENGTH BUT DIFFER ON DUCTILITY, BOND AND PROOF

Every major rebar standard builds its grades around a minimum yield strength of 400 to 500 MPa, so a buyer comparing labels sees little difference. The differences lie elsewhere. The European family (EN 10080 and its national versions BS 4449 and NF A 35-080-1, read with Eurocode 2) guarantees ductility through two measured quantities, caps the yield strength, defines bond by rib geometry and is normally proven by third-party certification with statistical evaluation. The general American bar standard, ASTM A615 Grade 60, guarantees minimum strength and elongation but not ductility in the European sense, nor weldability. A Cameroonian specifier should therefore name a full grade, a standard and a proof, never "Fe500" alone.

3.1 Five families of standards meet in the Cameroonian market

Steel used in Cameroonian buildings reaches site through several channels: domestic mills producing to the national standard, contractors bringing their home-country specifications, donors and development banks requiring European or American references, and designers trained in French, British or American practice. Five families of documents therefore coexist.

Eurocode 2 (EN 1992-1-1) is a design code, not a product standard. Its Annex C states what properties the designer may assume for reinforcement of classes A, B and C: a characteristic yield strength between 400 and 600 MPa, a minimum ratio $k = (f_t/f_y)_k$, a minimum characteristic strain at maximum force ϵ_{uk} , a fatigue stress range and a minimum relative rib area [S30][S36]. It is the bridge between the structural calculation and the product.

EN 10080:2005 sets general technical delivery conditions for weldable reinforcing steel but does not itself define grades; it was withdrawn as a harmonised European standard in 2008 because some countries' legal requirements for additional properties were not met, and grades continue to be defined nationally [S33][S39].

BS 4449:2005+A3:2016 defines grades B500A, B500B and B500C, which correspond to the three ductility classes of Eurocode 2, all with a characteristic yield strength of 500 MPa [S33][S38]. **NF A 35-080-1** plays the same role in France; its most common grade, B500B, is certified under the AFCAB scheme [S31][S42].

ISO 6935-2:2019 is the international standard for ribbed bars. It offers a menu of grades and ductility classes from which national bodies can choose, and many African standards are drafted from it [S43].

ASTM A615/A615M is the general American specification for deformed carbon-steel bars, with Grade 60 [420] the common choice; **ASTM A706/A706M** is its low-alloy counterpart for applications that require controlled tensile properties and weldability, notably seismic design [S34][S40][S41].

NC 236, the Cameroonian standard *Acier pour béton armé: fer à béton*, made mandatory by a ministerial order of 20 April 2022, recognises high-bond (ribbed) bars of grades Fe400 and Fe500 and smooth bars of grades Fe215 and Fe235 [S04][S05]. The press has referred to its 2021 edition (NC 236:2021) and, in 2026, to an edition coded

NC 236/2024/06 [S04][S06]. The designations echo the older French grades FeE 400 and FeE 500, which France has since replaced by the B500 family [S72]. The full text of NC 236 is not freely available online; this paper therefore describes its grades and legal status but does not reproduce its numerical requirements (see the evidence-gaps chapter).

Contractors from China often add a sixth reference, GB/T 1499.2, whose grades HRB400 and HRB500 have seismic "E" variants with a minimum strength ratio and a cap on overstrength [S73]. The point is not to choose one family for its own sake, but to recognise that the same nominal "500 MPa bar" can carry very different guarantees.

3.2 Strength: similar numbers, different meanings of "minimum"

Source: Cameroon Steel schematic; definitions after ISO 6892-1 and EN ISO 15630-1 [S44][S45].

The headline yield strengths converge: 500 MPa for the European B500 grades and Cameroon's Fe500, 420 MPa for ASTM Grade 60. What differs is the statistical meaning of the number.

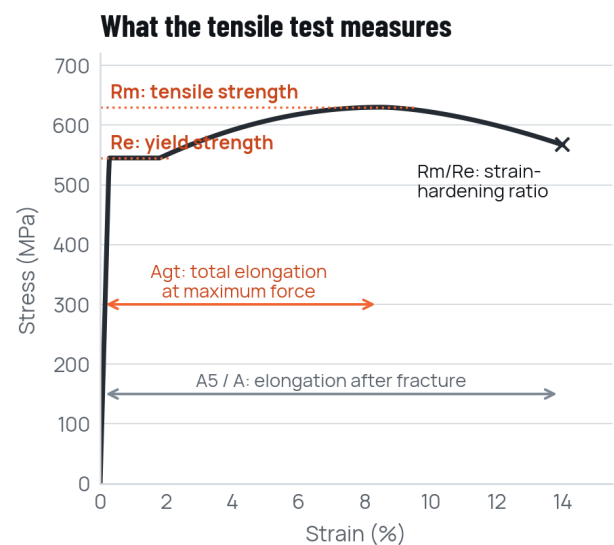
In the European family the 500 MPa is a **characteristic value**: the long-term production must show, with stated statistical confidence, that no more than 5% of bars fall below it, and each individual test must also exceed a minimum slightly below it. Under the French scheme for B500B, for example, the characteristic yield is 500 MPa and the individual minimum 475 MPa [S31]. In ASTM practice the 420 MPa of Grade 60 is a **minimum for each test**, without a stated fractile [S34] [S40].

The European family also **caps the yield strength**.

Under the AFCAB scheme the ratio of actual to nominal yield must stay below 1.30 as a characteristic value and below 1.32 for any test [S31]; several national versions cap the yield at 650 MPa [S32]. ASTM A706 caps Grade 60 at 540 MPa (78 ksi) [S34], while ASTM A615 sets no maximum [S34]. A cap may look odd in a quality standard, but a bar that is much stronger than declared shifts the failure from the ductile steel to the brittle concrete, and makes a structure designed for ductile hinging behave less predictably.

The tensile strength requirement is where ASTM A615 has moved most. Editions of the CRSI reference material show Grade 60 with a minimum tensile strength of 90,000 psi (620 MPa) [S34]; the current edition, as summarised by a major US producer in 2021, requires 80,000 psi (550 MPa) and sets no minimum ratio of tensile to yield strength for Grade 60 [S35]. ASTM A706 Grade 60, by contrast, requires a tensile strength of at least 80,000 psi and at least 1.25 times the actual yield strength [S34].

The figure on the right defines the quantities. Re is the yield strength; Rm the tensile strength; Agt the total elongation at maximum force, the strain the bar can sustain while still carrying increasing load; A (or A5) the elongation after fracture, which includes the local necking just before the bar breaks. Agt is the more meaningful measure of usable ductility because necking happens over a very short length of bar.



ILLUSTRATIVE Figure 3.1. The tensile test gives five numbers; standards differ in which they control.

3.3 Ductility: the largest difference between the families

The European family controls ductility directly, by setting a minimum Agt and a minimum Rm/Re for each class. ASTM A615 controls it indirectly, through the elongation after fracture measured over a 200 mm (8 in) gauge length: 9% for the smaller sizes, falling to 7% for the larger ones [S34][S35]. Elongation after fracture is a useful screen for brittle steel, but it is not the same property: a bar can show 9% elongation after fracture, most of it concentrated in the neck, and still have a small uniform elongation and a low strength ratio. This is why Eurocode-based designs should not treat A615 Grade 60 as equivalent to B500B without checking Agt and Rm/Re on the mill certificate.

Table 3.1 How the main reference documents define a grade 500 class (or Grade 60) reinforcing bar (summary)

Property	EN 1992-1-1 Annex C, class B (design)	B500B under BS 4449 / NF A 35-080-1	ASTM A615 Grade 60 [420]	ASTM A706 Grade 60 [420]	NC 236 Fe500 (Cameroon, mandatory)
Nature	Properties the designer may assume	Product standard, usually with third-party certification	Product standard	Product standard, low-alloy, weldable	Mandatory national product standard
Yield strength	f _{yk} 400 to 600 MPa	500 MPa characteristic; 475 MPa individual minimum (NF)	420 MPa minimum per test	420 MPa minimum, 540 MPa maximum	Grade 500 by designation
Maximum yield	Not set for class B	Re _{act} /Re _{nom} ≤ 1.30 characteristic, ≤ 1.32 any test (NF); 650 MPa in several versions	None	540 MPa	Not public
Strength ratio	k ≥ 1.08	Rm/Re ≥ 1.08 characteristic (≥ 1.06 any test, NF)	Tensile ≥ 550 MPa (620 MPa in earlier editions); no ratio	Tensile ≥ 550 MPa and ≥ 1.25 × actual yield	Not public
Ductility	ε _{uk} ≥ 5.0%	Agt ≥ 5.0% characteristic (≥ 4% any test, NF)	Elongation after fracture in 200 mm ≥ 9% to 7% by size	Elongation after fracture ≥ 14% to 10% by size	Not public
Bendability	Bend or rebend test required	Rebend test: no brittleness after ageing	Bend test, 180° round a pin of 3.5d to 9d by size	Bend test round a pin of 3d to 8d	Not public
Mass tolerance	±6.0% (d ≤ 8 mm), ±4.5% (d > 8 mm)	±6.0% / ±4.5%	Each bar ≥ 94% of nominal mass	Each bar ≥ 94% of nominal mass	Not public
Weldability	Weldable steel assumed	C _{eq} ≤ 0.50%, C ≤ 0.22%, P and S ≤ 0.050%, N ≤ 0.012%, Cu ≤ 0.80%	No carbon-equivalent limit	CE ≤ 0.55% with C, Mn, P, S, Si limits	Not public
Bond	f _R minimum by size (Table 3.3)	Rib geometry and f _R as certified	Deformation spacing, height and gap limits	As A615	Ribbed ("haute adhérence")
Proof of conformity	Assumed by the design	Factory production control, initial and audit testing, surveillance by a certification body	Mill test report	Mill test report	ANOR conformity certificate

Source: [S30][S36] for Eurocode 2; [S31][S32][S38] for the European product standards (NF values from the AFCAB certificate summary); [S34][S35][S40][S41] for ASTM; [S04][S05] for NC 236. Summary for orientation only; the current edition of each standard governs.

The table explains a common confusion in Cameroonian procurement. A bid can offer "Fe500 equivalent to B500B or A615 Grade 60" as if these were interchangeable. They are not: the European grade promises a strength ratio and a uniform elongation; A615 Grade 60 promises a higher elongation after fracture but no strength ratio, a lower yield and no weldability; A706 promises the strongest ductility controls and weldability but at grade 420 strength.

3.4 Section: mass per metre is the honest measure of a bar's size

Because ribs make a bar's outline irregular, standards define its size through its mass per metre rather than through a measured diameter. The nominal cross-sectional area is that of a circle of the nominal diameter d , and the nominal mass follows from the density of steel, $7,850 \text{ kg/m}^3$:

mass per metre (kg/m) = $\pi/4 \times d^2 \times 7,850 \times 10^{-6} \approx 0.00617 \times d^2$, with d in millimetres.

This simple formula is the most powerful quality tool available to a site: weighing a full bar and dividing by its length tells a buyer, within a few per cent, how much steel he has actually bought.

Table 3.2 Nominal mass per metre and mass tolerances of common bar sizes

Nominal diameter (mm)	Area (mm^2)	Mass (kg/m)	Mass of a 12 m bar (kg)	EN family tolerance	Lightest 12 m bar allowed (kg)	Bars per tonne (12 m)
6	28.3	0.222	2.66	$\pm 6.0\%$	2.50	375
8	50.3	0.395	4.74	$\pm 6.0\%$	4.46	211
10	78.5	0.617	7.40	$\pm 4.5\%$	7.07	135
12	113.1	0.888	10.66	$\pm 4.5\%$	10.18	93
14	153.9	1.208	14.50	$\pm 4.5\%$	13.84	68
16	201.1	1.578	18.94	$\pm 4.5\%$	18.08	52
20	314.2	2.466	29.59	$\pm 4.5\%$	28.26	33
25	490.9	3.853	46.24	$\pm 4.5\%$	44.16	21
32	804.2	6.313	75.76	$\pm 4.5\%$	72.35	13
40	1,256.6	9.865	118.38	$\pm 4.5\%$	113.05	8

Source: area, mass, 12 m mass and bars per tonne derived from the nominal diameter and a density of $7,850 \text{ kg/m}^3$ (Annex A); tolerances from the European reference standards [S31][S32][S38]. Under ASTM A615 and A706 no individual bar may weigh less than 94% of its nominal mass [S34]. Bars per tonne rounded down.

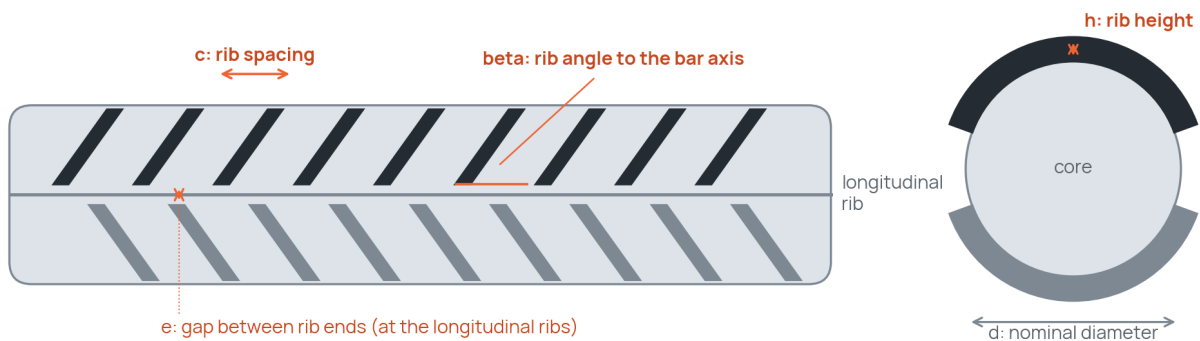
The tolerance is a band around the nominal mass, not a licence to produce at its lower edge. A mill that aims its rolling at the bottom of the band to save steel will, through normal scatter, produce bars outside it. Certified mills aim close to nominal mass and record the deviation of each lot on the inspection certificate.

3.5 Bond: ribs are specified by geometry and verified by measurement

The ribs on a bar are what make it a high-bond bar. Their height, spacing, inclination and the gaps between their ends determine how much force the bar can transfer to the surrounding concrete over a given length, and therefore the anchorage and lap lengths a designer may use. Eurocode 2 summarises rib geometry in a single parameter, the relative rib area f_R , the projected area of the ribs per unit length divided by the bar's circumference [S36].

Bond is a geometry: rib height, spacing and angle are specified and measured

Two-row transverse rib pattern of a ribbed bar with the parameters used to compute the relative rib area f_R (schematic)



Ribs transfer force from steel to concrete by bearing. Too low, too sparse or worn by a tired roll pass, and the bar slips.

ILLUSTRATIVE **Figure 3.2.** Bond is a geometry. Rib height (h), spacing c , angle (β) and the gaps between rib ends (e) are specified and measured, and combine into the relative rib area f_R .

Source: Cameroon Steel schematic. Parameter definitions after EN 1992-1-1 and the AFCAB certification summary [S31][S36].

Table 3.3 How bond and identification are specified (summary)

Requirement	European family (Eurocode 2, EN 10080, BS 4449, NF A 35-080-1)	ASTM A615 / A706
Bond parameter	Minimum relative rib area f_R : 0.035 for 5 to 6 mm, 0.040 for 6.5 to 12 mm, 0.056 above 12 mm (Eurocode 2 recommended values)	Deformation geometry rather than f_R
Rib geometry	Rib height, spacing and inclination within ranges; for a two-row crescent pattern, f_R is computed as $0.56 \times h / c$ in the French certification scheme	Average spacing not more than $0.7 d$; sum of gaps not more than 12.5% of the nominal perimeter; deformations inclined at least 45° to the axis; minimum height by size
Identification	Rolled-in pattern identifying the producing country and mill; label with heat, grade, standard and certification mark	Rolled-in symbols for mill, size, type (A615 or A706) and grade
Bundle label	Heat number, mass, diameter, length, standard, certification logos	Heat number on mill test report

Source: [S31][S32][S36] (European family); [S34][S40][S41] (ASTM). Recommended values may be modified by national annexes.

A practical consequence of the f_R formula is worth spelling out. For a 16 mm bar with a crescent rib pattern, an f_R of 0.056 requires the ratio of rib height to spacing to be at least 0.10 (derived: $0.056 / 0.56$). With a rib spacing of 10 mm, the ribs must stand at least 1.0 mm proud of the core. A worn finishing roll that produces ribs of 0.7 mm on the same spacing gives an f_R of about 0.039, below the minimum, and the bar no longer anchors as the designer assumed (derived). Rib height is measurable on site with a depth gauge, and rib spacing with a ruler laid along ten ribs.

3.6 Bendability: the rebend test catches what the tensile test misses

Bars are bent cold on site into hooks, links and cranks, and some are straightened again after being cast into a starter joint. A bar that cracks on the outside of a bend has a hidden defect at the place where the force must be anchored. Standards therefore require a **bend test** (bending a sample through 180° round a mandrel of specified diameter and checking for cracks) or a **rebend test** (bending, artificially ageing, then bending back, which reveals embrittlement from nitrogen or excess carbon) [S31][S38][S40]. The ASTM A615 bend test uses a pin of

3.5 bar diameters for small sizes rising to 9 diameters for the largest; A706, being more ductile, uses a tighter pin of 3 to 8 diameters [S40][S41]. The French certification scheme requires the absence of brittleness in a bend and rebend test and certifies separately the ability of a bar to be straightened after bending [S31].

The bend test is also the simplest mechanical test a site can perform without a laboratory, as the chapter on defects explains.

3.7 Proof is the part of a standard that buyers forget

A standard says what a bar must be. It does not by itself prove that a given bundle is what it says. The European family relies on **third-party product certification**: a certification body assesses the mill's factory production control, conducts initial type testing, audits the mill periodically, takes its own samples for independent testing, and evaluates the long-term statistics of the mill's results before granting the right to use its mark. The AFCAB certificate summarised in this paper, for example, is valid for a stated period, subject to periodic surveillance, and its validity can be checked online by any buyer [S31]. In the United Kingdom the CARES scheme plays the same role for BS 4449 [S33].

ASTM product standards do not themselves require third-party certification; conformity is shown by the producer's mill test report and, where the purchaser wishes, by acceptance testing.

In Cameroon, the conformity of domestic rebar with NC 236 is attested by a conformity certificate issued by ANOR, the national standards and quality agency. The case of October 2024, in which ANOR withdrew a certificate it had issued on 15 January 2024 and ordered the recall of bars marketed as Fe450, a grade absent from NC 236, shows both that the system works and that a certificate is only as good as the surveillance that follows it [S04][S05].

"FE500" ON A LABEL IS A STRENGTH CLAIM. A SPECIFICATION MUST ALSO NAME THE DUCTILITY CLASS, THE WELDABILITY LIMIT AND THE PROOF.

Practical rule for Cameroonian specifiers

3.8 What this means for a Cameroonian specifier

Three practical conclusions follow from the comparison.

First, **name the full requirement**. A specification that reads "NC 236 Fe500" fixes the legal grade. It should add the properties a Eurocode-based design assumes: ductility class B ($A_{gt} \geq 5.0\%$ and $R_m/Re \geq 1.08$ as characteristic values), a maximum yield ratio, a carbon equivalent of 0.50% or lower when bars will be welded, and mass tolerances to the European family. Wording for such clauses is proposed in the chapter on specification and acceptance.

Second, **do not accept equivalence claims without numbers**. "Equivalent to B500B" should be demonstrated on the mill certificate for each heat: A_{gt} , R_m/Re , C_{eq} and mass per metre, not only yield strength.

Third, **ask for the proof, not only the product**. A valid third-party certificate with surveillance, or an ANOR conformity certificate that is checked to be current, is worth more than any individual test report, because it covers the production that was not tested.



**THE RIBS ARE A SPECIFICATION: HEIGHT, SPACING
AND ANGLE DECIDE HOW WELL A BAR HOLDS IN
CONCRETE.**

Illustrative view. Generated image of transverse ribs on reinforcing bars; not a photograph of any project, place or person.

CHAPTER 4

CAMEROON HAS THE LEGAL TOOLS FOR REBAR QUALITY; SURVEILLANCE AND TESTING ARE THE GAPS

Cameroon already has a law on standardisation, a standards agency that writes standards, certifies products and checks imports, a mandatory rebar standard, an import ban that channels demand to domestic mills and a price-homologation regime. Since 2021 these rules have tightened quickly, and between 2024 and 2026 the State showed that it would enforce the rebar standard and refuse to dilute it. What remains weak is the layer between the mill gate and the building: routine sampling at merchants, published results, accredited testing capacity in every main city, and acceptance checks on site.

4.1 A complete legal chain runs from the 1996 law to a mandatory rebar standard

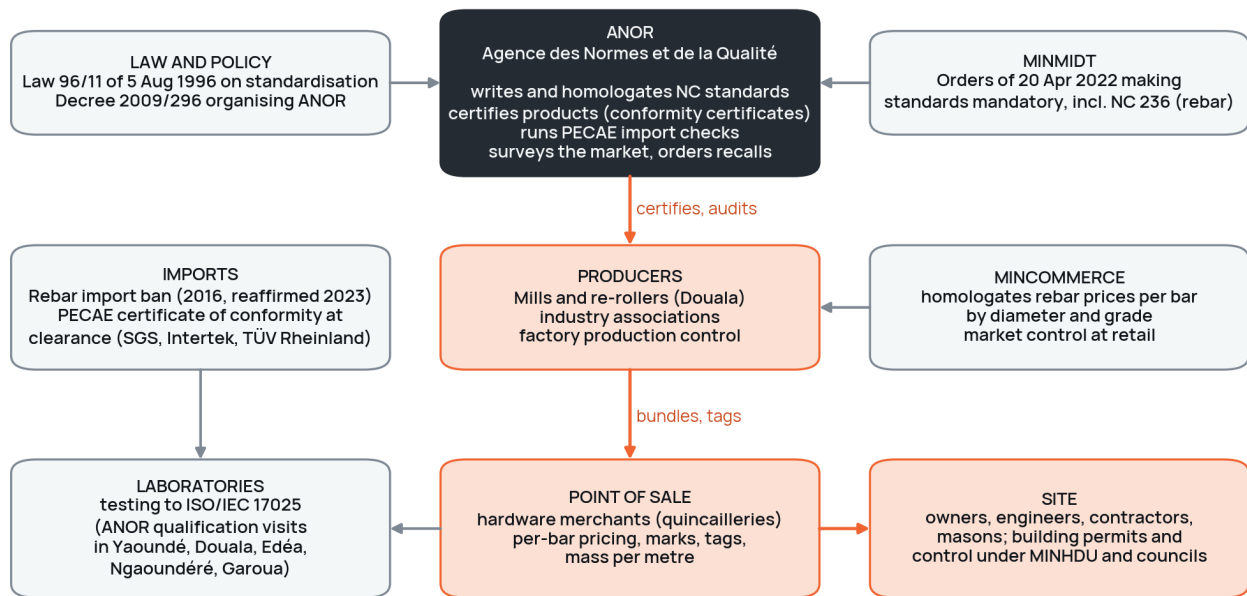
The foundation is Law No. 96/11 of 5 August 1996 on standardisation. Decree No. 2009/296 of 17 September 2009 organises the Agence des Normes et de la Qualité (ANOR), and a Prime Minister's circular of 12 November 2010 frames the national standardisation programmes [S14]. By October 2024 Cameroon had enacted about 3,000 national standards (normes camerounaises, NC) [S14]. As in most countries, a standard is voluntary unless a regulatory text makes it mandatory [S14].

ANOR describes its mission in three parts: standardisation (drafting, homologating and revising Cameroonian standards with technical committees), certification (of products and systems, including the conformity assessment of imports before shipment), and quality control and market surveillance, including the withdrawal of products that do not conform to the standards in force [S16]. Its standards are drafted in technical committees following ISO/IEC procedures and are put to public enquiry before homologation; two enquiries on draft standards were open on 10 October 2026 [S74][S75]. ANOR also relays the work of the African Organisation for Standardisation (ARSO) [S74].

For reinforcing steel, the decisive step was taken on 20 April 2022, when an order of the Ministry of Mines, Industry and Technological Development (MINMIDT) made the national rebar standard NC 236 mandatory, among other standards made mandatory that day [S04][S09]. The standard recognises ribbed bars of grades Fe400 and Fe500 and smooth bars of grades Fe215 and Fe235; other grades cannot lawfully be placed on the market as conforming rebar [S05].

Cameroon has every institutional layer; the weak links are at the point of sale and on site

Who does what in the quality infrastructure for reinforcing steel in Cameroon (simplified)



Orange: the product chain where the declared grade must survive. Grey: the institutions that set and police the rules.

SOURCED Figure 4.1. Cameroon has every institutional layer; the weak links are at the point of sale and on site. Law and ministerial orders give ANOR the standard to certify against; producers, merchants and sites form the chain along which the declared grade must survive.

Source: Cameroon Steel, from [S04][S05][S09][S11][S12][S14][S15][S16][S18][S20]. Simplified; not an organisational chart of any institution.

4.2 The State has enforced the standard and refused to dilute it

Three episodes between 2023 and 2026 show how the system behaves under pressure.

Counterfeit and substandard bars, 2023. In June 2023 an industry body of steel processors and a consumer foundation publicly denounced rebar sold as grade 500 that reportedly did not even meet the requirements of grade 400; ANOR was among the authorities they contacted [S09]. Two months earlier, after the import ban was reaffirmed, engineers and property developers had complained in the press about the quality of some locally produced bars, which producers disputed [S10].

A certificate withdrawn, 2024. On 15 January 2024 ANOR had issued a conformity certificate to a Douala producer covering bars of grades Fe400, Fe450 and Fe500. After the steel processors' organisation reported on 9 October 2024 that a product was being sold under a certificate that did not exist for it, and after the Minister of Commerce wrote on 15 October, ANOR's Director General withdrew the certificate on 16 October 2024 and ordered the recall of all Fe450 bars on the market, because NC 236 does not provide for that grade [S04][S05]. The Minister of Commerce had expressed concern that unapproved bars could endanger building safety [S05].

A revision refused, 2026. On 28 November 2025 a second industry association asked for the standard to be revised. On 19 January 2026 the Prime Minister's office replied that a revision appeared inappropriate in the current context of a fast-growing sector; the press linked the decision to deadly collapses and to the State's effort to clean up and structure the industry [S06][S07][S08].

Since 2021 the rules for rebar have tightened quickly

Milestones in standardisation, conformity assessment and market control for reinforcing steel in Cameroon

		Source
5 Aug 1996	Law 96/11 on standardisation sets the legal basis for Cameroonian standards (NC)	S14
17 Sep 2009	Decree 2009/296 organises ANOR, the standards and quality agency	S14
1 Jul 2015	Decree 2015/1875/PM creates PECAE, conformity assessment of imports before shipment	S15
31 May 2016	Prime Minister's office suspends rebar imports until further notice	S13
31 Aug 2016	PECAE becomes operational (SGS, Intertek, TÜV Rheinland)	S15
31 May 2021	Decree 2021/3306/PM amends and clarifies the PECAE programme	S15
2021	NC 236:2021, the national standard for rebar (acier pour béton armé), is issued	S04, S05
20 Apr 2022	Ministerial order makes NC 236 mandatory: Fe400 and Fe500 ribbed, Fe215 and Fe235 smooth	S04, S05, S09
Apr to Jun 2023	Import ban reaffirmed; engineers and consumers report substandard and counterfeit bars	S09, S10, S12
21 Oct 2023	Homologated producer prices per bar reduced by diameter and grade	S11
16 Oct 2024	ANOR withdraws a conformity certificate and recalls Fe450 bars absent from NC 236	S04, S05
19 Jan 2026	Government refuses an industry request to revise the rebar standard (NC 236/2024/06)	S06, S07
6 Oct 2026	ANOR simplifies the start of PECAE checks (IM number accepted)	S17

SOURCED Figure 4.2. Since 2021 the rules for rebar have tightened quickly. Mandatory status (2022), enforcement (2024) and the refusal to revise the standard (2026) followed each other within four years.

Source: as listed in the figure; Annex C.

The lesson of the Fe450 episode is not about one producer. It is that **a grade catalogue only protects buyers if labels mean one thing**. An intermediate grade that the standard does not recognise cannot be designed with, because no design code gives its properties, and it confuses buyers who read "450" as "almost 500". By holding the catalogue to Fe400 and Fe500, and by recalling bars outside it, the authorities protected the meaning of the label. The next step is to make sure that every bar carrying the label actually meets it.

4.3 The import ban and PECAE decide where the quality risk sits

Since 31 May 2016, when the Prime Minister's office suspended rebar imports "until further notice", almost all rebar used in Cameroon has been produced domestically [S13]. In December 2020 the authorities sealed more than 7,300 t imported by a construction contractor, and on 3 April 2023 the Director General of Customs confirmed that rebar imports remained prohibited [S12][S13]. Recorded imports of bars (HS 7214) fell to US\$3.3 million in 2023 [S52]. Cameroon is, in fact, a modest exporter: about 31,000 t of bars a year, mainly to Chad [S52] [S76].

The consequence for quality is direct. With imports closed, the quality of rebar in Cameroonian buildings is almost entirely the quality of domestic production and of its distribution. The ban protects mills from dumping; it also removes the competitive pressure that imported certified bars would exert. That makes domestic certification and market surveillance more important, not less.

For steel products that are still imported, such as wire, mesh and sections, the relevant control is the **Programme d'Évaluation de la Conformité Avant Embarquement (PECAE)**, which applies to goods imported into Cameroon; how far it covers industrial inputs such as billets for re-rolling is not clear from public documents. Created by Decree No. 2015/1875/PM of 1 July 2015, operational since 31 August 2016 and amended by Decree

No. 2021/3306/PM of 31 May 2021, it requires a certificate of conformity issued before shipment by one of three inspection bodies mandated by ANOR (SGS, Intertek or TÜV Rheinland) [S15]. Shipments follow one of three routes, from full physical inspection and laboratory testing of every consignment (route A) to documentary verification for registered products (route C), with inspection fees of 0.45%, 0.40% or 0.27% of the FOB value, between 196,787 and 4,591,699 FCFA per shipment [S15]. On 6 October 2026 ANOR simplified the start of the procedure by accepting the single-window import reference [S17].

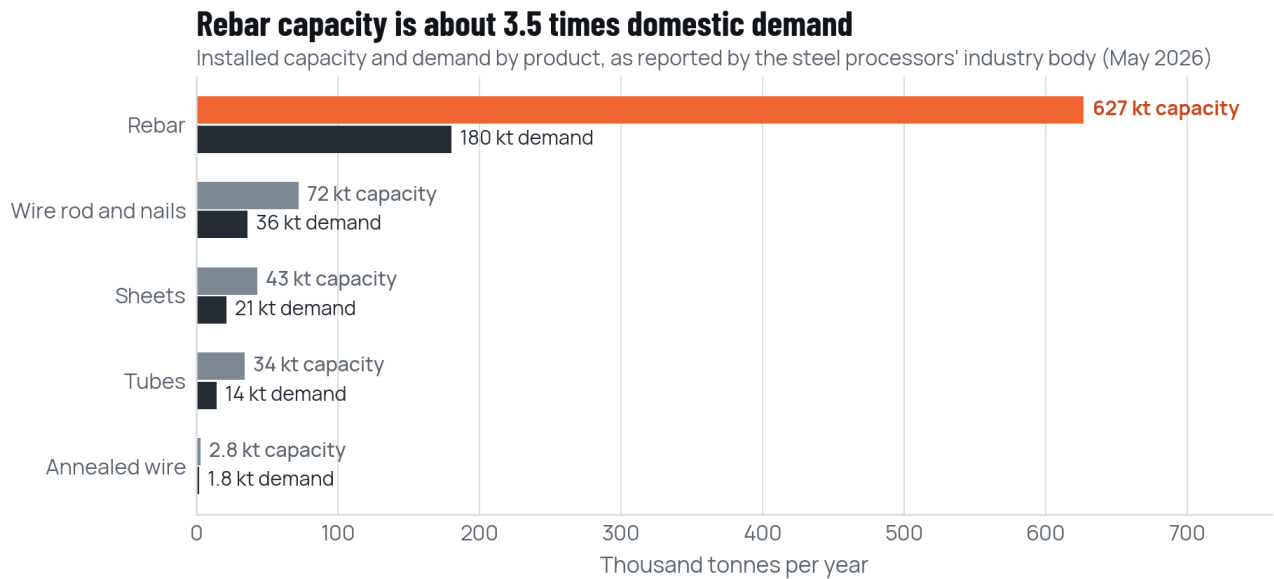
Table 4.1 The instruments that govern reinforcing steel quality and supply in Cameroon

Instrument	Reference and date	What it does for reinforcing steel	Source
Law on standardisation	Law No. 96/11 of 5 Aug 1996	Legal basis for Cameroonian standards and their mandatory application	[S14]
ANOR organisation	Decree No. 2009/296 of 17 Sep 2009	Creates the agency that drafts standards, certifies products, surveys the market	[S14][S16]
Rebar standard	NC 236:2021, later edition NC 236/2024/06	Defines Fe400 and Fe500 ribbed, Fe215 and Fe235 smooth bars	[S04][S05][S06]
Mandatory status	MINMIDT order of 20 Apr 2022	Makes NC 236 compulsory for products placed on the market	[S04][S09]
Product certification	ANOR conformity certificates	Attests that a producer's bars conform; can be withdrawn with a recall	[S04][S05]
Import ban	PM's office, 31 May 2016; Customs note, 3 Apr 2023	Suspends rebar imports until further notice	[S12][S13]
PECAE	Decree 2015/1875/PM; Decree 2021/3306/PM	Certificate of conformity before shipment for imported goods	[S15][S17]
Price homologation	MINCOMMERCE, list made public on 21 Oct 2023	Sets producer prices per bar by diameter and grade	[S11]
Environmental tax	Finance Law 2026, from 1 Jan 2026	5,000 FCFA per tonne of reinforcing bar (fer à béton), paid by local producers and importers	[S66][S89]
Public procurement code	Decree No. 2018/366 of 20 Jun 2018	Governs public works contracts, the natural vehicle for certified-steel clauses	[S54]

Source: as listed.

4.4 Overcapacity sharpens price competition and raises the stakes of enforcement

The domestic industry is large relative to its market. In May 2026 the steel processors' industry body reported installed rebar capacity of about 627 kt a year against domestic demand of about 180 kt, and capacity of roughly twice demand for wire rod and nails, sheets and tubes [S53].



SOURCED Figure 4.3. Rebar capacity is about 3.5 times domestic demand. Under capped prices and with imports closed, competition for a limited market is fought on cost, which is where quality is most easily lost.

Source: industry figures reported by Cameroon Tribune, 11 May 2026 [S53]; the rebar capacity, printed as "627 tonnes", is read as 627 thousand tonnes in line with the other figures in the article.

Overcapacity is not in itself a quality problem; it can drive efficiency. But in a market where prices are capped by homologation [S11], imports of the product are banned [S12][S13] and few buyers test what they buy, competition for a limited demand is fought on cost. The cheapest ways to cut the cost of rebar are precisely the ones that reduce its quality: rolling at or below the lower edge of the mass tolerance, buying cheaper and dirtier scrap, bypassing the ladle furnace or the laboratory, and running worn rolls. A producer who invests in quality control then competes, at the same homologated price per bar, against one who does not.

This is why enforcement matters more, not less, in a market with spare capacity. The industry's own organisations have recognised it: it was the steel processors' body that reported the uncertified Fe450 product to the authorities in October 2024 [S04]. Producers who have invested in compliance have a direct interest in visible surveillance of the market. Spare capacity also points towards exports: Cameroon already sells bars to Chad and other neighbours [S52][S76], and certified quality is an asset in any market where buyers ask for proof.

4.5 Prices are homologated per bar, which quietly rewards light bars

Rebar is a price-controlled product. The Ministry of Commerce homologates producer prices for each diameter and grade, expressed per bar. The published list does not state the bar length; this paper assumes 12 m, the standard commercial length. In October 2023, after negotiation, producers accepted reductions that brought the 12 mm Fe500 bar from 6,900 to 6,750 FCFA, with a street price for the same bar reported at 7,500 FCFA [S11].

Converting these prices to a price per kilogram, using the nominal mass of each bar, shows two things (table below). First, the homologated prices are internally consistent: about 600 to 650 FCFA/kg across diameters, with a premium for Fe500 over Fe400 of 5% to 6% per kilogram (derived). Second, and more important for quality, **pricing per bar makes the mass of the bar invisible to the price**. A bar rolled at the bottom of the 4.5% tolerance sells for the same price as a bar of nominal mass, which is a hidden price rise of 4.7% per kilogram; a bar rolled one millimetre undersize, illegally, delivers 16% less steel for the same money (derived). A producer who aims his rolling at nominal mass is penalised against one who aims light.

Table 4.2 Homologated rebar prices in Douala made public on 21 October 2023, converted to price per kilogram at nominal mass

Diameter and grade	Homologated price (FCFA per 12 m bar)	Nominal mass of a 12 m bar (kg)	Price per kg at nominal mass (FCFA)	Price per kg if the bar is 4.5% light (FCFA)
6 mm	1,532	2.66	575	602
8 mm Fe400	2,900	4.74	612	641
8 mm Fe500	3,070	4.74	648	678
10 mm Fe400	4,460	7.40	602	631
10 mm Fe500	4,700	7.40	635	665
12 mm Fe400	6,400	10.66	601	629
12 mm Fe500	6,750	10.66	633	663

Source: homologated prices [S11]; bar length of 12 m assumed; nominal masses and prices per kilogram derived by Cameroon Steel (Annex A). The 8 mm bar's tolerance is 6.0%; the 4.5% column is shown for comparison across sizes.

The remedy is simple and does not require any change to the level of prices: **homologate and display prices per tonne**, with the per-bar price derived from the nominal mass, and require merchants to sell by weight or to display the nominal mass per bar. A buyer who pays for kilograms has an incentive to weigh, and a producer who sells kilograms has no incentive to roll light. Cameroon already taxes steel by the tonne: the environmental tax introduced by the 2026 Finance Law charges 5,000 FCFA per tonne of reinforcing bar (fer à béton) to producers and importers alike [S66][S89]. The administrative logic of a tonnage basis therefore already exists.

4.6 The weak links are surveillance, testing capacity and the site

The institutional map has every layer, but three of them are thin.

Market surveillance at merchants. ANOR offers an online channel for reporting non-conforming products [S74], and its recall of Fe450 bars shows it can act. What is not visible in the public record is a routine programme of sampling rebar at hardware merchants (quincailleries), testing it and publishing the results by brand and diameter. Such a programme is the single most effective deterrent to light and mislabelled bars, because it makes non-conformity visible to buyers.

Testing capacity. Certification and surveillance depend on laboratories that can perform tensile, bend and mass tests to recognised methods with calibrated machines. In September 2024 ANOR began inspection visits to laboratories in Yaoundé, Douala, Edéa, Ngaoundéré and Garoua, with the aim of building a platform of qualified laboratories against the requirements of ISO/IEC 17025 for testing laboratories and ISO/IEC 17065 for product certification bodies [S18][S55][S56]. The number of laboratories able to test reinforcing bars to these requirements, and their locations, are not public.

The site. Building permits and their control fall to municipalities under the Ministry of Housing and Urban Development (MINHDU). After the July 2023 collapse the Minister noted that the building had no permit [S20], and in July 2026 the Douala urban community had sealed the building that later collapsed at Bonamoussadi [S22]. What is missing, as far as the public record shows, is a routine link between the permit and the materials used: a requirement that structural steel on permitted sites be certified and that deliveries be checked.

FINDING

The quality infrastructure for rebar in Cameroon is complete on paper and has been tested in practice: a mandatory standard, a certifying agency willing to withdraw certificates, import controls and price regulation. The binding constraints are downstream: no published market surveillance results, limited and unmapped testing capacity, per-bar pricing that hides mass, and no systematic acceptance testing on site. The recommendations chapter addresses each.

4.7 Neighbouring markets are moving in the same direction

Cameroon's choices are being made alongside those of its neighbours. They matter because Cameroonian mills already export bars, mainly to Chad [S52][S76], and because regional trade is opening under the African Continental Free Trade Area. In Gabon, the rectified finance law for 2026, published on 17 July 2026, cut the value-added tax on locally produced rebar from 10% to 3% to accelerate the development of the steel industry, while a Cameroonian group began building a rebar plant in the Nkok special economic zone [S87]. In September 2026 another group opened a scrap-based steel unit of 2,500 t a month at Port-Gentil, producing reinforcing bars mainly for the Gabonese market [S88]. In Nigeria, the national standards body sealed thirteen steel plants in 2020 after market surveillance found bars failing their minimum diameter and mass per metre [S25].

Two lessons follow for Cameroon. First, as neighbouring countries build and protect their own mills, Cameroonian exports will increasingly compete on proven quality rather than on availability; a certificate recognised beyond the border is a commercial asset. Second, regional harmonisation of standards, promoted by the African Organisation for Standardisation whose work ANOR relays [S74], will tend towards the international grade families described in the previous chapter. A national standard and a certification system already aligned with those families, in their ductility requirements, tolerances and proof of conformity, would make that transition easy rather than disruptive.

CHAPTER 5

A MILL PROVES QUALITY WITH STATISTICS AND TRACEABILITY, NOT WITH SINGLE TESTS

A certified rebar mill demonstrates conformity in three ways: it measures the chemistry of every heat, it tests every lot mechanically and dimensionally by standard methods, and it evaluates its results statistically over time so that characteristic values are proven rather than assumed. Traceability from heat number to bundle tag ties each certificate to real steel. A single test report, which is what most buyers see, proves very little on its own; a stable process with a documented history proves a great deal.

5.1 Chemistry is measured on every heat, before it is cast

The first test is the cheapest and the most decisive. Before a heat is released from the ladle furnace to the caster, a sample is taken and analysed by spark optical emission spectrometry, the standard method for carbon and low-alloy steels [S77]. Within minutes the melt shop knows the carbon, manganese, silicon, phosphorus, sulphur, copper and other residuals, and can trim the heat with alloy additions if it is off target. Nitrogen, which governs strain-ageing and rebend performance, requires an instrument capable of measuring it or a separate analyser.

The final ladle analysis becomes the **cast analysis** printed on the inspection certificate, together with the carbon equivalent calculated from it. Product standards also define a **product analysis**, taken on the finished bar, with slightly wider limits to allow for segregation [S38]; certified mills check it periodically, and buyers or surveillance bodies can use it to verify a certificate. A spectrometer is only as good as its calibration: it must be checked daily against certified reference materials and its results compared periodically with an external laboratory.

5.2 Mechanical and dimensional tests follow defined methods

Reinforcing bars have their own test standard, EN ISO 15630-1, which specifies how to perform the tensile, bend and rebend tests, how to measure the total elongation at maximum force (Agt), how to determine the mass per metre and how to measure rib geometry and calculate the relative rib area [S44]. The tensile test itself follows the general method for metallic materials, ISO 6892-1 [S45]. ASTM bars are tested to the methods referenced in their own specifications [S40].

The tensile test gives the yield strength, the tensile strength, their ratio, Agt and the elongation after fracture. The bend or rebend test checks for cracks after bending round a mandrel. The geometry check confirms rib height, spacing, inclination and gaps. The mass test, made by weighing a straight length measured to the millimetre, confirms the cross-section. The table below shows a typical factory production control plan. Frequencies are set by each product standard and certification scheme, and the plan shown is indicative.

Table 5.1 An indicative factory production control plan for reinforcing bar

Control	Method	Indicative frequency	Recorded on the certificate	Typical acceptance basis
Cast chemistry (C, Mn, Si, P, S, N, Cu, Cr, Ni, Mo, V) and Ceq	Spark optical emission spectrometry; nitrogen by suitable method	Every heat, before casting	Yes	Cast limits of the product standard
Product chemistry	Same, on finished bar	Periodically, and on demand	On request	Product limits (slightly wider)
Yield and tensile strength, Rm/Re, Agt, elongation after fracture	Tensile test, ISO 6892-1 and EN ISO 15630-1	Several tests per heat and per diameter	Yes, per heat	Characteristic values (statistical) and individual minima
Bend or rebend	EN ISO 15630-1	Per heat or per lot	Yes	No cracks visible to the naked eye
Rib geometry and fR	Measurement of rib height, spacing, gaps; fR calculation	Each roll change and each shift	On request	Minimum fR and geometry ranges
Mass per metre and diameter	Weighing of a measured length	Each lot and each shift	Yes	Tolerance of the standard
Surface condition and marking	Visual inspection on the cooling bed	Continuous	No	No laps, seams, cracks; legible mill mark
Fatigue (where certified)	Axial load test, 2 million cycles	Periodic, by the certification body	Certificate option	Stress range of the scheme, e.g. 150 MPa

Source: methods from [S44] [S45]; fatigue parameters from the AFCAB scheme [S31]. Frequencies are indicative assumptions for illustration; the governing standard and certification scheme set the actual plan.



ILLUSTRATIVE Illustrative view. Generated image of a universal testing machine for tensile tests on reinforcing bars; not a photograph of any project, place or person.

Two practical points matter in a laboratory serving a rebar mill. First, **the test machine and extensometer must be calibrated** and the laboratory's competence demonstrated, ideally by accreditation to ISO/IEC 17025 [S55]; a machine that reads 3% high turns a weak heat into a passing one. Second, **Agt must be measured properly**. Because Agt is the strain at maximum force, it is easily mis-read from a chart or confused with the elongation after fracture. EN ISO 15630-1 sets out how to determine it, either with an extensometer or by a manual method on marks made before the test [S44]. A certificate that reports elongation after fracture but no Agt cannot demonstrate a Eurocode ductility class.

Testing is also where a mill's own staff learn what the process is doing. A tensile curve with an unusually short yield plateau, an Agt that drifts down over a week, or a rebend specimen that shows fine cracks at the edge of the ribs are early signals of a change in chemistry, quench or rolling that a well-run mill invest-

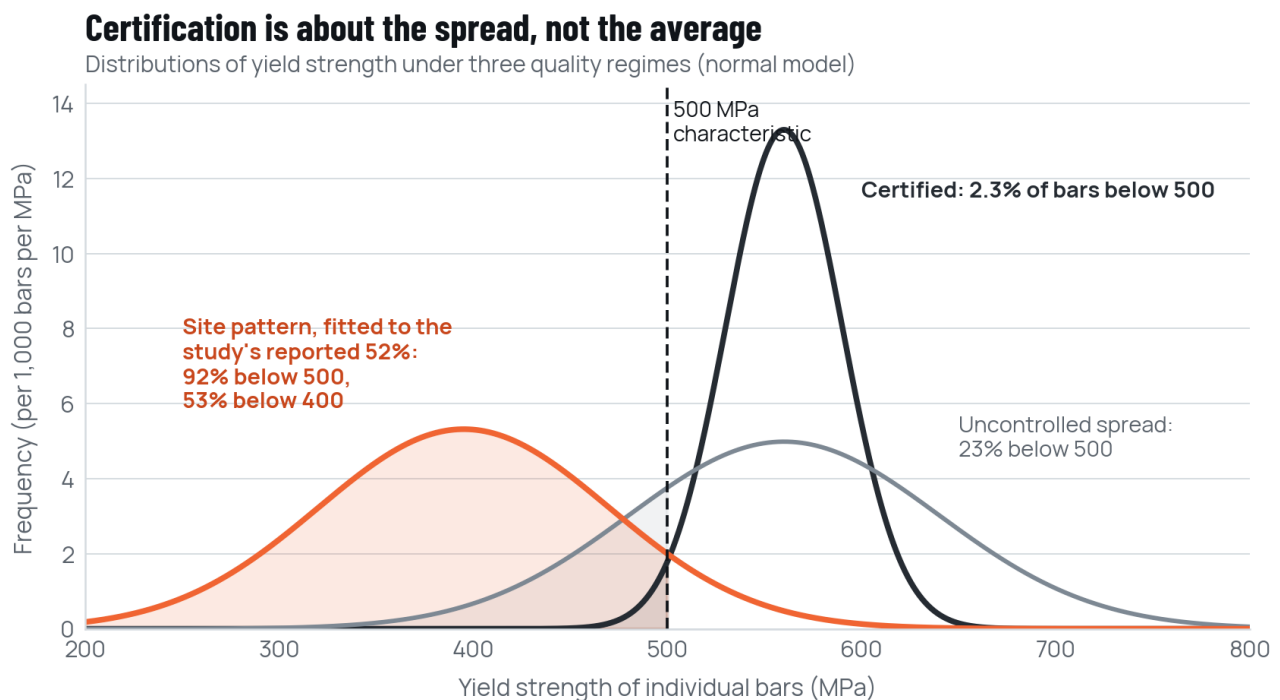
igates before any result falls outside the standard.

5.3 Statistics turn a set of tests into a guarantee

A characteristic yield strength of 500 MPa is a statement about the whole production: at most 5% of bars may fall below it. No mill can test every bar, so the guarantee must be inferred from samples. The method used by product standards and certification schemes is a statistical tolerance limit: the mean of n test results minus k times their standard deviation must be at least the characteristic value, where k depends on the number of results and on the confidence required [S57]. For a 95% coverage at 90% confidence, k is about 2.33 for 15 results, 2.08 for 30 and 1.97 for 50 (derived; Annex A).

The consequence is that **a mill with more scatter must aim higher**. With a standard deviation of 30 MPa, typical of well-controlled production [S29], and 30 results, the mean yield must be at least $500 + 2.08 \times 30 = 562$ MPa (derived). This is why the mean yield of a good B500 mill sits around 550 to 580 MPa, and why the probabilistic model used by structural reliability analysts sets the mean at the nominal value plus two standard deviations [S29]. A mill that cannot hold its scatter near 30 MPa must either raise its mean, at a cost in alloy or quench intensity, or accept that more of its bars fall below 500 MPa.

The same logic applies to A_{gt} and R_m/R_e , which also have characteristic values in the European family [S31]. Individual minimum values, such as 475 MPa for yield and 4% for A_{gt} under the French B500B scheme [S31], act as a safety net that no single test may breach.



DERIVED Figure 5.1. Certification is about the spread, not the average. With the same mean yield of 560 MPa, a standard deviation of 30 MPa puts 2.3% of bars below 500 MPa; a standard deviation of 80 MPa puts 23% below. A population fitted to the share the study reports for a small Cameroonian site sample (52% of 24 bars below 400 MPa; its own counts give 46%) puts 92% below 500 MPa.

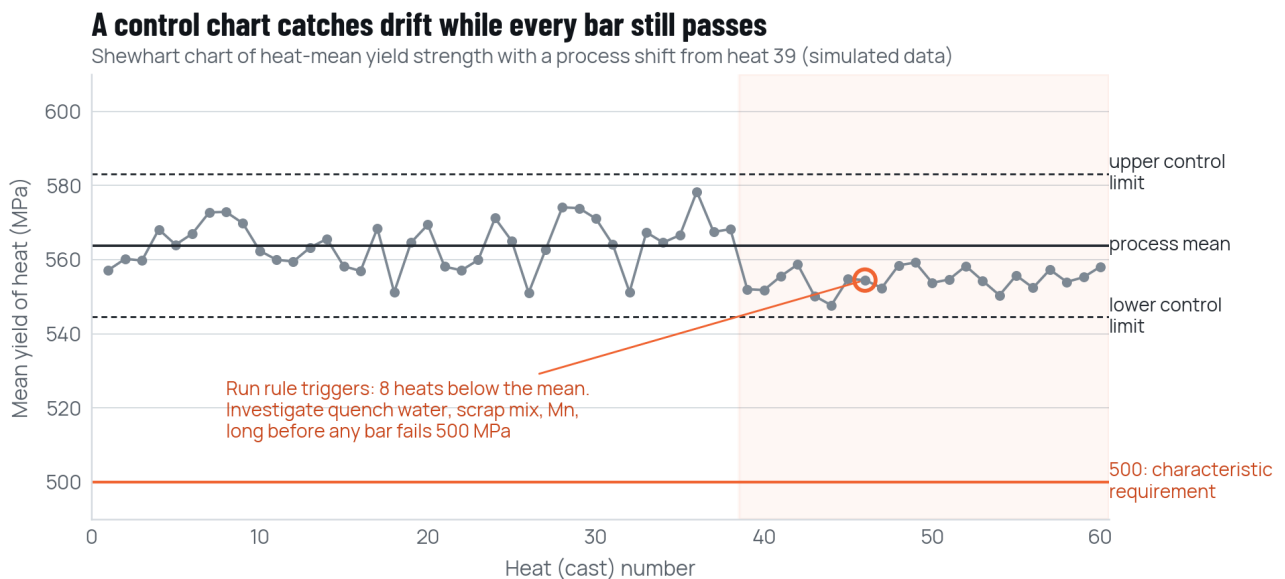
Source: Cameroon Steel calculation with normal distributions: $\sigma = 30$ MPa from [S29]; coefficient of variation of 14% from [S28]; site pattern fitted to the 52% share below 400 MPa reported in [S19] (24 bars; the study's own counts give 46%) with an assumed σ of 75 MPa (illustrative). Annex A.

Field evidence shows how far uncontrolled supply can depart from this. A study of 329 bars bought on the Ethiopian market between 2015 and 2020, local and imported, found coefficients of variation of yield strength of 14.5% and 14.2% in two lots, two to three times the scatter of controlled production, and found that most samples fell short of the tensile-to-yield ratio of 1.25 that the authors used as a reference for ductile behaviour [S28]. In Cameroon, a study of bars sampled on active building sites in Bamenda, Douala, Maroua and Yaoundé found that 11 of 24 bars (46%; the study itself reports 52%) had yield stresses below 400 MPa, that the largest

deviation in yield strength was 22.5%, and that bars without a marked manufacturer's name failed all the tests [S19]. The figure shows what these numbers imply: the problem is not that the average bar is a little weak, but that a large share of the population is far below grade.

5.4 Statistical process control catches drift while every bar still passes

Release testing tells a mill whether a lot conforms. Statistical process control (SPC) tells it whether the process is changing, and does so early enough to correct it. The tool is the control chart: each heat's mean yield, Agt, mass deviation or rib height is plotted against control limits calculated from the process's own recent history, typically at three standard deviations either side of the mean. Run rules flag non-random patterns, such as eight successive heats below the mean, even when every individual result is still within specification.



ILLUSTRATIVE Figure 5.2. A control chart catches drift while every bar still passes. In this simulated example the mean yield shifts down by about 10 MPa from heat 39; the run rule triggers at heat 46, while every heat remains more than 40 MPa above the 500 MPa requirement.

Source: Cameroon Steel simulation (normal random data, seed recorded in the chart data file). Illustrative of the method only.

In a QST mill, the usual causes of drift are well known: a change in the scrap mix that lowers manganese or raises residuals, worn or partly blocked quench nozzles, a change in finishing temperature or rolling speed, and the temperature of the cooling water. The last point matters in a coastal tropical climate, where process water runs warm for much of the year and the quench must be compensated by flow or pressure to deliver the same cooling. Rib height drifts as finishing rolls wear, which is why geometry is checked at each roll change. A mill that charts these variables, and links each to the heat number, can explain and correct a downward trend before it produces a failed test or a complaint.

5.5 Traceability ties every certificate to real steel

A test result has value only if it can be linked to the steel it describes. Traceability in a rebar mill rests on four links:

1. **The heat number**, assigned at the furnace, stamped or painted on every billet, and carried through reheating and rolling.
2. **The rolled-in mark**, a pattern of ribs or symbols that identifies the producing mill (and, in the European family, the country) on every metre of bar [S31][S34].

3. **The bundle tag**, which repeats the heat number and gives the grade, standard, diameter, length, mass, date and certification marks [S31][S32].
4. **The inspection document**, which reports the results for the heats delivered.

The European standard on inspection documents, EN 10204, distinguishes a test report type 2.2, which gives results of non-specific inspection on similar production, from an inspection certificate type 3.1, which gives results of specific inspection on the products supplied and is validated by the manufacturer's authorised inspection representative, independent of the manufacturing department, and a type 3.2, which is also validated by the purchaser's representative or a third-party inspector [S46]. For structural reinforcement, a type 3.1 certificate tied to heat numbers is the appropriate minimum, and type 3.2 can be required for critical works. The chapter on specification shows how to read one.

Traceability also makes **recall** possible. When the Cameroonian authorities ordered the recall of a non-conforming grade in October 2024 [S04][S05], the effectiveness of the recall depended on being able to identify the bars in the market. Rolled-in marks and tags are what make that identification possible for merchants and site engineers.

A TEST RESULT IS WORTH SOMETHING ONLY IF IT CAN BE TRACED TO THE STEEL IT DESCRIBES.

Traceability in one line

5.6 Calibration, retained samples and complaints close the loop

Three routines distinguish a laboratory that produces reliable results from one that merely produces numbers. **Calibration and verification**: the force measurement of the testing machine and the extensometer are calibrated at defined intervals by an accredited calibration service and verified between calibrations with reference specimens. **Proficiency testing**: the laboratory periodically tests specimens that other laboratories also test and compares the results, which exposes systematic bias that internal checks cannot reveal; participation in such comparisons is an expectation of ISO/IEC 17025 [S55]. **Retained samples**: a short length of bar from each heat is kept for a defined period, so that a later complaint can be investigated against the original material.

The last element is complaint handling. A well-run mill records every complaint from merchants and sites, investigates it against its heat records and retained samples, and reports the outcome and the corrective action. Complaints are information: a cluster of reports of bars cracking at bends, for example, may point to a nitrogen or quench problem during a specific period that release testing did not catch. Handled openly, complaints build the trust between producers, merchants and engineers on which a quality market depends; ignored, they turn into the kind of public dispute about quality that Cameroon saw in 2023 [S09][S10].

5.7 Certification adds an independent check on the mill's own testing

Everything described so far is the mill testing itself. Product certification adds an independent party. Under schemes such as AFCAB in France or CARES in the United Kingdom, the certification body assesses the mill's factory production control before granting the mark, audits it periodically, takes its own samples for independent testing, reviews the long-term statistics of the mill's results and can suspend or withdraw the certificate [S31][S33]. The mark on the bundle then tells the buyer that someone other than the seller has checked the evidence.

It is important not to confuse product certification with management-system certification. An ISO 9001 certificate shows that a company operates a documented quality management system [S78]; it does not certify that its bars meet a grade. When a producer in a dispute about bar quality cites ISO 9001, as happened in Cameroon in 2023 [S10], buyers should ask for the product certificate and the inspection certificates for the heats delivered.

PUBLIC-RECORD EXAMPLE

Cameroon Steel's planned first phase at Mboro includes, in its indicative layout, an on-site laboratory alongside the melt shop and the rebar and wire-rod mills (indicative plan, subject to detailed design). Cameroon Steel's objective, stated in this paper, is that every heat be analysed by spectrometer before casting, every lot tested to EN ISO 15630-1 methods, results charted statistically, and products certified by ANOR to NC 236 and by an independent body to a recognised international reference, with heat-number traceability to the bundle tag. This is an objective of a project under development, not a description of existing production.

5.8 A minimum laboratory for a rebar mill is modest; competence is the larger investment

What does a mill need in order to prove its product? The core equipment of a rebar laboratory is modest by industrial standards:

- **An optical emission spectrometer** with calibration standards for carbon and low-alloy steel, and a means of measuring nitrogen, close to the melt shop so that each heat can be corrected before casting [S77].
- **A universal testing machine** large enough for the largest bar produced. A 40 mm bar at the 650 MPa maximum yield of several national versions carries about 820 kN at yield (derived: $1,256.6 \text{ mm}^2 \times 650 \text{ MPa}$), so a machine of 1,000 kN capacity with grips for ribbed bars covers the full size range.
- **An extensometer**, or the marking equipment needed to determine Agt by the manual method of EN ISO 15630-1 [S44].
- **Bending and rebending equipment** with mandrels of the diameters the standards require, and an oven for the artificial ageing step of the rebend test.
- **A balance and length measurement** for mass per metre, and **gauges** for rib height and spacing.
- **A sample-preparation area** with a cut-off saw, and storage for retained samples.

Equipment is the smaller part of the effort; competence is the larger. Trained technicians, documented procedures, calibration, participation in proficiency testing and, in time, accreditation to ISO/IEC 17025 [S55] are what make a laboratory's numbers trustworthy to a certification body and to buyers. A laboratory established at a mill can also serve the wider market: testing samples for contractors and public authorities is one way in which a producer's investment in quality can help build the national testing capacity that the chapter on the quality infrastructure found lacking.

CHAPTER 6

MOST DEFECTIVE BARS CAN BE CAUGHT ON SITE WITH A SCALE, A TAPE AND A BEND

The defects found in African rebar markets fall into a short list: bars lighter than their declared size, bars weaker than their declared grade, brittle bars, bars with poor ribs, damaged or heavily corroded bars, and counterfeit or untraceable bars that carry a false mark or none. Most can be detected on delivery with simple tools: weighing full bars, reading the rolled-in mark and the tag, measuring the ribs and bending a sample. Laboratory tests then confirm strength and ductility where doubt remains. The evidence from Cameroon and its neighbours shows that unmarked bars are the highest-risk category of all.

6.1 Seven defects account for most problems

The table sets out the defects, how they arise, why they matter and how each can be detected. Several usually occur together: a bar re-rolled from mixed scrap is often light, irregular in its ribs, erratic in strength and unmarked.

Table 6.1 The seven common rebar defects and how to detect them

Defect	How it typically arises	Structural consequence	Site check	Laboratory confirmation
Underweight or undersize	Rolling aimed at or below the lower tolerance; a smaller size sold as a larger one	Less steel area: lower yield force, wider cracks, longer laps needed	Weigh three full bars per diameter; measure length	Mass per metre to EN ISO 15630-1
Under-strength (wrong grade)	Grade 400 steel labelled 500; low manganese; failed or absent quench	Bar yields below the design force (Figure 1.3)	Check mark, tag and certificate; none can measure strength	Tensile test: Re, Rm
Brittle (low ductility)	High carbon, phosphorus or nitrogen; re-rolled scrap; over-quenched rim	Fracture at small strain; cracked hooks and links; no warning before failure	Bend 180° round a mandrel; look for cracks	Tensile test: Agt, Rm/Re; rebend test
Poor ribs (low bond)	Worn finishing rolls; shallow or irregular ribs	Slip at anchorages and laps; wide cracks	Measure rib spacing over ten ribs and rib height	Rib geometry and fR
Surface and internal defects	Poor billets; laps and seams from rolling; inclusions	Local cracking, especially at bends; fatigue weakness	Inspect cut ends and surface; bend test	Macro-etch, metallography
Heavy corrosion or contamination	Long storage near the sea or on bare ground; oil, mud, paint	Loss of section by pitting; loss of bond	Wire-brush a sample; check pitting; weigh after brushing	Mass after cleaning; tensile on pitted bar
Counterfeit or untraceable	No mill mark; copied marks; printed tags with no certificate; mixed bundles	Any of the above, with no way to trace or recall	Read the rolled-in mark; match tag, heat number and certificate	Full test series; report to ANOR

Source: Cameroon Steel synthesis from the standards and studies cited in this paper [S19][S25][S26][S28][S31][S34][S44].

6.2 The regional evidence points the same way

Published tests of market rebar in Cameroon and comparable countries are few, use different methods and are not directly comparable, but they converge on the same pattern: a significant share of the bars tested, on sale or on site, do not meet their declared grade, and the shortfall is concentrated among unmarked or weakly controlled products.

Table 6.2 Published evidence on the quality of rebar on sale or on site (selected)

Country	Source and date	Sample	Main findings
Cameroon	Bame, Yamb and Ndigui, 2023 [S19]	24 bars of 10, 12 and 14 mm sampled on active building sites in Bamenda, Douala, Maroua and Yaoundé (sampling years not stated); tensile, elongation and bend tests	11 of 24 bars had yield stresses below 400 MPa (reported as 52%; the counts give 46%); largest deviation in yield strength 22.5%; bars without a marked manufacturer's name failed all tests; authors recommend properly marked grade 500 bars for the Cameroonian national annex to Eurocode 2
Cameroon	Industry and consumer bodies, reported June 2023 [S09]	Market complaint, no test data published	Bars sold as grade 500 reportedly did not meet grade 400 requirements
Nigeria	Standards Organisation of Nigeria, February 2020 [S25]	Nationwide market surveillance, Nov 2019 to Jan 2020	13 steel plants sealed; most samples failed minimum diameter and mass per metre under NIS 117:2004; products on hold tampered with; an unregistered identification mark found
Nigeria	Akinpelu and Salman, 2021 [S26]	Six bar sizes from four brands; tensile tests and spectrometry	70.8% of bars failed the characteristic tensile strength requirement assessed against BS 4449, while meeting elongation; failed bars showed low carbon or excess phosphorus
Nigeria	Shuaib-Babata and others, 2019 [S79]	Market bars from four cities	Most identification-mark information required by standards was absent; properties inconsistent between samples
Ethiopia	Achamyeleh and others, 2022 [S28]	329 market bars, local and imported, 2015 to 2020	Few yield failures (0% to 6% by size) but coefficient of variation of yield about 14%; most bars below the tensile-to-yield ratio of 1.25 used as a ductility reference

Source: as listed. Methods, standards and sampling differ between studies; the table shows patterns, not comparable failure rates.

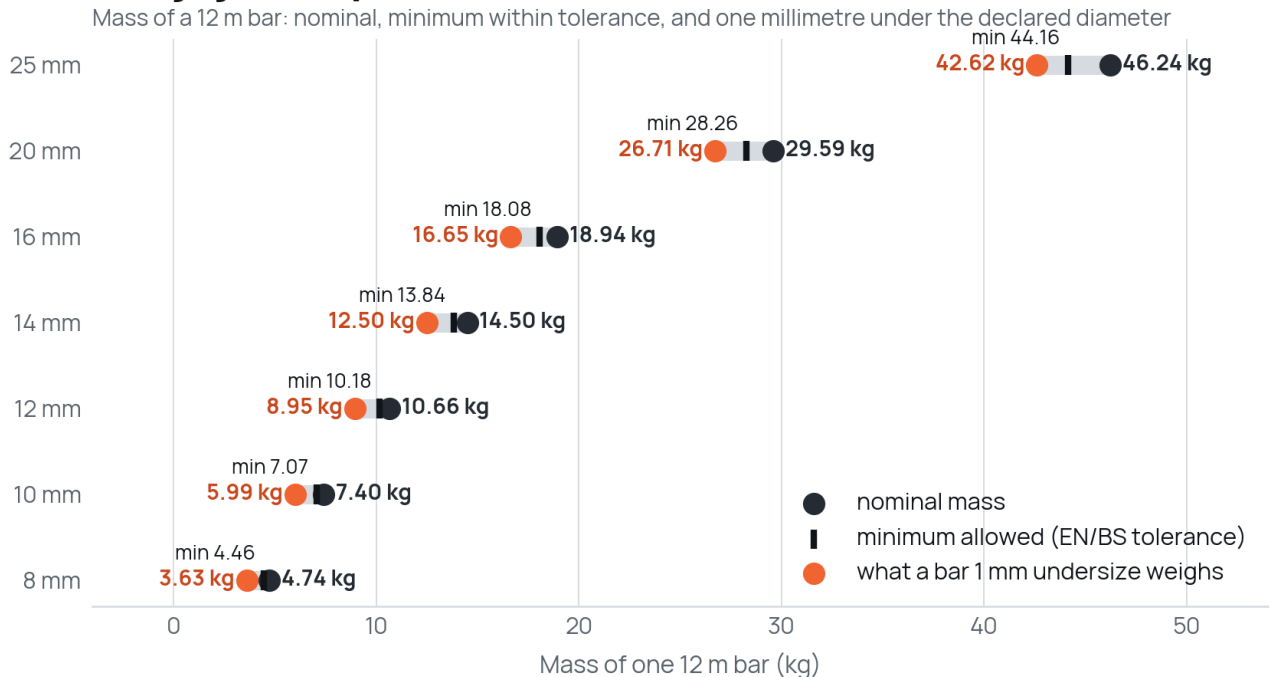
Two observations stand out. First, **marking matters more than any other single attribute**: the Cameroonian study found that unmarked bars failed every test [S19], and the Nigerian regulator found unregistered marks and tampering [S25]. Second, **the failures are not only in strength**. The Ethiopian bars mostly met their minimum strength but showed scatter and strength ratios that limit ductility [S28]; the Nigerian bars failed on diameter and mass [S25]. A site that checks only the grade printed on a label misses most of the problem.

6.3 Weigh the bar: the single most useful site test

Mass per metre is the honest measure of a bar's size (see the standards chapter), and it can be checked with a hanging or platform scale that any builders' merchant owns. The procedure takes ten minutes per diameter:

1. Choose three full-length bars of each diameter at random from the delivery, not from the top of the bundle.
2. Measure each bar's length with a tape, to the nearest centimetre.
3. Weigh each bar on a scale with a resolution of 0.05 kg or better, checked against a known mass.
4. Divide mass by length to get kg/m and compare with the nominal value less the tolerance: 4.5% for bars larger than 8 mm, 6.0% for 8 mm and smaller [S31][S32].

A hanging scale exposes an undersize bar in seconds



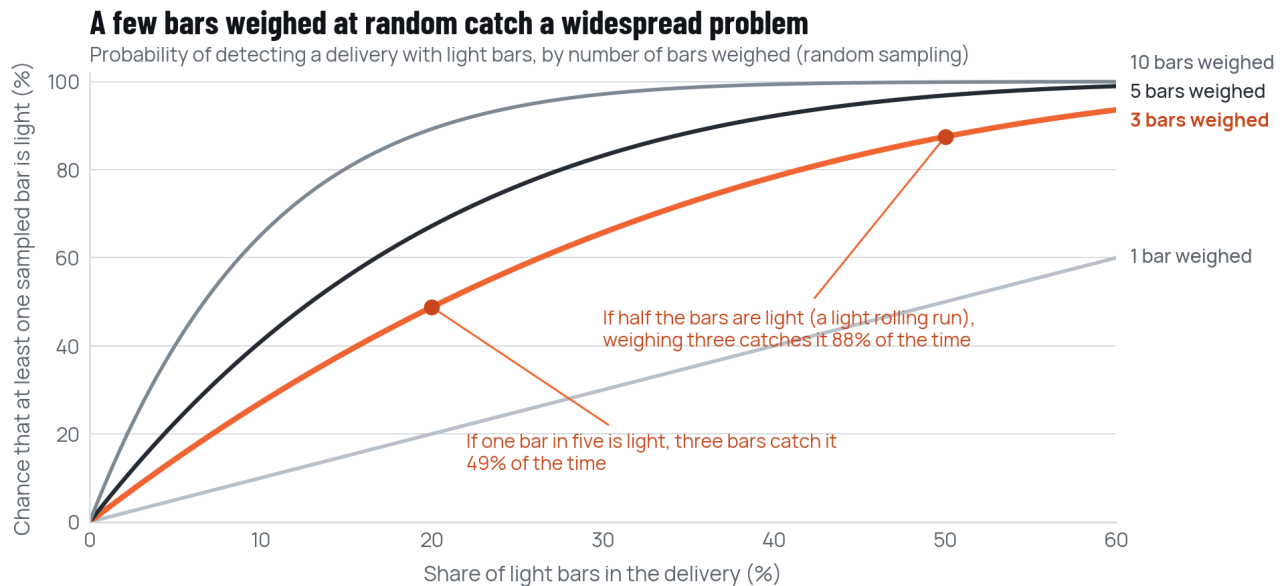
DERIVED **Figure 6.1.** A hanging scale exposes an undersize bar in seconds. A 12 m bar of 12 mm should weigh 10.66 kg and may not weigh less than 10.18 kg; a bar rolled at 11 mm weighs 8.95 kg, a difference of 1.7 kg that no tolerance can explain.

Source: Cameroon Steel calculation from nominal diameters and a density of 7,850 kg/m³; tolerance from the European reference standards [S31][S32]. Annex A.

The differences are large enough to be unmistakable. One millimetre of undersize removes 16% of the steel from a 12 mm bar and 19% from a 10 mm bar (derived). These are not marginal failures that depend on the accuracy of a scale; they are visible on any calibrated scale. Because merchants usually sell by the bar, the buyer who weighs also protects his budget: every missing kilogram is a kilogram paid for and not delivered (see the price analysis in the next chapter).

6.4 A few bars weighed at random catch widespread problems

How many bars must be weighed? Weighing is cheap, but on a busy site three bars per diameter is a realistic routine. Elementary probability shows what such a sample can and cannot detect. If a fraction p of the bars in a delivery are light and n bars are drawn at random, the chance that at least one light bar is found is 1 minus (1 minus p) to the power n (derived).



DERIVED Figure 6.2. A few bars weighed at random catch a widespread problem. When half the bars in a delivery are light, three bars weighed reveal it 88% of the time; when one bar in five is light, 49% of the time in a single delivery.

Source: Cameroon Steel calculation (binomial sampling from a large lot). Annex A.

Two conclusions follow. First, small samples catch **systematic** problems reliably. When a whole rolling campaign has been rolled light, which is what happens when a mill aims below nominal or runs worn rolls, half or more of the bars are light, and three bars weighed will expose the problem in nearly nine deliveries out of ten (derived). Second, small samples catch **occasional** light bars less reliably in any single delivery, but repetition compensates: with one bar in five light, weighing three bars in each of four deliveries gives a 93% chance of detection (derived: $1 - 0.8^{12}$). The rule is therefore not to weigh many bars once, but to weigh a few bars every time and keep a record.

6.5 Read the bar: marks, tags and certificates

The second check is documentary and takes a few minutes. A conforming bar carries a **rolled-in mark**, a pattern of ribs or symbols that identifies the mill, repeated along its length [S31][S34]. The **bundle tag** should give the producer, the grade and standard, the diameter, the heat number and, for certified products, the certification mark and certificate number [S31][S32]. The **delivery note** and the **inspection certificate** should list the same heat numbers.

The rule that follows from the regional evidence is blunt: **bars without a legible rolled-in mill mark should not be used in structural members**. A printed tag can be produced by anyone; a rolled-in mark requires a set of rolls and is the producer's signature on every metre of steel. Even a rolled-in mark can be imitated by a rogue mill, which is why the mark, the tag, the certificate and, where applicable, the certificate's current validity with ANOR or the certification body should all be cross-checked. A merchant who cannot produce a certificate matching the heat numbers on the tags is offering an untraceable product.

6.6 Bend the bar: a ten-minute ductility check

No site tool measures yield strength. Ductility, however, reveals itself to a simple bend. The site bend test is an adaptation of the standard bend test [S44]:

1. Cut a sample about 0.5 m long from a bar of each diameter in the delivery.

2. Using a bar-bending machine or a manual bender with a former of about four bar diameters for sizes up to 16 mm, and larger for bigger bars, bend the sample cold through 180°.
3. Inspect the outside of the bend in good light. Any crack, split or tearing at the root of the ribs is a failure.
4. For bars that will be bent and straightened in service (starter bars, for example), partially straighten the sample and inspect again.

A brittle bar, whether from excess carbon or phosphorus, nitrogen ageing, a seam or a laminated re-rolled section, usually cracks or splits in this test. A bar that passes may still be weak, but it is unlikely to be dangerously brittle. The test should be performed cold: heating a bar to bend it changes its properties, and quenched and self-tempered bars, whose strength comes from their thermal treatment, must never be heated.

While a sample is in hand, the **ribs** can be checked: lay a ruler along the bar and measure the length of ten rib spacings; measure the rib height at mid-rib with a depth gauge or vernier caliper. Comparing these with the producer's data, or with a known good bar, exposes worn rolls and shallow ribs. Cut ends deserve a look too: a lamination, split or dark inclusion in the cross-section of a cut end is a sign of a poor billet or of re-rolled scrap.

Five checks on delivery catch most bad bars before they reach a column

Acceptance routine for a rebar delivery on a building site (recommended practice)



ILLUSTRATIVE Figure 6.3. Five checks on delivery catch most bad bars before they reach a column. Any failure sends the lot to quarantine and to the laboratory; only lots that pass go to fabrication.

Source: Cameroon Steel recommended practice, based on the product requirements in [S31][S34][S38][S44] and the test methods in [S44][S45].

6.7 Look at the bar: corrosion and contamination

Bars stored for months on bare ground in Douala or Kribi will rust. Light, uniform surface rust that wipes off is not harmful and does not reduce bond. What matters is **loss of section**: flaking rust, pits and reduced rib height. American practice provides a practical rule: rusty bars are acceptable if a hand-wire-brushed sample still meets the minimum dimensions, mass and rib height of the specification [S34]. The same rule works with European-family bars: brush a sample, weigh it, measure its ribs. Oil, paint, mud and release agents reduce bond and should be cleaned off before placing.

Prevention is cheaper. Bars should be stored on timber bearers off the ground, covered against rain, segregated by diameter and grade so that bundles are not mixed, and, near the sea, sheltered from spray. A site that buys a month's steel at a time rarely has a corrosion problem; one that buys a year's supply when prices are low often does.

6.8 When in doubt, test in a laboratory, and report

Any failure in the site checks, any missing or inconsistent document, or any doubt on an important structure justifies laboratory testing. The practical rule is to **quarantine the lot**, mark it clearly so that no bar is used, and send three samples per diameter, long enough for tensile and bend testing, to a competent laboratory, preferably one accredited to ISO/IEC 17025 [S55]. The laboratory should report Re, Rm, Rm/Re, Agt and the bend result, and the mass per metre; where bars will be welded, a chemical analysis gives the carbon equivalent.

The cost of these tests is small against the cost of the steel in a single floor slab, and negligible against the cost of demolishing and recasting a column. If a lot fails, it should be rejected, the supplier and the supervising engineer informed in writing, and the case reported to ANOR, which operates a channel for reporting non-conforming products [S74]. Reports from sites are the raw material of market surveillance: an agency that never receives complaints cannot target its sampling.

FINDING

On a typical Cameroonian building site, five low-cost checks on each delivery (paperwork, marks, weighing, measuring, bending) would expose most of the defects documented in the region. The one defect they cannot expose, a bar of correct size and ductility but lower strength than declared, is the one that certification and market surveillance are designed to prevent.

CHAPTER 7

SPECIFY THE FULL GRADE, DEMAND THE PROOF AND VERIFY EVERY DELIVERY

Designers and contractors control the last two gates before steel disappears into concrete: the specification and the acceptance of deliveries. A specification that names the national grade, the ductility class, the weldability limit, the tolerances and the form of proof, and a contract that pays for steel by weight only after acceptance checks, will exclude most substandard bars at negligible cost. Public works contracts are the natural place to start, because the State is the largest single buyer of construction in Cameroon and can make certified steel a condition of payment.

7.1 The specification is the designer's first quality control

A structural design is a set of assumptions about materials. When an engineer designs a slab to Eurocode 2 with class B reinforcement, the calculation assumes a characteristic yield of 500 MPa, a strength ratio of at least 1.08, a strain at maximum force of at least 5%, adequate bond and, if the bars are to be welded, a weldable chemistry [S30][S36]. None of these assumptions reaches the site unless it is written into the specification and the contract. A drawing note that reads "steel: Fe500" transmits only the first.

The table below proposes model clauses that a Cameroonian specification can adopt. They combine the mandatory national grade with the properties that a Eurocode-based design relies on, and they define the evidence that the contractor must produce. They are a starting point for project-specific drafting, not a substitute for it.

Table 7.1 Model specification clauses for reinforcing steel in Cameroonian projects

No.	Subject	Clause (summary)	Evidence required
1	Grade and standard	Ribbed bars to NC 236 grade Fe500, having in addition the properties of ductility class B of EN 1992-1-1 Annex C (B500B of BS 4449 or NF A 35-080-1)	ANOR conformity certificate; inspection certificate per heat
2	Ductility	Characteristic $A_{gt} \geq 5.0\%$ and $R_m/Re \geq 1.08$; no test below the individual minima of the reference standard; class C where the engineer requires enhanced ductility	Tensile results per heat, with A_{gt} measured to EN ISO 15630-1
3	Overstrength	Ratio of actual to nominal yield not above 1.30 (characteristic)	Tensile results per heat
4	Weldability	Cast $Ceq \leq 0.50\%$ where any welding, including tack welding, is permitted; otherwise no welding without the engineer's written approval; welding to EN ISO 17660-1	Cast analysis and Ceq on the certificate
5	Section	Mass per metre within $\pm 4.5\%$ (bars above 8 mm) or $\pm 6.0\%$ (8 mm and below)	Mass deviation per heat; site weighing
6	Bond	Relative rib area not less than the Eurocode 2 minimum, or rib geometry as certified	Certified rib geometry; site rib measurement

No.	Subject	Clause (summary)	Evidence required
7	Marking and traceability	Rolled-in mill mark on every bar; bundle tags with heat numbers; type 3.1 inspection certificate to EN 10204 for every heat delivered	Tags, certificate and delivery note with matching heat numbers
8	Certification	Supplier's ANOR certificate valid on the delivery date; third-party product certification preferred where available	Copy of certificate; validity confirmed
9	Acceptance on site	Paperwork, marking, weighing, measuring and bend checks on each delivery; laboratory tests on samples taken by the engineer where any check fails, for uncertified supply and for critical works	Site acceptance record; laboratory reports
10	Non-conformity	Non-conforming lots quarantined, removed and replaced at the supplier's cost; report to the engineer and to ANOR	Non-conformity record
11	Measurement and payment	Steel measured and paid by mass (kg), at nominal mass for accepted bars; no payment for rejected lots	Weighbridge tickets; reconciled schedules
12	Bending and fixing	Cold bending only, to the mandrel diameters of the design code and BS 8666 or equivalent; no heating; no rebending of bent bars without approval	Bar schedules; inspection before concreting
13	Substitution	No change of size, grade or standard without the engineer's written approval; equivalence must be shown property by property (Agt, Rm/Re, Ceq, mass)	Comparison sheet with certificates
14	Storage	Bars stored off the ground, covered, segregated by size and grade, protected from sea spray	Site inspection

Source: Cameroon Steel proposal, based on [S04][S05][S30][S31][S36][S38][S44][S46][S67][S71]. Model wording for adaptation by the project engineer; not legal advice.

Three of these clauses deserve a comment because they change behaviour rather than paperwork.

Clause 4 (weldability) addresses a practice that is common and rarely specified: tack-welding cages for convenience. A tack weld on a high-carbon or high-Ceq bar creates a hard, brittle spot that can crack under load or during bending, at exactly the point where the bar must later carry tension. Either the steel is certified weldable and the welding is controlled, or there is no welding.

Clause 11 (payment by mass) aligns the contractor's and the owner's interests with the quality of the product. A contractor paid per tonne of accepted steel has no incentive to buy light bars, because the measurement of his payment is the mass that the bars actually have.

Clause 13 (substitution) prevents the most common route by which a carefully specified grade is lost: a supplier or contractor proposes an "equivalent" product late in the job, under time pressure. The comparison table in the standards chapter shows why equivalence must be demonstrated property by property.

7.2 Read the mill certificate before the lorry is unloaded

The inspection certificate is the document that links a delivery to the evidence of its quality. Under EN 10204, a type 3.1 certificate reports the results of specific tests on the products supplied, validated by the manufacturer's inspection representative who is independent of production [S46]. Six checks take less time than unloading the lorry.

Six things to read on a mill certificate before accepting a delivery

Specimen inspection certificate for reinforcing bars (illustrative layout, invented values)

INSPECTION CERTIFICATE EN 10204 TYPE 3.1										1 Type 3.1: signed by an inspector independent of production
Manufacturer: [Mill name, address] Certificate no. [...]										2 Grade and standard match your specification, not a near miss
Product: ribbed bars, d = 12 mm, length 12 m, weldable										
Standard and grade: NC 236 Fe500 / BS 4449 B500B										
Customer order [...] Delivery note [...] Mass 24.6 t										
Heat no.	Bundles	C	Mn	P	S	N	Cu	Ceq		3 Heat numbers match the bundle tags on the lorry
H-2611	B001-B024	0.20	0.85	0.021	0.018	0.009	0.28	0.38		
Tensile (EN ISO 15630-1) Re MPa Rm MPa Rm/Re Agt % Bend/rebend										4 Chemistry within limits; Ceq at or below 0.50 if bars are welded
Specimen 1			562	651	1.16	9.8	no cracks			
Specimen 2			571	660	1.16	9.4	no cracks			
Mass per metre: 0.871 kg/m (nominal 0.888; deviation -1.9%)										5 Mass per metre within tolerance
Product certification: [body], licence no. [...], valid to [date]										6 Certificate of a third-party product certification still valid
Factory production control under ISO 9001 and the certification scheme										
We certify that the products comply with the order and the standard.										
Inspection representative, independent of production: [signature]										
All values are invented for illustration and do not refer to any producer.										

ILLUSTRATIVE Figure 7.1. Six things to read on a mill certificate before accepting a delivery: the type of document, the standard and grade, the heat numbers, the chemistry and Ceq, the mass deviation and the validity of the product certification. All values shown are invented.

Source: Cameroon Steel illustrative layout, after the content requirements of EN 10204 [S46] and the European product standards [S31][S38]. All names and values are invented.

First, the type of document. A type 2.2 test report gives results for similar production, not for the steel delivered, and is not sufficient for structural reinforcement [S46]. A type 3.1 certificate is the minimum; a 3.2, countersigned by a third party, can be required for critical works.

Second, the standard and grade. The certificate must name the grade specified, not a near miss. "Fe450", "Fe500 type" or a foreign grade without demonstrated equivalence are not the grade specified. The Fe450 episode of 2024 showed that grades outside the national catalogue can reach the market [S04][S05].

Third, the heat numbers. Each heat on the certificate must match a tag on the bundles delivered, and every bundle's tag must appear on the certificate. Bundles whose heat numbers do not appear are, in effect, uncertified.

Fourth, the chemistry. The cast analysis should show carbon, phosphorus, sulphur, nitrogen and copper within the limits of the reference standard, and a carbon equivalent of 0.50% or below if any welding is permitted [S31][S32].

Fifth, the mechanical results and mass. Each heat should show Re, Rm, Rm/Re and Agt, the bend or rebend result and the mass deviation. Results that sit just above every minimum, heat after heat, deserve a closer look; real production shows scatter.

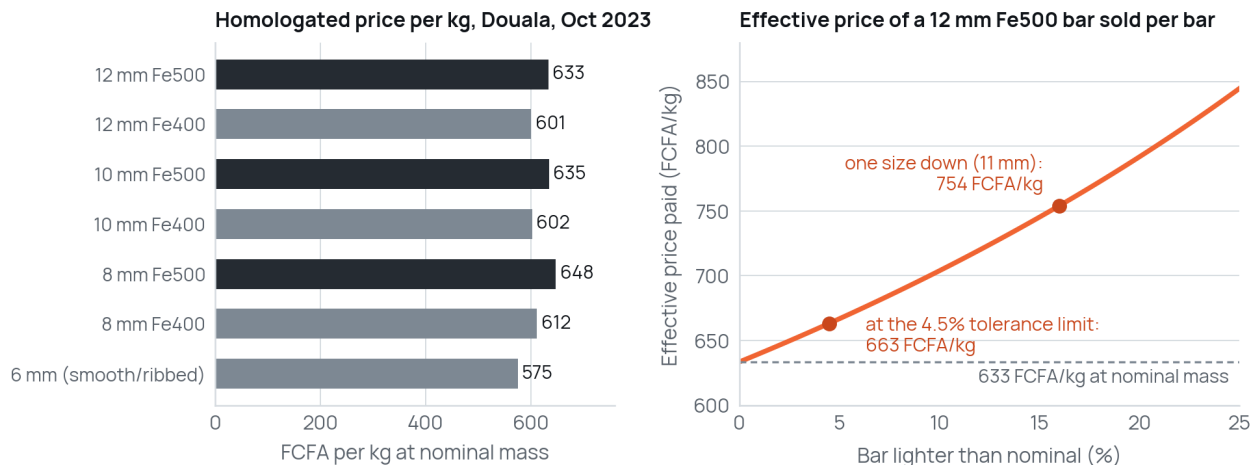
Sixth, the certification. The certificate should cite the product certificate (ANOR, and any third-party scheme) by number, and the buyer should confirm that it is current. Certification bodies such as AFCAB publish the validity of their certificates online so that any buyer can check them [S31].

A certificate is a document, and documents can be copied or altered. Photocopied certificates with handwritten heat numbers, certificates whose results are identical for every heat, or certificates from a producer whose rolled-in mark does not appear on the bars should all trigger laboratory testing.

7.3 Buy by weight and pay on acceptance

The chapter on the quality infrastructure showed that homologated prices are set per bar. On site, many purchases are also made per bar. The figure below shows what this means for the buyer.

Buying by the bar hides a price rise in every missing kilogram



DERIVED Figure 7.2. Buying by the bar hides a price rise in every missing kilogram. At the homologated price of October 2023, a 12 mm Fe500 bar costs 633 FCFA per kg at nominal mass, 663 FCFA per kg if it is 4.5% light and 754 FCFA per kg if it is one size down.

Source: homologated prices [S11]; price per kilogram derived by Cameroon Steel from nominal masses (Annex A).

A contractor who buys light bars therefore pays more per kilogram of steel, and gets less steel in the structure. The arithmetic gives the owner a simple defence: **specify, measure and pay for reinforcement by mass**, as bills of quantities normally do, and reconcile the mass delivered (from weighbridge tickets or from weighing on site) with the number of bars and their nominal mass. A delivery of 1,000 bars of 12 mm should weigh about 10.66 t; if it weighs 9.5 t, either the count or the bars are wrong (derived).

7.4 Good steel performs only if it is detailed and fixed correctly

Certified bars can still be wasted by poor detailing and fixing. Four points are worth enforcing on every site.

Bending: bars must be bent cold round formers of adequate diameter; BS 8666, the British standard for scheduling and bending reinforcement, sets minimum former diameters that increase with bar size, of the order of four bar diameters for the common sizes [S67]. Bending a bar round a nail or a sharp edge concentrates strain and can crack even a good bar. **Laps and anchorages:** the lap and anchorage lengths of design codes assume bars of the specified bond and concrete of the specified strength; shortened laps, laps all placed at the same section, or laps in zones of high tension are common causes of distress. **Links:** column and beam links confine the concrete and restrain the main bars from buckling; they must be closed with hooks bent far enough to anchor into the core, and spaced as drawn, especially near joints. **Cleanliness and position:** bars must be free of loose rust, mud and oil, tied so that they do not move during concreting, and held at the specified cover by spacers.

A short inspection of the reinforcement before each pour, against the drawings and bar schedules, catches most of these errors while they are still cheap to correct. The engineer's inspection record, signed before concrete is ordered, is the counterpart for fixing of the acceptance record for delivery.

7.5 Use third-party testing where it adds information

Laboratory testing of rebar on behalf of the owner is most valuable in five situations: when the supplier is not certified; on the first delivery from a new supplier; when any site check has failed or any document is missing; for critical buildings such as schools, hospitals and buildings of several storeys; and on a sample basis throughout a large project to keep the supply honest.

The value of a test depends on how the sample is taken. **Samples should be selected and cut by the engineer's representative**, not by the supplier, from bars chosen at random in the delivery, labelled with the heat number, sealed and transported with a simple chain-of-custody record to a competent laboratory, preferably accredited to ISO/IEC 17025 [S55]. The laboratory should test to EN ISO 15630-1 or the method of the specified standard [S44] and report every result, not only a pass or fail.

Interpreting a small number of tests also needs care. Three tensile results cannot prove a characteristic value, which is a statement about a whole production and requires statistical evidence (see the testing chapter). A practical acceptance rule for a lot is that every result must meet the individual minimum values of the reference standard, and that the mean of the results should comfortably exceed the characteristic values. A lot that meets the individual minima only narrowly, with a low mean, should be treated as suspect and investigated further, typically with more samples.

PRACTICAL RULE

Samples for owner testing are chosen and cut by the engineer's representative, labelled with the heat number, sealed and sent to a qualified laboratory. Three results can show that a lot meets the individual minima; they cannot prove a characteristic value, which only certified production statistics can.

7.6 Public procurement can move the whole market

The State is the largest buyer of construction in Cameroon. The 2026 State budget allocates 2,026.3 billion FCFA to public investment [S80], a large share of which becomes concrete buildings, bridges, culverts and drainage works. Public works are procured under the public procurement code set by Decree No. 2018/366 of 20 June 2018 [S54], with standard bidding documents published by the Ministry of Public Contracts.

Three changes in public procurement would raise the floor for the whole market:

1. **A standard clause** in the technical specifications of every public works contract requiring certified NC 236 bars with the properties of ductility class B, type 3.1 inspection certificates and site acceptance checks, along the lines of the table above.
2. **Payment conditions** that make certified steel a condition of payment: interim certificates for reinforced concrete work would require the acceptance records and certificates for the steel used.
3. **Supervision** that includes materials: the supervising engineer's terms of reference would include rebar acceptance checks and a sampling plan for laboratory testing.

Projects financed by development banks already follow international standards and supervision rules. Aligning national procurement with that practice would create a large, stable demand for certified steel, which in turn rewards the producers who invest in quality control. Private buyers would follow, particularly where lenders and insurers ask for evidence of material quality before financing or covering a building.

THE STATE BUYS MORE REINFORCED CONCRETE THAN ANYONE ELSE. IF IT PAYS ONLY FOR CERTIFIED STEEL THAT HAS BEEN CHECKED ON DELIVERY, THE MARKET WILL FOLLOW.

Procurement as a quality instrument

7.7 Masons and foremen make the last decision

Specifications and certificates are read in offices; bars are accepted, cut and bent on site by foremen and masons. In most Cameroonian building, and especially in owner-built housing, there is no engineer present when steel is delivered. The quality of the steel actually built into a house therefore depends on what the person unloading it knows.

Five habits make the difference and can be taught in a day: refuse bars without a rolled-in mark; weigh three bars of each size; bend a sample cold; never heat a bar to bend it; and store bars off the ground and under cover. A sixth, ensuring the specified concrete cover with proper spacers, belongs to durability and is discussed in the next chapter. Before concrete is poured, the reinforcement should be inspected against the drawings: bar sizes and numbers, spacing, laps, links, cover and cleanliness.

FINDING

A specification that names the full grade, a certificate read in six checks, payment by mass and five site habits cost almost nothing and exclude most substandard bars. Public procurement can make them the norm by making certified, accepted steel a condition of payment.

7.8 A one-page acceptance record makes the routine stick

Routines survive on paper. A one-page acceptance record, completed for every delivery and kept with the site diary, makes the checks described above auditable and links them to payment. It needs only ten entries:

1. Date, supplier and delivery note number.
2. Diameters and number of bars or bundles delivered, and the delivered mass from the weighbridge ticket.
3. Heat numbers read on the tags.
4. Inspection certificate numbers and type (3.1 or 3.2), and whether every heat on the tags appears on a certificate.
5. Product certificate (ANOR, and any third-party scheme) and its validity on the day.
6. Rolled-in mark observed on the bars, and whether it matches the certificate.
7. Masses and lengths of the bars weighed, and the computed kg/m against the minimum allowed.
8. Rib spacing and height measured on one bar per diameter.
9. Result of the bend test on one sample per diameter.
10. Decision (accept, quarantine for testing, reject), with the name and signature of the person responsible.

Kept consistently, these records do more than protect a single building. They give the owner evidence for payment, the engineer evidence for sign-off and the supplier feedback on its product; shared with ANOR when a delivery fails, they give the market surveillance system the information it needs to target its sampling.

CHAPTER 8

ON THE COAST, COVER AND CONCRETE PROTECT THE BAR MORE THAN THE STEEL ITSELF

In Douala and Kribi, mean relative humidity stays above 80% in every month and averages close to 90%, rainfall at Kribi exceeds 2,800 mm a year, and sea spray carries chlorides inland. Corrosion of reinforcement is therefore the main long-term threat to concrete buildings on the coast. A bar is protected by the alkalinity of sound concrete and by the thickness of the cover, not by its own chemistry; coatings and stainless steel help only where exposure is severe. The decisive measures are cover, concrete quality and curing, which Eurocode 2 and EN 206 set by exposure class, and which have to be enforced on site with spacers and inspection.

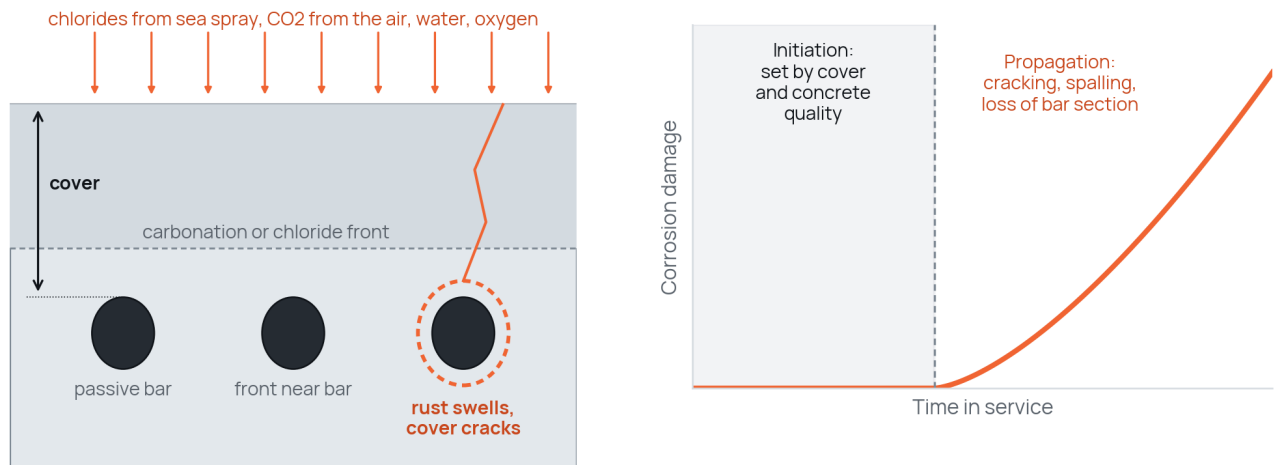
8.1 Steel in concrete is protected by chemistry until the cover is breached

Fresh concrete is strongly alkaline. In that environment a thin, stable oxide film forms on the steel surface and protects it: the bar is passive. Two processes destroy this protection. **Carbonation**: carbon dioxide from the air diffuses into the concrete and gradually lowers its alkalinity; when the carbonated front reaches the bar, the passive film is lost over a wide area. **Chlorides**, from sea spray, sea water, contaminated sand or aggregates, or some admixtures, diffuse inwards and, once their concentration at the bar exceeds a threshold, break the passive film locally, causing pitting.

Once the film is lost and moisture and oxygen are present, the steel corrodes. Rust occupies several times the volume of the steel it replaces, so it pushes the cover off: first a crack along the bar, then spalling, then exposed and thinning bars. The service life of a reinforced concrete element is usually described in two stages, after the model proposed by Tuutti: an **initiation period**, during which carbonation or chlorides travel through the cover to the bar, and a **propagation period**, during which corrosion progresses until cracking, spalling and loss of section become unacceptable [S65].

Durability is decided before the first bar rusts

How chlorides and carbonation reach the steel, and the two-stage service-life model (after Tuutti, schematic)



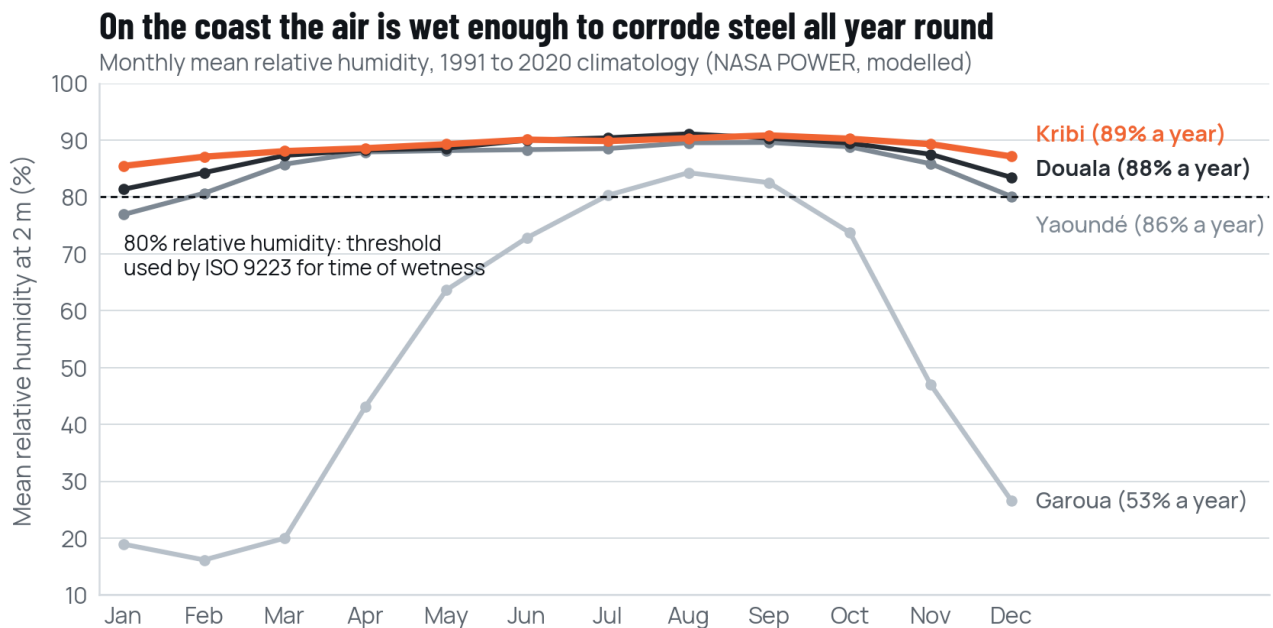
ILLUSTRATIVE Figure 8.1. Durability is decided before the first bar rusts. The cover and the quality of the concrete set the length of the initiation period; once corrosion starts, damage accelerates.

Source: Cameroon Steel schematic, after the two-stage service-life model of Tuutti [S65].

This model explains why durability is decided long before any rust appears. The length of the initiation period depends almost entirely on two things the designer and the builder control: **how thick the cover is**, and **how hard it is for carbon dioxide and chlorides to move through the concrete**. The steel's own quality matters too, but mostly in a different way: a bar that is light or brittle to begin with has less margin to lose when corrosion starts.

8.2 The coastal climate is aggressive in every month

Steel corrodes fastest when its surface is wet. International practice, codified in ISO 9223, counts the "time of wetness" as the time during which relative humidity exceeds 80% at temperatures above freezing [S47]. On that measure the Cameroonian coast is wet almost all year. Modelled climatology for 1991 to 2020 gives mean relative humidity of 89% at Kribi and 88% at Douala, with no month below 80% at Kribi; Yaoundé averages 86%, while Garoua, in the dry north, averages 53% with a long dry season [S50]. Station records at Kribi show daily maxima of 92% to 96%, daily minima of 70% to 78% and annual rainfall of about 2,836 mm [S51]. Mean temperatures of about 26 °C in both coastal cities [S50] accelerate every chemical process involved.



SOURCED Figure 8.2. On the coast the air is wet enough to corrode steel all year round. Kribi and Douala stay above the 80% humidity threshold in every or nearly every month; Garoua falls far below it in the dry season.

Source: NASA POWER climatology 1991 to 2020, modelled at the location of each city [S50]; threshold from ISO 9223 [S47].

ISO 9223 classifies the corrosivity of atmospheres from C1 (very low) to CX (extreme) on the basis of the first-year corrosion loss of reference metal samples; for carbon steel the bands rise from below about 1.3 μm per year in C1 to 50 to 80 μm in C4 and 80 to 200 μm in C5 [S47]. Coastal sites exposed to salt spray commonly fall in the high categories. No published measured corrosivity map exists for the Cameroonian coast, and this paper does not assign a category to any location (see the evidence-gaps chapter). What can be said is that the combination of permanent humidity, warmth and airborne salt places buildings within reach of the sea in the most demanding exposure classes of the design codes.

The atmospheric category matters for exposed steel, such as bars left waiting on site or starter bars protruding from a slab for months. For bars inside concrete, the relevant classification is the exposure class of the concrete, discussed next.

8.3 Eurocode 2 and EN 206 set cover and concrete quality by exposure class

European practice links durability to a small number of **exposure classes** defined in EN 206 and used by Eurocode 2 [S36][S37]. For reinforcement corrosion the important ones are XC (corrosion induced by carbonation, in four levels from dry to cyclically wet), XD (chlorides other than from sea water) and XS (chlorides from sea water): XS1 for structures exposed to airborne salt but not in direct contact with sea water, XS2 for permanently submerged parts and XS3 for tidal, splash and spray zones [S36][S37].

For each class, Eurocode 2 gives a minimum cover for durability and EN 206 recommends limiting values for the concrete. The table summarises the recommended values for a 50-year design life (structural class S4); national annexes may modify them, and the status of a Cameroonian national annex to Eurocode 2 could not be confirmed from public sources (see the evidence-gaps chapter).

Table 8.1 Recommended minimum cover and concrete limits by exposure class (Eurocode 2 and EN 206, recommended values)

Exposure class	Typical situation in Cameroon	Minimum cover for durability, $c_{min,dur}$ (mm)	Nominal cover with 10 mm tolerance (mm)	Maximum water/cement ratio	Minimum strength class	Minimum cement content (kg/m ³)
XC1	Interiors of dry or air-conditioned buildings	15	25	0.65	C20/25	260
XC2	Foundations, permanently wet	25	35	0.60	C25/30	280
XC3	Sheltered exterior, humid interiors (kitchens, bathrooms)	25	35	0.55	C30/37	280
XC4	Facades, balconies and columns exposed to rain	30	40	0.50	C30/37	300
XS1	Buildings near the coast exposed to airborne salt	35	45	0.50	C30/37	300
XS2	Parts permanently submerged in sea water	40	50	0.45	C35/45	320
XS3	Tidal, splash and spray zones: quays, sea walls, beach fronts	45	55	0.45	C35/45	340

Source: EN 1992-1-1 Table 4.4N (structural class S4) and recommended allowance for deviation of 10 mm [S36]; EN 206 Annex F recommended limiting values [S37]. Recommended values; the cover must also be at least the bar diameter for bond, and national provisions may differ.

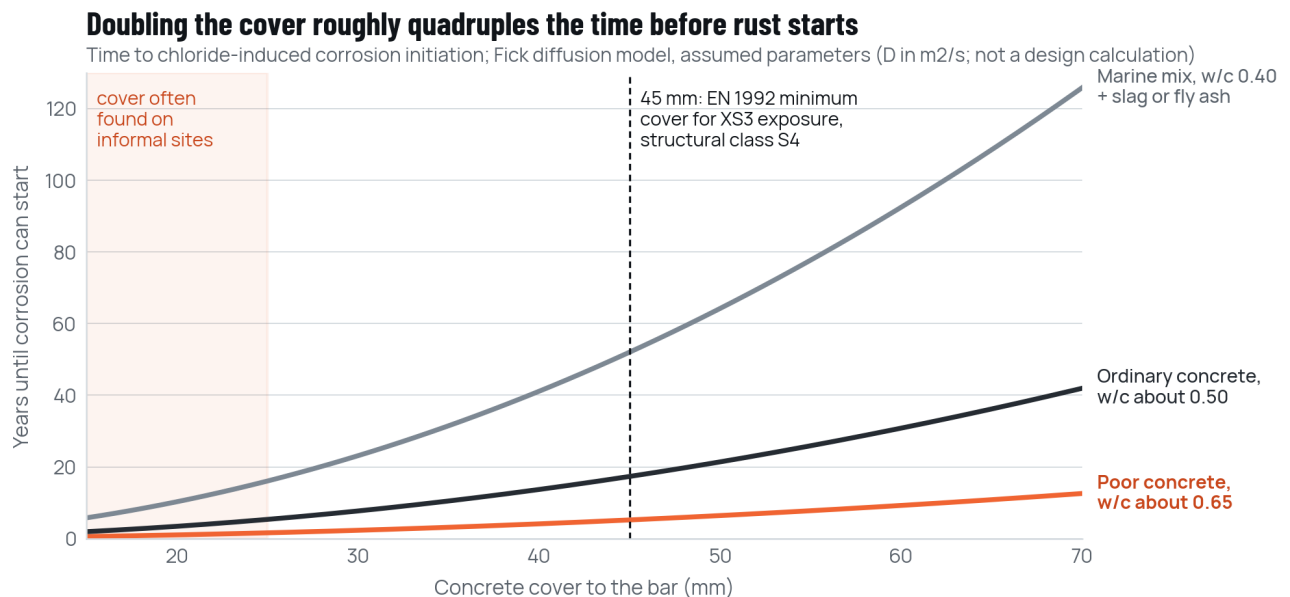
The older French rules for reinforced concrete, BAEL 91, which shaped the training of many engineers in francophone Africa, set the same order of magnitude: 5 cm of cover for works exposed to the sea or to salt spray, 3 cm for faces exposed to weather or condensation [S82]. Whatever code is used, the message is consistent: within reach of the sea, structural concrete needs about 45 mm or more of cover and a dense concrete with a low water/cement ratio.

8.4 Cover is lost on site, not in the design office

Durability failures in coastal buildings rarely start with a wrong number on a drawing. They start on site, in five ways:

- **No spacers.** Bars laid on the formwork or on stones end up with 10 mm of cover or less, whatever the drawing says. Purpose-made concrete or plastic spacers, fixed at close centres, are the cheapest durability measure available.
- **Water added for workability.** Site-batched concrete is often made wetter so that it can be placed by hand. Every litre of extra water raises the water/cement ratio and the permeability of the cover.
- **Poor compaction.** Honeycombed concrete around bars offers almost no protection.
- **No curing.** In hot, windy conditions the surface layer dries before the cement has hydrated, leaving the outer 20 to 30 mm, the cover itself, the most porous part of the element.
- **Contaminated materials.** Unwashed beach sand or sea water used in mixing brings chlorides directly to the bar from the first day.

The effect of cover and concrete quality on the time before corrosion can start is strongly non-linear. A simple diffusion model, with assumed but plausible parameters, shows the pattern: the time to initiation grows with the square of the cover, so doubling the cover roughly quadruples it, and a dense concrete with supplementary cementitious materials can multiply it again by a factor of three or more compared with ordinary concrete.



ILLUSTRATIVE Figure 8.3. Doubling the cover roughly quadruples the time before rust starts. With the assumed parameters, a poorly made concrete with 25 mm of cover could reach the corrosion threshold in under two years; ordinary concrete with 40 mm in about 14 years; a durable marine mix with 50 mm in about 64 years.

Source: Cameroon Steel calculation with Fick's second law, constant diffusion coefficients and surface chloride content of 1.5% and threshold of 0.4% by mass of binder (assumptions, Annex A). Illustrative of trends only; not a design method.

The absolute numbers in the figure depend on assumptions and should not be used for design; real diffusion coefficients fall over time as concrete matures, which lengthens the times shown. The relative effects are robust, and they are large. They also explain an observation made after the July 2023 collapse in Douala, where residents described exposed and rusted reinforcing rods on the building before it fell [S20]: rust staining and spalling are the visible end of a process that began, years earlier, with insufficient cover or permeable concrete.

8.5 Six practical rules protect reinforcement on coastal sites

Translated into site practice, the durability requirements reduce to six rules that any contractor can follow:

1. **Fix spacers** of concrete or plastic, of the thickness of the specified cover, at close centres under bottom bars and against side forms, and tie them so that they stay in place during concreting.
2. **Check the cover before every pour** with a rule at a sample of points, and correct any bar that sits on the formwork; after striking, a cover meter can confirm the result on critical elements.
3. **Hold the water/cement ratio**: batch or order concrete to the specified mix and do not add water at the pour; where workability is needed, use a plasticising admixture instead of water.
4. **Use clean materials**: washed sand and fresh water only, never sea water or unwashed beach sand, which bring chlorides straight to the bar.
5. **Cure the concrete**: keep exposed surfaces wet or covered for several days after casting, longer in hot and windy weather, so that the cover, the outer layer that protects the steel, is not the most porous part of the element.
6. **Protect waiting steel**: starter bars and bars stored near the sea should be protected or cleaned of loose rust before they are cast in, and stockpiles kept off the ground and under cover.

Maintenance completes the picture. Cracks along bars, rust stains and spalling are early warnings; repairing them promptly, by removing contaminated or carbonated concrete around the bar, cleaning the steel and restoring the cover with a suitable repair mortar, costs far less than replacing a corroded element later.

8.6 Coatings and stainless steel are for the most severe exposures

Where cover and concrete quality cannot provide enough protection on their own, or where the consequences of corrosion are severe, the bar itself can be protected. Each option has costs and conditions.

Table 8.2 Options for protecting reinforcement in aggressive exposures

Option	Standard	How it protects	Conditions and limitations	Where it makes sense in Cameroon
Uncoated carbon steel with adequate cover and dense concrete	EN 1992-1-1, EN 206	Alkalinity of the concrete; slow ingress through thick, low-permeability cover	Depends entirely on site execution: spacers, compaction, curing	The default for all buildings, including coastal ones
Low-permeability concrete with slag or fly ash	EN 206	Reduces chloride diffusion and binds chlorides	Needs mix design, supply of materials and longer curing	Coastal buildings, marine structures, foundations in saline ground
Hot-dip galvanised bars	ASTM A767	Zinc layer, sacrificial to steel	Bending before galvanising or controlled after; damaged areas need repair; less effective at high chloride levels	Facades and balconies near the sea, architectural concrete
Epoxy-coated bars	ASTM A775, ASTM A934	Barrier coating isolates steel	Coating easily damaged in handling and bending; longer anchorage lengths; site repair of damage essential	Marine and industrial structures with controlled handling
Stainless steel bars	BS 6744	Corrosion-resistant alloy	High material cost; used selectively in the most exposed zones; check compatibility with carbon-steel bars	Splash zones of quays, sea walls, critical elements
Corrosion inhibitors, coatings on concrete, cathodic protection	Various	Slow corrosion chemically or electrically	Specialist design and maintenance	Port and marine structures, repairs

Source: [S36][S37] for cover and concrete; [S58][S59][S60] for coated and stainless bars. Qualitative summary.

For most buildings the first two rows are the right answer. Coated and stainless bars are expensive tools for specific problems, and a coated bar placed with 15 mm of cover in a porous concrete gives little more protection than a plain one.



**ON THE ATLANTIC COAST THE AIR ITSELF IS AN
EXPOSURE CLASS: HUMID EVERY MONTH, WARM,
AND SALTED BY THE SEA.**

Illustrative view. Generated image of a brushed steel surface; not a photograph of any project, place or person.

8.7 Rebar quality and durability interact in three ways

The steel's own quality still matters for durability, for three reasons.

Section reserve. Corrosion removes steel. A bar that was 10% light on delivery reaches any critical loss of section 10% sooner. Durability margins and mass tolerances are the same margin, seen from two ends of a building's life.

Ductility after corrosion. Pitting does not only remove section; it concentrates strain at the pits, so corroded bars lose ductility faster than they lose strength. Research on corroded bars, including quenched and self-tempered bars, has documented this behaviour and compared steel types [S49]. A bar that starts with good ductility retains a useful margin after some corrosion; a bar that starts with little may become brittle.

Condition on arrival. Bars that arrive heavily rusted or pitted, or that have been stored for months near the sea, start life with damage. The wire-brush and weighing check described in the chapter on defects applies here, and storage rules in specifications matter more on the coast than anywhere else.

CHAPTER 9

WIRE ROD, MESH AND SECTIONS NEED THE SAME DISCIPLINE, WITH THEIR OWN TESTS

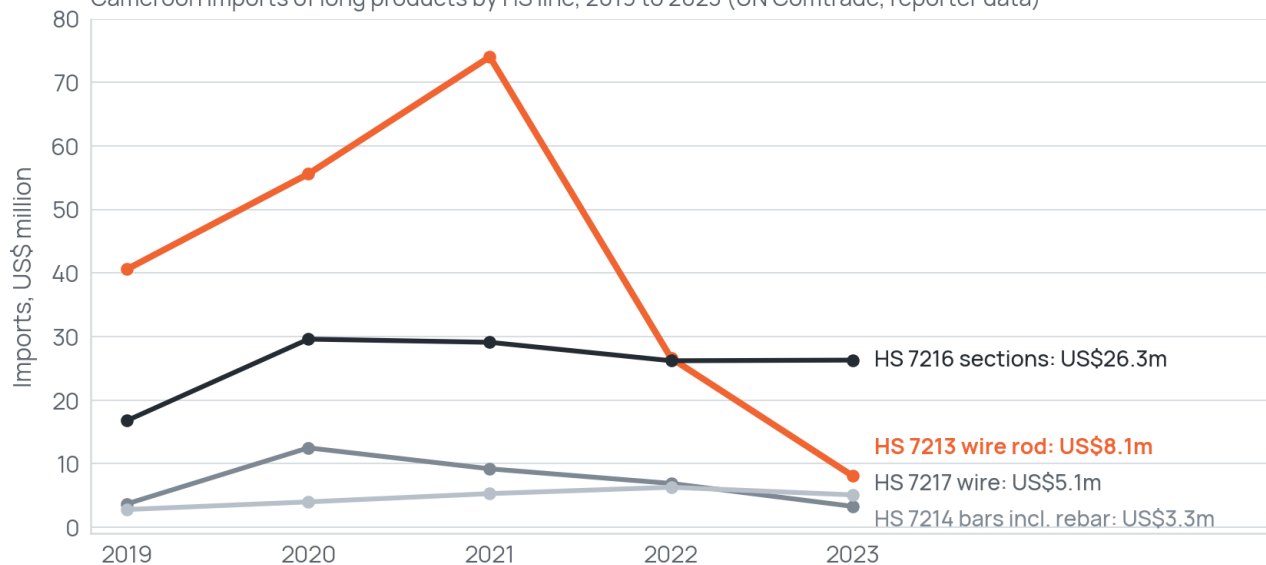
The arguments made for rebar apply to the other long products that hold buildings together. Wire rod is converted into binding wire, nails and the cold-worked wire used in welded mesh, whose ductility is lower by nature and must be declared and controlled; welded mesh adds the strength of its welds to the list of properties; and structural sections are governed by a different family of standards with their own grades, tolerances and toughness requirements. Wire rod is now largely rolled in Cameroon, while sections are still imported, which places the quality burden on domestic mills for the first and on import controls and buyers for the second.

9.1 The product mix is shifting from imports to domestic production

Customs data show how quickly the supply of long products has changed. Recorded imports of wire rod (HS 7213) peaked at US\$74.0 million in 2021 and fell to US\$8.1 million in 2023, from about 58 kt to under 8 kt, as domestic rolling replaced them [S52]. Imports of bars including rebar (HS 7214) were already marginal because of the 2016 ban. Imports of sections (HS 7216), by contrast, held steady at around US\$26 million a year between 2020 and 2023, and imports of fabricated structures (HS 7308) reached US\$58.0 million in 2023 [S52]. The domestic industry reports capacity of about 72 kt a year for wire rod and nails against demand of about 36 kt [S53].

Wire rod is now made at home; sections are still imported

Cameroon imports of long products by HS line, 2019 to 2023 (UN Comtrade, reporter data)



SOURCED Figure 9.1. Wire rod is now made at home; sections are still imported. Wire-rod imports fell by about nine-tenths between 2021 and 2023, while section imports remained at about US\$26 million a year.

Source: UN Comtrade public API, Cameroon reporter data, HS 7213, 7214, 7216 and 7217, 2019 to 2023 [S52]. Values in current US dollars; later years not yet reported.

For quality, the shift has a simple meaning. For wire rod and the products made from it, the controls that matter are those of domestic mills, ANOR certification and market surveillance, exactly as for rebar. For sections and fabricated steelwork, the controls that matter are import conformity assessment under PECAE [S15], the inspection certificates that accompany imported steel, and the checks made by fabricators and site engineers.

9.2 Wire rod: the quality of every wire product starts in the rod

Wire rod is hot-rolled in coils, typically 5.5 to 12 mm in diameter, and is the feedstock for drawing into wire. Its quality is defined less by its own strength than by its **drawability**: the ability to be drawn through successive dies into fine wire without breaking. Drawability depends on chemistry (low residual elements and low nitrogen, which otherwise cause strain-ageing and breakage), on surface quality (laps, seams and scale pits become breaks in the drawn wire), on dimensional accuracy and ovality, and on microstructure, which is set by controlled cooling of the coil after the last stand. The European and international reference for non-alloy steel wire rod intended for drawing is the EN ISO 16120 series [S62].

Three wire products made from rod matter for building safety:

- **Binding (tying) wire**, an annealed soft wire used to tie cages. It carries no structural load, but brittle or undersize tying wire lets cages deform during concreting, moving bars out of position and reducing cover.
- **Cold-drawn or cold-ribbed wire** for welded mesh and for small-diameter reinforcement. Cold working raises strength but lowers ductility; such wire typically falls into ductility class A [S33].
- **Nails and fixings** for formwork, whose quality affects formwork stability and therefore the geometry of the finished concrete.

A mill rolling wire rod controls it with the same tools as rebar: heat chemistry, surface inspection, dimensional checks, tensile tests and, for drawing grades, tests that reflect drawability. A merchant or user can check diameter with a caliper, and coil mass against the label.

9.3 Welded mesh: declared ductility and strong welds

Welded mesh (welded fabric) is a grid of longitudinal and transverse wires or bars welded at every intersection. It is widely used in slabs, ground-bearing floors, walls and precast elements because it is fast to place and holds bar spacing accurately. Two properties distinguish it from loose bars.

Ductility class. Mesh is often made from cold-worked wire, which is usually class A. Eurocode 2 defines the same three ductility classes for fabric as for bars, with the same limits on the strength ratio and strain at maximum force, and a lower fatigue stress range for fabric (100 MPa against 150 MPa for bars) [S30]. In the United Kingdom, fabric to BS 4483 is made from BS 4449 material, apart from two light wrapping fabrics [S33] [S63], and below 8 mm diameter BS 4449 steel does not conform to the Eurocode 2 ductility requirements [S33]. The practical consequence is that a slab designed with moment redistribution that assumes class B behaviour should not be built with class A mesh unless the designer has checked it.

Weld strength. The welds must be strong enough to anchor the transverse wires, because in many uses the transverse wires provide anchorage of the main wires. Test methods for welded fabric, including the shear test of welded joints, are given in EN ISO 15630-2 [S84]. A mesh whose welds break when the sheet is handled, or whose wires are burned through at the welds, has a hidden weakness at every intersection.

On site, mesh can be checked by measuring wire diameters and spacing, weighing a sheet against its nominal mass, inspecting welds for burn-through and broken joints, and reading the label for the producer, the standard, the wire grade and the ductility class.

Table 9.1 Quality requirements and checks for long products other than rebar (summary)

Product	Examples of governing standards	Key quality parameters	Typical defects	Practical checks
Wire rod for drawing	EN ISO 16120 series	Chemistry (residuals, N), surface, diameter and ovality, microstructure	Laps and seams, high residuals, poor coil cooling	Diameter, coil mass, mill certificate
Binding wire	Producer specification	Softness (annealed), diameter	Brittle or undersize wire	Twist and bend by hand, diameter
Cold-worked wire and bars	BS 4449 (B500A), ISO 6935 family	Strength, Agt (class A), rib geometry	Low Agt, cracking at bends	Bend test, certificate showing Agt
Welded mesh	BS 4483; EN 1992 Annex C (fabric classes); EN ISO 15630-2 (tests)	Wire grade and class, mesh geometry, weld shear strength	Class A mesh where class B is assumed; weak or burned welds	Spacing, diameter, sheet mass, weld inspection, label
Light and medium sections (angles, channels, flats)	EN 10025-2 grades S235, S275, S355; ASTM A36	Yield, tensile, elongation, impact toughness grade, thickness tolerance	Undersize thickness, wrong grade, lamination	Thickness by caliper, mass per metre, inspection certificate
Heavy sections (I and H beams)	EN 10025-2; ASTM A992	As above, plus flatness and straightness	Wrong grade, poor toughness for welded connections	Inspection certificate 3.1, PECAE certificate, dimensions
Fabricated structures	Execution standards for steel structures	Welding procedure and welder qualification, coating	Poor welds, corrosion protection	Fabrication records, weld inspection

Source: [S30][S33][S61][S62][S63][S84]; summary for orientation only.

9.4 Structural sections belong to a different family of standards

Angles, channels, I and H sections and flats used in steel frames, roofs, mezzanines and composite construction are governed not by rebar standards but by structural steel standards. In the European family, EN 10025-2 defines non-alloy structural steels by minimum yield strength (S235, S275, S355) and by impact toughness sub-grade (JR, JO and J2, tested at plus 20 °C, 0 °C and minus 20 °C respectively), with chemistry and carbon-equivalent limits that ensure weldability [S61]. American practice uses ASTM A36 for general sections and ASTM A992 for wide-flange beams. Chinese suppliers use their own national grades, such as Q235 and Q355.

For sections, three quality issues recur in import markets:

- **Thickness and mass.** A section rolled thinner than its nominal dimensions carries less load and buckles sooner. Mass per metre, again, is the simplest check: a channel or angle weighed and compared with the producer's table reveals undersize rolling.
- **Grade.** S235 and S355 look identical. Only the inspection certificate, matched to markings on the product, distinguishes them, and the difference in yield strength is 50%.
- **Toughness for welded and exposed structures.** Welded connections in thick sections, and structures exposed to impact or fatigue, need a toughness sub-grade appropriate to their use; a JR grade where JO or J2 is specified is a hidden defect.

Because sections are imported, the first line of control is PECAE, under which consignments are verified against Cameroonian or equivalent international standards before shipment, with physical inspection and laboratory tests depending on the verification route [S15]. The second line is the buyer: a type 3.1 inspection certificate per heat, matched to markings, and a check of dimensions and mass on delivery. Fabricators who cut and weld sections should also keep the heat traceability through fabrication, so that each member of a finished structure can be linked to its certificate.

9.5 Hollow sections and fabricated steelwork deserve the same scrutiny

Tubes and hollow sections are used for columns, trusses, canopies, handrails and scaffolding. Cameroon imported US\$26.0 million of welded tubes and hollow sections (HS 7306, about 9.5 kt) in 2023, while domestic capacity for tubes was reported at 34 kt against demand of 14 kt [S52][S53]. For structural hollow sections, the European references are EN 10219 for cold-formed sections and EN 10210 for hot-finished ones [S86]. The common defects are a wall thicker on the drawing than in the tube, a weld seam that is incomplete or brittle, and a grade lower than specified. Wall thickness is measurable with a caliper at the tube ends; mass per metre, again, confirms it.

Fabricated steel structures, which Cameroon imported to a value of US\$58.0 million in 2023 (HS 7308) [S52], add the quality of fabrication to that of the steel: welding procedures, welder qualification, bolt grades and corrosion protection. A buyer should ask for the inspection certificates of the steel used, the welding procedure records and, for important structures, independent inspection of welds. The heat traceability of members, from mill certificate to fabrication drawing, is the equivalent for sections of the bundle tag for rebar.

On delivery, the checks are as simple as for bars. For **mesh**, count and measure the wire spacing, measure wire diameters, weigh a sheet against its nominal mass, and inspect welds for burn-through and broken joints. For **sections and tubes**, measure flange, web and wall thicknesses at several points, weigh a length against the producer's table, read the markings and match them to the certificate.

PUBLIC-RECORD EXAMPLE

Cameroon Steel's public-record first phase is an electric arc furnace melt shop whose billets are rolled into reinforcing bar and wire rod or sold to existing re-rollers [S01][S02]. Its indicative development plan adds light and medium sections in a second phase and heavy sections in a third (planned, subject to studies and approvals). The same quality architecture proposed in this paper for rebar, with heat traceability, laboratory testing and third-party certification, would apply to each product as it is introduced. These are objectives, not descriptions of existing production.

9.6 Imported long products need checks matched to their risk

Because sections, tubes and much of the mesh used in Cameroon are imported, the decisive question for buyers is how much to rely on the documents that accompany them. PECAE offers three verification routes, from inspection and laboratory testing of every consignment to documentary checks for registered products from regular exporters [S15]. A buyer of structural steel should know which route a consignment followed, keep its certificate of conformity with the mill's inspection certificates, and match both to the markings on the steel. Where the steel will carry significant loads, as in the frames of warehouses, schools and markets, an independent check of thickness, mass and, if in doubt, tensile properties on a few samples is inexpensive insurance.

9.7 Domestic production of sections will need its own certification

Several producers in the region, including Cameroon Steel in its indicative later phases, plan to roll angles, channels and eventually heavier sections. When sections are made in Cameroon rather than imported, the quality burden will shift from import controls to domestic certification, exactly as it did for rebar after 2016. It is worth preparing for that shift now, for three reasons.

First, **structural sections are certified against different properties**. In addition to yield and tensile strength and elongation, structural steels are graded by impact toughness, measured with a Charpy pendulum on notched specimens at a specified temperature, and their chemistry is limited for weldability [S61]. A mill rolling sections needs an impact-testing machine, notch-cutting equipment and the ability to cool specimens to the test temperature, none of which a rebar laboratory requires.

Second, **dimensional tolerances are more complex**. Sections are checked for flange and web thickness, depth, width, out-of-square, straightness and mass per metre, and each of these affects buckling and connection design. Rolling sections to tolerance requires roll design, roll-change discipline and measurement routines that go beyond those of a bar mill.

Third, **there is no Cameroonian standard yet in the public record for structural sections comparable to NC 236 for rebar**, and this paper did not find one. If domestic production grows, ANOR and the industry will need to decide whether to adopt an international reference, such as the EN 10025 family, as a national standard, whether to make it mandatory, and how to certify producers against it. Doing so before the first domestic sections reach the market would avoid repeating the experience of rebar, where a mandatory standard arrived in 2022, years after the import ban had made the market almost entirely domestic.

For buyers in the meantime, the rule is the one applied throughout this paper: name the grade and toughness sub-grade, ask for the inspection certificate tied to the heat, and check thickness and mass on delivery.

A STANDARD FOR SECTIONS ADOPTED BEFORE THE FIRST DOMESTIC SECTIONS REACH THE MARKET WOULD AVOID REPEATING THE REBAR EXPERIENCE.

Preparing for domestic sections

9.8 One quality system can serve all long products

The disciplines that make good rebar are the same for every long product, which is why mills and regulators can extend them at little extra cost:

1. **Heat traceability** from the furnace to the bundle, coil or section.
2. **Chemistry on every heat**, with the carbon equivalent reported.
3. **Mechanical and dimensional tests** by standard methods, in a laboratory whose competence is demonstrated.
4. **Inspection certificates** of type 3.1 tied to heat numbers.
5. **Third-party certification**, by ANOR and, where available, by an independent product certification body.
6. **Simple checks by the user**: dimensions, mass, markings and certificates.

For a country whose domestic industry now covers rebar and wire rod and whose sections are imported, this means two things in practice. ANOR's certification and market surveillance should extend from rebar to wire rod and mesh as domestic production of these products grows, and import controls and buyers' checks on sections should be applied with the same rigour as for domestic bars. A rebar standard enforced in isolation leaves the rest of the structure unguarded.

CHAPTER 10

TEN MEASURES WOULD RAISE THE FLOOR OF REBAR QUALITY WITHIN FIVE YEARS

Cameroon does not need a new legal framework for rebar quality; it needs the existing one to reach the merchant's yard and the building site. Ten measures, most of them administrative and inexpensive, would do this: make the standard and the list of certified producers public, strengthen certification with surveillance and statistics, sample and publish at merchants, price by the tonne, require certified steel in public contracts and permitted buildings, build accredited testing capacity, train the people who handle steel, set durability rules for the coast and report annually. Three of them, transparency of certification, stronger certification and a public procurement clause, carry most of the benefit and can start in 2027.

10.1 The strategy is to make good bars easy to recognise and bad bars risky to sell

The previous chapters lead to a simple diagnosis. The mandatory standard is right and has been defended. The weak points are information and incentives downstream of the mill: buyers cannot easily tell a certified bar from an uncertified one, merchants are paid per bar rather than per kilogram, few sites check deliveries, and non-conformity is rarely made public. A substandard bar therefore competes on price with a good one, and often wins.

The ten measures below change that balance in three ways:

- **Transparency:** buyers can see which producers are certified, what their marks look like and how their products performed in surveillance.
- **Incentives:** price and payment are tied to the mass and certification of steel, not to the number of bars.
- **Checks at every layer:** mills test themselves and are audited, merchants are sampled, sites accept deliveries against a routine, and public contracts pay only for accepted steel.

None of the measures relaxes the standard, imports a new regulator or requires large public spending. Most can be implemented by the institutions that already exist, with modest budgets for sampling, testing and training.

Table 10.1 Ten recommendations to raise the floor of rebar quality in Cameroon

No.	Measure	Lead	Instrument	Start or window	Indicator of success
R1	Publish the essential requirements of NC 236 and a public register of certified producers, with their rolled-in marks and certificate validity	ANOR	Website register; free summary of the standard	2027	Register online and updated monthly
R2	Strengthen certification: surveillance audits, independent sampling, statistical evaluation of characteristic values, mandatory reporting of Agt, Rm/Re and Ceq	ANOR, producers	Certification rules; scheme document	2027	All certified producers audited and sampled at least twice a year
R3	Sample rebar at merchants in the main cities and publish results by brand and diameter	ANOR, MINCOMMERCE	Market surveillance programme	2027	Share of conforming samples rising year on year
R4	Homologate prices per tonne and require the nominal mass per bar to be displayed; allow sale by weight	MINCOMMERCE	Homologation decision	2027	Price lists in FCFA per tonne; mass displayed at merchants
R5	Require certified NC 236 bars with class B ductility, type 3.1 certificates and site acceptance in all public works contracts; pay only for accepted steel	Ministry of Public Contracts, contracting authorities	Standard bidding documents; supervision terms of reference	2027	Clause in all new public works contracts
R6	Link building permits for multi-storey and public buildings to certified steel, acceptance records and inspection before concreting	MINHDU, municipalities	Permit conditions; inspection checklists	2027 to 2029	Share of permitted sites with acceptance records
R7	Build accredited testing capacity for rebar in each main city, including mobile testing for sites	ANOR, public and private laboratories, universities	ISO/IEC 17025 accreditation; ANOR qualification platform	2027 to 2029	Number of laboratories qualified for rebar tests, by city
R8	Train masons, foremen and engineers in steel acceptance, bending, cover and storage	Producers, professional bodies, vocational and engineering schools	One-day site module; curriculum updates	2027 onwards	People trained per year; modules in curricula
R9	Set durability rules for coastal construction: cover, spacers, concrete mixes and curing by exposure class	MINHDU, ANOR	Technical guidance; national annex values	2027 to 2028	Guidance published; cover checked in inspections
R10	Publish an annual report on rebar conformity, surveillance results and enforcement actions	ANOR	Annual report	2028 onwards	Report published each year

Source: Cameroon Steel proposals based on the analysis in this paper. Leads are indicative; institutions decide their own programmes.

10.2 Transparency comes first because it costs least and helps everyone

R1. Publish the essentials and the register. The full text of NC 236 is a priced document, which is normal for standards. But a buyer does not need the full text to protect himself; he needs to know which grades are lawful, what properties they guarantee, how bars must be marked, and which producers hold a valid certificate. ANOR

already publishes communiqués and runs an online reporting channel [S74]; a public register of certified rebar producers, with a photograph of each producer's rolled-in mark, the grades and diameters covered and the validity dates, would let any merchant, engineer or mason verify a bundle in minutes. Certification bodies abroad already publish their certificates for this reason [S31].

R10. Report every year. An annual report on rebar conformity, giving the number of samples tested, the share conforming by city and by brand, and the enforcement actions taken, turns surveillance into deterrence. Published results reward compliant producers in the market, which is the most durable incentive available.

10.3 Certification must prove the population, not the sample

R2. Strengthen certification. A conformity certificate is valuable to the extent that the production it covers is audited and sampled after the certificate is granted. The Fe450 episode showed both the value and the limits of certification: a certificate covering a grade absent from the standard was issued, then withdrawn nine months later [S04][S05]. A certification scheme for rebar should include, at a minimum:

- an initial assessment of factory production control, laboratory competence and traceability;
- periodic surveillance audits, unannounced where possible;
- independent sampling at the mill and in the market, with testing in a qualified laboratory;
- statistical evaluation of the producer's results against the characteristic values of the standard (see the testing chapter);
- mandatory reporting of ductility (Agt and Rm/Re) and of the carbon equivalent, so that buyers can see the properties a Eurocode-based design relies on;
- clear rules for suspension and withdrawal, and publication of both.

International practice offers tested models, such as the AFCAB and CARES schemes [S31][S33], and Cameroonian producers who already hold management-system certificates under ISO 9001 [S10][S78] have part of the documentation in place.

A CERTIFICATE IS WORTH AS MUCH AS THE SURVEILLANCE THAT FOLLOWS IT.

Certification after the certificate

10.4 Surveillance and pricing reach the point of sale

R3. Sample at merchants and publish. Market surveillance closes the loop between the mill and the buyer. A programme that buys bars anonymously at hardware merchants in Douala, Yaoundé and the regional capitals, weighs and tests them, and publishes the results by brand and diameter, would expose light and mislabelled products quickly. Weighing alone, which costs almost nothing, would catch the commonest defect. The programme can be shared between ANOR, which certifies and surveys products [S16], and the Ministry of Commerce, which already controls prices at retail [S11].

R4. Price by the tonne. Homologating prices per tonne, with the per-bar price derived from the nominal mass, removes the incentive to roll light bars without changing the price level (see the chapter on the quality infrastructure). Requiring merchants to display the nominal mass of each bar and allowing sale by weight gives buyers the information to protect themselves. The fiscal system already uses a tonnage basis for steel, through the environmental tax introduced in 2026 [S66].

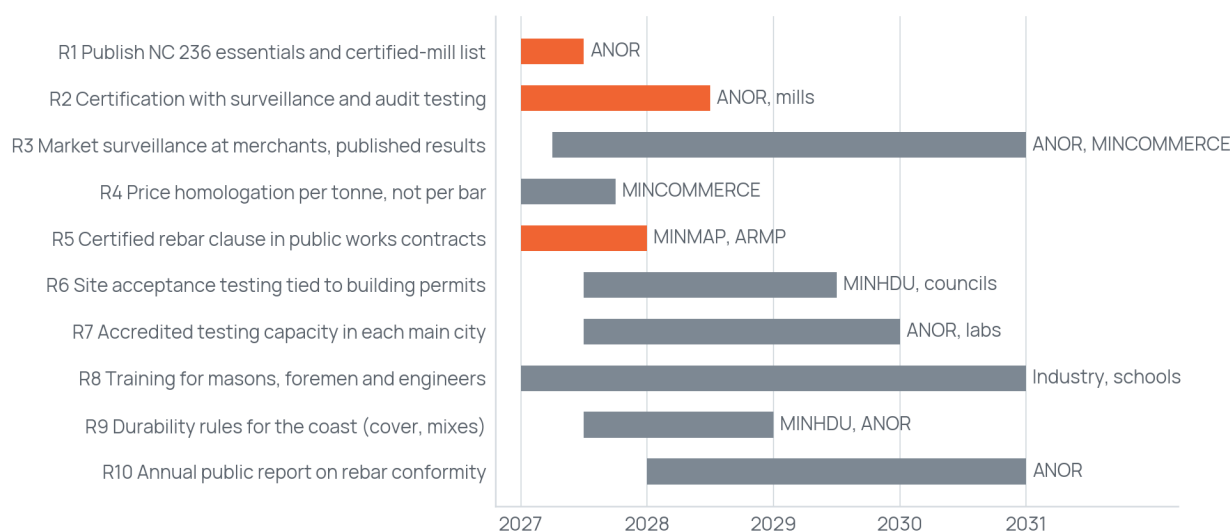
10.5 Public procurement and building permits create demand for certified steel

R5. Make certified steel a condition of payment in public works. The State's public investment budget of 2,026.3 billion FCFA in 2026 [S80] makes it the decisive buyer. A standard clause in the technical specifications of public works contracts, based on the model clauses in this paper, together with supervision terms of reference that include rebar acceptance and payment conditions that require acceptance records, would create a large and predictable demand for certified bars. The public procurement framework set by Decree No. 2018/366 [S54] and the standard bidding documents of the Ministry of Public Contracts [S81] are the natural vehicles.

R6. Link permits to materials. For multi-storey and public buildings, the building permit could carry conditions requiring certified steel, a site acceptance record for each delivery and an inspection of reinforcement before each concrete pour. Municipalities already seal buildings at risk, as in Douala in 2026 [S22]; adding a materials condition at the permit stage moves control from the end of a building's life to its beginning.

Three early measures carry most of the benefit; all ten fit in five years

Indicative implementation calendar for the recommendations (orange: first-year priorities)



ILLUSTRATIVE Figure 10.1. Three early measures carry most of the benefit; all ten fit in five years. Transparency (R1), stronger certification (R2) and the public procurement clause (R5) can start in 2027 with existing institutions.

Source: Cameroon Steel indicative calendar. Timing depends on decisions by the institutions concerned.

10.6 Testing capacity and skills make the measures work

R7. Build accredited testing capacity. Certification, surveillance and site acceptance all need laboratories that can test rebar reliably: a calibrated universal testing machine with an extensometer, bending equipment, a balance and trained staff working to EN ISO 15630-1 and ISO 6892-1 [S44][S45], with competence demonstrated under ISO/IEC 17025 [S55]. ANOR's programme of laboratory qualification visits in five cities [S18] is the right starting point. The aim should be at least one qualified laboratory for rebar in each main city, with mobile capacity for sites far from them, and with fees low enough that a contractor will use them.

R8. Train the people who handle steel. The person who decides whether a bundle is used is often a foreman or a mason. A one-day practical module, covering marks, weighing, bending, storage, cover and spacers, can be delivered on site by producers, professional bodies and vocational schools. Engineering curricula should give future engineers a firm grounding in steel properties, standards and certificates; the departments of the national polytechnic school in Yaoundé include civil, mechanical and industrial engineering but no dedicated metallurgy department [S85].

R9. Set durability rules for the coast. Guidance on cover, spacers, concrete mixes and curing by exposure class, consistent with Eurocode 2 and EN 206 recommended values [S36][S37], would make durability on the coast a matter of routine rather than individual judgement. Values chosen for a national annex should be published so that designers use them consistently.

10.7 Producers have their own part to play

The measures above are mainly for public institutions. Producers, including new entrants, can raise the floor faster than any regulation by competing on proven quality. In practice this means rolling every bar with a legible mill mark, aiming at nominal mass rather than the edge of the tolerance, publishing the properties their certificates guarantee, supplying a type 3.1 certificate with every delivery, inviting independent sampling, and supporting training for the masons and foremen who use their products.

PUBLIC-RECORD EXAMPLE

Cameroon Steel, which is developing a steel complex at Mboro in the Kribi industrial-port zone with a first phase built around an electric arc furnace melt shop whose billets are rolled into reinforcing bar and wire rod or sold to existing re-rollers [S01][S02][S03], has set itself the objective, stated in this paper, of supplying only certified products: bars certified by ANOR to NC 236 and by an independent body to a recognised international reference, with heat-number traceability, published guaranteed properties and support for site acceptance and training. This is a stated objective of a project under development; delivery will depend on construction, commissioning and certification.

10.8 The benefits are large and fall on the public

The costs of these measures are modest: sampling and testing budgets, laboratory equipment and accreditation, training days and administrative time. Their benefits fall on the people who live and work in Cameroonian buildings, most of whom never see the steel inside their walls. A higher floor of rebar quality protects them in three ways: against the loss of strength that a light or mislabelled bar silently imposes, against the loss of warning that a brittle bar brings, and, on the coast, against the early corrosion that thin cover and poor concrete invite.

For the steel industry the measures are also an opportunity. A market in which quality is visible rewards investment in melt shops, laboratories and certification, and supports exports to neighbouring countries, which already absorb about 31,000 t of Cameroonian bars a year [S52][S76], and where buyers increasingly ask for proof. The policy already chosen by the Government, to hold the standard rather than dilute it [S06][S07], points in the same direction. The task now is to make that standard visible in every bundle sold and every column cast.

10.9 Progress should be measured and published

The measures will only be judged effective if their results are measured. Five indicators, published each year in the conformity report proposed under R10, would tell the public, the industry and the Government whether the floor is rising:

1. **Market conformity:** the share of bars sampled at merchants that meet the mass tolerance, carry a legible mill mark and pass tensile and bend tests, by city and by producer.
2. **Certified output:** the number of producers holding a valid certificate and the share of domestic rebar output that they represent.

3. **Public procurement coverage:** the share of new public works contracts that include the certified-steel clause, and the share of interim payments supported by acceptance records.
4. **Testing capacity:** the number of laboratories qualified for rebar tests in each main city, and the average time and cost of a test.
5. **Skills:** the number of masons, foremen and engineers trained each year in steel acceptance and fixing.

A baseline for the first indicator requires the national sampling survey described in the evidence-gaps chapter. Once it exists, targets can be set; this paper proposes, as an aim for discussion rather than a forecast, that within five years at least 95% of bars sampled at merchants should meet the mass tolerance and carry a legible mill mark. Publishing the indicators is itself a measure: it rewards the producers and merchants who comply, and tells buyers where to buy.

CHAPTER 11

EVIDENCE GAPS: WHAT IS NOT YET KNOWN, AND HOW IT CAN BE FOUND OUT

The paper's conclusions rest on the mandatory status of NC 236, the published enforcement record, the international standards and the few published tests of market and site rebar. Several facts that would sharpen the analysis are not in the public record: the full technical requirements of the current edition of NC 236, a representative national picture of rebar conformity, official findings on recent collapses, the testing capacity of Cameroonian laboratories and measured corrosion on the coast. None changes the direction of the recommendations; each would improve their targeting. Most can be resolved within a year at modest cost.

11.1 Ten gaps matter for policy and practice

The table lists the gaps, why each matters, how it could be closed and by whom. Cost ranges are Cameroon Steel estimates for budgeting orientation only, not quotations.

Table 11.1 Evidence gaps, resolution methods and indicative costs

No.	Gap	Why it matters	How to resolve	Who	Indicative duration	Indicative cost (estimate)
G1	Full technical requirements of the current edition of NC 236 (NC 236/2024/06): ductility, maximum yield, mass tolerances, chemistry, marking, conformity assessment	Determines whether the national grade guarantees the properties Eurocode-based designs assume	Obtain the standard from ANOR; publish a free summary of essential requirements	ANOR	1 to 3 months	Staff time
G2	Register of ANOR-certified rebar producers, scope and validity of certificates, and mill marks	Buyers cannot verify certification without it	Publish and maintain a public register	ANOR	3 months	Staff time; website
G3	Representative national data on rebar conformity at merchants and on sites	Only one peer-reviewed Cameroonian site study is public [S19]; no surveillance results are published	Stratified sampling in six cities: about 200 bar samples, tensile, bend, mass, chemistry	ANOR with a qualified laboratory; academic partner	6 to 9 months	25 to 60 million FCFA

No.	Gap	Why it matters	How to resolve	Who	Indicative duration	Indicative cost (estimate)
G4	Official technical findings on the July 2023 and July 2026 Douala collapses	Without findings, debate on causes, including steel, remains speculative	Publish investigation conclusions; include material tests in future investigations	Ministry of Housing and Urban Development; judicial authorities	Ongoing	Not applicable
G5	Testing capacity: number, location and accreditation of laboratories able to test rebar to EN ISO 15630-1	Certification, surveillance and site acceptance all depend on it	Survey of public and private laboratories, building on ANOR's qualification visits [S18]	ANOR; laboratories	3 to 6 months	5 to 15 million FCFA
G6	Status of a Cameroonian national annex to Eurocode 2 and the values adopted for reinforcement and cover	Designers need nationally determined values for yield, ductility and durability	Confirm status; publish values; align with NC 236	Ministry of Housing and Urban Development; ANOR; professional bodies	6 to 18 months	Staff time and committee costs
G7	Measured atmospheric corrosivity and chloride deposition on the coast (Douala, Kribi, Limbe)	Cover and protection choices depend on exposure, which is unmeasured	One-year exposure of steel coupons and chloride candles at 8 to 12 sites, to ISO 9223 methods	University or research centre with ANOR	12 to 15 months	15 to 40 million FCFA
G8	Actual cover and concrete quality in existing buildings, especially on the coast	Indicates the scale of the durability problem and the value of guidance	Cover-meter and carbonation-depth survey of a sample of buildings	Engineering schools; municipalities	6 months	10 to 25 million FCFA
G9	Coverage of steel products by PECAE (billets, wire, mesh, sections) and results of checks on steel	Imported sections and wire depend on PECAE for conformity control	Publish product lists and aggregate results for steel	ANOR; inspection bodies	3 months	Staff time
G10	Current homologated rebar prices after October 2023, and street prices by city	Needed to quantify the effect of per-bar pricing over time	Publish current homologation decisions; price survey	Ministry of Commerce	1 to 3 months	Staff time; 2 to 5 million FCFA for a survey

Source: Cameroon Steel analysis. Costs are estimates for orientation, in 2026 FCFA, excluding taxes.

11.2 Three gaps deserve priority

The content of NC 236 (G1). This paper deliberately does not reproduce the numerical requirements of the national standard, because its full text was not available from public sources at the evidence cut-off. Whether NC 236 requires a strain at maximum force and a strength ratio equivalent to ductility class B, caps over-strength, sets mass tolerances like those of the European family and requires a carbon-equivalent limit, determines how much a Cameroonian specifier must add to "NC 236 Fe500" in a contract. A free summary of essential requirements, of the kind many standards bodies publish, would close this gap at almost no cost.

A national conformity baseline (G3). The only peer-reviewed Cameroonian study found by this research sampled bars on building sites in four cities and found that 11 of 24 bars (46%; the study reports 52%) had yield stresses below 400 MPa [S19]. The sample is small (bars of 10 to 14 mm), the sampling dates are not stated, and

the headline share in the article does not match its own counts; its findings may not represent the market of 2026, after the mandatory standard and the 2024 enforcement action. A properly stratified survey, repeated annually, would both measure progress and form the backbone of the annual conformity report recommended in Chapter 10.

Testing capacity (G5). Every recommendation that involves testing, from certification to site acceptance, assumes that a contractor in Douala, Yaoundé or Garoua can have three bars tested reliably within a few days at a reasonable price. Whether this is true today is not known from public sources.

PRIORITY GAPS AT A GLANCE

The three priority gaps (G1, G3 and G5) could be closed within about a year. Using the indicative ranges in Table 11.1, their combined cost is estimated at 30 to 75 million FCFA, mostly for the national sampling survey, plus staff time at ANOR (estimate).

11.3 What the answers could change, and what they could not

It is worth stating in advance how the resolution of each priority gap could alter the paper's conclusions, so that new evidence can be read against them.

- **If NC 236 already requires class B ductility, an overstrength cap, European-family mass tolerances and a carbon-equivalent limit (G1)**, specifiers would need to add little to "NC 236 Fe500", and the model clauses of Chapter 7 would shrink to a reference to the national standard and the proof of conformity. If it does not, the clauses become more important, and a revision of the standard to add those properties, rather than to add grades, would deserve consideration.
- **If a national survey finds high conformity among marked bars and failures concentrated among unmarked ones (G3)**, as the Cameroonian site study suggests [S19], the priority would shift further towards market surveillance, refusal of unmarked bars and site acceptance (R3, R6, R8). If it finds non-conformity among certified products as well, certification itself (R2) would need to be strengthened first.
- **If accredited testing capacity is already adequate in the main cities (G5)**, R7 becomes a lower priority. If it is not, it becomes a precondition for surveillance and for the public procurement clause, because neither can work without laboratories that contractors and authorities trust.
- **If investigations identify reinforcement as a contributing cause of recent collapses (G4)**, the urgency of every recommendation increases. If they do not, the case for the measures stands on its own: they are inexpensive ways of verifying, before construction, a component whose failure is otherwise invisible.
- **If measured corrosivity on the coast proves very high (G7)**, protective options for splash zones, such as low-permeability concrete and coated or stainless bars, would move from special cases to standard practice for buildings on the seafront.

None of these outcomes would reverse the direction of the paper. Each would change the order and emphasis of the measures, which is why the annual conformity report proposed in Chapter 10 should also report progress on closing these gaps.

11.4 Evidence from laboratories and sites can be pooled

Much of the missing evidence already exists in scattered form: in the test reports that laboratories issue to contractors, in the acceptance records of well-run sites and in the files of engineers who investigate damaged buildings. Pooled, these records would give a far better picture of the market than any single study. The

minimum useful record for each bar tested is short: city and date of sampling; where the bar was obtained (merchant, site, mill); declared diameter and grade; rolled-in mark, if any; measured mass per metre; yield strength, tensile strength and Agt; bend result; and the laboratory and test method.

Cameroon Steel invites laboratories, engineers, contractors and public bodies to share such records, stripped of client and project names, so that aggregated and anonymised results can be published in later editions of this paper. The format is deliberately the same as the one proposed for ANOR's annual conformity report, so that the two can eventually be merged into a single public data set.

11.5 How this paper will be updated

Cameroon Steel will revise this paper as gaps close: when ANOR publishes the essentials of NC 236 or a register of certified producers, when surveillance results or new studies appear, and when the status of the national annex is confirmed. Corrections and additional sources are welcome. The edition date on the cover and in the document control table identifies each version.

ANNEX A

METHODS, ASSUMPTIONS AND DERIVED CALCULATIONS

This annex explains how every derived number in the paper was obtained, states the assumptions behind the illustrative models with their plausible ranges, and records the conventions used. The scripts that generate the charts, and the data behind each chart in machine-readable form, are published with the web edition.

A.1 Evidence statuses and conventions

Each figure and table carries one of four statuses. **Sourced**: the value was read in the cited source (Annex C). **Derived**: the value is Cameroon Steel's arithmetic on sourced inputs, with the method given below. **Assumed**: a stated modelling or planning assumption. **Illustrative**: a schematic or simulated example that shows a mechanism, not data.

Currency is the CFA franc (FCFA, XAF), pegged at 655.957 FCFA to the euro. Prices are quoted as published, without inflation adjustment. Stresses are in megapascals (MPa = N/mm²); forces in kilonewtons (kN); masses in kilograms (kg) or tonnes (t). Bar sizes are nominal diameters in millimetres. Percentages of composition are by mass. Standards are cited by their reference; summaries of requirements are for orientation and the current edition of each standard governs.

A.2 Bar geometry and mass per metre

The nominal cross-sectional area of a bar of nominal diameter d (mm) is $A = \pi d^2 / 4$ (mm²). Its nominal mass per metre is $A \times 7,850 \text{ kg/m}^3 \times 10^{-6} = 0.0061654 \times d^2 \text{ kg/m}$, usually rounded to $0.00617 \times d^2$. This reproduces the nominal masses tabulated in the product standards (for example 0.888 kg/m for 12 mm). The mass of a 12 m bar is 12 times the mass per metre; the lightest bar allowed is the nominal mass multiplied by (1 minus the tolerance), with tolerances of 6.0% for $d \leq 8 \text{ mm}$ and 4.5% for $d > 8 \text{ mm}$ [S31][S32]. Bars per tonne are 1,000 divided by the mass of a 12 m bar, rounded down.

The mass of a bar one millimetre undersize is computed for diameter d minus 1 mm. The loss of section is 1 minus $((d \text{ minus } 1)/d)^2$: 16.0% for 12 mm, 19.0% for 10 mm, 12.1% for 16 mm.

A.3 Yield force, design value and the capacity ratio

The yield force of a bar is $F = A \times f_y$, with A the actual area and f_y the actual yield strength. The design value assumed by the engineer under EN 1992-1-1 is $F_d = A_{\text{nom}} \times f_{yk} / \gamma_s$, with $f_{yk} = 500 \text{ MPa}$ and $\gamma_s = 1.15$ [S36]. For a 12 mm bar: $A_{\text{nom}} = 113.1 \text{ mm}^2$, $F_d = 49.2 \text{ kN}$, characteristic yield force 56.5 kN.

The scenarios in Figure ES.1 use: typical certified production, $f_y = 560 \text{ MPa}$ (the mean of a population with characteristic value 500 MPa and standard deviation 30 MPa, following the JCSS model in which the mean equals the nominal value plus two standard deviations [S29]); a bar of 11 mm ($A = 95.0 \text{ mm}^2$) at 500 MPa; a 12 mm bar at 400 MPa; and an 11 mm bar at 400 MPa. The capacity ratio of Figure 1.3 is $(1 \text{ minus mass deficit}) \times f_y / (500 / 1.15)$, on the basis that mass deficit equals area deficit for a bar of constant density.

These ratios concern the bar alone. The safety of a structural member also depends on load factors, concrete strength, detailing and workmanship; the calculation does not estimate the probability of failure of any structure.

A.4 Statistical evaluation of characteristic values

A characteristic value is the 5% fractile of the population. Conformity is commonly demonstrated with a one-sided statistical tolerance limit: the mean of n results minus k times their standard deviation must be at least the characteristic value. The factor k for a coverage of 95% at a confidence of 90% was computed from the non-central t distribution, $k = t'(n \text{ minus } 1, \delta = 1.645 \sqrt{n}; 0.90) / \sqrt{n}$, following the method of ISO 16269-6 [S57]. The required mean in the table assumes a standard deviation of 30 MPa [S29].

Table A.1 Tolerance factor k (95% coverage, 90% confidence) and required mean yield for a characteristic value of 500 MPa

Number of results n	Factor k	Required mean yield with $s = 30$ MPa (MPa)
5	3.40	602
10	2.57	577
15	2.33	570
20	2.21	566
30	2.08	562
40	2.01	560
50	1.97	559
100	1.86	556

Source: derived by Cameroon Steel (non-central t distribution); method after [S57]; standard deviation from [S29]. Certification schemes may use different confidence levels and sample rules.

A.5 Yield-strength distributions (Figure 5.1)

All three distributions are normal. Certified production: mean 560 MPa, standard deviation 30 MPa [S29]; share below 500 MPa = 2.3%. Uncontrolled spread: same mean, standard deviation 80 MPa, a coefficient of variation of about 14% as reported for market bars in Ethiopia [S28]; share below 500 MPa = 22.7%, below 400 MPa = 2.3%. Site pattern: mean 395 MPa, standard deviation 75 MPa (assumed), chosen so that about 52% of bars fall below 400 MPa as reported in [S19] (the study's own counts give 46%, 11 of 24 bars); share below 500 MPa = 91.9%. With an assumed standard deviation of 60 or 90 MPa instead of 75, the share below 500 MPa for the site pattern would be 95.7% or 87.7%. The site pattern is an illustrative fit to one reported statistic, not a reconstruction of the study's data.

A.6 Prices per kilogram (Table 4.2 and Figure 7.2)

Price per kg = homologated price per bar [S11] divided by the nominal mass of a 12 m bar (the list does not state the length; 12 m, the standard commercial length, is assumed). The effective price of a bar lighter than nominal by a fraction δ is the price at nominal mass divided by $(1 \text{ minus } \delta)$. The Fe500 premium per kilogram is 5.9% at 8 mm, 5.4% at 10 mm and 5.5% at 12 mm. A delivery of 1,000 bars of 12 mm at nominal mass weighs $1,000 \times 10.66 \text{ kg} = 10.66 \text{ t}$.

A.7 Carbon equivalent map (Figure 2.3)

$C_{eq} = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$ [S31]. Residual elements were fixed at $Cu + Ni = 0.35\%$ and $Cr + Mo + V = 0.15\%$, plausible for scrap-based electric arc furnace steel; the range 0.20% to 0.50% for $Cu + Ni$ moves every C_{eq} contour by about plus or minus 0.01. The "QST window" (C 0.17% to 0.22%, Mn 0.65% to 1.05%) and the "high-carbon window" (C 0.26% to 0.31%, Mn 1.15% to 1.55%) are indicative illustrations, not data from any producer.

A.8 Chloride initiation model (Figure 8.3)

The time t for the chloride content at depth x (the cover) to reach a threshold C_{crit} , with a constant surface content C_s and apparent diffusion coefficient D , follows from Fick's second law: $t = x^2 / (4 D z^2)$, where $z = \text{erf}^{-1}(1 - C_{crit}/C_s)$. The model ignores the decrease of D with age, binding, cracking, convection by wetting and drying, and temperature, and is therefore illustrative only. Its value lies in the relative effects: t is proportional to the square of the cover and inversely proportional to D .

Table A.2 Assumptions of the illustrative chloride model, with plausible ranges and sensitivity

Parameter	Value used	Plausible range	Effect on time to initiation for 40 mm of ordinary concrete (base 13.7 years)
Surface chloride C_s (% by mass of binder)	1.5	0.75 to 3.0	43.6 years at 0.75; 7.5 years at 3.0
Threshold C_{crit} (% by mass of binder)	0.4	0.2 to 0.6	7.5 years at 0.2; 23.9 years at 0.6
D , poor site-batched concrete (m^2/s)	5×10^{-12}	3 to 10×10^{-12}	Times inversely proportional to D
D , ordinary structural concrete (m^2/s)	1.5×10^{-12}	1 to 3×10^{-12}	As above
D , durable marine mix with slag or fly ash (m^2/s)	0.5×10^{-12}	0.2 to 1×10^{-12}	As above

Source: assumptions by Cameroon Steel for illustration; sensitivity derived with the same model. Not a design method; durability design should follow EN 1992-1-1 and EN 206 [S36][S37] or a validated performance-based method.

A.9 Other data and simulations

Humidity (Figure 8.2). Monthly relative humidity at 2 m and temperature from the NASA POWER climatology API (1991 to 2020, modelled), at Douala (4.05° N, 9.70° E), Kribi (2.94° N, 9.91° E), Yaoundé (3.87° N, 11.52° E) and Garoua (9.30° N, 13.40° E) [S50]. Modelled values smooth local extremes; station data at Kribi are consistent with them [S51].

Control chart (Figure 5.2). Sixty heat means drawn from normal distributions (mean 566 MPa, standard deviation 8 MPa for heats 1 to 38; mean 556 MPa, standard deviation 4 MPa thereafter; random seed 10). Control limits are the mean of the first 30 heats plus or minus three standard deviations. The run rule flags the eighth successive heat below the mean.

Import values (Figure 9.1). UN Comtrade reporter data for Cameroon, HS 7213, 7214, 7216 and 7217, current US dollars [S52]. Later years were not yet reported at the cut-off.

Indicative costs (Table 11.1). Cameroon Steel estimates based on typical scopes of sampling, laboratory testing and survey work, for budgeting orientation only.

A.10 Worked examples for site acceptance

The two examples below show how the weighing check of Chapter 6 and the chemistry check of Chapter 7 are applied. All bar masses and lengths are invented for illustration.

Weighing. The nominal mass of a 12 mm bar is 0.888 kg/m; with the 4.5% tolerance the minimum is 0.848 kg/m (derived). Three bars are taken at random from each of two deliveries, weighed and measured.

Table A.3 Worked example of the weighing check on two deliveries of 12 mm bars (invented values)

Delivery	Bar masses (kg)	Bar lengths (m)	Mass per metre (kg/m)	Deviation from nominal	Decision
1	10.48; 10.31; 10.62	12.00; 11.98; 12.02	0.873; 0.861; 0.884	-1.6%; -3.1%; -0.5%	All above 0.848 kg/m: accept
2	9.05; 8.98; 9.10	12.01; 11.99; 12.00	0.754; 0.749; 0.758	-15.1%; -15.6%; -14.6%	All below 0.848 kg/m, consistent with 11 mm bars: quarantine, test, reject if confirmed

Source: invented values; nominal mass and tolerance as in this annex [S31][S32].

The second delivery fails by a margin that no weighing error can explain: a deviation of about 15% matches a bar rolled at 11 mm instead of 12 mm (16% less section). Weighing three bars was enough to expose it.

Carbon equivalent. The specimen certificate of Figure 7.1 shows a cast analysis of 0.20% C, 0.85% Mn and 0.28% Cu. With residuals of 0.06% Cr, 0.02% Mo, 0.01% V and 0.10% Ni, which a full certificate would also report, the carbon equivalent is $0.20 + 0.85/6 + (0.06 + 0.02 + 0.01)/5 + (0.10 + 0.28)/15 = 0.385\%$, below the 0.50% limit for weldable steel (derived). A certificate that reports Ceq without the individual elements, or elements without Ceq, should be queried: the buyer should be able to repeat the calculation.

A.11 Limitations

The paper relies on published sources, several of them press reports, for the Cameroonian regulatory and enforcement record; it does not have access to the full text of NC 236, to ANOR's certification files or to official investigation reports on building collapses. Published studies of market rebar use different methods, standards and sample sizes and are not directly comparable. Standards are summarised from secondary sources and certificates where the primary text is priced; the current edition of each standard governs. Project information about Cameroon Steel is limited to the public record and to stated objectives.

ANNEX B

GLOSSARY OF TERMS AND ABBREVIATIONS

The glossary defines the technical terms and abbreviations used in the paper in plain language. Where a term has a precise definition in a standard, the definition given here is a simplified explanation, and the standard governs.

Table B.1 Terms and abbreviations

Term	Meaning
Agt	Total elongation at maximum force: the strain, in per cent, that a bar reaches in a tensile test at the moment it carries its highest load. The main European measure of usable ductility
Anchorage length	Length of bar embedded beyond the point where it is needed, over which bond transfers its force to the concrete
ANOR	Agence des Normes et de la Qualité, Cameroon's standards and quality agency, organised by Decree No. 2009/296. Drafts and homologates national standards, certifies products and runs PECAE
ARSO	African Organisation for Standardisation
ASTM A615, A706	American specifications for deformed carbon-steel bars (A615) and low-alloy weldable bars with controlled properties (A706)
B500A, B500B, B500C	European reinforcing steel grades with a characteristic yield of 500 MPa and ductility classes A, B and C
BAEL 91	Former French rules for the design of reinforced concrete, widely used in francophone Africa before the Eurocodes
Bend test, rebend test	Tests in which a bar is bent round a mandrel (bend) or bent, aged and bent back (rebend) and inspected for cracks; they reveal brittleness
Billet	Square semi-finished steel cast in a continuous caster, reheated and rolled into bars or rod
Bond	The transfer of force between a bar and the surrounding concrete, provided mainly by the bar's ribs
Carbon equivalent (Ceq, CEV)	Index combining carbon and alloying elements to predict hardenability and weldability; for European reinforcing steels $Ceq = C + Mn/6 + (Cr+Mo+V)/5 + (Ni+Cu)/15$, limited to 0.50%
Carbonation	Reaction of carbon dioxide from the air with concrete, which lowers its alkalinity and can lead to corrosion of reinforcement
Characteristic value	A value that a stated proportion of production (usually 95%) is expected to exceed; the basis of design strengths
Charpy impact test	Test in which a notched specimen is broken by a pendulum to measure toughness, used to grade structural steels (JR, JO, J2)
Chloride threshold	Chloride content at the steel surface above which the passive film breaks down and corrosion can start
Class A, B, C (ductility)	Eurocode 2 classes of reinforcement defined by minimum strength ratio and strain at maximum force; class C is the most ductile
Cold working	Strengthening steel by deforming it at room temperature (stretching, twisting, cold-rolling), which reduces ductility

Term	Meaning
Control chart	Chart of process results against control limits, used in statistical process control
Cover	The thickness of concrete between the surface of a bar and the nearest concrete surface
Curing	Keeping fresh concrete moist and protected so that cement hydrates fully, especially in the cover zone
Direct reduced iron (DRI), hot briquetted iron (HBI)	Iron produced by reducing iron ore in the solid state, used with scrap in electric arc furnaces to dilute residual elements
Ductility	The ability of steel to deform plastically before breaking
EAF	Electric arc furnace: a furnace that melts scrap and direct reduced iron using electric arcs
EN 10080	European standard giving general technical delivery conditions for weldable reinforcing steel
EN 10204	European standard defining types of inspection documents (2.2 test report, 3.1 and 3.2 inspection certificates)
EN 1992-1-1 (Eurocode 2)	European code for the design of concrete structures
EN 206	European standard for the specification and production of concrete, including exposure classes and limiting values
Exposure class	Classification of the environment of a concrete element (for example XC carbonation, XS sea water) used to set cover and concrete quality
Fe215, Fe235, Fe400, Fe500	Grades of NC 236: smooth bars (Fe215, Fe235) and ribbed high-bond bars (Fe400, Fe500); the number indicates the yield strength in MPa
FOB	Free on board: the value of goods loaded on the ship at the port of export
fR	Relative rib area: projected area of ribs per unit length divided by the bar's circumference; Eurocode 2's measure of bond geometry
Heat (cast)	One batch of steel melted and refined together, identified by a heat number
Homologation (of prices)	Official approval of producer prices by the Ministry of Commerce
ISO/IEC 17025, 17065	International standards for the competence of testing laboratories (17025) and of product certification bodies (17065)
Ladle furnace (LF)	Secondary metallurgy unit in which a heat is refined, alloyed and brought to casting temperature
Lap	Overlap of two bars that transfers force from one to the other through the concrete
Link (stirrup)	Closed bar enclosing the main bars of a beam or column, resisting shear and confining the concrete
Mandrel (former)	Round tool round which a bar is bent; its diameter limits the strain in the bar
Mass per metre	Mass of one metre of bar; the reference measure of a bar's cross-section
Microalloying	Adding very small amounts of vanadium, niobium or titanium to strengthen steel without extra carbon
Mill test report, inspection certificate	Document from the producer reporting chemical and mechanical results for the steel supplied
MINCOMMERCE, MINHDU, MINMIDT	Cameroonian ministries of Commerce; Housing and Urban Development; Mines, Industry and Technological Development
NC	Norme camerounaise: a Cameroonian national standard
NC 236	The Cameroonian standard for steel for reinforced concrete (rebar), mandatory since 2022

Term	Meaning
Overstrength	Actual yield strength well above the specified value; limited by some standards because it changes how structures fail
Partial factor	Safety factor applied to a material or a load in limit-state design; 1.15 for reinforcing steel in Eurocode 2
Passivity	Protection of steel in alkaline concrete by a thin, stable oxide film
PECAE	Programme d'Évaluation de la Conformité Avant Embarquement: conformity assessment of imports before shipment
Proficiency testing	Comparison of a laboratory's results with those of other laboratories on the same specimens
QST, Tempcore	Quenching and self-tempering: in-line water quenching of a hot bar that produces a hard tempered-martensite rim and a ductile core
Re (fy), Rm (ft)	Yield strength and tensile strength
Re-rolling	Reheating and rolling down scrap steel (rails, plates, old bars) without remelting it
Rm/Re (k)	Ratio of tensile to yield strength, a measure of strain hardening and of ductility in structures
Rolled-in mark	Pattern of ribs or symbols rolled into a bar to identify the producing mill, grade or country
Spacer	Block or chair that holds reinforcement at the specified cover during concreting
SPC	Statistical process control: monitoring of process results with control charts to detect drift
Spectrometer (OES)	Optical emission spectrometer: instrument that analyses steel chemistry from a spark on a sample
Strain ageing	Loss of ductility of steel after deformation, caused mainly by free nitrogen
Time of wetness	Time during which a metal surface is likely to be wet, counted in ISO 9223 as time with relative humidity above 80% and temperature above 0 °C
Welded mesh (fabric)	Grid of wires or bars welded at their intersections, used as reinforcement
Wire rod	Hot-rolled steel in coils, typically 5.5 to 12 mm in diameter, used for drawing into wire
Yield strength	Stress at which steel begins to deform permanently

Source: Cameroon Steel, after the standards and sources cited in the paper.

ANNEX C

SOURCES

Every source cited in the paper with an [S-id] marker is listed below with its title, publisher, date and address. Press articles are cited for the facts they report, which are attributed in the text. Priced standards are listed with the publisher's catalogue address; the current edition governs. Web pages were accessed between 1 and 10 October 2026. Identifiers S27, S64, S68 to S70 and S83 are not used in this edition. In line with the series' disclosure rules, no producer is named in connection with a sanction; where a source names one, the name is omitted from its title (marked [...]) and its web address is not reproduced; the article can be found by title and date.

Table C.1 Sources cited

Id	Title	Publisher or author	Date	Address
S01	Kribi: le Premier ministre, chef du gouvernement est là	Cameroon Tribune	30 Dec 2024	https://cameroon-tribune.cm/article.html/68499/fr.html/details_2
S02	Cameroun: complexe moderne de sidérurgie de Kribi, le PM Joseph Dion Ngute effectue la pose de la première pierre	Camer.be	5 Jan 2025	https://www.camer.be/87795/12:1/cameroun-complexe-moderne-de-siderurgie-de-kribi-le-pm-joseph-dion-ngute-effectue-la-pose-de-la-premiere-pi-cameroon.html
S03	Industrialisation: la voie royale de l'émergence	Cameroon Tribune	2 Jan 2025	https://cameroon-tribune.cm/article.html/68558/fr.html/details_2
S04	Cameroun: pour non-respect des normes, le fer à béton de la société [...] retiré du marché (name of the producer omitted here)	EcoMatin	21 Oct 2024	ecomatin.net, article of 21 Oct 2024 (address not reproduced: it contains the producer's name)
S05	Cameroon revokes [...] compliance certificate for rebar, orders recall of products (name of the producer omitted here)	Business in Cameroon	17 Oct 2024	businessincameroon.com, Public management section, 17 Oct 2024 (address not reproduced: it contains the producer's name)
S06	Cameroun: le gouvernement rejette une demande de révision de la norme du fer à béton	EcoMatin	5 Feb 2026	https://ecomatin.net/cameroun-le-gouvernement-rejette-une-demande-de-revision-de-la-norme-du-fer-a-beton
S07	Cameroon rejects fresh push to revise rebar standard	Business in Cameroon	26 Jan 2026	https://www.businessincameroon.com/construction/2601-15657-cameroon-rejects-fresh-push-to-revise-rebar-standard
S08	Fer à béton: le gouvernement ferme la porte à toute révision de la norme et recadre la filière sidérurgique	Cameroun24	Jan 2026	https://cameroun24.net/article/72504-fer-a-beton-le-gouvernement-ferme-la-porte-a-toute-revision-de-la-norme-et-recadre-la-filiere-siderurgique.html

Id	Title	Publisher or author	Date	Address
S09	Métallurgie: les industriels du secteur dénoncent la présence du fer à béton contrefait sur le marché camerounais	EcoMatin	22 Jun 2023	https://ecomatin.net/metallurgie-les-industriels-du-secteur-denoncent-la-presence-du-fer-a-beton-contrefait-sur-le-marche-camerounais
S10	Interdiction des importations du fer à béton: les consommateurs dénoncent la mauvaise qualité de la production locale	EcoMatin	13 Apr 2023	https://ecomatin.net/interdiction-des-importations-du-fer-a-beton-les-consommateurs-denoncent-la-mauvaise-qualite-de-la-production-locale
S11	Fer à béton: les producteurs acceptent une baisse des prix	EcoMatin	23 Oct 2023	https://ecomatin.net/fer-a-beton-les-producteurs-acceptent-une-baisse-des-prix
S12	Métallurgie: les importations du fer à béton interdites jusqu'à nouvel ordre	EcoMatin	10 Apr 2023	https://ecomatin.net/metallurgie-les-importations-du-fer-a-beton-interdites-jusqua-nouvel-ordre
S13	Press report of the sealing by customs of more than 7,300 t of imported reinforcing bar, December 2020 (headline and address not reproduced: they name the importer)	Business in Cameroon	16 Dec 2020	businessincameroon.com
S14	Normes sur les produits de grande consommation: quel impact sur la qualité	Cameroon Tribune	10 Oct 2024	https://cameroon-tribune.cm/article.html/67368/fr.html/details_2
S15	Informations sur le PECAE (cadre légal, procédure, routes, frais, partenaires, questions fréquentes)	Agence des Normes et de la Qualité (ANOR)	accessed 10 Oct 2026	https://www.anor.cm/projet-pecae/informations
S16	Nos missions	ANOR	accessed 10 Oct 2026	https://www.anor.cm/articles/nos-missions
S17	Communiqué portant modification de la procédure d'initiation du PECAE	ANOR	6 Oct 2026	https://www.anor.cm/articles/communiqu%C3%A9-portant-modification-de-la-procedure-dinitiation-du-programme-devaluation-de-la-conformite-avant-embarquement-des-marchandises-importees-en-republique-du-cameroun-pecae
S18	L'ANOR et les laboratoires camerounais renforcent leur collaboration: une plateforme d'échanges et de conformité voit le jour	ANOR	17 Sep 2024	https://www.anor.cm/articles/lanor-et-les-laboratoires-camerounais-renforcent-leur-collaboration-une-plateforme-dechanges-et-de-conformite-voit-le-jour
S19	Assessment of Deviation in Quality of Steel Reinforcing Bars Used in Some Building Sites in Cameroon. World Journal of Engineering and Technology, 11 (4), pp. 917 to 931	P. C. Bame, B. E. Yamb, B. Ndigui; Scientific Research Publishing	2023	https://doi.org/10.4236/wjet.2023.114061
S20	Officials to Investigate After Cameroon Building Collapse Kills Over 30	VOA Africa	24 Jul 2023	https://www.voaafrica.com/a/cameroon-building-collapse-kills-over-30-/7193868.html
S21	Cameroon: death toll rises to 40 in building collapse	Africanews	27 Jul 2023	https://www.africanews.com/2023/07/27/cameroon-death-toll-rises-to-40-in-building-collapse/
S22	Cameroun: Douala, 6 morts dans l'effondrement d'un immeuble à Bonamoussadi	Camer.be, republished by AllAfrica	11 Jul 2026	https://fr.allafrica.com/stories/202607130741.html

Id	Title	Publisher or author	Date	Address
S23	Why 21-storey Ikoyi building collapsed, panel reveals after submitting report	Sahara Reporters	5 Jan 2022	https://saharareporters.com/2022/01/05/why-21-storey-ikoyi-building-collapsed-%E2%80%93-panel-reveals-after-submitting-report-lagos
S24	Nigerian preacher TB Joshua skips trial as judge adjourns case	Nation (Nation Media Group)	30 Nov 2015, updated 3 Jul 2020	https://nation.africa/kenya/news/africa/nigerian-preacher-tb-joshua-skips-trial-as-judge-adjourns-case-1149920
S25	SON seals 13 steel firms for standards infractions	Economic Confidential	11 Feb 2020	https://economicconfidential.com/son-seals-firms-standards-infractions/
S26	Evaluation of mechanical properties and chemical composition of some selected steel reinforcements used in Nigeria	M. Akinpelu, A. Salman; Mouloud Mammeri University of Tizi-Ouzou (repository record, Kwara State University)	2021	https://kwasuspace.kwasu.edu.ng/handle/123456789/3589
S28	Mechanical strength variability of deformed reinforcing steel bars for concrete structures in Ethiopia. Scientific Reports 12, 2600	T. Achamyelch, H. Çamur, M. A. Savaş, A. Evcil; Nature Portfolio	2022	https://doi.org/10.1038/s41598-022-06654-1
S29	Probabilistic Model Code, Part 3: Resistance models, 3.2 Static properties of reinforcing steel	Joint Committee on Structural Safety (JCSS)	2001 edition	https://www.jcss-lc.org/publications/jcsspmc/rebar.pdf
S30	EN 1992 Eurocode 2: Design of concrete structures (J. Walraven), workshop "Eurocodes: background and applications", Brussels, 18 to 20 Feb 2008	European Commission (DG Enterprise and Industry, Joint Research Centre)	Feb 2008	https://www.eurocodes.fi/wp-content/uploads/1992/sahkoinen1992/EN-1992.pdf
S31	Certificat N° B03/176 rév. 16, aciers pour béton armé, NF A 35-080-1 nuance B500B (fiche descriptive and caractéristiques certifiées)	Association Française de Certification des Armatures du Béton (AFCAB), AFNOR Certification	6 Jun 2025	https://feralpi-stahl.com/sites/default/files/media/certifications/NF%20AFCAB-FR-B500B-BS_0.pdf
S32	Technical specification SPF400 rev. 12, Rebars B500 (chemical, mechanical and dimensional requirements under EN 10080 and national standards)	Ferriere Nord S.p.A. (Pittini group)	14 Sep 2021	https://www.pittini.it/wp-content/uploads/Pittini-Group-Reinforcing-Steel-Bars-B500.pdf
S33	Standards for reinforcement	The Concrete Centre (UK)	accessed Oct 2026	https://concretecentre.com/Codes/European-standards-for-reinforcement.aspx
S34	Rebar 101 (presentation: ASTM bar specifications, tensile and elongation tables, permissible variation in weight, marking)	Concrete Reinforcing Steel Institute (CRSI), hosted by New Jersey Institute of Technology	n.d.	https://web.njit.edu/~washd/cim101/download/notes/CRSI/Rebar101_University%20%5bCompatibility%20Mode%5d.pdf
S35	Engineering Bulletin # 1: Mechanical properties, ChromX (ASTM A1035) compared with ASTM A615 Grades 60, 80 and 100	Commercial Metals Company (CMC)	12 May 2021	https://www.cmc.com/getmedia/83bc1448-b2ed-47b1-9b4e-56951d4b7212/1_Mechanical_Properties-NEW.pdf
S36	EN 1992-1-1:2004 Eurocode 2: Design of concrete structures, Part 1-1: General rules and rules for buildings (with corrigenda)	European Committee for Standardization (CEN)	2004	https://eurocodes.jrc.ec.europa.eu/EN-Eurocodes/eurocode-2-design-concrete-structures

Id	Title	Publisher or author	Date	Address
S37	EN 206:2013+A2:2021 Concrete: specification, performance, production and conformity	CEN	2021	https://standards.cencenelec.eu (catalogue: EN 206)
S38	BS 4449:2005+A3:2016 Steel for the reinforcement of concrete. Weldable reinforcing steel. Bar, coil and decoiled product. Specification	British Standards Institution (BSI)	2016	https://www.boutique.afnor.org/en-gb/standard/bs-44492005-a32016/steel-for-the-reinforcement-of-concrete-weldable-reinforcing-steel-bar-coil/eu100392/205471
S39	EN 10080:2005 Steel for the reinforcement of concrete. Weldable reinforcing steel. General	CEN	2005	https://standards.cencenelec.eu (catalogue: EN 10080)
S40	ASTM A615/A615M Standard specification for deformed and plain carbon-steel bars for concrete reinforcement	ASTM International	current edition	https://store.astm.org (catalogue: A615/A615M)
S41	ASTM A706/A706M Standard specification for deformed and plain low-alloy steel bars for concrete reinforcement	ASTM International	current edition	https://store.astm.org (catalogue: A706/A706M)
S42	NF A 35-080-1 Aciers pour béton armé: aciers soudables, partie 1: barres et couronnes	AFNOR	current edition	https://www.boutique.afnor.org (catalogue: NF A35-080-1)
S43	ISO 6935-2:2019 Steel for the reinforcement of concrete, Part 2: Ribbed bars	International Organization for Standardization (ISO)	2019	https://www.iso.org (catalogue: ISO 6935-2)
S44	ISO 15630-1:2019 Steel for the reinforcement and prestressing of concrete, Test methods, Part 1: Reinforcing bars, rods and wire (EN ISO 15630-1)	ISO; CEN	2019	https://www.iso.org (catalogue: ISO 15630-1)
S45	ISO 6892-1:2019 Metallic materials, Tensile testing, Part 1: Method of test at room temperature	ISO	2019	https://www.iso.org (catalogue: ISO 6892-1)
S46	EN 10204:2004 Metallic products, Types of inspection documents	CEN	2004	https://standards.cencenelec.eu (catalogue: EN 10204)
S47	ISO 9223:2012 Corrosion of metals and alloys, Corrosivity of atmospheres, Classification, determination and estimation	ISO	2012	https://www.iso.org (catalogue: ISO 9223)
S48	Tempcore: a new process for the production of high-quality reinforcing bars. Iron and Steel Engineer 61 (3), pp. 53 to 57	P. Simon, M. Economopoulos, P. Nilles	1984	https://openalex.org/W3176967943
S49	Corroded TempCore vs dual-phase steel reinforcing bars. Construction and Building Materials	S. Caprili, W. Salvatore, R. Valentini; Elsevier	2021	https://doi.org/10.1016/j.conbuildmat.2021.122301
S50	POWER climatology API, parameters T2M, RH2M, PRECTOTCORR, 1991 to 2020, at Douala, Kribi, Yaoundé and Garoua	NASA Langley Research Center	accessed 10 Oct 2026	https://power.larc.nasa.gov/api/temporal/climatology/point?parameters=T2M,RH2M,PRECTOTCORR&community=RE&longitude=9.91&latitude=2.94&format=JSON
S51	Monographie du Nyong et des fleuves côtiers, tome 1 (climate records for Kribi)	J.-C. Olivry; ORSTOM and IRGM	Jul 1979	https://horizon.documentation.ird.fr/exl-doc/pleins_textes/divers11-03/01948.pdf

Id	Title	Publisher or author	Date	Address
S52	UN Comtrade public API, Cameroon (reporter 120), imports and exports by HS line, chapters 72 and 73, 2019 to 2023	United Nations Statistics Division	accessed 10 Oct 2026	https://comtradeapi.un.org/public/v1/preview/C/A/HS?reporterCode=120&period=2023&partnerCode=0&flowCode=M&cmdCode=7213,7214,7216,7217
S53	Production: les acteurs en présence	Cameroon Tribune	11 May 2026	https://cameroon-tribune.cm/article.html/76600/fr.html/details_2
S54	Agence de Régulation des Marchés Publics, website (references to Decree No. 2018/366 of 20 June 2018 on the public procurement code)	ARMP	accessed 10 Oct 2026	https://www.armp.cm
S55	ISO/IEC 17025:2017 General requirements for the competence of testing and calibration laboratories	ISO; IEC	2017	https://www.iso.org (catalogue: ISO/IEC 17025)
S56	ISO/IEC 17065:2012 Conformity assessment, Requirements for bodies certifying products, processes and services	ISO; IEC	2012	https://www.iso.org (catalogue: ISO/IEC 17065)
S57	ISO 16269-6:2014 Statistical interpretation of data, Part 6: Determination of statistical tolerance intervals	ISO	2014	https://www.iso.org (catalogue: ISO 16269-6)
S58	ASTM A775/A775M Epoxy-coated steel reinforcing bars; ASTM A934/A934M Epoxy-coated prefabricated steel reinforcing bars	ASTM International	current editions	https://store.astm.org (catalogue: A775, A934)
S59	ASTM A767/A767M Zinc-coated (galvanized) steel bars for concrete reinforcement	ASTM International	current edition	https://store.astm.org (catalogue: A767)
S60	BS 6744:2016 Stainless steel bars for the reinforcement of and use in concrete	BSI	2016	https://knowledge.bsigroup.com (catalogue: BS 6744)
S61	EN 10025-2:2019 Hot rolled products of structural steels, Part 2: Technical delivery conditions for non-alloy structural steels	CEN	2019	https://standards.cencenelec.eu (catalogue: EN 10025-2)
S62	ISO 16120 series Non-alloy steel wire rod for conversion to wire (EN ISO 16120-1 to 16120-4)	ISO; CEN	current editions	https://www.iso.org (catalogue: ISO 16120)
S63	BS 4483:2005 Steel fabric for the reinforcement of concrete	BSI	2005	https://knowledge.bsigroup.com (catalogue: BS 4483)
S65	Corrosion of steel in concrete. CBI Research Report 4:82	K. Tuutti; Swedish Cement and Concrete Research Institute, Stockholm	1982	Print report; no stable web address
S66	Cameroon, Republic of: Corporate, Other taxes (environmental tax under the 2026 Finance Law)	PwC Worldwide Tax Summaries	reviewed 14 Aug 2026	https://taxsummaries.pwc.com/republic-of-cameroon/corporate/other-taxes
S67	BS 8666:2020 Scheduling, dimensioning, cutting and bending of steel reinforcement for concrete. Specification	BSI	2020	https://knowledge.bsigroup.com (catalogue: BS 8666)
S71	ISO 17660-1:2006 Welding, Welding of reinforcing steel, Part 1: Load-bearing welded joints (EN ISO 17660-1)	ISO; CEN	2006	https://www.iso.org (catalogue: ISO 17660-1)

Id	Title	Publisher or author	Date	Address
S72	NF A35-016 Concrete reinforcing steels, weldable ribbed bars and coils of grade FeE500 (catalogue record)	AFNOR	catalogue accessed Oct 2026	https://www.boutique.afnor.org/en-gb/standard/nf-a35016/concrete-reinforcing-steels-weldable-ribbed-bars-and-coils-of-grade-fee500-/fa041963/47760
S73	GB/T 1499.2-2018 Steel for the reinforcement of concrete, Part 2: Hot rolled ribbed bars	Standardization Administration of China	2018	https://openstd.samr.gov.cn (catalogue: GB/T 1499.2)
S74	Home page, communiqués and online reporting service (Dénonciation)	ANOR	accessed 10 Oct 2026	https://www.anor.cm
S75	Enquêtes publiques: draft Cameroonian standards under public enquiry	ANOR	accessed 10 Oct 2026	https://www.anor.cm/enquetes-publiques
S76	Évolution du commerce extérieur en 2025 (version provisoire)	Institut National de la Statistique (INS), Cameroon	Feb 2026	https://ins-cameroun.cm/wp-content/uploads/2026/04/Note-sur-le-commerce-exterieur-en-2025-version-provisoire_FR.pdf
S77	ASTM E415 Standard test method for analysis of carbon and low-alloy steel by spark atomic emission spectrometry	ASTM International	current edition	https://store.astm.org (catalogue: E415)
S78	ISO 9001:2015 Quality management systems, Requirements	ISO	2015	https://www.iso.org (catalogue: ISO 9001)
S79	Quality evaluation of commercially available steels in some selected Nigerian markets. Annals of Faculty Engineering Hunedoara, International Journal of Engineering	Y. L. Shuaib-Babata and others	2019	https://uilspace.unilorin.edu.ng/handle/20.500.12484/11417
S80	Budget 2026: 8 816,4 milliards FCFA pour consolider la stabilité et accélérer le développement du Cameroun	Ministry of Finance (MINFI)	26 Nov 2025	https://minfi.gov.cm/budget-2026-8-8164-milliards-fcfa-pour-consolider-la-stabilite-et-acceler-le-developpement-du-cameroun/
S81	Ministry of Public Contracts, website (standard bidding documents, DAO-types)	MINMAP	accessed 10 Oct 2026	https://www.minmap.cm
S82	BAEL 91 révisé 99: Règles techniques de conception et de calcul des ouvrages et constructions en béton armé suivant la méthode des états limites	CSTB; Eyrolles (Fascicule 62, titre I, section I)	2000	Print publication; no stable web address
S84	ISO 15630-2:2019 Steel for the reinforcement and prestressing of concrete, Test methods, Part 2: Welded fabrics and lattice girders (EN ISO 15630-2)	ISO; CEN	2019	https://www.iso.org (catalogue: ISO 15630-2)
S85	École Nationale Supérieure Polytechnique de Yaoundé, home page (departments)	ENSP Yaoundé	accessed Oct 2026	https://polytechnique.cm/
S86	EN 10219-1:2006 Cold formed welded structural hollow sections of non-alloy and fine grain steels; EN 10210-1:2006 Hot finished structural hollow sections	CEN	2006	https://standards.cencenelec.eu (catalogue: EN 10219, EN 10210)

Id	Title	Publisher or author	Date	Address
S87	Le Gabon réduit la TVA sur le fer à béton local pour stimuler son industrie sidérurgique	EcoMatin	4 Aug 2026	https://ecomatin.net/le-gabon-reduit-la-tva-sur-le-fer-a-beton-local-pour-stimuler-son-industrie-siderurgique
S88	Gabon: le groupe Fokou lance une nouvelle unité d'acier à Port-Gentil	EcoMatin	18 Sep 2026	https://ecomatin.net/gabon-le-groupe-fokou-lance-une-nouvelle-unite-dacier-a-port-gentil
S89	Projet de loi portant loi de finances de la République du Cameroun pour l'exercice 2026, article 23 (articles 228 septies to 228 decies of the General Tax Code: environmental tax on cement, fer à béton, tiles and ceramics; rate per tonne of iron)	Ministry of Finance, Directorate General of the Budget (DGB)	26 Nov 2025 (bill as tabled; final wording to be checked against the Official Gazette)	https://www.dgb.cm/wp-content/uploads/2025/11/PROJET-DE-LOI-FINANCES-2026_FR_26112025.pdf

Source: compiled by Cameroon Steel.

ANNEX D

DATA TABLES BEHIND THE EXHIBITS

This annex gives the values plotted in every chart of the paper, with units, evidence status and sources, so that readers can check them and reuse them. The same values are published as machine-readable files with the web edition (one JSON file per chart, generated by the script that draws the chart). Schematic diagrams that carry no data are listed in the first table with a note.

Index of exhibits and their data

Table D.1 Exhibits, their data files and evidence status

Exhibit	Content	Data file	Status	Values
Figure ES.1	Yield force of a 12 mm bar under compliant and defective scenarios	hero_capacity.json	derived	Table D.2
Figure 1.1	How a reinforced concrete beam works (schematic)	beam_ductility.json	illustrative	No data
Figure 1.2	Stress-strain curves by ductility class (schematic)	stress_strain.json	illustrative	Table D.3
Figure 1.3	Capacity ratio by mass deficit and yield strength	capacity_heatmap.json	derived	Table D.4
Figure 2.1	QST cross-section and temperature history (schematic)	qst_section.json	illustrative	No data
Figure 2.2	Nine quality control points in a mini-mill	process_qc.json	illustrative	Table D.5
Figure 2.3	Carbon equivalent map	cev_map.json	derived	Table D.6
Figure 3.1	What the tensile test measures (schematic)	tensile_definitions.json	illustrative	No data
Figure 3.2	Rib geometry parameters (schematic)	rib_geometry.json	illustrative	Formula in Table 3.3
Figure 4.1	Quality infrastructure for rebar in Cameroon	qi_map.json	sourced	Sources in caption
Figure 4.2	Milestones in standardisation and control	timeline.json	sourced	Table D.7
Figure 4.3	Capacity and demand by product	capacity_demand.json	sourced	Table D.8
Figure 5.1	Yield-strength distributions under three regimes	yield_distributions.json	derived	Table D.9
Figure 5.2	Control chart of heat-mean yield (simulated)	spc_chart.json	illustrative	Table D.10
Figure 6.1	Mass of a 12 m bar: nominal, minimum and undersize	mass_check.json	derived	Table D.11
Figure 6.2	Probability of detecting light bars by sample size	detection_probability.json	derived	Table D.12
Figure 6.3	Site acceptance routine	site_flow.json	illustrative	Table D.13
Figure 7.1	Specimen mill certificate (invented values)	mill_certificate.json	illustrative	No data
Figure 7.2	Price per kilogram and effective price of light bars	price_per_kg.json	derived	Table D.14
Figure 8.1	Corrosion mechanism and two-stage model (schematic)	corrosion_mechanism.json	illustrative	No data
Figure 8.2	Monthly relative humidity in four cities	humidity.json	sourced	Table D.15
Figure 8.3	Time to corrosion initiation by cover (model)	chloride_initiation.json	illustrative	Table D.16

Exhibit	Content	Data file	Status	Values
Figure 9.1	Imports of long products by HS line	imports_products.json	sourced	Table D.17
Figure 10.1	Indicative implementation calendar	roadmap.json	illustrative	Table D.18

Source: Cameroon Steel. Data files are published with the web edition.

Safety margin and capacity

Table D.2 Yield force of one nominal 12 mm bar (Figure ES.1)

Scenario	Yield force (kN)	Ratio to design value
Certified B500B, typical production (mean yield about 560 MPa)	63.3	1.29
Certified B500B at the characteristic yield of 500 MPa	56.5	1.15
Bar 1 mm undersize (11 mm), yield 500 MPa	47.5	0.97
Fe400 steel sold as Fe500 (yield 400 MPa)	45.2	0.92
Both defects together (11 mm, 400 MPa)	38.0	0.77
Design value: 500 MPa / 1.15 × 113.1 mm ²	49.2	1.00

Source: derived by Cameroon Steel; partial factor [S36]; mean yield of controlled production [S29].

Table D.3 Parameters of the schematic stress-strain curves (Figure 1.2)

Curve	Yield Re (MPa)	Tensile Rm (MPa)	Rm/Re	Agt (%)	Strain at fracture (%)
Class C type	530	647	1.22	12.0	17.0
Class B type	545	627	1.15	8.0	13.0
Class A type (cold-worked, proof stress)	520	560	1.08	3.0	4.5
Out-of-specification bar	410	440	1.07	1.5	2.2

Source: illustrative parameters chosen by Cameroon Steel to show the class limits of EN 1992-1-1 Annex C [S30][S36]; not test data.

Table D.4 Marked points of the capacity map (Figure 1.3)

Point	Mass deficit (%)	Yield (MPa)	Ratio to design value
Certified bar (typical)	0.0	560	1.29
At mass tolerance	4.5	500	1.10
Fe400 sold as Fe500	0.0	400	0.92
1 mm undersize (12 to 11 mm)	16.0	500	0.97
Both defects	16.0	400	0.77

Source: derived: ratio = (1 minus deficit) × fy / (500/1.15). Axes span 0% to 20% deficit and 350 to 620 MPa.

Metallurgy

Table D.5 Process steps and quality control points (Figure 2.2)

Step	Control point
Scrap and DRI/HBI yard	Sorting, radiation portal, no sealed containers
Electric arc furnace	Bath samples, temperature, oxygen activity
Ladle furnace	Spectrometer: C, Mn, Si, P, S, N, Cu, Ceq

Step	Control point
Continuous caster	Heat number stamped on every billet
Billet yard, reheating	Surface defects, macro-etch, furnace profile
Rolling mill	Diameter, ovality, rib height and spacing
QST quench and temper	Water flow and pressure, surface temperature
Cooling bed, cut, bundle	Tensile, bend, rebend, mass per metre
Tag and dispatch	Bundle tag, 3.1 certificate, lot release

Source: Cameroon Steel schematic; common factory production control practice [S31][S38].

Table D.6 Assumptions and windows of the carbon-equivalent map (Figure 2.3)

Item	Value
Formula	$C_{eq} = C + Mn/6 + (Cr+Mo+V)/5 + (Ni+Cu)/15$
Assumed Cu + Ni (%)	0.35
Assumed Cr + Mo + V (%)	0.15
Cast limit C_{eq} (%)	0.50
QST B500B window: C (%) / Mn (%)	0.17 to 0.22 / 0.65 to 1.05
High-carbon window: C (%) / Mn (%)	0.26 to 0.31 / 1.15 to 1.55

Source: derived; formula and limit [S31][S32]; residuals and windows assumed (Annex A).

Cameroon's quality infrastructure and market

Table D.7 Milestones plotted in Figure 4.2

Date	Event	Source
5 Aug 1996	Law 96/11 on standardisation sets the legal basis for Cameroonian standards (NC)	S14
17 Sep 2009	Decree 2009/296 organises ANOR, the standards and quality agency	S14
1 Jul 2015	Decree 2015/1875/PM creates PECAE, conformity assessment of imports before shipment	S15
31 May 2016	Prime Minister's office suspends rebar imports until further notice	S13
31 Aug 2016	PECAE becomes operational (SGS, Intertek, TÜV Rheinland)	S15
31 May 2021	Decree 2021/3306/PM amends and clarifies the PECAE programme	S15
2021	NC 236:2021, the national standard for rebar (acier pour béton armé), is issued	S04, S05
20 Apr 2022	Ministerial order makes NC 236 mandatory: Fe400 and Fe500 ribbed, Fe215 and Fe235 smooth	S04, S05, S09
Apr to Jun 2023	Import ban reaffirmed; engineers and consumers report substandard and counterfeit bars	S09, S10, S12
21 Oct 2023	Homologated producer prices per bar reduced by diameter and grade	S11
16 Oct 2024	ANOR withdraws a conformity certificate and recalls Fe450 bars absent from NC 236	S04, S05
19 Jan 2026	Government refuses an industry request to revise the rebar standard (NC 236/2024/06)	S06, S07
6 Oct 2026	ANOR simplifies the start of PECAE checks (IM number accepted)	S17

Source: as listed; Annex C.

Table D.8 Installed capacity and demand by product, kt per year (Figure 4.3)

Product	Capacity (kt/yr)	Demand (kt/yr)	Capacity / demand
Rebar	627	180	3.5
Wire rod and nails	72	36	2.0
Sheets	43	21	2.0
Tubes	34	14	2.4
Annealed wire	2.8	1.8	1.6

Source: industry figures reported in Cameroon Tribune, 11 May 2026 [S53]; ratios derived.

Testing and statistics

Table D.9 Parameters and shares of the yield-strength distributions (Figure 5.1)

Regime	Mean (MPa)	Standard deviation (MPa)	Share below 500 MPa	Share below 400 MPa
Certified production: mean 560, sd 30 MPa	560	30	2.3%	0.0%
Same mean, uncontrolled spread: sd 80 MPa (CoV 14%)	560	80	22.7%	2.3%
Site sample pattern: median below 400 MPa (fitted, sd 75)	395	75	91.9%	52.7%

Source: derived (normal model); $\sigma = 30$ MPa [S29]; CoV 14% [S28]; site pattern fitted to [S19] (illustrative).

Table D.10 Simulated heat-mean yield strengths, MPa (Figure 5.2; mean of heats 1 to 30 = 563.8, control limits 544.5 and 583.2, run rule at heat 46)

Heats	+0	+1	+2	+3	+4	+5	+6	+7	+8	+9
1 to 10	557.2	560.2	559.7	568.1	564.0	567.0	572.7	572.9	569.8	562.4
11 to 20	560.0	559.5	563.2	565.6	558.2	556.9	568.4	551.2	564.6	569.4
21 to 30	558.1	557.1	559.9	571.2	565.0	551.0	562.6	574.1	573.9	571.0
31 to 40	564.1	551.2	567.4	564.6	566.6	578.3	567.5	568.2	552.0	551.8
41 to 50	555.5	558.7	550.2	547.7	554.8	554.5	552.4	558.4	559.2	553.7
51 to 60	554.6	558.3	554.3	550.4	555.7	552.4	557.3	554.0	555.2	558.1

Source: Cameroon Steel simulation, random seed 10 (illustrative).

Defects and site acceptance

Table D.11 Mass of a 12 m bar (Figure 6.1)

Diameter (mm)	Nominal (kg)	Minimum within tolerance (kg)	1 mm undersize (kg)	Undersize shortfall
8	4.74	4.46	3.63	23.4%
10	7.40	7.07	5.99	19.0%
12	10.66	10.18	8.95	16.0%
14	14.50	13.84	12.50	13.8%
16	18.94	18.08	16.65	12.1%
20	29.59	28.26	26.71	9.8%

Diameter (mm)	Nominal (kg)	Minimum within tolerance (kg)	1 mm undersize (kg)	Undersize shortfall
25	46.24	44.16	42.62	7.8%

Source: derived: nominal mass per metre as tabulated (to three decimals) at 7,850 kg/m³; undersize bar and shortfall from the diameters; tolerance [S31][S32].

Table D.12 Probability that at least one light bar is found (Figure 6.2)

Bars weighed	10% of bars light	20% light	33% light	50% light
1	10%	20%	33%	50%
3	27%	49%	70%	88%
5	41%	67%	87%	97%
10	65%	89%	98%	100%

Source: derived: 1 minus (1 minus p) to the power n.

Table D.13 Site acceptance steps (Figure 6.3)

Step	Action
1 Paperwork	Delivery note, mill certificate (EN 10204 type 3.1), product certificate number, heat numbers on tags
2 Marks and tags	Rolled-in mill mark and grade on the bar; bundle tag matches certificate and delivery note
3 Weigh	Weigh three full bars per diameter; compare with nominal mass less 4.5% (6% at 8 mm and below)
4 Look and measure	Measure diameter over ribs and rib spacing; no laps, cracks, deep pitting or flaking rust
5 Bend	Bend a sample 180 degrees round a mandrel of about 4d (larger for big bars): no cracks on the outside

Source: Cameroon Steel recommended practice.

Table D.14 Homologated price per kilogram and effective price of light bars (Figure 7.2)

Bar	FCFA/kg at nominal mass	4.5% light	10% light	16% light (one size down at 12 mm)
8 mm Fe400	612	641	680	728
8 mm Fe500	648	678	720	771
10 mm Fe400	602	631	669	717
10 mm Fe500	635	665	705	756
12 mm Fe400	601	629	667	715
12 mm Fe500	633	663	704	754
6 mm	575	602	639	685

Source: homologated prices made public on 21 October 2023 [S11]; per-kilogram values derived (Annex A).

Durability

Table D.15 Mean relative humidity at 2 m, %, 1991 to 2020 (Figure 8.2)

City	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Kribi	85	87	88	89	89	90	90	90	91	90	89	87	89
Douala	81	84	87	88	89	90	90	91	90	89	88	83	88
Yaoundé	77	81	86	88	88	88	88	90	90	89	86	80	86
Garoua	19	16	20	43	64	73	80	84	82	74	47	27	53

Source: NASA POWER climatology API, modelled [S50].

Table D.16 Years to corrosion initiation in the illustrative chloride model (Figure 8.3)

Concrete	D (m ² /s)	25 mm cover	40 mm cover	50 mm cover
Poor concrete: w/c about 0.65, site-batched	5.0×10^{-12}	1.6	4.1	6.4
Ordinary structural concrete: w/c about 0.50	1.5×10^{-12}	5.4	13.7	21.4
Durable marine mix: w/c 0.40 with slag or fly ash	5.0×10^{-13}	16.1	41.1	64.2

Source: illustrative model: Cs = 1.5%, Ccrit = 0.4% by mass of binder (assumptions, Annex A).

Products and implementation

Table D.17 Cameroon imports by HS line, US\$ million (Figure 9.1)

HS line	2019	2020	2021	2022	2023
HS 7213 wire rod	40.6	55.6	74.0	26.6	8.1
HS 7216 sections	16.8	29.6	29.1	26.2	26.3
HS 7214 bars incl. rebar	3.7	12.5	9.2	6.9	3.3
HS 7217 wire	2.8	4.0	5.3	6.3	5.1

Source: UN Comtrade public API, Cameroon reporter data [S52].

Table D.18 Indicative implementation calendar (Figure 10.1)

Measure	Start	End	Lead
R1 Publish NC 236 essentials and certified-mill list	2027 Q1	2027 Q2	ANOR
R2 Certification with surveillance and audit testing	2027 Q1	2028 Q2	ANOR, mills
R3 Market surveillance at merchants, published results	2027 Q2	2030 Q4	ANOR, MINCOMMERCE
R4 Price homologation per tonne, not per bar	2027 Q1	2027 Q3	MINCOMMERCE
R5 Certified rebar clause in public works contracts	2027 Q1	2027 Q4	MINMAP, ARMP
R6 Site acceptance testing tied to building permits	2027 Q3	2029 Q2	MINHDU, councils
R7 Accredited testing capacity in each main city	2027 Q3	2029 Q4	ANOR, labs
R8 Training for masons, foremen and engineers	2027 Q1	2030 Q4	Industry, schools
R9 Durability rules for the coast (cover, mixes)	2027 Q3	2028 Q4	MINHDU, ANOR
R10 Annual public report on rebar conformity	2028 Q1	2030 Q4	ANOR

Source: Cameroon Steel indicative calendar; quarters approximate.

CAMEROON STEEL

FROM MINERAL RESOURCE TO INDUSTRIAL VALUE

Cameroon Steel is developing a steel complex at Mboro, in the Kribi industrial-port zone, to turn Cameroonian iron into the bars, rods and sections that Central Africa builds with. This paper is published for information and does not constitute an offer or a commitment.