Technical study of Kongo-Central colonial steel houses belonging to the DRC patrimony

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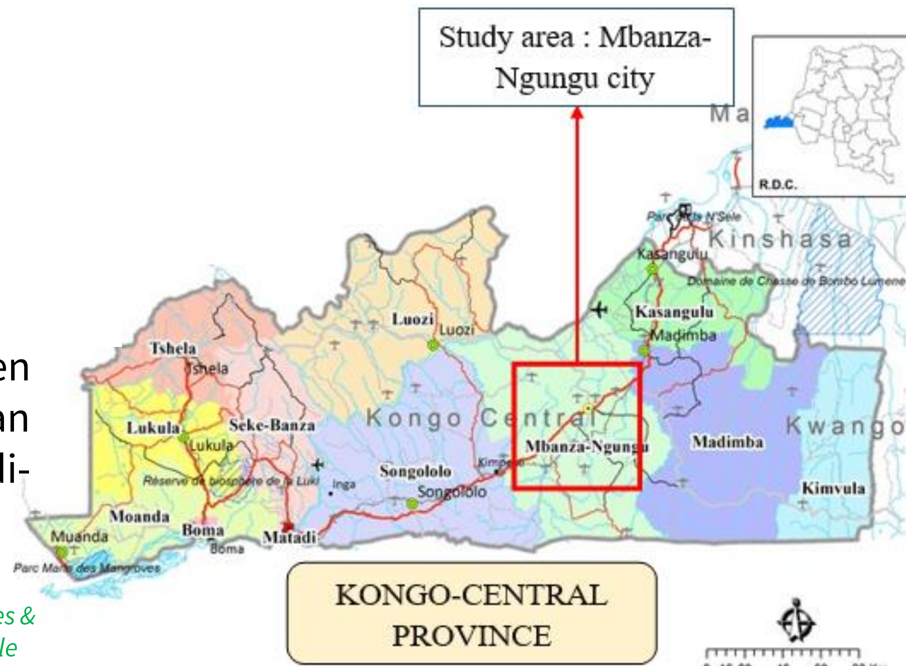
Context of the study

The railroad lines of the Democratic Republic of the Congo (source : Aliesin, 2007)

- ❑ Matadi-Kinshasa - non navigable section of the Congo River = Railway line construction needed



- ❑ Several colonial steel houses have been identified in the city of Mbanza-Ngungu (an obligatory crossing point of the Matadi-Kinshasa railway line).

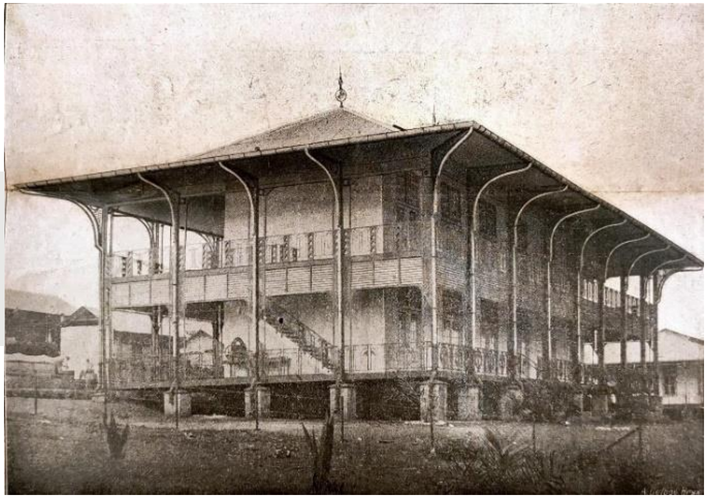
Kongo-Central Province with its 10 territories & description of the study area (source: Cellule d'Analyses des Indicateurs de Développement (CAID))

What does our study focus on ?

Single-storey houses (source: NEPTUNE newspaper of 20 January 1914)

Technical study of steel frame houses with masonry or wood infill

Thysville Hotel, built in 1906 by the Société Anonyme des Grandes Chaudronneries de l'Escaut



Multi-storey houses (source: NEPTUNE newspaper of 20 January 1914)

Objectives

- ❑ Identification of technical characteristics of these steel houses

- ❑ Identification of pathologies affecting these houses

Phase 1

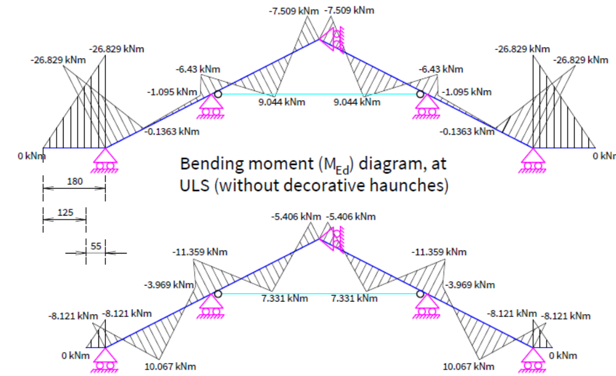
- ❑ Proposal of rehabilitation and reallocation solutions for these houses

Phase 2

Some specific constructive details

- Structural contribution of the decorative haunches

Decorative haunch

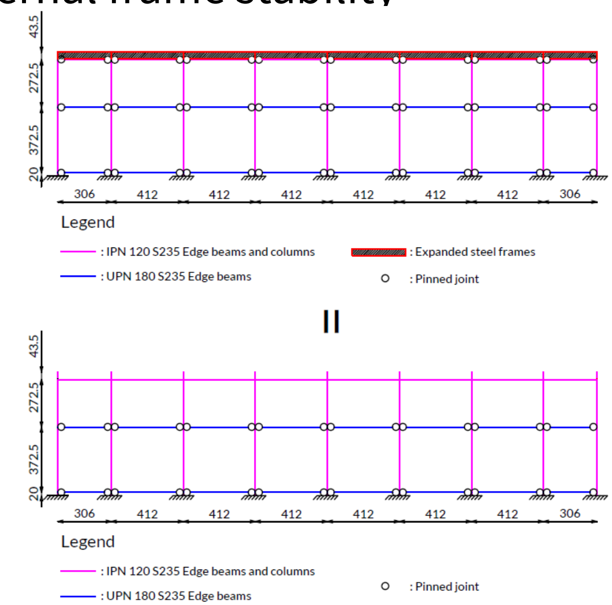


Bending moment (M_{Ed}) diagram, at ULS (without decorative haunches)

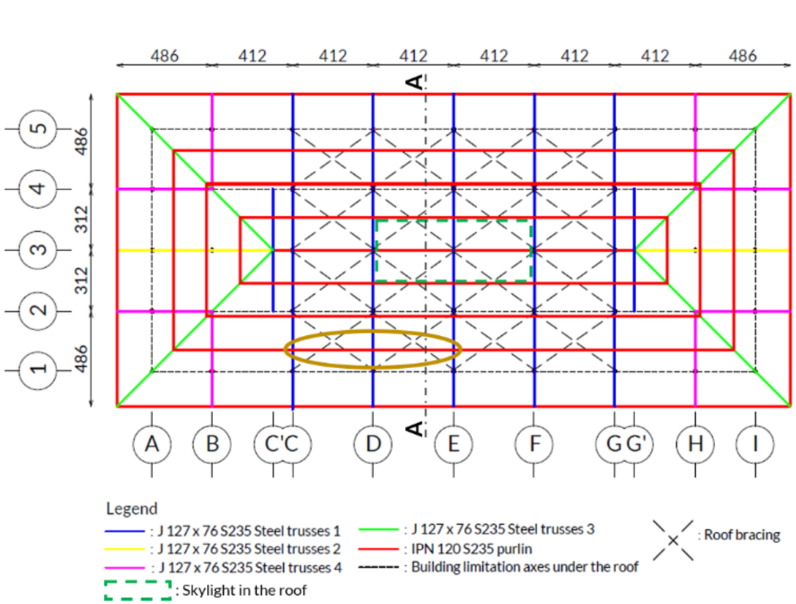
Bending moment (M_{Ed}) diagram, at ULS (with decorative haunches)

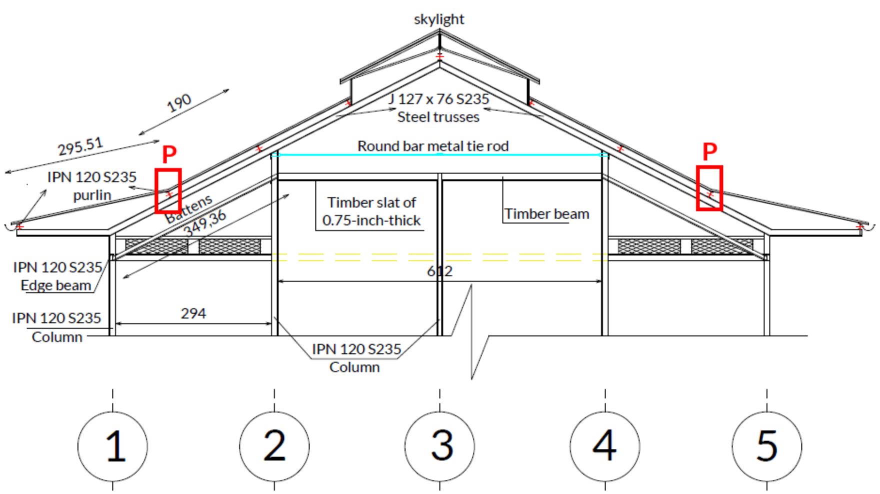
- Effect provided by expanded steel frames on the external frame stability

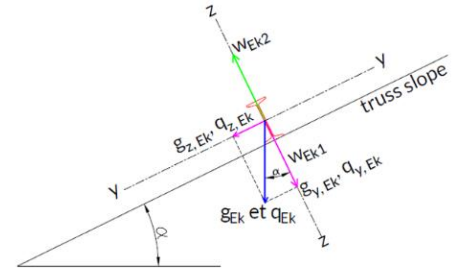
Expanded steel frames placed above the IPN 120 beams



Detailed study of an IPN 120 S235 purlin







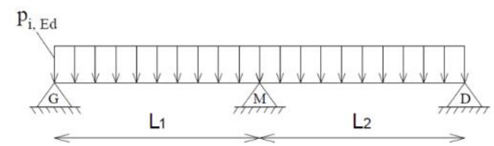


Table 1: checking of the studied steel purlin

Checks	z-z axis	y-y axis
Shear strength	$V_{Ed} = 22.57$ kN $V_{pl,\,y,\,Rd} = 89.95$ kN No M-V interaction Symmetrical I-section profile	$V_{Ed} = 0.82$ kN $V_{pl,\,z,\,Rd} = 120.28$ kN No M-V interaction
Cross-section resistance	$\left[\frac{M_{y,Ed}}{M_{pl,y,Rd}}\right]^{\alpha} + \left[\frac{M_{z,Ed}}{M_{pl,z,Rd}}\right]^{\beta} < 1$ $\left[\frac{9{,}30}{14{,}95}\right]^{2} + \left[\frac{0{,}33}{2{,}91}\right]^{1} = 0.39 + 0.12 = 0.51 < 1$	
Lateral-torsional buckling	The lateral-torsional buckling is satisfied with a loading rate of 93% (i.e., 0.93 < 1)	
Check of the deflection	$w_{max} = 6.9$ mm $w_{lim,\,max} = L/200 = 20.6$ mm $\Rightarrow w_{max} < w_{lim,\,max}$	$w_{max} = 6.1$ mm $w_{lim,\,max} = L/200 = 20.6$ mm $\Rightarrow w_{max} < w_{lim,\,max}$

Main causes of damage of these structural elements:

Increase of loads (not initially planned) on structural elements

Corrosion

Lack of maintenance of these structures & deterioration of corrosion protection

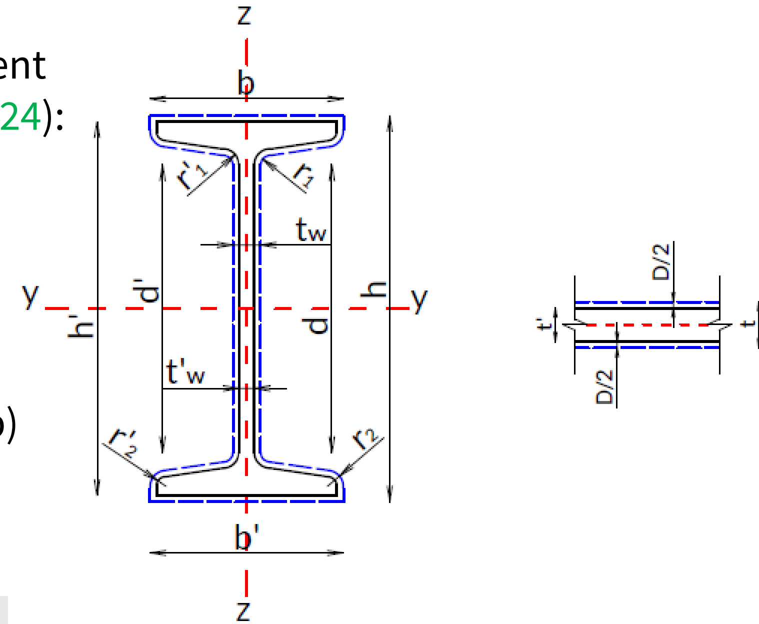
New geometric characteristics of a corroded profile at time t:

The total corrosion attack (D) of the corroded element is determined by the following formulas (see ISO 9224):

$D = r_{corr} \cdot t^B$ for $t \leq 20$ years
$D = r_{corr} \cdot [20^B + B\,(20^{B-1})\,(t-20)]$ for $t > 20$ years

With:

- B = B2 = 0.575 + 0.026 < 1 (the specific time exponent of the metal-environment relationship)
- r_{corr}: corrosion rate (see table 2)
- t: time in year



New dimensions of the corroded profile at time t:

$(h', b', t'_w, t'_f) = [(h, b, t_w, t_f) - D]$ (mm)
$(r'_1, r'_2) = [(r_1, r_2) + D/2]$ (mm)

New geometrical characteristics ($A', I'_y, I'_z, W'_{pl,y}, W'_{pl,z}$...)

values of carbon steel corrosion rate

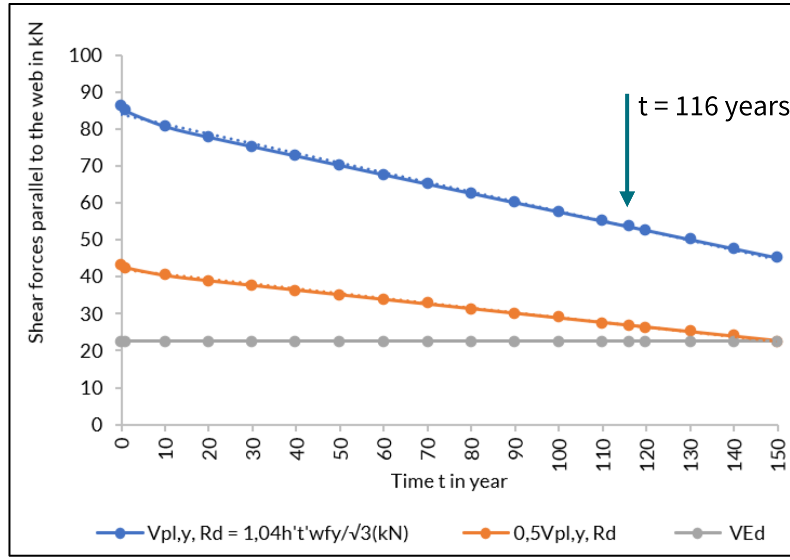
Table 2: Atmospheric corrosivity categories and examples of typical environments (ISO 9223 & EN12500)

Corrosivity category		**Corrosion rate of steel**		**Standard environments (examples)**	
Corrosivity category	**Corrosivity**	**g / (m². a)**	**µm/a**	**Indoor**	**Outdoor**
C1	Very low	$r_{corr} \leq 10$	$r_{corr} \leq 1,3$	Heated spaces, low relative humidity, and insignificant pollution, e.g. offices, schools, museums.	Dry or cold zone, atmospheric environment, very low pollution and time of wetness, e.g. certain deserts, central Antarctica.
C2	Low	$10 < r_{corr} \leq 200$	$1,3 < r_{corr} \leq 25$	Unheated spaces. varying temperature and relative humidity. Low frequency of condensation and low pollution, e.g. storage rooms, sports halls.	Temperate zone, low pollution atmosphere (SO_2 < 12 µg/m³), e.g. rural areas, small towns. Dry or cold zone, atmospheric environment with short time of wetness, e.g. deserts, sub-arctic areas.
C3	Medium	$200 < r_{corr} \leq 400$	$25 < r_{corr} \leq 50$	Spaces with moderate frequency of condensation and moderate pollution from industrial production, e.g. food processing plants, laundries, breweries, dairies	Temperate zone, atmospheric environment with medium pollution (SO_2: 12 to 40 µg/m³) or certain effect of chlorides, e.g. urban areas, coastal areas with low deposition of chlorides. Tropical zone, atmosphere with low pollution.
C4	High	$400 < r_{corr} \leq 650$	$50 < r_{corr} \leq 80$	Spaces with high frequency of condensation and high pollution from industrial production, e.g. industrial processing plants, swimming pools.	Temperate zone, atmospheric environment with high pollution (SO_2: 40 to 80µg/m³) or substantial effect of chlorides, e.g. polluted urban areas, industrial areas, coastal areas without spray of salt water, strong effect of decaying salts. Tropical zone, atmosphere with medium pollution.
C5	Very high	$650 < r_{corr} \leq 1500$	$80 < r_{corr} \leq 200$	Spaces with almost permanent condensation and/or with high pollution from industrial production, e.g. mines, caverns for industrial purposes, unventilated sheds in humid tropical zones.	Temperate zone, atmospheric environment with very high pollution (SO_2: 80 to 250 µg/m³) and/or strong effect of chlorides, e.g. industrial areas, coastal and off shore areas with salt spray. Tropical zone, atmosphere with high pollution and/or strong effect of chlorides.
CX	Extreme	$1500 < r_{corr} \leq 5500$	$200 < r_{corr} \leq 700$	Industrial areas with excessive humidity and aggressive atmosphere	High salinity sea areas, industrial areas with excessive humidity and aggressive atmosphere, and tropical and subtropical atmospheres

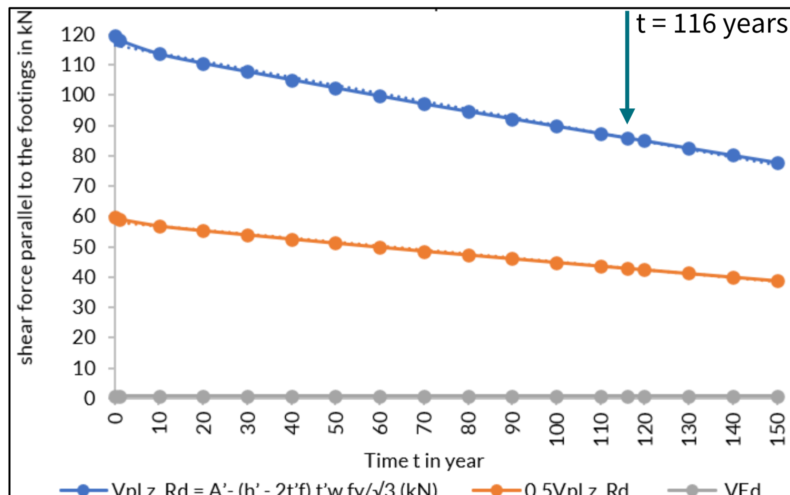
Influence of corrosion on the resistance of the IPN 120 profile

refer to EN 1993-1-1

At time t = 0	At time t = 116 years
$V_{pl, y, Rd}$ = 89.95 kN	$V_{pl, y, Rd}$ = 53.652 kN
$0.5V_{pl, y, Rd}$ = 44.975 kN	$0.5V_{pl, y, Rd}$ = 26.826 kN
V_{Ed} = 22.57 kN	V_{Ed} = 22.57 kN
No M-V interaction	No M-V interaction



At time t = 0	At time t = 116 years
$V_{pl, z, Rd}$ = 120.28 kN	$V_{pl, z, Rd}$ = 85.972 kN
$0.5V_{pl, z, Rd}$ = 60.14 kN	$0.5V_{pl, z, Rd}$ = 42.986 kN
V_{Ed} = 0.82 kN	V_{Ed} = 0.82 kN
No M-V interaction	No M-V interaction



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Influence of corrosion on the resistance of the IPN 120 profile

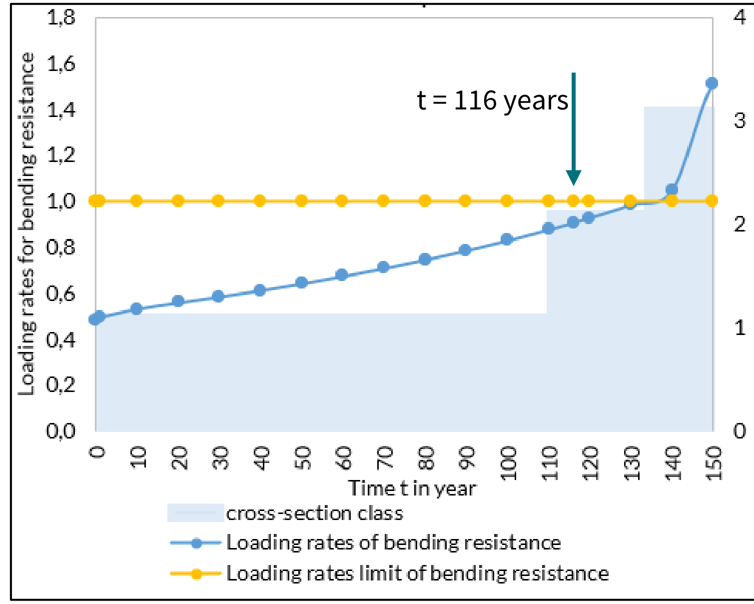
refer to EN 1993-1-1

At time t = 0

$[M_{y,Ed}/M_{pl,y,Rd}]^{\propto} + [M_{z,Ed}/M_{pl,z,Rd}]^{\beta} = 0.51 < 1$

At time t = 116 years

$[M_{y,Ed}/M_{pl,y,Rd}]^{\propto} + [M_{z,Ed}/M_{pl,z,Rd}]^{\beta} = 0.906 < 1$



At time t = 0
The lateral-torsional buckling is satisfied with a loading rate of 93% (i.e., 0.93 < 1)

theoretically, after 6 years of atmospheric exposure , the loading rate of the IPN 120 corroded purlin is > 1

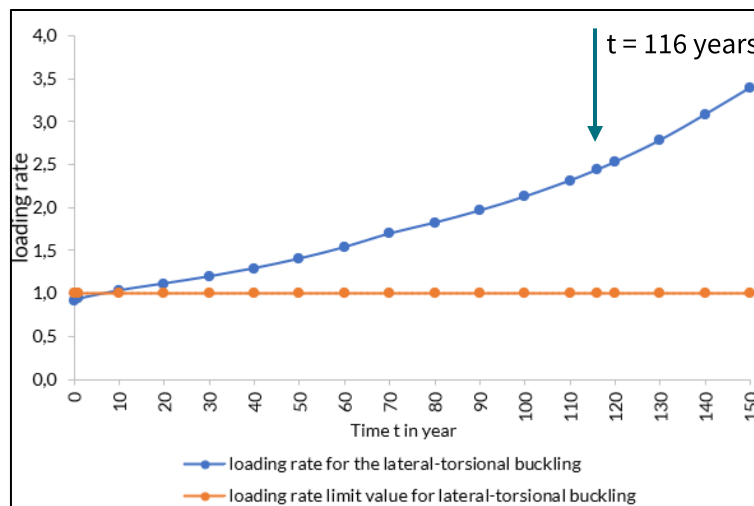


Illustration of a corroded purlin

Conclusion & Perspectives

- ❑ The structure studied, in its initial state, satisfies all the limit states in terms of deformation, resistance, and stability.
- ❑ Some structural elements, such as the studied purlin, are sensitive to the effects of corrosion and are expected to have limited lifespans.

- ❑ Complete study of the structure in its current state without considering the influence of corrosion
- ❑ Consideration of the influence of corrosion on the global structural behaviour
- ❑ Proposal of reinforcement and repair solutions of the structure

Norms & sources of images

- Norms used for the initial design of the structure: EN 1990 ; EN 1991-1-1 ; EN 1991-1-4 ; Règles NV 65 ; EN 1993-1-1
- Norms used for taking account the influence of corrosion: ISO 9223 ; ISO 9224 ; EN 12500

- Aliesin, (2007). Railway lines of the Democratic Republic of the Congo https://fr.m.wikipedia.org/wiki/Fichier:Train_rdc.svg
- Cellule d'Analyses des Indicateurs de Développement. (s. d.). CAID. Consulté 12 mai 2022, à l'adresse https://caid.cd/index.php/donnees-par-province-administrative/province-de-kongo-central/?donnees=fiche
- Goffin, L. (1907). Le chemin de fer du Congo : Matadi – Stanley – Pool. M. Weissenbruch, imprimeur du roi 49, rue du poinçon, Bruxelles, 229 p.
- Photo library of Tervuren, Royal Museum for Central Africa Collection, AfricaMuseum.

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Thank you for your attention !

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