THE PAPERS OF MAURICE KOECHLIN (1856-1946)

C. Fivet[1], J. A. Ochsendorf[2], and D. Zastavni[3]

Keywords

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Abstract

In 1879, the then-23-years-old Maurice Kœchlin became the lead structural engineer of Gustave Eiffel's construction company founded 13 before. Together, they pushed the boundaries of steel and iron structural design. They have been responsible for the design of the Garabit viaduct (1879-1884), the Tarde viaduct (1881-1884), the inner reinforcement of the Statue of Liberty (1881-1886) and the 300 meters-high Eiffel tower in Paris (1884-1889). In 1900, Kœchlin succeeded Gustave Eiffel to head the company, a position he held until his retirement in 1940. Whereas Maurice Kœchlin's engineering works are known by many and considered as masterpieces, very little is known about his written scientific contribution.

This paper first attempts to draw a comprehensive list of Kœchlin's publications. A total of 28 have been identified among which 1 book and 14 papers provide original findings on structural engineering science. Written between 1984 and 1925, they address the resolution of specific structural problems using graphic statics or numerical methods, they develop the design process of structures built by the Eiffel Company or they describe pioneering implementations for steel.

As this original survey sheds new lights on Kœchlin's research interests and their chronology, the paper also restates Maurice Kœchlin's influence on the introduction of graphic statics in French-speaking Europe and further contextualizes the collaboration between Maurice Kœchlin and Gustave Eiffel and the contribution of Maurice Kœchlin to the *Société de constructions de Levallois-Perret.*

Figure 1: Maurice Kœchlin around 1939

[1] Massachusetts Institute of Technology, Cambridge MA, USA, corentin@mit.edu
[2] Massachusetts Institute of Technology, Cambridge MA, USA, jao@mit.edu
[3] Université catholique de Louvain, Louvain-la-Neuve, Belgium, denis.zastavni@uclouvain.be

INTRODUCTION

Maurice Kœchlin (1856-1946) and Gustave Eiffel (1832-1923) were both greatly committed to their work, highly complementary but had very opposite personalities. While Eiffel was charismatic and greatly engaged with the public, Kœchlin preferred the seclusion and scarcely talked about his work (Trautz 2002). Although Kœchlin was the brilliant and creative mind behind Eiffel's engineering success, Eiffel was likely to take public authorship upon the team work. And the 24-years-younger Kœchlin didn't seem to be really bothered by that. As a result, Kœchlin's actual contribution to the shaping and design of Eiffel Company's greatest pieces is not fully understood yet. Also, written and drawn documents to assess Kœchlin's legacy are few and haven't been compiled yet.

This paper proposes a study of Kœchlin's written contributions to the field of structural engineering. The following is organized in four sections. The first briefly summarizes Maurice Kœchlin's life and career. The second lists and reviews the papers and books written by Kœchlin. The third and fourth sections respectively built on this review in order to clarify Kœchlin's contributions to graphic statics and his relationships with Gustave Eiffel.

THE CAREER OF A TALENTED ENGINEER

Family and Education

Kœchlin was born on March 8, 1856 to a family who had established various entrepreneurial ventures in Alsace (Trautz 2002). His father Jean Frederique (1826-1914) was a textile manufacturer. His great-uncle André (1789-1875) founded a foundry in Mulhouse from which a machine factory for steam locomotives developed in 1839. Maurice consequently grew up in a middle-class industrial environment and naturally directed his career towards engineering. His younger brothers followed him in that path. Following the Treaty of Frankfurt in 1872, Maurice's father decided to keep his French citizenship and moved back to Strasbourg where Maurice obtained his high school diploma in 1873 (Walbrach 2006). His father sent him the same year to the Institute of Technology in Zürich. Maurice obtained his Swiss citizenship in 1876.

From Karl Culmann to Gustave Eiffel.

In Zürich, Maurice studied civil engineering and became a pupil of prof. Karl Culmann (1821-1881), one of the founders of graphic statics, a then novel method to compute stresses and deformations of structural systems by means of graphical constructions (Culmann, 1866). The method became quite popular among engineers in the following decades and stood out for clarifying the resolution of then complex structural problems. Culmann's particular approach was to teach graphic statics as a way to optimize the geometry of the structure (Maurer 2006).

In 1877, Kœchlin joined the railway company *Chemins de Fer de l'Est* (France) for two years. At that time, Gustave Eiffel (who has been trained in the same company from 1856 to 1864) had ran his own construction company for 11 years (Bergier 1990). Based in Levallois-Perret near Paris (France), his biggest achievements were then a bridge over the Gironde near Bordeaux (France, 1860), the "Galerie des Machines" (Paris, 1867) and the Maria-Pia Bridge over the Douro in Porto (Portugal, 1876). These spectacular iron and steel projects were mainly designed by Théophile Seyrig (1843-1923), an excellent engineer trained in the *École Centrale* in Paris. When Seyrig asked for more financial recognition regarding the design of the Garabit viaduct over La Truyère (France, 1879-1884), Eiffel dismissed him and hired Maurice Kœchlin instead. Maurice directly headed the design and technical team as the *Chef du bureau des études*.

Culmann's recommendation letter to Gustave Eiffel obviously played an important role in Eiffel's decision to fill the emptied position with a 23-years-old engineer.

In Eiffel's Company, Maurice Kœchlin was to work together with Emile Nouguier (1840-1898), a French engineer who studied in Paris and joined the company in 1867 as chief of construction operations.

Early Career

Kœchlin fully displayed his skills right from the start as he began working on the design of the Garabit viaduct. Although mainly inspired by the Douro Bridge, the design of the Garabit viaduct showcases a number of improvements regarding construction details and the optimization of the arch geometry (Trautz 2002). Some subsequent projects became famous as well. For instance, Kœchlin and Nouguier developed the viaduct over the Tarde (1881-1884). From 1881 to 1886, they worked on the inner supporting structure of the Statue of Liberty sculpted by Auguste Bartholdi for the USA. In 1884, Kœchlin drafted the design of a 300 meters-high tower. Although not convinced right from the start, Eiffel later undertook this challenging enterprise for the World Exhibit held in Paris in 1889 and the tower remained the highest building on earth for 40 years.

Late Career

In 1893, Eiffel, then aged 61 years, was profoundly diminished by the Panama case and retired. Kœchlin is appointed in Eiffel's stead by the board of the Company and the *Compagnie des établissements Eiffel* becomes the *Société de constructions de Levallois-Perret* (Carouge 2009). In 1902, Kœchlin was made an Officer of the French Legion of Honor (Avoiron 1902). Gustave Eiffel had received the same honor back in 1889 on the inauguration day of the Eiffel tower (Charton 1889).

After 1893, the Company specialized in the construction of pre-fabricated "dismountable and economic" bridges for the French colonies throughout Asia, South America and Africa. After the First World War, reinforced concrete construction developed and the need for large-scale engineering works in steel vanished. The Company consequently focused its activities on smaller projects like pre-fabricated steel hangars, workshops and power line towers (Carouge 2009).

Kœchlin retired at the age of 86 in 1940 and died six years later on June 12, 1946 in Veytaux (Lake Geneva), in the house he built for himself in 1900.

KOECHLIN'S SCIENTIFIC WRITTEN CONTRIBUTIONS

During his career as a structural designer, Kœchlin took the opportunity to write several papers and three books. Table 1 lists all the written communications that can be attributed with confidence to Maurice Kœchlin. This list has been conducted through requests on various online databases: worldcat.org, retro.seals.ch, cnum.cnam.fr, gallica.bnf.fr and google.com.

1882	*Théorie des arcs à rotation libre sur les appuis*	Les Annales des Travaux Publics, n°26, February 1882 ; pages 562-565.
1884a	*Concours pour la construction d'un pont sur le Danube et sur la Borcea près de Cernavoda.*	Schweizerische Bauzeitung, (1) vol.3, #4, January 26, 1884; pages 19-22. (2) vol.3, #12, March 22, 1884; pages 71-72.
1884b	*Efforts engendrés par les moments fléchissant dans les barres de treillis et les montants des poutres à treillis multiple*	Schweizerische Bauzeitung, vol.4, #18, November 1; 1884, pages 112-114.

1884c	*Problème de statique : détermination des efforts agissant dans les différentes pièces d'un système ayant les dispositions de la Fig.1*	Schweizerische Bauzeitung, vol.4, #10, September 6; 1884, page 61.
1886	*La Ligne élastique et son application à la poutre continue traitée par la statique graphique (Translated by M.Kœchlin, written by Ritter)*	Baudry, Paris ; 1886 (63 pages)
1887	*Arc parabolique supportant une charge uniformément répartie sur toute sa longueur et suivant l'horizontale*	Schweizerische Bauzeitung, vol.9, #10, March 5, 1887; pages 63-64.
1888	*Brevet d'Invention n°164364 en date du 18 septembre 1884, à MM. Eiffel, Nouguier et Kœchlin, pour une disposition nouvelle permettant de construire des piles et des pylônes métalliques d'une hauteur pouvant dépasser 300 mètres.*	Description des machines et procédés. Office national de la propriété industrielle, tome 53, Paris, 1888 ; page 16.
1889a	*Applications de la Statique Graphique*	Encyclopédie des Travaux Publics, Paris, 1889.
1889b	*La tour de 300 mètres à l'exposition universelle de Paris*	Schweizerische Bauzeitung, (I) vol.13, #25, June 22, 1889; pages 146-148. (II) vol.14, #2, July 13, 1889; page 7. (III) vol.14, #15, October 7, 1889; pages 87-88. (IV) vol.14, #23, December 12, 1889; pages 136-138. (V) vol.14, #24, December 14, 1889; pages 141-144. (VI) vol.14, #25, December 21, 1889; pages 147-149.
1890	*Les ponts métalliques par Jean Résal*	Le Génie Civil, vol.17, #7, June 14, 1890; page 109.
1898	*Applications de la Statique Graphique*	Second Edition. Encyclopédie des Travaux Publics, Paris, 1898.
1899	*Calcul des tôles rectangulaires*	Le Génie Civil, vol.36, #4, November 25,1899; pages 57-60.
1900	*Calcul des réservoirs en tôle*	Le Génie Civil, vol 36, #18, March, 3, 1900; pages 275-278.
1905a	*Recueil de types de ponts pour routes*	Encyclopédie des Travaux Publics, Paris, 1905.
1905b	*Forme rationnelle des bâtis en C pour les riveuses*	Le Génie Civil, vol 47, #4, May, 27, 1905; page 62.
1905c	*L'araignée et sa toile.*	La Nature, revue des sciences et de leurs applications aux arts et à l'industrie, 1903, premier semestre ; pages 394-395.
1905d	*The Spider and his web.*	Scientific American Supplement , September 23 1905, vol. 60, page 24848.
1908	*La résistance des billes et des rouleaux*	Le Génie Civil, vol 53, #2, May, 9, 1908; pages 23-24.
1911	*Travail d'une aile de cornière ou de fer en U sous l'action d'une charge concentrée agissant sur le bord de l'aile*	Le Génie Civil, vol 58, #25, April 22, 1911; pages 521-522.
1912	*Dispositions défectueuses des armatures dans les travaux en ciment armé*	Le Génie Civil, vol.60, #20, March 16, 1912; pages 392-393.
1915	*Calcul et expérimentation des poutres solidaires de leurs supports*	Le Génie Civil, vol.57, #8, August 21, 1915; page 125.

1922	*Note sur la résistance des tôles comprimées et à joints par recouvrement*	Le Génie Civil, vol.81, #24, December 9, 1922; page 546.
1925	*La déduction de la section des trous de rivets dans les calculs de résistance*	Le Génie Civil, vol.87, #14, October 3, 1925; page 295.

Table 1: Maurice Kœchlin's written publications. Book titles are underlined.

All publications are written in French. The table comprises three books. The first one (1886) is a translation of the second edition of a book that was originally written 15 years before by Wilhelm Ritter (1847-1906), the former assistant and successor of Karl Culmann at the ETH in Zürich (Ritter 1871). It presents a graphical method to compute the deflection of a continuous beam on multiple supports. The second book (1889) is an original treatise on graphic statics (see next section). The same year, Kœchlin published a series of six articles describing the form-finding methods, the structural analysis and the construction process of the Eiffel tower (1889b). The third book (1905a) is a handbook for engineers to size prefabricated bridges currently produced by the Company.

Most of Kœchlin's contribution are papers tackling specific iron or steel engineering issues. (1882) and (1887) addresses the structural analysis of arches. (1884b) studies the stresses in bracing members of a regular truss and (1884c) proposes the graphical resolution of a Fink truss. In (1899), (1900) and (1922), Kœchlin suggests a numerical method to determine the strength of steel slabs, in (1908) he presents a method to determine the strength of balls and rollers compressed between two plates, in (1911) he studies the lateral torsional buckling effect of flange beams and in (1925) he comments the influence of the size of the rivets on the strength of steel plates. The (1905b) paper suggests the improvement of a rivet machine, common tool used by the Company. Finally, the (1912) paper critiques two configurations of rebars in reinforced concrete. Obviously, all these papers reflect practical issues that he or his team faced while designing or repairing the Company's bridges.

The texts of (1890) and (1915) are small comments on a book and a paper written by others. The publication of (1888) is the patent Gustave Eiffel, Emile Nouguier and Maurice Kœchlin obtained to protect the design of the Eiffel tower. Finally, the papers of (1905c) and (1905d) are the French and English versions of an accurate description on how the spider builds her web. The signature "*Maurice Kœchlin, Administrateur directeur de la Société de constructions de Levallois-Perret*" is the only element that links these two curious papers on entomology with the other engineering production of Maurice Kœchlin.

Trained as a chemical engineer, Gustave Eiffel became a self-taught structural engineer and a dynamic entrepreneur. However he didn't have Kœchlin's in-depth knowledge on engineering design. As Eiffel's publications in table 2 reproduce many calculations and illustrations already published in papers authored by Kœchlin in table 1, Eiffel may have asked Kœchlin to write or supervise some of his chapters. The three following references are comprehensive reports that describe the process, design and construction of the Eiffel tower and the Garabit viaduct.

1885	*Projet d'une tour en fer de 300m de hauteur*	Mémoires et compte rendu des travaux de la Société des Ingénieurs Civils, premier volume, séance du 20 Mars 1885, Paris ; pages 328-332, 344-370; plate 91.
1889	*Mémoire présenté à l'appui du projet définitif du Viaduc de Garabit*	Extrait des mémoires de la Société des Ingénieurs Civils, Paris, Juillet 1888 ; 182 pages & 19 plates
1900	*La tour de trois cents mètres*	Paris, Société des Imprimeries Lemercier, 1900 ; 383 pages, 47 plates & 16 photographs

Table 2: Gustave Eiffel's publications that may have been partially written by Maurice Kœchlin.

Additional papers and books that are most likely to be authored by another Maurice are listed in table 3 in the appendix.

More than a systematic compilation, tables 1 and 2 provide insights on two important aspects of Kœchlin's career: his contribution to the deployment of graphic statics in France and his working relationship with Gustave Eiffel. These aspects are covered in the next sections.

MAURICE KOECHLIN AND THE GRAPHIC STATICS: FROM "GRAPHISCHE STATIK" TO "STATIQUE GRAPHIQUE"

When the young Maurice Kœchlin moved from Zürich to France in 1877, he was well-trained in graphic statics thanks to his mentor Karl Culmann. However, graphic statics were not yet fully introduced in France (Chatzis 2004). Founding papers and books were written in English (papers by W.J.M.Rankine and J.C.Maxwell), German (F.Reuleaux and K.Culmann) and Italian (L.Cremona). The only available publications in French at that moment were the translation of a book written by Franz Reuleaux (Reuleaux 1873), a colleague of Karl Culmann in Zürich, introductory papers by Stéphane Pichault, a Belgian engineer (Pichault 1873), and a full theoretical treatise by Maurice Lévy, a French engineer (Lévy 1874). The years following 1877 were marked by the translation in French of books originally written in Italian and German, as well as by original papers resolving specific engineering problems (Chatzis 2004). Maurice Kœchlin took part in this common effort when he wrote the paper published in September 1884 (table 1, 1884c) and when he translated Wilhelm Ritter's book (table 1, 1886).

Aside from Lévy's 1874 book, the first original treatises about graphic statics written in French appeared only in the late 1880's. Kœchlin's book (table 1, 1889) is one of them, amongst three others by Arthur Thiré (Thiré 1888), Eugène Rouché & Charles de Comberousse (Rouché 1889) and Théophile Seyrig (Seyrig 1898), the engineer whom Kœchlin replaced when he joined Eiffel's Company in 1879. These books have the distinctive feature of directly tackling operational problems and providing practical advices. Kœchlin's book was well received by French engineers (Foy 1889) and has been enlarged in a second edition in 1898.

From that, one can easily extrapolate that Kœchlin's ability for innovative structural developments is closely connected to his mastery of graphic statics. Further in-depth research is needed to support that assumption.

MAURICE KOECHLIN AND GUSTAVE EIFFEL: THE CREATIVE ENGINEER AND THE SUCCESSFUL ENTREPRENEUR

The amount of scientific papers written by Kœchlin emphasizes his commitment to innovative engineering topics. Kœchlin loved accuracy, regularity and discipline. He was a great engineer who sought to avoid public appearances. He preferred to give journalists details of construction rather than details about himself and his life. He was modest, taciturn, introspective and sincere (Walbrach 2006). What Kœchlin realized during his career would have been unattainable without Eiffel's personal and corporate commitment (Trautz 2002).

The 24-years-older Gustave Eiffel was a man of public affairs and had great economic skills. He was constantly seeking for simple and cost-saving solutions, leaving out the superfluous. He had a gift to organize the work carefully and deal sensitively and generously with his employees.

Whereas Kœchlin could write expert papers on accurate calculation methods (table 1), Eiffel was keener to gather different topics in a broader book (see table 2 for instance). Both characters had different skills and motivations. Throughout the years, the two maintained a relationship built on mutual respect and recognition. Kœchlin never seemed bothered by Eiffel greater public

recognition during Eiffel's lifetime. At the Jubilee of the Eiffel tower in 1939, Kœchlin however recalled that "The father of the tower is Eiffel, but the idea and the calculations are mine". The literature led by Kœchlin clearly assesses this statement.

CONCLUSION

This paper brought to light the consequent amount of scientific papers written by Maurice Kœchlin, the inventor of the Eiffel tower. They highlight Kœchlin's numerous topics of interests and give insight into the daily issues he and his firm had to tackle. Also, the existence of these papers emphasizes Kœchlin's contribution to the deployment of graphic statics in France and gives substance to Kœchlin's personal relationship with Gustave Eiffel. As a consequence, this paper calls for thorough research on Kœchlin's original papers with regards to their contemporary counterparts in the field of graphic statics and iron and steel constructions.

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APPENDIX

The following table references publications that the authors assume to be written by three other Maurice Kœchlin, all engineers, members of the same family and originating from the Mulhouse area.

1891	*Electric Meter.*	United States Patent Office. No 458,755, September 1, 1891.
1917	*Conseils pratiques pour la construction des grands postes de transformation à haute tension*	Revue Générale d'Électricité, Tome II, Paris, October 20, 1918 ; pages 617-624.
1919	*Les forces hydrauliques du Rhin et le canal latéral entre Strasbourg et Bâle*	Bulletin Technique de la Suisse Romane, #22, November 1, 1919; pages 229-231.
1921	*Le canal alsacien entre Bâle et Strasbourg*	Bulletin Technique de la Suisse Romane, #5, March 5, 1921; pages 52-55.
1921	*Observations sur la tarification de l'énergie réactive et sa réalisation pratique*	Revue Générale d'Électricité, Tome IX, #17, Paris, April 23, 1921 ; pages 572-574.
1922	*Note sur les tarifs de vente de l'énergie électrique*	Revue Générale d'Électricité, Tome XI, #17, Paris, April 29, 1922 ; pages 623-628.
1924	*Mécanisme de l'eau et principes généraux pour l'établissement d'usines hydro-électriques (authored primarily by René Koechlin)*	C. Béranger, Paris, 1924-1926 (3 vol.)

Table 3: Papers and book (underlined) most probably written by another Maurice Kœchlin.

The U.S. patent (1891), authored by "Maurice Kœchlin, residing in Belfort" is most likely to refer to another Maurice Kœchlin, born in Mulhouse in 1864 and deceased in Paris in 1934, chief-engineer in the *société anonyme des engrenages Citroën* (Municipalité du Blanc-Mesnil 2000) who has lived some time in Belfort, France. Both Maurice are related through their great-great-grand-father Samuel Kœchlin (1719-1776).

The other papers are all signed by "*Maurice Kœchlin, ingénieur à Bâle*". They relate to electrical consumption and to the use of the future canal from Strasbourg to Basel as an electric generator. This project was of great interest to René Kœchlin, Maurice's younger brother. Also trained at the *Polytechnikum* in Zürich, René Albert Kœchlin (1866-1951) was a successful entrepreneur who founded many companies among which is the *Société des Forces Motrices du Haut-Rhin*, a company whose purpose was to build and run hydroelectric plants on the Rhine, between Strasbourg and Basel (Koechlin.net 2011). Since the Maurice Kœchlin who invented the Eiffel tower never worked in Basel, these papers may either be authored by André Maurice Kœchlin (1899-1988) who is René Kœchlin's child, or by Maurice Samuel Kœchlin (1890-1976) who is Maurice Kœchlin's child. The book on hydraulics and hydroelectric plants (1924) is a book primarily written by René Kœchlin and may be co-authored by one of these two children as well.