The Holy Spirit, Science, and Theological Education: Fourth Annual Conference in Renewal Theology
Regent University, March 18–19, 2016

Taking the Last Voyage with Newton and Pascal: The Life of Saint-Venant

Don C. Warrington, P.E., M.S., M.ASCE
University of Tennessee at Chattanooga
Department of Civil Engineering

He is not widely known outside of the fields he specialized in, but Adhémar Jean Claude Barré de Saint-Venant (1797-1886), usually known in the Anglophone world as simply Saint-Venant, was one of the premier scientists, engineers and mathematicians of the nineteenth century. Yet his religious and political stances made him unpopular in his native France, whose struggle over the place of Christianity in the life of the nation occupied most of his lifetime and beyond. Saint-Venant's achievements took place in a context of lost career opportunities, recognition of his achievements outside of the country and even among committed secularists, and finally the admiration of the French scientific establishment. This overview of his life and work shows his struggles and achievements in a familiar field of conflict but in an entirely different legal and social environment from the one we have today, with lessons for our own time.

Keywords: Saint-Venant, Civil Engineering, Christianity, Roman Catholicism, France

Introduction

It is axiomatic in some circles that theistic faith and scientific activity are mutually exclusive. This proposition is readily falsifiable, both with historical examples and with people living and active in their fields. Many times conflicts between secularists and theists get caught up in the political and social conflicts of the time that may or may not be related to the work of a specific scientist or engineer.

This paper will discuss these issues in the context of the life of one French engineer and mathematician who is not well known outside of engineering community: Adhémar Jean Claude Barré de Saint-Venant (1797-1886), usually known in the Anglophone world as simply Saint-Venant. Today his theories and achievements are used every day in the design of many products and structures. Not as well known is his personal struggle in getting the recognition he has, the interesting ways in which his work was propagated in spite of the difficulties he experienced at home, and his views on engineering and public works in relationship with his Christian life and faith.

Most of the material in this paper comes from Timoshenko (1953), whose own work in the theory of elasticity was in many ways a continuation of Saint-Venant's. Saint-Venant was not an avid seeker of fame. This accounts in part for his obscurity; however, is a mark of his Christian character as much as anything else. Perhaps this brief review will encourage interest for this fascinating figure in both Christianity and the physical sciences.

My special thanks to Dr. Edwin Foster, Professor Emeritus of Civil Engineering at the University of Tennessee at Chattanooga, for his review of the manuscript. He engendered a greater interest in me for the history of Civil Engineering in general and structures in particular. He originally donated my copy of Timoshenko (1953) to UTC's library, which sold it to me in a surplus sale.

Overview of His Achievements

In a review of his life, Saint-Venant's colleague Joseph Valentin Boussinesq (himself eminent in the field of elasticity) stated the following:

> He was the honor of the group specializing in bridges and roads and one of the scientific glories of France; he was a part of that noble race of spirits, at once the strength, ornament and consolation of our species, who together or in isolation leave after them a luminous trail in history which enlightens new intelligences to form a current, always more vast, of true and high civilization...Only his disciples and his friends will know, without sufficient ability to express it, how his heart was rich with affection, thoughtful expressions and rare devotion which is priceless. (Debauve (1893), p. 431; also Saint-Venant (1889))

Such an elegy points to a person who was both technically proficient and personally attractive. So did the scientific and engineering achievements match Boussinesq's glowing assessment? Without a detailed explanation of all the things

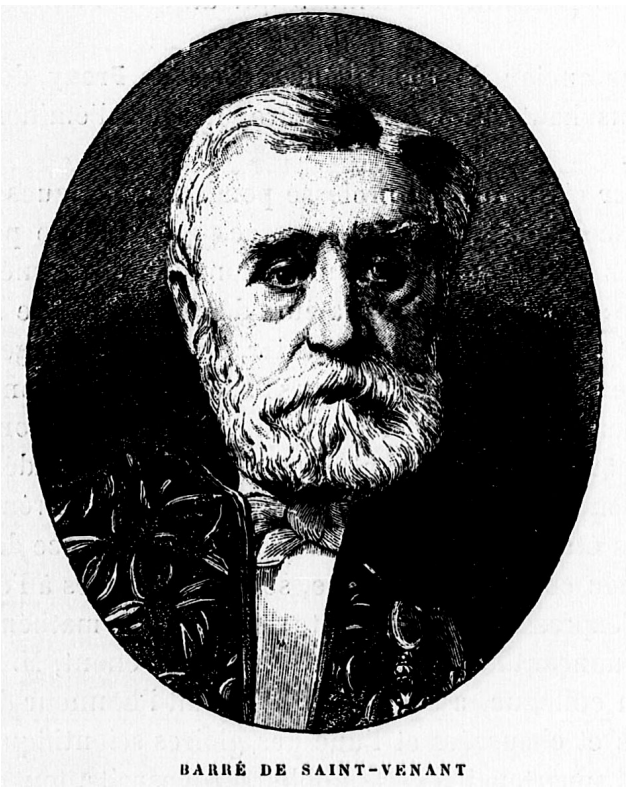

Figure 1. Adhémar Jean Claude Barré de Saint-Venant (from Debauve (1893))

Saint-Venant accomplished, the mention of a few very important ones should answer this question.

He successfully derived the Navier-Stokes Equations for a viscous flow before Stokes; these equations are the basis of computational fluid dynamics and the analysis of things that fly (Anderson (1997)). He also developed the one-dimensional shallow water equations (Saint-Venant (1851)). These, especially when expanded to two-dimensions, are important in the analysis of tidal flows, tsunamis, currents and contaminant transport (Behzadi (2016)).

He systematized and developed methods in the theory of elasticity of solids, including his semi-inverse methods for torsion, important in things such as automobile crank shafts. An example of torsional analysis from his work is shown in Figure 2.

He developed methods for the analysis of wave mechanics in solid bars, which we see in many places, from musical instruments to driven foundation piles. Although the theory is fairly simple, the implementation can be complex, as shown in Figure 3. His analysis of the subject, for example, was a direct inspiration for the development of inverse methods in pile dynamics (Rausche (1970)).

One final accomplishment was the result of his review of his colleague Henri Tresca's work on metal flow in plasticity. Once materials reach their elastic limit, they deform perma-

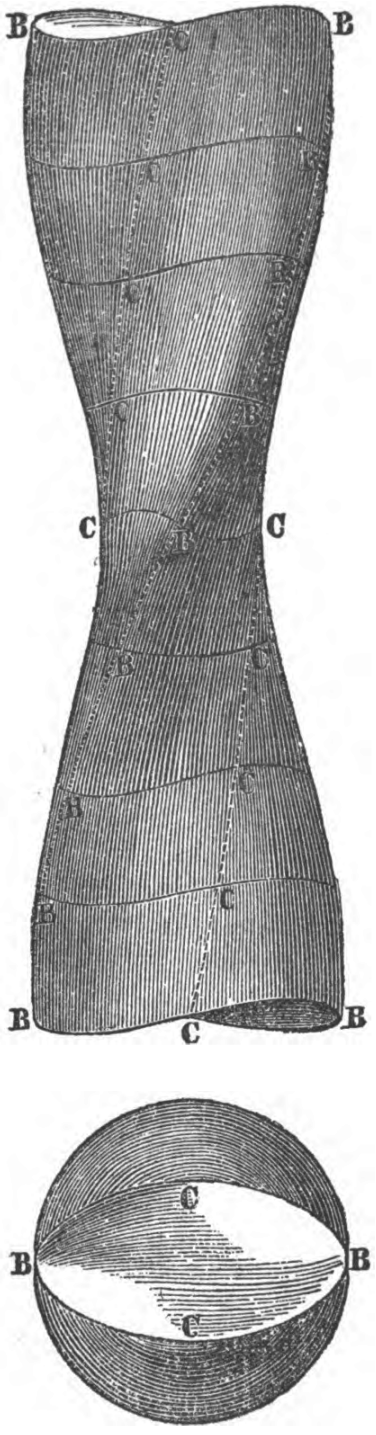

Figure 2. Torsional Deflection of a Shaft (from Todhunter and Pearson (1889))

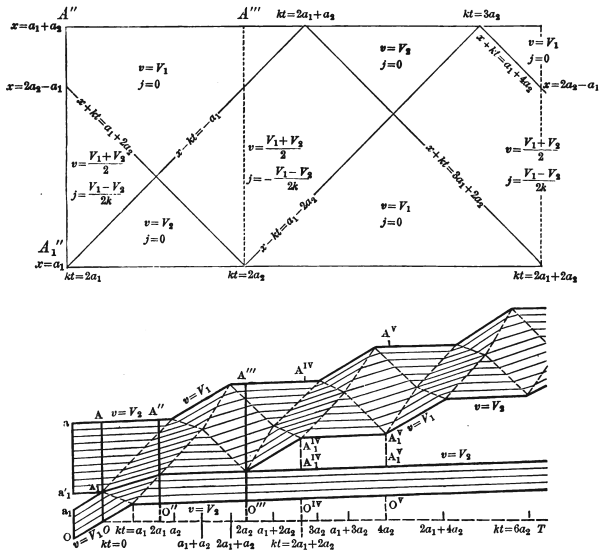

Figure 3. Analysis of One-Dimensional Wave Propagation (from Todhunter and Pearson (1889))

nently, something that can be seen every day. Saint-Venant took this information and developed the fundamental equations of plastic flow and stress. Plasticity takes the designer past the linear, non-path-dependent equations of elasticity that dominates much engineering design. It was many years before this theory could be implemented on a widespread basis, but today finite element analysis with plasticity (Owen and Hinton (1980)) is well-established in engineering practice.

These examples barely begin to scratch the surface of the scope of his work on these and many other subjects.

One theme that emerges in Saint-Venant's approach is his idea that engineering cannot be advanced using purely empirical formulas and techniques but that these must be combined with theoretical advances in order to produce progress. This idea appears both in his research and his pedagogy. In nineteenth century Europe the two were not always hand-in-hand; for example, the British emphasized the empirical and the Germans the theoretical. The development of computer based methodologies where Saint-Venant's principles are repeated millions if not billions of times during an analysis has vindicated his approach.

Early Years and Struggle

As outlined by Sarrau (1893), Barré de Saint-Venant (as the French style his last name) was born on August 24, 1797, at the Château de Fortoiseau, southwest of Melun. His father had been a colonial official; he was born into an aristocratic family during the Directory, which became the transition from the Reign of Terror to rule by Napoleon Bonaparte. In 1813 he was admitted to the École Polytechnique, which was and is France's premier technical institute of higher learning. Unfortunately Saint-Venant soon found himself caught in the conflict he was born into. As described in Timoshenko (1953):

> The political events of 1814 had a great effect on Saint-Venant's career. In March of that year, the armies of the allies were approaching Paris and the students of the École Polytechnique were mobilized. On March 30, 1814, they were moving their guns to the Paris fortification when Saint-Venant, who was the first sergeant of the detachment, stepped out from the ranks with the exclamation: "My conscience forbids me to fight for an usurper..." His schoolmates resented that action very much and Saint-Venant was proclaimed a deserter and never allowed to resume his study at the École Polytechnique.

Saint-Venant's statement of conscience was at once a political and religious statement. Many French Catholics, nurtured by works such as Jaques-Bénigne Bossuet's *Politics Drawn from the Very Words of Holy Scripture*, believed that the French Bourbon absolute, hereditary monarchy was ordained by God. Such ideas were one major reason why the Church was attacked so vociferously during the French Revolution. Not all French Catholics were averse to cooperating with Napoleon's regime, not even in Saint-Venant's profession, as Augustin-Louis Cauchy demonstrated (Bell (1937)), although Cauchy himself ultimately went into exile after the overthrow of Charles X.

The Restoration did not gain Saint-Venant readmission to École Polytechnique; instead, he worked in the gunpowder industry for nine years, then was admitted to the École des Ponts et Chausées, where his fellow students shunned him. He still graduated first in his class in 1825. He went on to hydrological work and also worked for the city of Paris, where he resigned in 1843 in a dispute. Through all this he married Rohaut de Fleury in 1837. In 1850 he received his only academic appointment with the Institut Agronomique de Versailles; two years later he left this to devote himself to his scientific pursuits.

Even with his work, he pursued both his writing and his research. In addition to his work on fluid mechanics, he also revised Navier (1864). "Revised" is an understatement; by the time he was done, there was very little left of Navier's work in it, but Saint-Venant still referred to it as Navier's book! He published articles and gave addresses on a wide variety of subjects, some of which were touched on earlier, but his past disputes still haunted him. In 1843 he was nominated for the Academy of Sciences chair vacated by the death of Gaspard-Gustave de Coriolis, but the nomination was rejected.

Reputation Outside of France

In spite of his difficulties within France, his reputation outside of her was another matter. This was the discovery of the Abbé François-Napoléon-Marie Moigno, who wrote a comprehensive textbook on statics and the mechanics of materials. While researching for the book, he discovered the following, which he included in the preface (Moigno (1868); Timoshenko (1953)):

> In the end, it is left to give a general overview, but also one as complete as possible, all following Cauchy, on the theory of molecular actions. Mr. Barré de Saint-Venant, student and continuer of the great master, offered to edit this part, and I warmly accepted his offer. Fatally belittled in France of which he is the purest mathematical glory, Mr. de Saint-Venant enjoys a reputation in foreign countries which we dare to call grandiose.
>
> In the field of theories and calculations relative to elasticity, stress, torsions, and flexure with sliding, he has advanced past all others, and there is no one across the English Channel or the Rhine who does not place him at first rank. Each time that, for these precise matters, I addressed to an English or German expert, I always received the same answer: "You have there, close to you, the authority par excellence, M. de Saint-Venant, consult him, listen to him, follow him." For example, Mr. von Ettingshausen wrote me in response to my question of whether he had finished his *Theory Of Elasticity*, and added that our Academy of Sciences makes a mistake, a great mistake when it does not open its doors to a mathematician who is so highly placed in the opinion of the most competent judges. Let us hope that this mistake will be repaired soon.

That adulation continued and took an even stranger course in the Anglophone world. Isaac Todhunter was one of Britain's best known writers of technical books in the nineteenth century. When he died in 1884, he left his last work *A History of the Theory of Elasticity and of the Strength of Materials* (Todhunter and Pearson (1893)) unfinished. Completing and editing that work was left to the British mathematician and statistician Karl Pearson. Pearson–Darwinist, eugenicist, and atheist–was an unlikely admirer of the work of a deeply religious person such as Saint-Venant. However, in his preface to Todhunter and Pearson (1889), Pearson noted the following:

> The more I studied Saint-Venant's work, the more new directions it seemed to me to open up for original investigation of the most valuable kind. It suggested innumerable unsolved problems in atomic physics, in impact, in plasticity and in a variety of other branches of elasticity, which do not seem beyond solution, and the solution of which if obtained would be of extreme importance. I felt convinced that a study of Saint-Venant's researches would be a most valuable directive to the several young scientists, whose recent memoirs shew their interest in elasticity as well as their mathematical capacity. Many of the problems raised by Saint-Venant's suggestive memoirs were quite beyond my powers of analysis, and I recognized that the most useful task I could undertake, was by a careful account of the memoirs themselves to lead the more competent on to their solution.

Thurston (1907) noted the following in a context that is certainly relevant more than a century later:

> Whether Professor Pearson knew anything of M. de Saint-Venant's religious convictions does not appear, but it is at any rate obvious that, though the French scientist venerated from the depth of his soul those "superstitions" of Catholic belief and practice which Mr. Pearson has in some sense spent his life in combating, they had not in the latter's judgment interfered either with the supreme value of his services to science or with that modesty and kindliness of disposition which is ability's noblest adornment.

Vindication at Home and Death

The hope that Saint-Venant would be vindicated in France was realized the same year that Moigno (1868) was published, when Saint-Venant was admitted into the Academy of Sciences to take the place of Jean-Victor Poncelet. He continued his work, much of it from his home in Saint-Ouen, up until the time of his death on January 6, 1886. When the President of the Academy announced that passing, he made the following statement (Timoshenko (1953)):

> Old age was kind to our great colleague. He died, advanced in years, without infirmities, occupied up to the last hour with problems which were dear to him and supported in the great passage by the hopes which had supported Pascal and Newton.

Europeans of the time would not have missed the import of the last statement: Pascal and Newton were Christians, and Saint-Venant was being identified with them as one also, by an establishment that had been, for much of his life, hostile to those convictions. It was also a statement that Saint-Venant, for all of his achievements and interests which have enriched the world, also had an eternal goal as well.

But for Saint-Venant the future life was not the only thing for consideration about Christianity; he also looked back at the beginning of creation and its course until the present. Saint-Venant lived at a time when both the pedagogy and the application of engineering mechanics–statics, dynamics and the mechanics of materials for which he is best known–was working towards its settled form which is taught in engineering schools today and applied to practical problems. Concepts such as force, velocity, acceleration, and power were examined from both a physical and a metaphysical point of view. In the course of this many questions arose. Do forces have a physical reality or a metaphysical one? Are they the result of physics or continual outside intervention? Do these unknowns explain the uncertainties that are observed in phenomena varying from what one would expect from the mechanics? Especially with moving objects, the effect of one on another, and yet another, suggested the chain of causality which occupied ancient and medieval philosophers and theologians, and ultimately the question of the First Cause comes into consideration. In addressing these problems, Saint-Venant himself stated the following (Moigno (1868)):

> (André-Marie) Ampère told me...and furnished the proof that *it is always impossible to devise mechanics without forces envisioned and calculated as such*...The sage Scotsman Reid...well remarked that their goal was not to determine and evaluate *efficient causes* unknown from phenomena, but to discover and apply the laws which they observe constantly in their succession. In practice, be it a problem of terrestrial or celestial mechanics under consideration, the forces do not come either in the data or in the result sought in the solution. One makes them intervene to resolve, and one then eliminates them, to only have at the end time, distances, speeds, as in the beginning...It is thus possible that the forces, those sort of problematic beings, or rather the added substances which are not either material or spirit, blind and unknowing beings, which it is necessary to endow the marvelous ability to perceive distances and to proportion punctually their intensity, to be more and more expelled and excised from mathematical sciences. They will take places according to laws not only *geometric*, but also *physical*, which rule the circumstances, the durations and the sizes of the changes of speed and of position...The time is not very far where, without denying at all the principle of causality, which pertain to a more elevated sphere of ideas, but leaving the cause or causes to their true place, which is not physics, one will renounce the pretense of making them the subject of calculations.

While he is addressing the issues on several levels, Saint-Venant attempts to resolve the issue of causality with the forces present in mechanics. While mindful of the need for causality to explain how things come into being and arrive at their present state, he places that divine intervention outside of the work of the scientist and engineer. The job of the latter, Saint-Venant is saying, is to work with the physical reality in front of them; the role of causality that comes from outside the physical realm is, to use his expressive phrase, in a "more elevated sphere of ideas." The advent of quantum mechanics (Guillemin (1968)) has softened Newtonian determinism (especially with phenomena which are either complex or at a high energy level or both) and would have given greater play to the elevated sphere.

In any case his idea, which is not as far-reaching as, say, Georg Cantor's development of set theory and transfinite numbers (Boyer (1968)), is a sensible approach that Christian scientists and engineers have taken, implicitly or explicitly, ever since. There is also an implied challenge in his idea: that, instead of simply chalking up variances in results to causes outside of the physical world, the scientist or engineer should apply the resources at his or her disposal to investigate these and find a physical cause for them, if it be possible to do so. Saint-Venant, however, had some definite ideas as to where the work of the civil engineer in particular fit into the divine plan, and it is that which will be discussed next.

Civil Engineering as Apostolate

Three years after his death, Saint-Venant's children put together one of his nearly-finished works as a memorial to his life, while including Boussinesq's elegy quoted earlier and another from Karl Pearson. That work was *Saint Bénézet, Patron of Engineers* (Saint-Venant (1889),) which is summarized in English by Thurston (1907). Saint Bénézet was the shepherd who, in 1177, came out of the fields and proclaimed that he had been sent by God to build a bridge over the Rhône at Avignon, and then proceeded to begin the work. The book is a combination of biography, account of the French engineers who were the saint's "clientele" (to use Saint-Venant's own word) and their gatherings, historical data on the saint and the bridge, and other information. In the typically detailed approach for which Saint-Venant was famous, little was left undone; the book even includes a plan and elevation view of the house (with scale and dimensions) the saint was born in, as shown in Figure 4.

Towards the end of all of this detail, Saint-Venant, writing in 1880, makes the following observation (Saint-Venant (1889); Thurston (1907)):

> Our profession, which, by God's Providence, was also his, is not only a glorious profession, but it is something consecrated and holy.

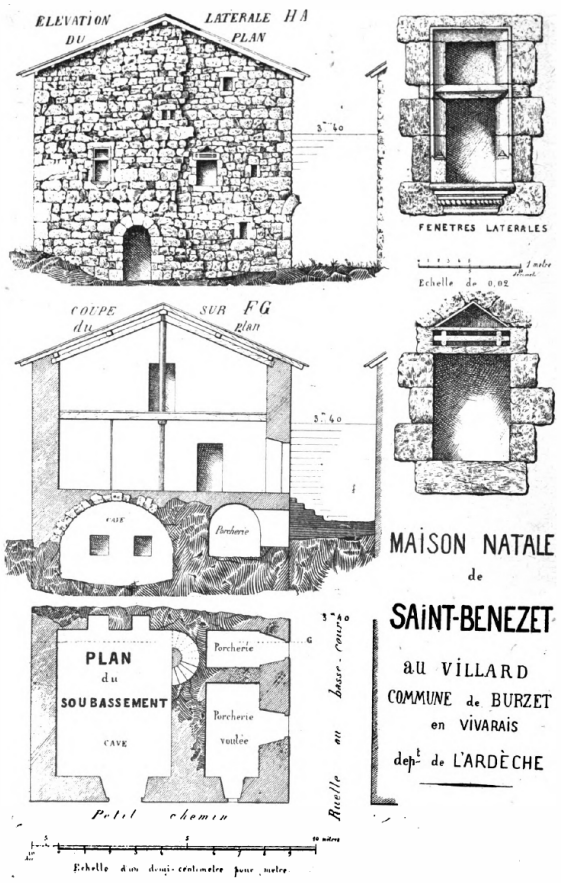

Figure 4. Partial Plan and Elevation View of Saint Bénézet's Place of Birth (from Saint-Venant (1889))

> It is a work of active charity, embracing travelers and traders and missionaries of every kind; but more than that, benefiting even the sedentary portion of the population, for lack of proper communication breeds famine, and the dearth or excess of water bring in their train loss of life, devastation, and impoverishment.

At this point, it is worthwhile to pause and reflect on what he is saying here.

Christian churches and parachurch organizations engage in an enormous number of charitable works for the purpose of improving the human condition. Yet it is worth noting that civil engineering, next to medicine, has done more to eliminate disease and extend life than any other profession. It does so through preventative measures such as clean water, functioning sewage systems, transportation infrastructure which facilitates bringing food, clothing and shelter, and many other improvements. And yet Christians of all kinds routinely concede such improvements (except in special cases) to the state or sometimes private enterprise, preferring to stick with relief efforts and medical missions. Saint-Venant opposes this neglect; he not only makes engineering a type of apostolate (to use the Catholic term) but also challenges the profession when it works outside of the confines of the church, which is generally the case and was certainly so for Saint-Venant and his colleagues, to regard their profession as "consecrated and holy." Is this lacuna of emphasis something that Christianity needs to revisit? For those who agree with Saint-Venant on the benefits of engineering and the nature of the profession, the answer is certainly "yes."

In the same work Saint-Venant has some other advice for his contemporaries:

> All is not rosy...in even the most beloved occupations. There are fears in birthing a project: there are more in efforts in making it understood and accepted. Similarly, the (project's) execution finally decided, repeated disappointments await its designer, from rebellious nature and men who are even more so. Instead of abandoning ourselves to impatience, to recriminations, think of the engineer-shepherd for whom refusals have neither impeded nor discouraged. He will get us calm, the spirit of counsel and good harmony, and the light will be in us.

In the 1880's France was a nation in conflict between its mostly Catholic right and its secularist left. Daniel-Rops (1966) noted that the Catholic side tended to be belligerent in pursuit of its agenda, which encouraged the backlash of the Dreyfus Affair, the near nationalization of the Church, and the final establishment of *laïcité* as the official policy of both the Third Republic and the two that have come after it. Would the calmer approach espoused by Saint-Venant, who uses the construction process as an analogy, obtained a better result both for the Catholics and the nation? Such a conclusion is hard to avoid given subsequent events in France, and is a lesson for Christian communities elsewhere.

Conclusion

Saint-Venant, little known outside of the engineering profession, is nevertheless one of the most attractive figures, both personally and with the quality of his scientific work, in the explosion of science and mathematics of nineteenth century Europe. Those qualities were evident in his response to the expulsion from the École Polytechnique and the years he spent "in the wilderness" after that. They are also evident in the response he obtained from those outside of France who appreciated his works before his fellow inhabitants of the Hexagon, even those who did not share and in some cases were very hostile to his Catholic Christian convictions. Given the state of both science and Christianity during the times he was on the earth, it is difficult to find someone who more successfully combined Christian life and scientific and

engineering excellence than Adhémar Jean Claude Barré de Saint-Venant.

References

Anderson, J. (1997). *A History of Aerodynamics*. Cambridge, England: Cambridge University Press.

Behzadi, F. (2016). *Solution of Fully-Coupled Shallow Water Equations and Contaminant Transport Using a Primitive Variable Riemann Solver and a Semi-Discrete SUPG Method* (Unpublished doctoral dissertation). University of Tennesee at Chattanooga, Chattanooga, TN.

Bell, E. (1937). *Men of Mathematics*. New York, NY: Simon and Schuster.

Boyer, C. (1968). *A History of Mathematics*. New York, NY: John Wiley & Sons, Inc.

Daniel-Rops, H. (1966). *A Fight for God 1870-1939*. New York, NY: E.P. Dutton & Co.

Debauve, A. (1893). *Les Travaux Publics et les Ingénieurs des Ponts et Chaussées Depuis le XVIIe Siècle*. Paris, France: Librairie des Corps Nationaux des Ponts et Chausées, des Mines et des Télègraphes.

Guillemin, V. (1968). *The Story of Quantum Mechanics*. New York, NY: Charles Scribner's Sons.

Moigno, F. (1868). *Leçons de Méchanique Analytique*. Paris, France: Gautier-Villars.

Navier, C.-L. (1864). *De la Résistance des Corps Solides* (Third ed.). Paris, France: Libraire des Corps Impériaux des Ponts et Chaussées et des Mines.

Owen, D., & Hinton, E. (1980). *Finite Elements in Plasticity: Theory and Practice*. Swansea, Wales: Pineridge Press.

Rausche, F. (1970). *Soil Response from Dynamic Analysis and Measurements on Piles* (Unpublished doctoral dissertation). Case Western Reserve University.

Saint-Venant, A. d. (1851). *Formules et tables nouvelles pour la solution des problèmes relatifs aux eaux courantes*. Paris, France: Carilian-Goeury et Vor. Dalmont.

Saint-Venant, A. d. (1889). *Saint Bénézet, Patron des Ingénieurs*. Bourges, France: Tardy-Pigelet.

Sarrau, E. (1893). De Saint-venant. *Livre du Centenaire de l'Ecole polytechnique*, *I*, 189–193.

Thurston, H. (1907, December). Bénézet, Saint, and his Biographer. *Catholic World*, *86*(513), 289–302.

Timoshenko, S. (1953). *History of Strength of Materials*. New York, NY: McGraw-Hill Book Company, Inc.

Todhunter, I., & Pearson, K. (1889). *The Elastical Researches of Barré de Saint-venant*. Cambridge, England: Cambridge University Press.

Todhunter, I., & Pearson, K. (1893). *A History of the Theory of Elasticity and of the Strength of Materials* (Vol. II). Cambridge, England: Cambridge University Press.