
FROM ENGINEER TO SCIENTIST, OR ABOUT THE VULNERABILITY AND INVINCIBILITY OF THE EARTHQUAKE ENGINEERING RESEARCHER

*Emil-Sever GEORGESCU**

To Prof. Dr. Eng. Dr. H. C. Horea Sandi, on the anniversary of 80 years

1. ASPECTS CONCERNING THE EVOLUTION AND SOCIAL STATUS OF CIVIL ENGINEERING

Those who chose the engineering profession, and specifically those in construction or civil engineering, were perceived differently by society through the ages, in comparison and correlation with other professions, acquired status and prestige, as well as in relation to branches of science. Even today, civil engineering, structural and earthquake engineering seem to be only branches of technology, so that the definition of an engineer as a scientist requires arguments. In the era of records, even building a bridge or a building of 1000 meter just awaken interest as a quantitative performance, not necessarily a scientific one.

Therefore, the tendency of modern society to classify and codify anything, to require performance at any cost countable, permanently launching competitions, claiming specialization and interdisciplinary approaches, can be a source of vulnerability for the human spirit and those professional careers which do not necessarily produce immediately visible physical objects, but create knowledge.

Example of Dr. Sandi, as a man and engineer, whose life and activity pursued steps in this context, can be a good opportunity for an exercise of analysis about the basic status of the professions and specialties that can be associated, in this case with the structural and earthquake engineering as

endeavors of scientific research. On the other hand, Dr. Sandi exceeds the specific profile of our profession, therefore some consideration will refer to the scientist in general.

The building, as an activity, science and art, governed by rules and laws exist since millennia, from the creators of temples and pyramids of Egypt, Hammurabi, since Apollodorus of Damascus or Vitruvius. However, until the seventeenth century many of the current components of civil engineer profession were incorporated in those of a builder, contractor and architect. In Greek and Roman antiquity, the one called “architecton” solved the conceptual and artistic tasks, but was also in fact “architecton mechanicos”, meaning today’s “engineer”, and even master coordinator.

For a long time, the contribution that was different of the professional talent to create forms, recognized as art, was not very visible to the public, as it was believed to be based only on tradition, good practice, experience or, perhaps, intuition. What was implicitly or explicitly devised and contributed to resistance to earthquakes in antiquity is revealed to us today by few temples and aqueducts who survived. We do not know exactly who and how thought and assembled such structures, but we see results.

Would have been science, intuition or experience the Leonardo’s statement that “each beam must go through the wall and will be provided with enough links to keep the walls together at the earthquake?”

*Ph D, Eng., Scientific Director for Constructions, N.I.R.D. URBAN-INCERC &, Senior Researcher, Laboratory for Seismic Risk Assessment and Actions in Constructions, INCERC Bucharest Branch of URBAN-INCERC, ssever@incerc2004.ro

In pre-modern era, Leon Battista Alberti (1404-1472) introduced the knowledge of earthquake resistant construction engineering in “De Re Aedificatoria”, (1485), stating that “buildings that have wooden floors withstand earthquakes better than those with arches and vaults”. After Alberti’s time, in XVI-th century, occur the specialization, the architect was in charge of “disegno”, exterior and interior appearance, and layout and the engineer (not yet named as such) was responsible for what today we call mechanical resistance of construction materials and for erection works.

Fundamentals of modern engineering, with theoretical and mathematical models, demonstrations, experiments, etc come from Francis Bacon (1561-1626), Galileo Galilei (1564-1642), the first theory of construction solidity (1638), Robert Hooke (1635-1703), Jakob Bernoulli (1654-1705), Leonard Euler (1707-1783) with the theory of elasticity etc., and in the nineteenth century we approach the modern engineering.

Name of the “engineer” as profession may be regarded as semantic parentage of several roots:

- Ingeniare (in Latin) – to invent or produce; ingenium – cleverness, intelligence; ingeniosus – man of much ingenuity, smart and quick mind, skilful, clever;

- Genius (in Latin) – genial person, spiritual endowment that leads to original creations, exceptional;

- Génie (in French) – military and professional branch carrying fortifications, roads, bridges, and later on any great public works etc.

The title “Ingeniosus” was awarded to skilled architects since the Middle Ages, but the “engineer” as a profession is recognized because of Vauban Sébastien, Marquis and Marshal of France, military engineer (1633-1707), who established the “Corps des ingénieurs” – 1675 – Builders of French Army - military engineers who built the fortifications and castles, towns and churches. Based on this specialization was created in Paris “École Nationale de Ponts et Chaussées”, 1747, the oldest civil engineering school in the world and the oldest engineering discipline after military, who served on

the model to Romanians. Since then, the public interest and social respect towards engineering became deep, and in 1794 was founded “École Polytechnique”, institution of higher education, which still belongs to the Ministry of Defense (!!!) and is headed by a general. From that “Corps des ingénieurs” came to us Saint-Venant, Biot, Cauchy, Coriolis, Navier.

It is interesting that in 1577 in France is quoted the use of the word designating the researcher and the French culture insists on the solid scientific culture of the engineer.

In Britain, the term “engineer” is not a title hunted by the public, as it may designate the common words even a plumber or a maintenance mechanic, occupations that do not require higher education. We must understand that today’s society has strong utilitarian tendencies and practices so that a physician, pharmacist, lawyer or officer of the Fiscal Office seem a desirable profession, being visible and often necessary, while the engineer is a less known actor at social scale. Despite the limited public perception of the engineering profession, it is worth to mention that in England was established in 1818 ICE – Institution of Civil Engineers, the engineering profession is recognized by Royal Charter in 1828 (with a pragmatic definition, object-oriented infrastructure), while the name and profession of “scientist”, appears in 1833. In Canada, the British dependence on public perception of engineering has evolved. In 2002, a survey conducted for the Ontario Society of Professional Engineers said that engineers are in third place of the most respected professions after physicians and pharmacists.

In the U.S., you can not work as an engineer if you are not certified, which shows, at least, that is perceived its social responsibility. Paradoxically, even if in this country the entrance to the Library of Congress has since 1896 a statue bearing a torch of knowledge from research and all are proud to have MIT, Harvard and Yale, Caltech and UCLA, the current public perception of profitability is not at all favorable to the engineering profession, and it is preferable to be a lawyer, finance businessman or manager. There is, anyway, an open discussion why the science and engineering became “harmful disciplines,” and students who strive to enter into such faculties are shamefully designated as

bookworms, nerds or glass-wearing. The crisis in these years seems to confirm a large error in social and political perception of education, as Clinton-Obama Plan 2011 envisages the granting of visas or import of engineering graduates to boost the manufacturing industry.

2. THE EVOLUTION AND STATUS OF CIVIL ENGINEERING AND RESEARCH IN THE FIELD IN ROMANIA

In 1818, it was set by Gheorghe Lazar, the first technical college with tuition in Romanian at St. Sava Monastery in Bucharest, which in 1832 was reorganized into the College of Saint Sava. In 1864 it was founded "School of Bridges, Roads, Mining and Architecture", which is October 30, 1867 became "School of Bridges, Roads and Mines", from April 1, 1881 it was the "National School of Bridges and Roads" and since June 10, 1920 was the Polytechnic School of Bucharest, with four sections: Electromechanics, Construction, Mining and Metallurgy, Industries.

In this context, many valuable civil engineers graduated and worked in Romania, since the late nineteenth and early twentieth century, especially in 1920-1940, and the best were visible primarily as university professors, officials in public boards and contractors for great public works.

Detached from the Polytechnic School since the education reform of 1948, the construction faculties became ICB – Institute of Constructions / Civil Engineering of Bucharest and the Faculty of Architecture became an independent institution of higher education, as "Institute of Architecture." After a brief period of independence, in October 1949 the Institute was incorporated under the name of the Faculty of Architecture in ICB but in 1952 became the Institute of Architecture, called "Ion Mincu" since 1953. Under this title the institution has functioned until 2000 when it became the University of Architecture and Urbanism "Ion Mincu". I. C. B. became after 1990 U.T.C.B. – The Technical University of Civil Engineering of Bucharest.

After 1948, it was a growing number of engineers needed for industrialization plans, and their

role in the social hierarchy increased; is not a secret that those firstly recognized were the directors and chief executives of trusts and large investment followed by designers.

Closely related to this evolution, especially after 1950, the materials testing and research in construction were also developed. The National Institute for Building Research – INCERC was a core of creation, to be appreciated in the context of a limited contact with Western Europe and advanced countries. In that epoch, researchers, designers and university staff were called upon to make or adapt new technologies to reduce any cost and consumption, or finding solutions when something goes wrong. The status of technical specialists was a little bit better than those in the humanities research, which had always problems on their work and dealing purely theoretical justification. At least it was in 1958, the year the young engineer Sandi entered into research.

After 1990, the construction sector has suffered some stagnation, which was reflected in an unequal battle with the forces of competition of large foreign companies and technical and financial difficulties. The efforts of professional associations, as AICR, AICPS, ARACO, PSC, are worthy, but they are still far from achieving major policy objectives, such as research funding to ensure competitiveness and safety of investments.

Currently, Ordinance No. 57 of 16 August 2002 on scientific research and technological development, in Romania, as amended in 2011, defines research and development as a national priority that has a role in sustainable economic development strategy. National research and development system consists of all establishments and institutions of public law and private law that the objects of research and development (R & D national institutes, institutions of higher education centers, companies, etc.). Except for fundamental research, for the applied research, development and innovation there is a strong demand for increasing applications under any form of organization and funding.

The research for constructions is currently carried-out NIRD URBAN-INCERC, in different universities and institutes (on specific issues) or in private centers. It may seem unusual, but after 60

years prestigious research in construction its place is not clearly defined in current areas for projects of Romanian Authority for Scientific Research and the EU - FP7. The current classifications of fields in EU and Romania can sometimes include those in “construction or built environment”, to “environment and society”, sometimes to the “product and process engineering, construction methods.”

We can ask where is rewarded the thinking based on scientific concepts and methods in construction? Where is the place of civil engineering sciences? Where we are, those working in civil engineering, structural and earthquake engineering? What is the engineer who actually starting from civil engineering structures will deal with earthquake engineering? But the one which is dealing with multidisciplinary or interdisciplinary aspects, such as social and economic impacts of earthquakes?

What would they be the professions or occupations of engineer, researcher, university professor and scientist today on a scale of values? There is a person that may cover them simultaneously? What common elements, differences, aggregations are possible? What is the status, social prestige and scientific role of the graduate with a Diploma and degree of civil engineer?

3. THE RELATIONSHIP BETWEEN THE ENGINEER, RESEARCHER AND SCIENTIST

Based on historical facts, we see that the fundamentals of civil engineering were broad since the beginning and their evolution involved creativity, and only later they became apparently limited the application of rules and methods of sizing, the physical realization of a project or to simply surveying a site. Currently, the situation of a graduated civil engineer with diploma, which does not design or work on site but seeks a research position, may be appealing, but ultimately hard to define.

Even current definitions can allow understanding of the status quo and trends. In various encyclopedias, the researcher is one who is seeking knowledge or conduct a systematic investigation to gather data to establish new facts, new ideas to test, develop new theories, usually with the use of scientific methods. Fundamental research aims at the

progress of human knowledge, while applications have a narrowly defined purpose, role and value given by society. Research can be exploratory or constructive (development of solutions to a problem) or empirical (testing the feasibility of a solution based on empirical evidence). To be original, the research has to produce new knowledge, based on own contribution and/or experiments or reinterpretations of previous results.

Scientists are defined as different of engineers, the first being entitled to explore nature to discover general principles, while for the latter are “reserved” at most for the applied sciences, based on previous scientific discoveries, especially the development of devices that serve practical purposes. In short, some definitions consider that scientists provide the study, while the engineers make the design and applications. This separation is overly simplistic, and can be demonstrated in many specific fields of earthquake engineering.

There are some exceptions based on the existence of professional double education, when the same person may be considered a scientist and engineer, its research and applications to be recognized, as appropriate, as being scientific and applications to be directly usable. It is significant that the use of mathematics and physics is recognized as an asset in order to “pass” from engineer to scientist, while academic publication of results based on peer-review evaluation is a defining practice. From lists of existing types of scientists in the encyclopedia, one can see that there are areas with very numerous specializations, such as the socio-humanistic, but less in engineering, although they exist. As authors of marketable images, yet to be built, architects enjoy a more visible social recognition, although not subject to the same requirements as engineers.

4. A CAREER AS AN ENGINEER, RESEARCHER AND SCIENTIST: THE EXAMPLE OF MAN AND ENGINEER SANDI

Dr. Sandi obtained a degree in mathematics in 1954, a degree in civil engineering in 1955 and his doctor degree in 1966. He worked as a designer between 1955 and 1957 and had university teaching activity since 1963, the complex and seemingly arid

topics, which applies to large-scale and responsibility works. As a Humboldt Fellow, he studied in Germany between 1968 and 1969. Looking retrospectively, to commit to a research life was then, as it is now, a choice with some hopes but also with risks.

Requirements that make you able for a career in research, even in construction technique and sciences, are special. A researcher is formed with difficulty and is sensitive or vulnerable to both stimuli and threats. To create knowledge begins with finding and incorporate knowledge that was up to you, which then must be evaluated critically. Creativity may arise from doubts, „Dubito ergo cogito, cogito ergo sum” is the basic Cartesian lesson since nearly 400 years. But even as an engineer, you may ask yourself how long to test a theory that looks obsolete? Can you conceive another theory? Would it be accepted by the society? Time, money and skills are never enough.

From his biography and list of published works, and related to definitions discussed above, it is found that Dr. Sandi is one of the researchers who can be called richly creative scientists in the field, which anticipated some requirements and induced specific developments, often at odds with official trends of an age under excessive political control.

From what I have learned over three decades in which I was professionally with Dr. Sandi, we can draw some clear lines that define him in our research:

- systemic knowledge and rational approach of Cartesian type;
- engineering applications, up to the design details;
- connectivity to other prospective areas such as mathematics, physics, earth sciences.

Since the 1960s, the engineer Sandi seemed concerned with relatively classical civil engineering, computers and test construction, with high theoretical level. But in the construction research of that time it was required always a low consumption in works, thus the need to invent new materials, all to be cheaper, lighter and possibly more resistant. But it was only a term of the equation. The second was that of action, known and often considered too high. The mission impossible of the researcher Sandi was to demonstrate the randomness of some actions and quantify the limits of variation in loads, which in many

cases required no cuts of size, but increases, especially for climate and seismic actions, associated with extreme distributions. This battle against compulsory reductions lasted until in 1989 and perhaps is not over, just advisers are others!

What to do as a researcher if your results seem unusable and are not cited in official records, quotes, i. e. they are not “fashionable”? Were they too simple or too complicated? How much can you get “down” in marketing of own science aimed to bring your recognition? Who are users and who are judges you must accept as to be not frustrated? What to do if other competitors come up with new solutions that seem successful but they seem risky to you? Where begins a scientific debate and where you feel the blockage based on obtuseness or envy?

At that time, earthquake engineering was barely evolving as a branch of structural engineering, to become closer to a science. It is important to note that just in that epoch Dr. Sandi initiated concepts and methods for soil-structure interaction assessment in earthquake resistant design that after five decades is still a matter of international interest in research. Statistical approaches have been combined with safety of structures studied since the 1960s. He initiated the automation of calculation in the 1970s, when computer access was a work of Sisypus, wrote books of reference “Matrix methods in structural mechanics”, Technical Publishing House, 1975 and “Elements of structural dynamics”, Technical Publishing House, 1983. A theoretical and experimental study of wind and snow loads was integrated within the parameters of regulations.

In 1970s he participated in the study of design requirements system for structures and was an important factor in promoting new methods of calculating the major works (dams, bridges, silos) under dynamic concept, with inferences of non-synchronous motions, spatial behavior, etc. Dr. Sandi anticipated and prepared the scientific integration through cooperation at European level, in the Balkans and international programs UN-ECE, UNDP, UNESCO, RILEM and working groups of EAEE and IAEE.

Based on his experience related to the harmonization of earthquake design codes, probabilistic and dynamic analysis methods, he was perfectly ready to build a vast fundamental and applied research program on hazard, vulnerability

and risk, based on data collected after earthquake March 4, 1977 and Vrancea accelerograms advanced processing. The earthquake engineering research division was reshaped with new directions and themes, new series of codes and zoning maps were drafted, etc. So far, in earthquake engineering Dr. Sandi promoted and supported both exploratory research and empirical observation, adding value to gathered data. What seemed before something theoretical without application has become the key to understanding the behavior of very specific types of construction.

After 1990 he went to study the seismic impact on socio-economic system built systems, introducing concepts and patterns as the vulnerability cell used in disaster scenarios. The conceptual framework and methodology for seismic risk assessment of the existing building stock was redesigned and put into another context.

After 2000, although nominally he was retired, he restarted a work at the Institute of Geodynamics of the Romanian Academy, integrating his data and concepts in large-scale applications, through the NATO and the World Bank program of seismic loss assessment for the establishment of compulsory insurance system.

I enjoyed numerous professional and private discussions with Dr. Sandi and I witness the example a general culture judiciously built on a solid basic education and knowledge of several languages, a culture in relationship of a logical accumulation and critical selection of information provided by other sciences.

As my doctoral supervisor, he was open for expansion of research in areas where earthquakes may have impact, i. e. the socio-economic issues, as it was suggested in my thesis. Although not all components were directly measurable for risk, we defined and presented some cause-effect relationships between the direct and indirect effects, for an integrated concept.

5. DR. SANDI AS A SCIENTIST AND LONG-TERM VICTOR

The activity of Dr. Sandi can lead to questions that are of great scientific and social interest. For example, when the scientist's quest ends? We have

the example of Dr. Sandi with research directions that have evolved over several decades, not be considered final, because the answers always cause new questions. Scientist is competing against the time, he is not necessarily and always willing to give his time to others, and that can be both good and bad. Forming a school around a researcher can be done explicitly or implicitly, including the model he provides. He can play a role leading driver or a desirable peak, often inaccessible to many, in his way to performance.

Sometimes he is not, nor seeks to be "nice" to anyone at any price, nor worldly cares about the consequences of his acts. "Noli tangere circulos meos" said Archimedes and he had not noticed that passed away ... No one remembers the name of the too zealous Roman soldier who killed him, and saw only an old man, a compass and some sand ... Archimedes remained over millennia!

The researcher has a certain vulnerability to the trendy amateurs of glory that launch unstudied solutions when the company needs attractive results quickly; he knows those who are on the wave did not last unless they have value. Practical applications in short-terms are required by public or private investors, but since the scientist want knowledge before any immediate praise, the dedicated researcher works apparently more slowly and is rather pessimistic until will have certainty, and even so, he is concerned about randomness of things.

Perhaps the scientist is somewhat vulnerable in the short term, in front of financing and administrative boards. But he is clearly invincible in his long term relationship with knowledge and studied phenomena, as a substance of things.

Humans are perishable, but properly designed and written equations are perennial. Logical concepts can be neglected for a while but can not be denied by decision of someone. If a number of valuable ideas were launched by a researcher and allowed the creation of several valuable ideas, leading to the formation of researchers, providing a de facto school of that researcher, the long-term role of the scientist was achieved. We appreciate that, based on the work and assets created by Dr. Sandi, we can and must continue to expand dissemination of the concepts of hazard, vulnerability and risk in society, to understand that exposure to seismic risk is

considerable and there is a potential for a national disaster and that governance involves scientifically based strategies.

We may also ask: does the society appreciate his scientists? Often there are not signs that the values spent for their training would be capitalized otherwise than by requiring them to submit as many applications for a patent or to publish numerous articles, always in the circumstances set by the employer...

But what scientists do for defending themselves? There are still problems in setting the role of engineers in construction activities, as well as the collaboration between engineers and some architects. It turned out that it is possible and beneficial a conjugation with teaching activity and formation of consortia to complex research projects. We have to do something in relation with the coordinating agencies. An artificial division of the university research versus research institutes would not save science in front of administrative measures, as much as merging does not solve financing.

As each scientist has a personality, there is less benefit from a formal hierarchy but from everyone

contribution to knowledge. To be present on the steep stair of scientific and social recognition, a field needs its own scale of values. The status of a civil engineer or of a researcher who has made his career in service to this area, should be strengthened and protected by individual and collective value creation.

With the contribution of Dr. Sandi, the research school in structural and earthquake engineering of Romania became known and appreciated in Europe and worldwide. Academy of Technical Sciences helped to confirm the place and rights of Romanian engineers in science and society, and Dr. Sandi credentials were found to be representative for Chairman of Department of Constructions and Urbanism.

In the life time of Dr. Sandi and in his research there are lines approaching him to the Titans of the major creative epochs of mankind, such as encyclopedic spirit, ability to think systemically and reflect all in the proposed approaches.

Dr. Horea Sandi is a victor, and all what he realized was based on a unique genetic endowment, to which he has added own value. This quality makes him shine beyond his time.