ARTHUR CASAGRANDE, 1902–1981

a tribute

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Arthur Casagrande died peacefully in his sleep on 6 September 1981, aged 79. He had known for several years that the end was inevitable, yet with characteristic strength of will he actively participated in his consulting and research activities until a few months before his death, when it became no longer physically possible to do so. The profession has lost one of the great civil engineers of this century. His former students have lost an inspiring teacher and his family and relatives mourn the loss of the beloved head of the closely-knit family group.

Arthur Casagrande, born on 28 August 1902 in Haidenschaft, Austria, was the first of two sons and one daughter of Angelo and Anna Nussbaum Casagrande. He spent his first year in school in Linz, after which the family moved to Trieste. For one year he was taught by his mother; he then completed the German Grammar School in Trieste. When he was ready to enter secondary school, he chose to enter the Realschule, where he would be trained to enter a technical university. Casagrande's choice of a technical career was influenced chiefly by his forebears on his mother's side, several of whom were mechanical and chemical engineers.

He received his civil engineering degree in 1924 (and subsequently the Doctor of Engineering degree in 1933 on the basis of the contributions that he had published during the years following his arrival in the USA) from the Technical University in Vienna. It was there that he served as an auxiliary assistant to Professor Schaffernak in the hydraulics laboratory, where he subsequently spent an additional year as full-time assistant.

Casagrande's father died in 1924, which left the major burden of supporting the family on Arthur's shoulders. The Austrian Empire had been dismembered after the First World War and very little construction was in progress. The salary of an assistant was very low, and Casagrande had to supplement it by tutoring high school students. These conditions forced him to take the gamble of going to the USA, much against the wishes of his mother and Professor Schaffernak, neither of whom could understand why he wished to leave. But his impatience, his strong desire to work on major civil engineering projects and the need for money to support his family all led him to take this course.

Arthur Casagrande

Casagrande arrived in the USA on 26 April 1926, with little money and no work, but with confidence in his training and ability. After spending 10 days in a YMCA hostel in New York, he obtained a position as draughtsman for Carnegie Steel near Newark, New Jersey. He immediately wrote to Professor Spofford, head of the Department of Civil Engineering at the Massachusetts Institute of Technology (MIT), and described his experience in the hydraulics laboratory in Vienna. Professor Spofford invited Casagrande to MIT for an interview. It was on this trip that Casagrande met Karl Terzaghi, who promptly offered Casagrande the opportunity to work as his private assistant for the summer of 1926.

On his first day of work, Terzaghi gave Casa-

grande some hand-written notes and told him to type them. Casagrande replied that he had no typewriter, whereupon he was told to get one. When he meekly countered that he also did not know how to type, Terzaghi ordered him to learn to type. This he did, developing his own style of rapid hunt-and-peck which served him well throughout his lifetime.

From 1926 to 1932, he was a research assistant with the US Bureau of Public Roads, assigned to MIT, where he assisted Terzaghi in his numerous research projects directed towards improving apparatus and techniques for soil testing. In those years Arthur developed the liquid limit apparatus, the hydrometer test, the horizontal capillarity test, the consolidation apparatus and the direct shear test equipment. Among his research projects, he conducted field investigations on frost action during a co-operative project between the Bureau of Public Roads and the New Hampshire State Highway Department. His criteria for the frost susceptibility of soils, resulting from this project, have been adopted by highway designers all over the world.

In 1929 he went with Terzaghi to Vienna to equip a soil mechanics laboratory. At this time he toured all soil mechanics laboratories in Europe and returned to the USA in 1930 with a thorough knowledge of developments in this field in Europe. During 1930–32 Casagrande constructed a triaxial compression cell and developed his shear box apparatus with which, for the first time, he studied volume changes during shear. This led to his recognition that pore pressures are induced during undrained shear. His report on the shear tests (written jointly with an assistant, S. G. Albert) and the paper on the difference between remoulded and undisturbed clay rank among the most significant contributions to the literature of soil mechanics. Also in 1932, he published his celebrated paper 'Research on the Atterberg limits of soils'. At this time he made the first consolidation tests on undisturbed soil samples which led to the development of his ideas on preconsolidation pressures and overconsolidation, presented shortly after 1932.

It was Casagrande in 1939 who persuaded the Waterways Experiment Station to sponsor the co-operative triaxial research programme that was carried out at Harvard and, under Donald Taylor, at MIT in 1940–44. The results of this work, contained in progress reports (seven by Casagrande himself) and summarized by Philip Rutledge, initiated a new era in soil testing and knowledge of soil strength.

Seeing no future with his Bureau of Public Roads research assignment at MIT, Casagrande decided in 1931 to leave and begin negotiations with universities on the west coast of America. At this juncture, his good friends Mr Harry Mohr and Mr J. Stuart Crandall convinced Dean Clifford of the School of Engineering at Harvard that soil mechanics should be introduced there, and that Casagrande was the man to do it. He was offered a half-time lectureship, which he gladly accepted. He was promoted to Assistant Professor in 1934.

In 1940 Harvard promoted Casagrande to a tenured position as Associate Professor and in 1946 he became Gordon McKay Professor of Soil Mechanics and Foundation Engineering. In 1973 he retired from Harvard and became Professor Emeritus. In 1970 he joined with his brother Leo and his nephew Dirk to form a geotechnical consulting group under the name of Casagrande Consultants. In addition to his consulting activities, he remained active as a teacher, lecturer and author of papers. During his long career, he wrote or co-authored more than a hundred professional papers.

Professor Casagrande often said that his interests in order of their importance were research, teaching and practice. He excelled in all three, yet those who knew him intimately over a number of years felt that he placed teaching first, followed by practice and then by research. His colleagues at Harvard in the 1930s and 1940s may not have appreciated that he taught more than a course or a series of courses. He taught a whole field. He developed the art of instruction in soil mechanics, established laboratory courses as an inherent part of the curriculum and, with the aid of his assistants, presented his subject from first principles to practical applications. It would hardly be an exaggeration to say that the teaching of soil mechanics, at least in the Western Hemisphere, was based for at least a generation on Arthur Casagrande's school at Harvard.

Those who were former students came to regard him as the great teacher. Always thoroughly prepared, not dramatic, but completely at home in every detail, he developed among his students a sense of being in the mainstream of soil mechanics. They felt as if they occupied ringside seats in every round of the development and growth of soil mechanics from its beginning. They learned, too, that they were not nameless faces assembled before him. They soon felt his personal interest, his genuine concern for their future, and the graciousness that was a hallmark of his personality. He became their friend, and his friendship persisted through the years. Genuine affection towards Arthur Casagrande is the hallmark of his students.

Typical of his attitude towards teaching is the following ancedote related by Wilson Binger.

> In May of 1939 our group of soil mechanics graduate students at Harvard gave a dinner for Casagrande,

at the end of which he gave us a short talk. I remember only one part of the talk, but that has stuck with me for more than 40 years.

Casagrande referred to the loyalty that students tend to have to their teachers, particularly those for whom they have some affection, and he said that such loyalty can result in holding onto the concepts and theories that were taught them even when later experience may suggest they should be dropped or modified. He pointed out that many engineers had persisted in calculating earth pressures by the classical Coulomb method, even though they could see with their own eyes that foremen did not put their heaviest bracing at the bottom of a sheeted trench. Casagrande then said, 'If what you learn from your own experience after you leave here differs from what I have taught you, then what I have taught you is wrong, and you should not hesitate to discard it.'

Only a great teacher could have made such a statement to his students. He was a great teacher.

Casagrande always picked out a key student in each class who would have trouble in following his lectures. Pretending to review his notes, he would covertly observe the face of this key student to see if he had understood the previous portion of the lecture. If he had not, Casagrande would start again, trying a different approach. Even this did not always work, as remembered by H. Q. Golder.

In 1960 I was asked by Casagrande to give the course on engineering geology at Harvard. During this time I was able to sit in on his course on 'Seepage'. There were 13 graduate students, not all of whom had English as their first language. On one occasion Casagrande came in to give his next lecture in the course, and said: 'There are 13 of you in this class. Since my last lecture 6 of you have come and asked me questions about it. I think that I did not give that lecture very well. I propose to repeat it today.' This he did! Such humility is a mark of greatness!

During his first year at Harvard—1932–33—Casagrande taught a course in soil mechanics over two semesters, much as Terzaghi had done, and Harvard continued to offer a course in foundation engineering that was given as a lecture series by practising engineers. In 1933 he introduced Harvard's course in laboratory testing, which was probably the first in the world. In 1934 he revised the course in foundation engineering considerably, and in 1935 he introduced his course on seepage through soil.

During 1942–44, at the request of the Corps of Engineers, Casagrande trained approximately 400 army officers on the soil mechanics aspects of airfield construction. In intensive, four-week courses he gave three lectures per day. The officers were charged with the responsibility of building airfields during the Second World War, chiefly in the Pacific area.

As part of these courses he introduced a two-hour Tuesday afternoon session in field identification and classification of soils. This unique tuition, which has never been successfully duplicated by anyone, consisted of the visual and manual identification of a seemingly infinite variety of soils from the Harvard soils laboratory. Casagrande would feel each soil, roll out a thread in the palm of his hand, taste it, bite it between his teeth, rub it between his fingernails, estimate its strength and conclude with a detailed description, the probable source, the suitability for road and airfield construction, permeability, potential problems, frost susceptibility and an estimate of the Atterberg limits—which his assistant invariably found to be nearly as precise as the laboratory determined value. Foreign students were often astounded to see this eminent professor revelling in this soil-handling process.

The years immediately following the Second World War were particularly busy ones as Casagrande's classes expanded to 80 or 90 students per year. During the subsequent two decades, he continued his very active teaching schedule of three or four courses each year and supervised several doctoral candidates. The number of doctoral degrees earned at Harvard by students under Professor Casagrande's supervision totals more than 20.

The students who studied soil mechanics at Harvard under Dr Casagrande total about 1400, and a roster of their names includes many of the outstanding professors, researchers and practising geotechnical engineers of the world. Perhaps no other person has influenced the development of a branch of engineering as much as Arthur Casagrande has been able to do through both his own teaching and that of his former students.

In 1962 Arthur conceived the idea of starting a special programme at Harvard to update teachers and practising engineers in all aspects of soil mechanics and foundation engineering. This intensive programme incorporated a unique blending of science, laboratory work and practical experience brought back from the field, and made an important contribution to the development of the profession over the six years that Arthur devoted to developing and running it.

Harvey Brooks, former Dean of the Division of Engineering and Applied Physics at Harvard, recalls that Casagrande gave him his first introduction to that subtle blending of practical experience, hard common sense and the profound theoretical insights that represented the tradition of soil mechanics as Casagrande and Terzaghi developed it at Harvard.

Arthur was always deeply loyal to Harvard and to the Division of Engineering and Applied Physics, even when he was in deep disagreement with some of the decisions that were being made and some of the things

> he saw going on. At many times and, in many areas, he constituted himself a gentle but firm loyal opposition in the most constructive and helpful sense, and he saved the University from many costly mistakes, though sometimes his advice was sought too late. The period of the 1960s and early 1970s was one of unprecedented building at Harvard as the campus was transformed physically. Arthur served as an unpaid consultant on the foundation aspects of almost every building at Harvard.
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> Reading through some of the correspondence between Arthur and various University officials in regard to the building program recalled to me Arthur's pungent and sometimes sarcastic expression and his ever present impatience with stupidity and waste.

Casagrande could not tolerate incompetence, and his assistants, as well as others, were made abundantly clear of his views in this regard.

A dominant influence in his life was his relationship with Karl Terzaghi. He was a student and disciple of Karl Terzaghi, who is universally considered to be the father of soil mechanics. They worked together first at MIT, after which Terzaghi returned to Europe and Casagrande established his school at Harvard. In the early days of the Second World War Terzaghi left Vienna and returned to the USA as an immigrant. Arthur provided the necessary guarantees and installed Terzaghi at Harvard, first as a lecturer and later as Professor of the Practice of Civil Engineering. Arthur had developed the entire programme at Harvard during Terzaghi's nine-year absence from the country, but Terzaghi—a strong personality—considered it perfectly natural to regard himself as the master in a master–disciple relationship. Moreover, Terzaghi disdained most academic duties other than his lectures. Arthur, often at considerable expenditure of time, fulfilled Terzaghi's academic obligations as well as his own. Those who knew them both appreciated that Arthur felt the greatest respect for and devotion to Terzaghi and retained Terzaghi's greatest admiration, but was surely often taxed to remain patient under sometimes trying circumstances.

It was Casagrande who proposed the first International Conference on Soil Mechanics and Foundation Engineering in 1936, and Terzaghi who considered it too great a gamble at such an early stage in soil mechanics. Casagrande proceeded, none the less, and created the conference that established soil mechanics as a legitimate and essential part of civil engineering. Terzaghi soon admitted that he had evaluated the situation incorrectly, and appreciated that Arthur's vision in establishing the conference had been the greatest single step in bringing soil mechanics to the attention of the engineering world.

In September 1938, after the major slide during the construction of Fort Peck Dam, Professor Casagrande was called on by the Corps of Engineers to join the consulting board that investigated the failure. His work on liquefaction, published two years earlier, and the probable role of liquefaction in the failure of the dam led the Corps to engage his services. This was the start of a close relationship which helped to shape his career for 40 years and which, at the same time, had a powerful effect on the Corps.

After the Second World War there was concern about the stability of the banks of the Panama Canal under the influence of a possible atomic bomb blast. This led the Corps of Engineers to begin sea level canal studies in 1946. Accordingly, Casagrande started research on the resistance of soils to dynamic stresses as part of the Corps' studies. The results were published in 1948. This work was followed by additional research, also financed by the Corps of Engineers, on the effect of time of loading on the stress–deformation and strength characteristics of soils.

Casagrande always kept his feet solidly on the ground, even though he sometimes gave free reign to his imagination. He was tremendously excited about the moon landings, and deeply interested in the probable soil conditions on the moon. On accepting a decoration for distinguished civilian service from the Army in 1967, he commented

> For the time being, however, the only soils that are of interest to some physicists are the soils on the moon. Soon we will learn more about them. Of course, we will find them entirely different from our earth soils; perhaps 'crunchy' as I have read predictions in some papers; although I cannot quite believe that without an atmosphere to transmit sound, anything could be crunchy on the moon. I expect that we will find the properties of the moon soils rather simple and eventually rather boring. I also foresee that the detour via the moon will some day lead physicists to discover what interesting materials earth soils really are, and what exciting opportunities for research they have to offer. Indeed, next to living matter, many of our highly colloidal clays are the most complex materials that nature has made on earth . . .

During the last decade of his life, the subject of liquefaction of sands (one of his first major interests) was very much on his mind. When he heard that the subject was to be discussed at the Waterways Experiment Station in March 1981 he wrote from bed in Massachusetts General Hospital, where he was receiving X-ray radiation treatments for bone cancer in his back, that he wanted his views to be fully represented in whatever discussions took place. Intuitively he felt that the use of the word liquefaction (with or without any accompanying adjectives) to describe the effects of earthquake loading or cyclic loading in building up pore water pressures and deformations in sands was inappropriate and led to unjustified concern on the

part of engineers not familiar with this terminology. It was mainly for this reason that in 1976 he published his paper entitled 'Liquefaction and cyclic deformation of sands—a critical review'. To Casagrande, who invented the term in soil mechanics, liquefaction meant a substantial loss of strength that persisted over very large deformations and led to flow-type behaviour. Always very precise about the meaning of words, he strenuously objected to the use of the term for more limited deformation behaviour, even though such movements might be damaging to engineered structures.

This led to a great debate among a small circle of his colleagues which persisted for about eight years. Casagrande always believed that a frank discussion of different views would eventually clarify the issues and in his 1976 paper he said

> I have always learned during these decades that whenever I found myself in disagreement with a highly experienced and respected colleague it was for one or more of the following reasons: (1) We looked at different aspects of the same problem, (2) We generalized too much on the basis of different sets of empirical data and (3) We used the same terminology for different phenomena.

Nevertheless agreement on terminology was difficult to achieve and the group discussions were discontinued. Casagrande still wanted a resolution of the problem, however, and in late 1976 he made his position on the matter of cyclic loading behaviour very clear: '. . . whatever you agree upon, I will accept, provided it does *not* include the word liquefaction'. This was not easily accomplished but, not surprisingly, his wishes were ultimately respected and a concerted effort was made to re-establish his original definition of the term. This pleased him enormously. It ended a long period of concern over the direction of studies in this area and led, in his words, to 'a major and urgently needed contribution to the profession'.

Such detailed and extensive discussions of important aspects of soil behaviour were a characteristic feature of Casagrande's *modus operandi*. He could strongly disagree with his colleagues (who were often former students) and yet accept their contrary views in a spirit of goodwill and mutual respect which engendered the deep feelings of loyalty and affection with which he was universally regarded.

It was during the Teton Dam investigations that he first learned of the seriousness of his illness. This sad news had no apparent effect on his way of life. He continued to work 12–15 hour days to help ensure that no stone was left unturned which would throw light on the cause of this important failure. His colleagues on the investigation panel were constantly amazed at his capacity for conducting concentrated inquiries leading to keen insights and extensive writings on this important study. The truth is that he had long before been able to equate work with pleasure, and his long-time love affair with soil mechanics and soil behaviour, in all its aspects, enriched both his life and the lives of those around him.

Casagrande was neat and orderly in everything except the arrangement of his desk and the adjacent table which were covered, sometimes to a depth of several feet, with a heterogeneous assortment of files, reports, magazines and papers. However, he knew exactly where, in all the apparent disorder, to locate a given file or scrap of paper.

When the morning mail arrived, he would open the top letter, read it, then turn to his typewriter (it may have been the same one he purchased for Terzaghi in 1926) and type a reply. Few letters went unanswered the same day. Also, at intervals whenever thoughts came to him, he would type out notes to be placed in his files or memos to his staff, to the administration or others. These memos, although usually brief, were nevertheless descriptive in great detail of what he expected or wanted.

In the laboratory every detail of new apparatus was critically examined to ensure that the results of tests were not adversely affected by friction in a bearing or by a leaky membrane. When samples of a new material arrived, they were subjected to the most detailed visual and manual classification techniques. Undisturbed samples of stratified clays, when extruded from Shelby tubes, were scraped to expose fresh surfaces which were then partially air dried and examined, each layer being minutely sketched and classified.

Despite meticulous attention to detail, or perhaps as a result of it, Casagrande developed a perspective of engineering judgement which his colleagues learned never to discount, and which gained the trust of his clients. His reputation spread throughout the world and his advice was much sought on many of the major soil engineering problems of the 20th century. Despite many demands on his time, he seldom cancelled a classroom lecture, as teaching and lecturing assignments always carried top priority. Although he spent more time away from home than he would have liked—he enjoyed his family and was immensely proud of their accomplishments—he felt an overwhelming obligation to fulfil his consulting commitments, and often these obligations took precedence over his family. It was not uncommon to see the lights on in his office in Pierce Hall, not only at weekends but even on Christmas Day and New Year's Eve.

Of all his consulting projects, dams were his favourite, and on these jobs he could only be described as an artist. He gave the greatest care to

the selection, treatment and arrangement of the materials to be placed in the dam. For him, it was not enough that the calculated factor of safety should have an accepted value. He worked towards the best dam that could be constructed within economic limits, and insisted on including every reasonable detail that could improve performance, even if the results of the details were difficult to quantify. He refused to debate the influence of these refinements on the value of the factor of safety; he simply pointed out that they produced a better dam. No one had a keener sense of the inadequacies of design procedures to take into account all the ways water may act to endanger man's structures, and no one devoted more attention to providing defences in depth against the ways in which nature might seek to weaken his structures.

He especially loved personal relationships with fellow board members and with clients, engineers and contractors. He called this aspect of consulting 'human engineering'. On a job, after dinner, when consultants and the people on the job gathered for fellowship, Arthur always became the centre of attention as he drew on his great store of anecdotes. He had a remarkable memory for enlightening or amusing incidents, many recalling the early days of soil mechanics, and he recounted them with great skill and relish. He often used a pertinent anecdote to break a tense moment or to enliven a dull period in meetings of consultant boards.

One of Casagrande's earliest consulting assignments was for the Corps of Engineers' Franklin Falls Dam. The right abutment and foundation of this 130ft high embankment dam were of fine to medium sand in a loose condition. Seepage analyses performed by Casagrande led to the adoption of an upstream blanket with a deep intercepting drainage trench. Because of the danger of flow slides, the sand foundation was made denser by blasting. The proposed grading tests of the filters of the drainage trench were performed by G. E. Bertram as part of a general programme of filter studies supervised by Dr Casagrande. The successful performance of the Franklin Falls Dam marked a milestone in design and construction of embankment dams on pervious foundations.

During the construction of Fort Peck Dam in 1938, a weakness in the underlying Bearpaw shale resulted in the development of strains in the overlying foundation sand stratum and in a portion of the upstream section of the dam consisting of a hydraulically deposited sand fill. Casagrande believed strongly that the massive failure was a combination of shear failure in bentonite layers within the Bearpaw shale and liquefaction of a large mass of overlying sand, both in the foundation and in the saturated upstream portion of the dam. His views were not shared by the remainder of the consulting board and in later years he often remarked that a reappraisal of the slide would be rewarding.

After the Fort Peck slide, Casagrande was involved in the great Corps of Engineers' dams on the Missouri, particularly Oahe Dam, at a time when soil mechanics was developing the understanding and techniques to make those dams possible.

During this same period his impact as an eminent consulting engineer and gifted and inspiring teacher was strongly felt in Canada. For 50 years he was consulted on the soil behaviour aspects of many of the largest civil engineering projects throughout Canada. These projects, in their success, form indelible and long-lasting monuments to his professional talents.

Included in these projects were Mica Dam—the highest earthfill dam in North America—Manicouagan III Dam, which has a 410ft deep concrete cut-off wall, and Gardiner Dam on the South Saskatchewan River Project. Gardiner Dam was founded on Bearpaw shale with bentonite seams (similar to the Pierre Shale on the Missouri). These foundation conditions presented unusual stability problems requiring stage construction, extensive instrumentation and major design modifications during construction. Casagrande, as chairman of the board of consulting engineers, not only provided advice and guidance throughout the design and construction (1940–68) but also was deeply involved in the post-construction performance of this project. He received monthly reports on instrumentation data which he reviewed promptly and commented on until he was physically unable to do so.

In 1955 the Southern Pacific Company decided to replace its 12 mile timber trestle across the Great Salt Lake with an embankment. Casagrande's assignment on this project, as he often expressed it, 'stretched his imagination to its elastic limit'. This underwater fill was supported over a portion of its length on a layer of crystalline salt underlain by very soft clay. Despite extensive explorations and theoretical analyses, numerous failures occurred in test fills and in the prototype embankment. In his classic paper entitled 'An unsolved problem of embankment stability on soft ground' he stated, 'It is discouraging to arrive at the conclusion that we do not know with any reasonable degree of accuracy the magnitude of the principal driving force, the earth pressure that is acting within the embankment, nor the effective shearing resistance of the foundation clay.' Nevertheless, he considered that to achieve maximum

economy it was reasonable to design and build the trestle with a factor of safety practically equal to unity, and that if it had been completed without a single failure it would have been overdesigned. (This was not his philosophy on embankment dams.) Just before completion of the project in 1959, a major failure occurred. Normally, such failures were buttressed and refilled slowly, but to do that in this instance would have delayed the project at least six months. Over the objection of the other Board members, Casagrande approved the rapid refilling of this particular failure, without stating the basis for his decision. To the delight of the owners and the amazement of his associates, it worked.

One of his last consulting assignments was on Itaipu Dam in Brazil—the largest concentrated hydropower development in the world. This capped a long list of embankment dams in Latin America for which he had a special fondness.

One of his more difficult assignments was for Tarbela Dam across the Indus in Pakistan. This enormous project—2745 m long and 145 m high—is founded on up to 220 m of river alluvium containing zones of open-work gravel. Casagrande played an active role in the exploration, design, construction and performance of this—the largest embankment dam in the world—for nearly two decades: from 1960 to during the last year of his life. Since the great depth of alluvium made a cut-off to bedrock impractical, the embankment incorporates in its design most of the defence mechanisms which Casagrande developed during his lifetime. These measures include an upstream impervious blanket, multiple zoning, downstream relief wells and drainage ditches, drainage galleries and grout curtains in the abutments, and self-healing well-graded non-cohesive materials in the core.

Casagrande was an active member of many professional societies. He was a Member of the National Academy of Engineering, a Fellow of the American Academy of Arts and Sciences, a Fellow of the Geological Society of America, an Honorary Member of the American and Boston Societies of Civil Engineering, an Honorary Member of the Mexican Soil Mechanics Society, the Venezuelan Soil Mechanics Society, the Japanese Soil Mechanics Society and the National Academy of Exact, Physical and Natural Sciences of Argentina. He was also a Member of the International Society for Soil Mechanics and Foundation Engineering, the US Committee on Large Dams, the American Geophysical Union, the Highway Research Board, the American Society for Engineering Education, the Society of Harvard Engineers and Scientists, and of Sigma Xi. In addition, he was past-President of the Boston Society of Civil Engineers and of the International Society for Soil Mechanics and Foundation Engineering.

He was the recipient of many awards and prizes, including the Clemens Herschel Prize (BSCE, 1933), Desmond Fitzgerald Medal (BSCE, 1936), SM (Hon.) of Harvard University (1942), Certificate of Appreciation from the War Department for services in a position of trust and responsibility during the Second World War, Structural Section Prize (BSCE, 1947), Arthur M. Wellington Prize (ASCE, 1950), Clemens Herschel Prize (BSCE, 1951), Honorary Doctor of Science (University of Mexico, 1952), President of the Boston Society of Civil Engineers (1957–58), Walter L. Huber Civil Engineering Research Prize (ASCE, 1959), First Rankine Lecturer (British National Society of Soil Mechanics and Foundation Engineering, 1961), Honorary Member of the Soil Mechanics Society of Venezuela (1961), President of the International Society of Soil Mechanics and Foundation Engineering (1961–65), First Karl Terzaghi Award (ASCE, 1963), Honorary President of the Second Pan-American Conference on Soil Mechanics and Foundation Engineering (1963), Second Terzaghi Lecturer (ASCE, 1964), Honorary Member of BSCE (1965), Honorary Member of ASCE (1965), Dr honoris causa (Technical University of Vienna, 1965), Member of the National Academy of Engineering (1966), Decoration for Distinguished Civil Service (31 January 1967, awarded by Secretary of the Army), Edmund Friedman Professional Recognition Award (ASCE, 1968), Honorary Member of the Mexican Soil Mechanics Society (1970), First Nabor Carrillo Lecturer (Mexican Society for Soil Mechanics, 1972), Honorary Dr L. C. (University of Liège, Belgium, 1975), Decorated order of Rio Branco (Brazil, 1980), Award of Merit (American Consulting Engineers Council, 1973), Goethals Medal (Society of Military Engineers) and Moles Award (1976).

In 1969 Arthur Casagrande retired to a half-time professorship. On that occasion, several hundred of his former students honoured him and his family at a dinner and presented him with a bound volume of testimonials from friends and associates. His old friend and associate H. A. Mohr—always a man of few words—wrote a one sentence testimonial: 'You taught me everything I know about soil mechanics'. The same could be said by many others.

In 1973 Casagrande became Professor Emeritus and gave up active teaching. He continued his research on the behaviour of non-cohesive sands and, to the fullest extent of his physical endurance, stepped up the pace of his lecturing and of his consultations. He could not say 'No' to a challenging assignment.

At the end he left behind three uncompleted tasks which he had established for himself long ago. The first was his book on soil mechanics. For nearly 40 years he typed notes for inclusion in various chapters and many times he wrote and rewrote the introduction, but the book had to be perfect and, because he was his own severest critic, he could not satisfy himself.

In the 1950s he agreed to prepare for the Corps of Engineers a comprehensive report on the Atterberg limits. Again, he set his goals too high and was never able to accomplish a finished product.

The behaviour of sand had always challenged him from the time he first developed the concept of critical void ratio. He hoped that the last missing elements, including an understanding of cyclic loading phenomena, would be resolved in his lifetime. Unfortunately the problems were too complex and progress was too slow.

Words are not adequate to express the deep sense of loss experienced not only by Arthur Casagrande's family, but also by his countless friends and associates all over the world. All will miss his seemingly tireless devotion to solving difficult problems and his devotion to passing his knowledge on to others. But perhaps most of all, he will be missed as a man who genuinely cared about others and a man who, even under most trying conditions, was able to maintain a great sense of humour.

He is survived by his wife Erna (née Maas), his brother Leo Casagrande, his sister Alix Robinson, his daughters Vivien McKanna and Sandra, and a grandson James McKanna, Jr.