Hist. Geo Space Sci., 10, 225–234, 2019
https://doi.org/10.5194/hgss-10-225-2019

Open Access History of Geo- and Space Sciences

Contribution to the knowledge of early geotechnics during the 20th century: Alec Westley Skempton

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Received: 17 May 2019 – Accepted: 18 July 2019 – Published: 29 August 2019

Abstract. Sir Alec Westley Skempton (4 June 1914–9 August 2001) was an English civil engineer and Professor of Soil Mechanics at Imperial College London from 1955 and Head of Department until he retired in 1981. He is often referred to as one of the founding fathers of soil mechanics in the UK and around the world and as one of the most important engineers of the 20th century. Skempton established the soil mechanics course at Imperial College London and not only helped to drive forward understanding of soil behaviours through his research and consultancy work, but also was a reference and inspiration for several engineering generations he taught. He was knighted at the New Year's Honours in 2000 for his services as engineer. He was also a notable contributor to the history of British civil engineering.

1 Origins

Alec Westley Skempton (Northampton, 4 June 1914; London, 9 August 2001) was the only child of the marriage formed by Alec Westley Skempton and Beatrice Payne. Skempton grew up in his hometown of Northampton, United Kingdom, living near a cricket field, one of the reasons his father, Alec, bought the house. His father was a great athlete and played rugby with Northampton Rugby Football Club, one of the best teams in the country in those days. This interest in sports was inherited by his son Alec. Beatrice Payne, who had emigrated with her family to the United States, was also fond of sports, especially hockey. Beatrice studied nursing, graduating in 1909, and later worked in Massachusetts Homeopathic Hospital in Boston, where she became chief nurse in the children's department.

Almost 2 years after the young Alec was born, in May 1916, his father was mobilized and sent to France, where he fought in the First World War as an artillery petty officer. On the front, he became the victim of a gas attack and the effect degenerated into pleurisy. Alec, the father, returned from the front in December 1918 and was demobilized in February 1919. In 1924 his health began to deteriorate and soon after he fell ill and died in November 1926 of tuberculosis. The young Skempton (Skempton will now be

Figure 1. Sir Alec W. Skempton (Skempton and Bishop Archive, Imperial College).

Published by Copernicus Publications.

used to refer to Sir Alec) was 12 years old at the time. The family doctor linked his death to the consequences of war, but there was no documentation to confirm this, and Beatrice, his widow, was not entitled to a pension. This marked Skempton, in that he always considered it a great injustice, and for all his life he had an aversion towards official government agencies. Skempton's father left considerable savings to allow his wife and his son to live without need, but, in a way, in a life of some austerity.

The young Skempton's elementary education began at the age of six at the Waynflete House preparatory college in Northampton and, later, in 1928, at the age of 14, he continued his secondary education at Northampton Grammar School, the same centre in which his father had studied.

Skempton was not a good student, especially in mathematics, a subject one cannot escape from, as his teacher told him. However, the teacher gave him the support needed with his studies, thus getting the High School Certificate in the necessary subjects to be able to enter university.

Figure 2. Skempton, in the middle of the image, captain of the Imperial College rugby team in 1936 (Niechcial, 2002).

2 First influence on civil engineering

With the loss of his father Skempton became closer to his grandparents, especially his maternal grandparents, Hector and Martha Payne, with whom he spent all the school holidays at their home on the coast of Torquay, until Hector died in 1930, after which his grandmother went to live with them, Skempton and his mother.

Hector Payne worked in the construction sector, becoming the director of British Reinforced Concrete Co. (BRC) at Old Trafford until retirement in 1922, and then moved to Torquay.

His grandfather's relationship with the BRC was of great importance to Skempton, and tipped him off to engineering. In 1932, when Skempton was 18 years old, he went to study civil engineering in London, at City and Guilds College, which in those days was still a separate part of Imperial College[1], entering as a student in the Department of Civil Engineering.

The decision to study at Imperial College was determined by the fact that Frederick George Butler, a former collaborator of his grandfather Hector in the BRC, told him that, once he had graduated, he would provide him with a job in the company. It was even Butler himself who suggested Skempton study at Imperial College, where he had studied.

In that same year, 1930, Lucy Payne, sister of his grandfather Hector, died, and, having no descendants, left an inheritance of some GBP 3000 to his niece, mother of Skempton. It was a significant amount at the time and helped to finance Skempton's studies at the university.

[1] Imperial College was created from the three existing colleges: the Royal School of Mines, City and Guilds of London Institute and the Royal College of Science. The three colleges eventually merged to create Imperial College.

As a student Skempton found time for activities other than academia and, during his last academic year, 1935–1936, he was vice president of the student Union of the City and Guilds, and he was captain, at the same time, of the rugby teams of the City and Guilds and Imperial College in the first division of "Rugby XV". This double schedule was possible because one team played on Wednesdays and the other on Saturdays.

The interest in sport, and especially rugby and cricket, lasted throughout his life. He was known to comment on the latest rugby matches in England and was always up to date on cricket matches, even during the years when the English results were somewhat disappointing, the latter being repeated with a certain frequency.

During his university training period, Skempton was an applied student who developed a great interest in geology and research, which he decided to dedicate his life to. At the age of 21 he completed his 3-year degree in 1935, graduating in engineering sciences.

During this time he met Mary Nancy Wood, an art student at the Royal College of Arts, which, because of its closeness to Imperial College, was frequently visited by students, mostly male students, from Imperial College. Nancy Wood graduated in art in 1936, specializing in wood engravings.

Professor Sutton Pippard, then responsible for the Civil Engineering Department and who Skempton would replace years later at Imperial College, encouraged Skempton to remain at Imperial College to do his doctorate. Sutton Pippard recommended Skempton for a scholarship of doctoral studies which allowed him to cover the annual registration fee of GBP 150 for doctoral studies and to have an additional weekly income of GBP 2.

Skempton began investigating reinforced concrete at the suggestion of William Henry Glanville, then engineering

director of the Building Research Station (BRS), though he was probably influenced by his grandfather Hector in the past. After a year of doctoral studies, and long before he could have finished his thesis, he had a job offer in the concrete section at the BRS in Garston, Hertfordshire. Glanville was the connection for this job offer.

At that time the possibility of doing research and collecting a salary was rare, so Skempton, encouraged by Sutton Pippard, decided to stop his doctoral studies at Imperial College and instead did a Master of Science. He adapted his doctoral work on reinforced concrete in a dissertation for the masters, which he was awarded in 1936.

3 Building Research Station

In that same year, 1936, Skempton accepted the position in the BRS and moved to live to Garston. The Building Research Station was a centre established by the Government's Department of Scientific and Industrial Research (DSIR). The DSIR was a public body that, because it was financed by government funds, had to maintain a totally independent criterion and was not allowed to charge for any work done. Skempton was hired in the BRS, implying his incorporation into the Civil Service with the grade of Scientific Official.

The Head of Glanville, director of all the divisions of the BRS, was Sir Reginald Stradling, who was married to the sister of his mentor, Sutton Pippard.

We have already said that Skempton started working at the BRS in the concrete section. But in the BRS there was a section, formed in 1933, dedicated to soil physics directed by Leonard Cooling, changing the name of this section in 1935 to Soil Mechanics.

Skempton, attracted by the new subject, asked Stradling (brother-in-law of his mentor Sutton Pippard) to be transferred to work under Cooling. Thus, in January 1937 Skempton abandoned his studies on reinforced concrete and joined the Soil Mechanics section, where he worked for the following 10 years, conducting tests in many fields of application. It was in Garston, at the BRS, where his interest in geology, which then also included soil mechanics, became his subsequent professional dedication.

One of his remarkable first works was his participation in the analysis of the failure produced during the construction, in 1937, of the Chingford[2] earth dam, in the Lea River Valley, in Chingford (Essex). Skempton had joined the Soil Mechanics section in January 1937, only a few months before this dam failed.

The Chingford Dam was designed by the engineering department of the dam-owning company, the Metropolitan Water Board (MWB), who previously and in the same valley of the Lea River had designed and built similar dams such as the King George V Dam, built in 1910 with absolute safety. So the reason for the collapse of this dam was not clearly evident.

The MWB through the chief engineer Jonathan Davidson requested advice from the BRS, specifically from the section of soil mechanics, in which the young Skempton came quickly to the conclusion that the failure of the dam was due to the speed of the construction. The construction, therefore, did not allow the interstitial tensions to dissipate, producing an incomplete consolidation of the clay strata. For this analysis Skempton used the consolidation theory published by Terzaghi and Fröhlich (1936).

This explanation showed the stability of the previous dams, which had been built at a much slower pace in the era of the horse and wagon, which provided them with the time needed for consolidation. In the case of the Chingford Dam, the experienced contractor John Mowles & Co. had used the new American earthmoving machinery, the first equipment to arrive in the United Kingdom, which allowed the company to build in 3 months the same volume that with the King George V Dam took 9 months to build.

Karl Terzaghi, who at that time resided in Paris, was the consultant chosen by the contractor to confirm the diagnosis. The contractor's delegate, engineer Wynne-Edwards, made the plans, cross sections, and sounding records available to Terzaghi. After a first analysis, Terzaghi considered that the dam presented a clear risk of failure, a ruling that had already been made. At that very moment Terzaghi began his collaboration with the contractor John Mowles. Despite being the contractor's advisor, Terzaghi began an intense relationship with the Soil Mechanics Group of the BRS.

Terzaghi's relationship with the BRS led to a friendship and a mutual professional respect between Terzaghi and Skempton.

The report presented by Terzaghi validated the report made by Skempton and the BRS, which meant an important professional support for Skempton, especially if one considers that it was his first consulting report.

This case generated in the United Kingdom an enormous interest in the soil mechanics practiced at the laboratory of the BRS. Several universities expressed their interest in teaching this new subject and the various civil engineering departments began to visit the BRS to broaden their knowledge. It was an exciting period, in which Skempton established his way of investigating. There were many questions to solve in real engineering problems, and he showed how to investigate them by taking real cases to the BRS, later documenting the results and explanations of the case studied. Skempton followed this pattern throughout his career.

[2]The dam known as Chingford Dam is now called the William Girling Reservoir Dam. The town of Chingford, which originally gave the name to the dam, is now part of the London Borough of Enfield. This dam was designed for the supply of potable water to London.

We briefly describe how the presence of Terzaghi during this time favoured the development of soil mechanics.

In the spring of 1939, Terzaghi taught a series of classes at Imperial College in London by fulfilling a commitment to the BRS during the works of the Chingford Dam and, also in 1939, at the invitation of Sutton Pippard, presented the 45th James Forrest Lecture at the Institution of Civil Engineers (ICE). Terzaghi was the second non-British engineer to have such an honour since its constitution in 1890. In this paper, titled "Soil mechanics – A new chapter in engineering science", Terzaghi tackled the contribution of soil mechanics to calculations of slope stability and the influence of interstitial pressure on clay shear strength. This paper was a great stimulus for the rapid growth of soil mechanics in Britain.

When the Second World War erupted in 1939, Skempton, who was a government research engineer for his post at the BRS and, therefore, a member of the Civil Service, felt no remorse for not participating in the armed struggle. He considered that his family had already paid their obligations to the country for the suffering endured by his father in the First World War and for the subsequent abandonment by the state when his mother did not receive any widow's pension.

In January 1940 Skempton was promoted to Senior Scientific Officer, with a salary of GBP 400 a year.

That same year in July of 1940, Alec Skempton married Nancy Wood, who was always his constant support and companionship. Nancy, who was a great wood recorder and an excellent bookbinder, bound many of Skempton's consulting reports.

In 1941 Skempton became an associate member of the Institution of Civil Engineers (AMICE), with a professional recognition obtained once he demonstrated his professional capacity for the work done. Skempton was 27 years old at this time.

His work with the BRS continued until 1946, including works like the Waterloo Bridge during the years 1938 and 1939, the Muirhead Dam, the Gosport shipyard, the Eau Brink Cut channel of the River Ouse and the dam in the Chew Valley Lake. Skempton designed for the Chew Valley Lake Dam a set of sand drains to accelerate the consolidation of a weak alluvial onto which it was cemented, this being the first time this procedure was applied in the United Kingdom. He also became interested in landslides and slope stability problems, participating in 1944 in the study of Fenland banks.

In 1944 the construction carried out by the MWB of Walton's new reservoir, later called Queen Elizabeth II, was possible with an important collaboration with the BRS. To help in conducting a lot of trials at the BRS, MWB assigned as a collaborator a newly hired young engineer. That engineer was Alan Bishop, with whom Skempton would develop a close friendship. For his great work and quick adaptation to the BRS, Cooling (Director of the Soil Mechanics section) tried to hire Bishop for the section, but being a Quaker the Civil Service was reluctant to offer a position to a pacifist with an official body like the BRS in a period of war. However, that was not an impediment to friendship with Skempton, who in addition to his personal abilities admired Bishop for his courage in keeping his convictions in such difficult times.

From his work at the Chingford Dam, Skempton maintained correspondence with Terzaghi, and among the many issues that were addressed there was one that was recurrent, the recognition of geological engineering as a prominent part within civil engineering and acceptance of soil mechanics as an essential branch of the profession. Both Skempton and Terzaghi shared the same opinion. In Britain the ICE criterion was contrary to the recognition of soil mechanics as an independent discipline in the profession, as was, for example, hydraulics.

In 1945, a series of four lectures under the general title "Principles and applications of Soil Mechanics" were developed against the prevailing trend. Skempton was chosen to give one of those lectures: "Land pressure and slope stability". The lectures were followed with great interest among the members of the profession. The ICE published these lectures the following year and, no doubt, contributed to soil mechanics being considered one of the basic disciplines in civil engineering, as it was finally recognized by the ICE. For Skempton that conference marked the beginning of an era as a professional engineer.

4 Imperial College

In the summer of 1945, Sutton Pippard, who as Professor of Civil Engineering was trying to introduce soil mechanics at Imperial College London, offered Skempton the opportunity to give a course on soil mechanics at the college. Initially this course only required a part-time position, which allowed Skempton to continue working with the BRS. This was very convenient for Skempton, since the annual salary for his part-time position at Imperial College was GBP 120 per year, a very limited amount on which to live in London with his family. In addition, Skempton mounted a laboratory of soil mechanics at Imperial College with equipment gathered from various sources: Imperial College itself, material given by the BRS and material donated by the Metropolitan Water Board. Skempton was 31 years old at the time.

In May of the following year, in 1946, Imperial College considered that the position of Skempton required the full dedication of an experienced teacher, in the Senior Lecturer category. This was officially formalized in October of that same year. That position led to an annual salary of GBP 700, which meant a great economic increase for Skempton. Almost at the same time, Alan Bishop, who still worked with the Metropolitan Water Board, was hired as Assistant Lecturer. From then on, both Skempton and Bishop would remain at Imperial College for all their professional lives.

Skempton developed the soil mechanics studies programme at Imperial College and, helped by Alan Bishop, got an international reputation for Imperial College. Finally, in March of 1947, as Pippard had wished, the subject of soil mechanics was established in the Imperial College curriculum and Skempton was named "university professor" of soil mechanics. He was 33 years old.

Continuing with the correspondence that Skempton maintained with Terzaghi, he wrote informing him of his promotion at the university, to which Terzaghi in his response congratulated him and added that

> So far, teachers really competent in this matter are scarce, because few of them are aware of the limitations of nature, limiting to a purely theoretical treatment of matter. Considering your previous work in this field and the concepts you have developed during the years worked in the Building Research Station, I think you are exceptionally well qualified to develop in your students a rational attitude towards the complex problems of the field engineering. (Niechcial, 2002)

In the summer of 1947, the Imperial College laboratory was properly equipped according to the standards of the time. In a letter that Skempton wrote to Arthur Casagrande explaining the progress of the laboratory, he said that he was considering asking students practical problems based on the work he was currently doing, thinking that in this way he could stimulate students, rather than discouraging mathematical problems, and added that

> In the ten years I have spent at the BRS, I have been working on practical problems and there has hardly been a case where a more far-reaching treatment than a static analysis was needed. On the other hand, almost all the problems needed a deep knowledge of the local conditions and the properties of the land.

Skempton was worried about his purchasing power in London. With his salary of GBP 700 per annum as a full-time teacher, after paying the rent, there was little left for other expenses. His friend Rudolph Glossop solved the problem. We have already mentioned that since 1938 Terzaghi had a paid collaboration agreement as a consultant with contractor John Mowles & Co. after the problem of the Chingford Dam, but since Terzaghi was established in the United States, that agreement was not suitable for both parties. Glossop spoke to the chairman of John Mowles & Co., indicating that the right person to succeed Terzaghi was Skempton. The answer was a proposal to Skempton to be the new external consultant with a fixed remuneration of GBP 100 a year plus the rate corresponding to each specific consultancy. This allowed Skempton to maintain a close connection with the advances in the construction world and, at the same time, to obtain a good complement to his income as a university professor, since the consultancies were frequent.

In 1947 Skempton founded the British Geotechnical Association, and he was also a founding member of the Committee on Soil Mechanics and Foundations Engineering at the Institution of Civil Engineers, with his first contribution to the 2nd International Conference on Soil Mechanics held in Rotterdam, Netherlands, in 1948.

At the congress in Rotterdam Terzaghi was the president, with Skempton acting as his deputy. During the Rotterdam Congress of 1948, the successes achieved by the Soil Mechanics Group of the BRS, and the successes achieved by Skempton, were all influenced by the leadership of Terzaghi.

In this congress Skempton was the author or co-author of more than 10 articles, 7 of them published in the proceedings and 2 published in the first two issues of the *Géotechnique* journal, a magazine that was founded in the same year of 1948 by a group of people, among them Skempton and Glossop.

Skempton's wife, Nancy, designed the cover of the journal, which is still in use today.

Years later, Skempton summarized the achievements of *Géotechnique*:

> There is no doubt that Géotechnique has been (and of course remains) a factor of the utmost importance in the world of Soil Mechanics. It is a journal of an impeccable level both from the technical point of view and from the point of view of the scientific production, for articles on the mechanics of soils, geological engineering and mechanics of rocks.

During the congress there was a visit to the laboratory of the University of Delft, the largest in the world at the time, where they had developed a soil testing system in many respects different from what Terzaghi had developed at Harvard University.

At the congress in Rotterdam Skempton met Laurits Bjerrum, a Danish civil engineer who later would be the director of the Norwegian Geotechnical Department (NGI). Skempton met him again 2 years later at the Symposium in London on Shear Strength (1950). Between them they established a professional relationship that was transformed later into a great friendship that influenced the works developed by both of them and transcended to their own families.

In 1949, the University of London awarded Skempton the distinction of Higher Doctor of Science (DSc) for his continued and varied research and for publishing the results of these research papers. Skempton never got the doctorate as such, although initially that was his intention: to obtain a doctorate. In this way the teaching career of Skempton could have more weight, because he could not become a full professor without being a doctor.

After this period his first work was in the classification of clays. The first articles published in the first issue of the *Géotechnique* magazine were about the geotechnical properties of post-glacial clays (Skempton, 1948). In those days it was not recognized geologically that the normally consolidated clays had an increase in resistance related to the depth at which they were located, because the methods of sampling often caused so much alteration that the phenomenon was not detected. That was the main message of the article.

In situ consolidation of natural clays was a topic that Skempton later studied with a greater interest.

In 1942 Skempton had investigated at the laboratory of the BRS the consolidation behaviour of London clays and, in 1944, in the article delivered at the Geological Society, Skempton presented a more general view of the different clays (Skempton and Jones, 1944). This line of work culminated in 1970 with another article again presented at the Geological Society on the geological compaction of natural clays, which was without a doubt one of his main contributions (Skempton, 1969).

At Imperial College, Pippard continued to insist that Skempton schedule postgraduate courses. At that time there were already three in progress, on structures, on concrete and on hydraulic energy, and another on sanitary engineering was beginning. In 1950, at the insistence of Pippard, the first postgraduate course on soil mechanics was established, which consolidated that branch of knowledge at Imperial College.

In June of that same year the Congress of Shear Strength took place in London. It was the next event, after the Rotterdam Congress, which allowed most of the European engineers related to this matter to meet. Laurits Bjerrum also attended the meeting, who Skempton had met in Rotterdam and with whom he had an important collaboration in the field of clay research.

The article Skempton presented to the London Congress, "The Shear Strength of Soils", was published in the second issue of *Géotechnique* in 1950 (Skempton and Bishop, 1950).

In 1953 Alec Skempton attended the 3rd International Congress on Soil Mechanics and Foundation Engineering in Zurich, Switzerland. That third congress, after Harvard in 1936 and Rotterdam in 1948, was transcendental because it consolidated the International Society of Soil Mechanics and Foundations Engineering. After the Zurich congress the society started holding congresses every 4 years.

Skempton presented an article at the Zurich Congress with the title The Colloidal "Activity" of Clays, which defined the concept of "Activity" as the quotient, approximately constant, between the index of plasticity and the content of the clayey fraction in any stratum of clay.

In Zurich Skempton met again with Laurits Bjerrum and personally met Ralph Peck. Peck was no stranger to Skempton, because both had corresponded professionally since 1948, when Skempton, encouraged by his friendship with Terzaghi, began to request information on Chicago clays and on the thixotropic clays of New Haven. Skempton, seeking a second opinion that alleviated the critical spirit that sometimes manifested Terzaghi, consulted with Peck many doubts. For example, with reference to which of the equations to use for calculating the bearing capacity, Peck replied that

> I prefer to adopt the attitude that theories can come and go, but the results of field observations will keep their value unchanged, and theories should conform to reality as much as possible. (Niechcial, 2002)

As part of the same congress a visit to the Marmorera earth dam was also included, which was well known by Bjerrum from his years of work at the Federal Technical College (ETH) of Zurich.

Skempton was clear that Laurits Bjerrum had become the person who in Europe would lead the difficult role of handling the concept of clay shear strength. Among many other shared interests, they agreed to assess the work of Juul Hvorslev on the taking of unaltered samples (Hvorslev, 1949). They were all convinced that field work was an essential part of soil mechanics and geology, which should always be taken into consideration, including the history of the soil. Both enjoyed working on soil mechanics and recognized their admiration for Terzaghi, whom they were fortunate enough to know.

Returning to England, as he had decided at the Zurich Congress, Skempton began to apply the principle of effective tensions to the study of slopes in London clays. The article about the landslide at Jackfield on the River Severn was their first contribution, though due to an overestimation of the probable interstitial tensions in the landslide, their efforts were also overestimated (Skempton and Henkel, 1955).

On his return trip to the United States Peck stopped in London, to become acquainted with Imperial College and the Building Research Station (BRS).

In 1954 Skempton published in *Géotechnique* the article "The pore-pressure coefficients A and B" clarifying and simplifying the problem of shear strength of saturated soils (Skempton, 1954). The evaluation of the horizontal stress in the clays of London generated a lively debate with Terzaghi. That article established Imperial College as a recognized research centre and teaching of shear strength. Their A and B coefficients of interstitial pressure are still taught at present and are widely used.

That same year, in April 1954, Skempton and his wife made a long trip to the United States, where Ralph Peck had invited Skempton to give a series of lectures at different universities across the country. The Skemptons spent 10 days living with Terzaghi and his wife, Ruth, in their house. Terzaghi took advantage to show him Harvard and his laboratory of soil mechanics and to meet with Arthur Casagrande, who had his office next to Terzaghi's.

Figure 3. Alec W. Skempton and R. Peck in London, 1953 (Peck Legacy Website).

In 1954 there was still time for another major trip for Skempton. In the company of his wife, Nancy, they visited the Norwegian Geotechnical Institute. Skempton there found a vibrant research centre in ideas and enthusiasm at work. It was quickly suggested to find parallels between the Norwegian clays and the post-glacier clays of England. Skempton was especially interested in the phenomenon that he called "flow slide", more common in Norway than anywhere else. In general, the process was as follows: when the thaw occurred after the last glacier era, there was an elevation of the terrain after the ice overload disappeared. The rain water washed the clays, originally marine, leaching the salt and leaving the clay in new conditions that made it prone to what could be called solifluction nowadays.

From then Imperial College and the NGI, through its leaders, developed an intense technical collaboration on the fundamentals of soil mechanics and especially the behaviour of clays. There was an intense exchange of correspondence ranging from the exchange of technical information to the planning of TRIPS, meetings and congresses, including comments on the promotion of colleagues to different posts and other agreements.

In 1955 Skempton was appointed full professor of soil mechanics at Imperial College, a chair expressly created for him by Pippard.

These final years of the 1950s and early 1960s proved to be a few golden years for Skempton, with one article being published after another. The work as a consultant resulted in articles on admissible seats in buildings, which are still widely used, as well as the pragmatic "Method-α" (Skempton, 1959) for the design of excavated piles into the London clays, for which he was awarded the prize of the British Soil Mechanics Society which later was called the Geotechnical Society Prize.

Skempton also worked with Victor Albert Sowa in investigating the behaviour of saturated clays during sampling and tests. This work was published in a series of articles that represented one of the most influential contributions published in soil mechanics (Skempton and Sowa, 1963).

In 1957 Skempton succeed Sutton Pippard as head and chair of the Engineering Department at Imperial College London. He became responsible for all branches of civil engineering and teaching of these subjects at the department.

The fourth International Congress on Soil Mechanics and Foundation Engineering was held in London in 1957. Skempton had an outstanding participation in both the organization and the congress itself. At the end of the congress Skempton was elected new president of the International Society for Soil Mechanics and Foundation Engineering (ISSMFE) to replace Terzaghi.

Skempton also decided to pay tribute to his predecessors in civil engineering, who had been forgotten. His main historical contribution was the study of the work by the first civil engineers, especially of the 18th century, whose achievements had been ignored by the historians of engineering. As a result, for many years, Skempton also taught civil engineering history classes. Initially these engineering history lectures were intended for non-graduate students, but their fame spread and many of the attendees were graduate students, which often generated a problem because there were not enough seats.

5 Professional fulfilments

Returning to Skempton's professional career in the 1950s, it must be mentioned that for many years he was also an external consultant for the engineering consultancy Binnie and Partners. His first project was in 1951 on the Usk Dam, but the most important project in this consultancy between the years 1958 and 1967 was the Manga Dam in Pakistan, where his geotechnical expertise in the location of the foundation of the dam was essential for its safe construction.

In 1957 and 1958 Skempton was involved in Avon Gorge stability problems. During the years 1962 and 1963 he worked on the M6 highway sliding at Walton's Wood in Staffordshire. This research led him to understand the important role that residual strength plays.

In 1958, to celebrate Terzaghi's 75th birthday, Arthur Casagrande had the idea of editing an anniversary volume with featured articles. A committee was formed that, in addition to Casagrande, included Bjerrum, Peck and Skempton, with the collaboration of Karl Terzaghi himself. The book, titled "From theory to practice in soil mechanics" (Bjerrum et al., 1961), did not meet the deadline of the anniversary date, but still exceeded the expectations of Terzaghi himself, who in a letter addressed to Skempton said "I wish to express once again my gratitude for the splendid work you have developed by unravelling the history of effective stress" (Niechcial, 2002).

On 16 March 1961, when Skempton was 46 years old, he was appointed a member of the Royal Society, which meant an important personal recognition and a great honour for soil mechanics in the United Kingdom.

That same year, 1961, the 5th International Congress on Soil Mechanics and Foundation Engineering was held in Paris. It was the first congress that Terzaghi could not attend because, as a result of an aneurysm in the aorta, a leg had to be amputated. Skempton read a message from Terzaghi; it was his last communication to the ISSMFE. However, the influence of Terzaghi, directed by Skempton, Bjerrum and Peck, resulted in the appointment of Arthur Casagrande as the new president of the ISSMFE replacing Skempton, which ended his presidency in that congress. In his presidential speech, at the opening of the congress, Skempton highlighted two important points: that the behaviour of soils could be analysed in a rational way and that the mechanics of soils had already been widely accepted in civil engineering and by most universities.

At the end of the 1950s and during the decade of the 1960s, Skempton was also dedicated to the study of slope stability and residual strength. Residual strength and its importance in the control of the behaviour of the reactivation of the slides were two more of the topics for which Skempton will always be remembered. That was also the central theme of his delivery in 1964 at the 4th Rankine Reading with the title of "Long-term stability of clay slopes" (Skempton, 1964). At that exhibition, Skempton again revaluated the analysis of the Jackfield slide along with other landslides and showed that residual strength was a fundamental property dependent, among other things, on soil mineralogy. Although some ideas about residual strength had already been developed, even with subsequent contributions from Skempton himself, this paper was one of the most important contributions by Skempton to soil mechanics. The words of gratitude were given by Laurits Bjerrum, highlighting the ability of Skempton to correlate apparently unrelated events common in soil mechanics and highlighting his extraordinary influence on the development of this science in the world.

During the years 1965 and 1967 his professional advice was requested on several large landslides, including that of the Sevenoaks Bypass between the M6 and the M4, attributing the slide to a previous shear effort due to the freezing of the ground in the Quaternary. The analysis was later published in a series of articles and presented at the debate meeting of the Royal Society about slopes on natural hillsides, which was organized by Skempton. These articles are of special interest because they show how deep Skempton's knowledge was on the geology of the Quaternary.

Between 1965 and 1967 Skempton participated in a group of experts who studied the problems of terrain settlements under the Leaning Tower of Pisa, Italy. Years later, Laurits Bjerrum and Ralph Peck would work on the project to fight the settlements in the Tower of Pisa.

He revised the foundations of St. Paul's Cathedral in London during the years 1970 and 1972 and of Salisbury Cathedral in 1982. Salisbury Cathedral was cemented on a layer of relatively thin gravel resting on limestones, which led Skempton to prepare an article on the bearing capacity of granular soils (unpublished data).

6 Retirement

Skempton retired in 1981 at the age of 67 from his post of full Professor of Civil Engineering. It was not a regular retirement. First, in 1976 he renounced his position as head of the Department of Civil Engineering to reduce his workload, but he extended his working life 2 years until reaching the maximum age of 67 years, increasing his retirement pension. Later he remained at Imperial College with the category of Professor Emeritus and Senior Research Fellow, which was only allowed to those teachers considered especially valuable for the university. Under that agreement, Skempton continued working in his office for 20 years, until only 3 or 4 months before his death.

Between 1991 and 1996 Skempton participated as a consultant on the Ghazi Dam on the Indus River (Pakistan), where there was great concern with the paralysis of open works on "gravels" whose susceptibility to tubing (piping) was known and considered a potential problem. This problem was thoroughly investigated, and its outcome had the corresponding article in collaboration with J. M. Brogan, published in the *Géotechnique* magazine with the title "Experiments on piping in sandy gravels" (Skempton and Brogan, 1994).

Again, with the Binnie company, Skempton participated in the proposal of the Kalabagh Dam, and from this participation came out the article on the methods of application of the SPT test (Skempton, 1986). The Manga Dam was the last commission of Binnie in the year 2000, in this case to evaluate proposals to raise the crowning of the dam around 12 metros. Skempton was 84 years old.

In more recent years his most important project was the review of the Carsington earth dam failure in Derbyshire, which collapsed by a landslide just before it was finished, in 1984. Skempton was hired by its owner, the Severn Trent Water company, to lead the investigation. The result of this research showed the importance of knowledge of the Quaternary geology in general, and of very plastic clays, since the progressive failure in this type of clay was what made the dam considerably less secure than it had been thought by its designers. His studies were published in a series of articles at the symposium on land work failures and in an article in *Géotechnique* magazine, 9 years later (Skempton and Vaughan, 1993).

7 Awards

Throughout his life Skempton accumulated numerous recognitions, many of them in early to mid professional career. In addition to the acknowledgements that have already been mentioned, Alec Skempton became a member of the MICE in 1957, was awarded the ICE James Alfred Ewing Gold Medal in 1968, the Lyell Medal of the Geological Society from London in 1972, and the Dickinson Medal of the Newcomen Society in 1974, was elected Foreign Associate of the National Academy of Engineering (USA) in 1976, and was granted the Karl Terzaghi Award from the American Society of Civil Engineers in 1981 and the Gold Medal of the Institution of Structural Engineers in 1981.

He was also awarded three Honorary Doctorates in Science, in 1968 by the University of Durham, in 1980 by Aston University and in 1982 by Chalmers University, Sweden, the latter when he was retired.

Throughout his life Skempton tried to avoid the committees in which he did not have an immediate and direct interest; however, he was Vice-president of the ICE between the years 1974 and 1976, president of the Newcomen Society for the Study of the History of Engineering and Technology between the years 1977 and 1979, member of the Advisory Council of Cathedrals between 1964 and 1970 and member of the Natural Environment Research Council between 1973 and 1976.

He was also a "special lecturer" at the Architecture Association between 1948 and 1957, and "Visiting Professor" at the School of Architecture at the University of Cambridge and at the University of California at 1976.

Internationally Skempton was known not only for being the second president of the International Society of Soil Mechanics and Foundations Engineering (as mentioned at the inauguration speech of the 1961 Paris Congress), but also for being a speaker on state-of-the-art studies at the International Congress of Soil Mechanics and Foundations Engineering of Mexico in 1969.

In addition, he was a speaker at the European and International Congresses in Oslo in 1976, in Tokyo at 1977, in Brighton in 1979 and in San Francisco in 1985.

As far as publications are concerned, Skempton also remained active until the end of his life, and in his last 5 years he was working on a biographical Dictionary of Civil Engineers of the British Isles during the period between 1500 and 1830, a period when the railroad era began. This work was published posthumously.

In the year of his retirement, Skempton donated his collection of historical books and his collection of soil mechanics articles, along with his reports from the early stages of engineering, to the Imperial College Civil Engineering Department Library.

In January 2000 Skempton was appointed a Knight for services rendered to engineering. He appeared on the Millennium List of Honours with the title of Sir added to his name. However, by this time he had shown disenchantment with such formalities. The investiture of his knighthood took place at Buckingham Palace in June 2000 by Queen Elizabeth II. In November 2000, he received the ICE Gold Medal for his contributions to civil engineering for more than 60 years.

Figure 4. Imperial College. Civil Engineering Department: Skempton Building (Imperial College Web).

Apart from engineering, his other great passion was classical music. Skempton was a prominent amateur flute player, although he also had a wide interest in the arts in general and painting.

Alec Skempton and his wife, Nancy, were both sports fans and were expert cricket players and active members of the Hurlingham Club for many years.

Nancy died in June 1993 at the age of 80 years, after a long degenerative disease diagnosed as cerebral atrophy, which gradually limited her vital functions.

Nancy and Skem (as he was called by everyone who knew him) had two daughters, Judith and Katherine (Kate), and five grandchildren. Beverly Beattie was his partner in recent years. Bev was hired to help with the care of Nancy, staying in the houses of the Skemptons, and after Nancy passed away Bev took care of Skempton. Over time Skempton's relationship with Bev became more romantic, but they never got married.

Alec Skempton died on 9 August 2001 at the age of 87 years as a result of lung cancer, but was still active until the end. His enthusiasm for knowledge and learning was an example in the world of civil engineering.

8 Conclusions

Skempton was an unusual man, a leader by example and not by imposition; an academic mind who considered research his first priority; a student who required close association with practical engineering and real structures in the field; a multifaceted person with multiple interests to be reinforced

and updated throughout his active career; and an engineer who never declared himself ready but had the remarkable habit of being right. As a teacher he always debated on the same level with his students but gave fellow professionals a hard time if they did not prepare their arguments properly. His own work habits were meticulous, and he did not accept anything until he had assembled, drawn and analysed the data himself, forming his own conclusions and putting them in writing with elegant and well-known prose.

Alec Westley Skempton was one of the greats in soil mechanics.

Data availability. The underlying information and research data of this paper can be found in the references. The doctoral thesis of Gonzalo Guillán (2015) is also useful.

Author contributions. All the authors contributed to the work. GGL was the author of the original doctoral thesis; ALG, RGA and VACdA wrote and reviewed the manuscript and translated it into English.

Competing interests. The authors declare that they have no conflict of interest.

Acknowledgements. We thank the anonymous referees for their reviews and useful suggestions.

Review statement. This paper was edited by Giovanni P. Gregori and reviewed by three anonymous referees.

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