SEM History

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Dr. Max Frocht was the best known American photoelastician of the twentieth century. His books, *Photoelasticity,* Volume I and Volume II, quickly became classics and were translated into Russian, Spanish, and Chinese. Through those books and his many research innovations Max became an internationally acclaimed photoelastician. He was an important contributor at all of the early SESA meetings and his excellent photoelastic fringe photographs and well written papers became his hallmark. Dr. Frocht habitually sat near the front of the room when papers on photoelasticity were presented. He took his position of leadership seriously, and discussed nearly every paper, sometimes with praise, often otherwise.

In 1959, Dr. Frocht was made an Honorary Member of SESA and presented the William M. Murray Lecture. He was known as a superb teacher in addition to being a gifted author and researcher. That is why the SESA (now SEM) created the M.M. Frocht Award in 1967 to recognize “outstanding achievement in education of experimental mechanics”. Of course, Max was the first recipient of that award. Dr. Frocht had many outstanding Ph.D. students who are mentioned in the article which follows. The author of the article is Dr. L.S. Srinath (called simply “Srinath” by his friends) who was one of Frocht’s students and is himself a very distinguished scientist and educator. Srinath is a Fellow in SEM and in the Indian Academy of Science and is the author of a book entitled *Scattered Light Photoelasticity,* co-author of another book , *Experimental Stress Analysis,* and has published many papers. As an educator Srinath has been a professor at the Indian Institute of Technology, Kanpur and at the Indian Institute of Science, Bangalore. He also served as Director (President) of the Indian Institute of Technology, Madras.

A biographical sketch of Max Frocht is available in *Who’s Who in America* and a very detailed biography is included in the beginning of the book, *“Photoelasticity - The Selected Scientific Papers of M.M. Frocht”,* edited by M.M. Leven (and the SESA) and published by Pergamon Press in 1968. However, mere listing of his education, positions, publications and honors does not even begin to tell the whole story of this complex man, who was sometimes controversial, usually cordial, and always interesting. Dr. Frocht and his frequent rival, A.J. Durelli, added immeasurably to progress in the science and application of the photoelastic method. For that we are all deeply indebted. Their discussions at the semiannual meetings of the SESA always added interest and excitement to the meetings and are an indelible part of our memory.

When he was asked to write about Max Frocht, the person, Srinath most graciously responded. I am certain that you will enjoy his article as much as I have.

C. E. Taylor, SEM Historian

by L.S. Srinath

Writing an article on Dr. Max M. Frocht is like writing a chronicle on photoelasticity itself; a subject which began as an interesting experiment in a physics laboratory and ultimately got developed into a powerful experimental tool for stress analysis. The man who brought about this transformation was Dr. M.M. Frocht, a colorful man, who was human with strong convictions, emotional, as dedicated to photoelasticity as to his wife Dora Frocht, ambitious and rightfully proud of his achievements, difficult to newcomers, but very gracious and friendly to his research students and close associates. Many articles have appeared describing his contributions to photoelasticity, the honors and awards he received and academic positions he occupied. His two volumes on photoelasticity speak a great deal about his dedication to experimental work, accuracy of experimentation, love for beautiful illustrations and photographs. The vita on Dr. Frocht by M.M. Leven covers in detail his earlier education, training, achievements and distinctions bestowed upon him. As a graduate student and a close associate, I thought it would be more appropriate and interesting to present the human side of Dr. Frocht. In the process of narrating interesting episodes, the names of his associates and contemporaries will naturally appear. However, in mentioning their names, no disrespect of any kind is intended to any of them. All these persons including Dr. Frocht, were actors; conscious of their self-images, and proud; who by their actions, professional achievements and academic one-upmanships, added color and excitement to their time periods. We, as graduate students of these persons, would exchange notes, share stories and enjoyed bonhomie relationships, which continue to these days among our students.

My familiarity with the name Max M. Frocht, began in the early 1950s when I was studying for my Masters Degree at the Indian Inst. of Science, Bangalore. His designation at IIT, “Research Professor of Mechanics and Director- Experimental Stress Analysis” somehow fascinated me. Another name that impressed me equally was: R.V. Southwell, famous for his books on Relaxation Methods and Theory Of Elasticity. It was Southwell’s degrees/titles: “MA, LLD, DSc, FRS” that impressed me. Curiously enough, I had taken up the problem of determining the stresses in a circular ring using photoelasticity and relaxation methods. Though it is a fairly simple problem today, two papers on this got published in “Applied Scientific Research”, and I had sent two copies of these to Prof. Southwell. He not only acknowledged, but also wrote saying that in England where his methods were developed, very few persons there appreciated his methods, whereas, in distant lands like India, persons were using them. It was indeed a great letter of appreciation. I was in Hull-England for two years as a trainee in an aircraft company and as my interest in photoelasticity and relaxation methods persisted, I wrote a letter to Dr. Frocht inquiring whether I could join his lab and work for my Ph.D. He replied saying that he would be coming to London on his way back to USA after attending a conference in Europe and that he would be happy to discuss this with me if I could meet him in London. I met him in the lounge of the hotel where he was staying at about 11:30 AM. After about two and a half hours journey from Hull, I was quite hungry and was hoping that Dr. Frocht would invite me to join him for lunch or at least suggest something to eat. After a few preliminaries, he looked at his watch and said, “Well, it is

almost lunch time; we may as well sit here and discuss your joining my lab so that you can get back to Hull before the evening" It was decided that I would be joining his lab in the winter of 1955; and I went back to Hull to have my supper at my landlady's place. Dr. Frocht's laboratory was located on the second and third floors of Chapin Hall (I do not think it exists anymore; at least not as it was then!) at the end of the long building, close to Armour Research Foundation - ARF (which later became the Armour Research Foundation of IIT, or IITRI). Chapin Hall was an old dilapidated building with creaking wooden flooring and stair cases. This building also housed the mathematics and psychology departments, counseling center and a few other offices. ARF building was in no better shape either. At the time I joined Dr. Frocht, others in his lab were: Abe Betser (from Israel), Ben C. Wang (from China), Robert Thomson (deputed from Univ. of Idaho) besides David Landsberg, who was the "mechanician" in Dr. Frocht's lab This was a strange word, which to us the graduate students, sounded as if the person could not be downgraded to the level of a mechanic (or a technician) nor could be upgraded to the level of a lab supervisor. Perhaps, this was an acceptable designation to IIT-Administration, but it did provide us a topic for discussion! Also, at the time I joined Dr. Frocht's lab the Mechanics department of IIT-Chicago had an assembly of giants who had made impressive academic contributions in their fields, like: Dr. Eli Sternberg, Dr. L.H. Donnell, Dr. W.R. Osgood, Dr. P.G. Hodge, and Dr. Frocht. I understand that Dr. D.C. Drucker had left IIT sometime earlier. At ARF across Chapin Hall, was Dr. A.J. Durelli with his graduate students: J.W. Dally , W. F. Riley, and among others. A couple of years later, C.S. Sciammarella joined Dr. Durelli. Sciammarella told me that he and Dr. Durelli were political prisoners and cell-mates in Argentina, South America, and were the last two persons to be released from that group. At about the same period, at Northwestern University, there was Dr. M. Hetényi.

All of us (excepting Robert Thomson) were given financial assistance, the money coming from Frocht's research grants and we were expected to work in the lab from 9:00 am to 5:30 pm with one hour lunch break. Those of us who had student visas, had to register for a minimum of twelve credits per semester, and Dr. Frocht was reluctant to let us register for courses offered during the lab hours. So, we ended up registered for a good number of experiment related courses which were taken in his own lab His dedication to experimental work was so intense, he would not like us to be seen studying course related books or doing library visits during lab hours. These had to be reserved for outside lab hours. Controversies between theoreticians and experimentalists were as intense in those days as they are today. Dr. Frocht had a statement pasted on the wall of his lab which read, "Nobody believes an experimental result except the experimentalist himself; and every one believes in a theoretical analysis except the theoretician himself." In one of the seminars in which the speaker, Dr. Chiarulli (who was the Chairman of the Dept. after Dr. Osgood had left) dwelt at great length on the mathematical analysis of a practical problem, Dr. Frocht at the end of the seminar remarked, "I respect mathematicians, but to me experimental results are more convincing," to which Dr. P. Chiarulli said, "I too respect you Max, though an experimentalist! " Dr. Peter Chiarulli was a theoretician who taught us Mechanics; and Goldstein's book on Classical Mechanics was his favorite book.

By the time I joined Dr. Frocht's laboratory, Paul Flynn and Ros Guernsey had left after completing their Ph.Ds. Frocht and Guernsey had developed the famous shear-difference method to separate the normal stresses at an interior point of a three-dimensional body using a stress frozen model and the sub-slice technique. Guernsey had studied the problem of a sphere under diametric compression for his Ph.D. work. The process was quite intense since it was the practice in Dr. Frocht's lab that casting photoelastic blocks, cutting, machining, polishing and making photoelastic observations on specimens, all had to be done by the investigator himself. Just by then, Sternberg and Rosenthall had published a theoretical paper on the determination of stresses in a sphere. Their solution needed some elaborate numerical computation to determine stresses along a general line inside the sphere. When Guernsey approached Sternberg for the theoretical solution so that he could compare with his experimental results, Sternberg would not reveal the values of his calculation until he saw the experimental results first. It was a case of mutual suspicion between a theoretician and an experimentalist, and it was Dr. Frocht who yielded saying, "The experimentalist reveals what stresses actually exists and it is up to the theoretician to show that his analysis correct." In this case however, both results agreed to their mutual satisfactions. Frocht admired Sternberg quite a bit and would make every effort to attend his lectures. We had registered for the course on Elasticity offered by Sternberg, which was a 4 credit course. Frocht had induced Sternberg to teach this course twice a week, each lecture lasting two hours. Frocht would attend all the lectures along with us without fail. Sternberg was known for his well organized lectures and beautiful board work. It was a real pleasure to attend his lectures. He was a man with strong views and opinions about his colleagues and fellow academic rivals which he would express in our class with a dry humor! He knew that Dr. Frocht was there in the class.

Paul Flynn had conducted photoelastic studies on stress wave propagation in solids for which, he and Landsberg had constructed a rotating drum-camera to the inner surface of which a long photographic film was attached. A slit of light (one hundredth of an inch wide) was focused on to this film surface through a lens system which was directed towards a photoelastic specimen through which stress waves were passing. The speed of the drum-camera was adjusted to record one million slits (continuous pattern) per second. In his thesis, Flynn had used the term "one million frames per second." Dr. Donnell, who was one of the thesis examiners, objected to this and said that the record was not that of discrete frames but that of streaks as observed through a slit. Dr. Frocht did not agree with this, and obviously words got exchanged which led to cool relationships between the two. Later on, Abe Betser working for his MS Degree, continued the work on stress wave propagation using photoelasticity and strain gages. When he submitted his thesis for approval, Dr. Donnell was once again an examiner and he was magnanimous enough to say that the work of Betser, if it could be complemented by some additional work, would even qualify for a Ph.D. This was indeed a pleasant surprise for Dr. Frocht and Betser did some additional work and obtained his Ph.D.

As mentioned, Dr. Frocht's lab was located on the second and third floors of Chapin Hall. Across the building on the Eastern side was a railroad for freight trains passing

frequently. On the Western side of the building, a little farther away, was the famous El-train track of Chicago. Every time the freight train or engine passed, the building would start shaking. This would upset Betser very much, since the pendulum impact machine with its long suspension rod would vibrate slightly and not hit the specimen squarely on its face. The experiment needed at least two hours of preparation before the actual test could be carried out. After the test, it would take another one hour for the film to be carefully taken out of the camera and go through the process of developing, fixing, etc., before one could see whether the experiment was successful or not. In short, not more than two tests could be conducted per day. It was Dr. Frocht more than Betser who would get upset if the experiment did not show a plane wave. It was not an easy experiment to conduct. The trains were more frequent in the afternoons than in the mornings. So, Betser would come to the lab fairly early in the morning to conduct the experiment. He lived on the South side of Chicago close to the apartment where Dr. Frocht lived, and would commute by bus. Dr. Frocht used to come to the lab by about 9:30 am and leave for home at about 4-4:30 pm. So, some times he would offer a lift to Betser. But, he was reluctant to make this a practice. So, some days the offers would be made and no offers on other days. It was amusing for us to witness the expectation on the part of Betser and hesitation on the part of Dr. Frocht. Both would make deliberate attempts to avoid each other around 4:00 pm!

A few months after Betser returned to Israel to join Technion, a paper appeared commenting on Betser's work stating that a careful investigation using strain gages had shown that the surface velocity of a stress wave was less than the wave front velocity inside a solid, whereas, Betser's work had shown that plane waves would remain plane. This upset Dr. Frocht quite a bit, and we had several discussions to decide whether we should repeat Betser's experiments. Suddenly it dawned upon Landsberg who was assisting Betser, that the researcher (I believe he was from Caltech) might have used a gage current as recommended by the manufacturer and the heat generated might have softened the surface of the specimen, thus reducing the wave velocity. Dr. Frocht suddenly shot up and asked what current was Betser using, to which Landsberg replied "much less, since Abe put his finger on the gage and found it hot!" While this brought some relief to all of us, there was a sense of disappointment on Dr. Frocht's face since nothing was mentioned about this important aspect in Abe's thesis and also not a correct way of conducting tests. Later on, a detailed investigation on the effect of gage currents on strain measurements was made by Wang and Landsberg and a paper was published.

It was common knowledge that there was considerable academic rivalry among the three famous experimentalists, namely, Dr. Frocht, Dr. Durelli, and Dr. Hetényi. As I could gather, all three had devoted their earlier activities to photoelasticity. Later on, while Dr. Frocht continued his interest in photoelasticity, Dr. Durelli started paying more attention to moiré and brittle lacquer, and Hetényi to strain gages. At any conference or paper presentation each one would attack the merits of the paper presented by the other. For us, the graduate students, and others in the audience who admired all the three, those moments of verbal attack were of great excitement. We would exchange stories and remarks we heard from one another. On one occasion when a paper on

stresses at an interior point in the head of a railroad rail where a tensile stress causing fatigue cracks was suspected to exist, Wang stated that a detailed investigation had shown otherwise, i.e. absence of tensile stress. Dr. Durelli, who as usual, was sitting in the front, got up and said, “such time and effort was spent on this investigation using the so-called shear-difference method, just to show that there were no critical stresses!” This was indeed a remark which could not be left unanswered and Dr. Frocht got up and said “If you suspect a cancerous spot in your body and subject yourself for a thorough investigation spending much time and money, do you regret if the doctor gives you a clean bill of health?” [Historian’s note: That typical exchange is recorded in the discussion of the paper. *See Proc. of SESA*, Vol. XIV, No. 1, pp 11-12.] This of course brought great mirth among the listeners. On another occasion, Dr. Hetényi made a remark that a particular scattered light pattern coming out of Dr. Frocht’s lab was not good since the fringes were not clear. What Dr. Hetényi was not aware of was that the absence of fringes indicated that observations were being made in the direction of one of the secondary principal stress axes; and if the experimentation was correct, no fringes should be seen. The point of interest is the story that Dr. Frocht told us at the coffee break.” A farmer observed that the dog he owned showed some unusual behavior. So he invited the village headman to witness it. They went to the village lake and the farmer threw a stick across the lake to the other side and asked his dog to fetch it. The dog looked at his master, ran over the surface of the water to the other side, picked up the stick, ran back on the water surface and dropped the stick at his master’s feet. The village headman looked at the dog in great surprise and after taking a couple of puffs on his pipe asked the farmer to do it again. When the dog again ran over the surface of the water and brought back the stick, the headman, after clearing his throat said, ‘The damn thing does not know how to swim!” Of course, the point was that one should not always expect the normal thing to occur and an unusual thing is not only interesting and may have a reason behind it.

Dr. Frocht was proud of the quality of work coming out of his laboratory, whether it be a fringe pattern or a research paper. The photographs in his two volumes on photoelasticity give ample evidence to this. Since he would go through every sentence of a thesis or a paper with his students and modify the statements to his satisfaction, he used to remark that a reader would readily recognize the work as coming out of his lab. When I joined his lab he had mentioned that in addition to many other things, his students would learn how to make good photoelastic models, make careful experimental investigations, take good photographs, and more than anything else, write good reports. Due to some earlier exposure and practice, I could write fairly acceptable technical reports. On several occasions when he used to go through my writings, he would say, “Srinath, what you have written is OK, and reads all right, but I would have written it differently,” and with these he would make minimum alterations. Upon completing my thesis, a copy of it was sent to Dr. Donnell for his approval, as he was one of the examiners. A few weeks later, on the day of my oral presentation, while Dr. Frocht and I were walking from Chapin Hall to the Mechanics Dept. where the presentation was to take place, he remarked, “Maybe I should tell you this, Dr. Donnell said that your style of writing is very good and easy to read. I was happy to hear that but, it does not appear to be a product from my laboratory.” A reluctant appreciation but

still adamant. He was not too generous with ready appreciation for any success coming without much labor or effort. One personal experience comes to my mind to illustrate this. His book on photoelasticity shows a beautiful fringe pattern of a simply supported beam centrally loaded. The pattern displays an isotropic point beneath the load, which is theoretically predicted (Wilson-Stokes theory) but requires extreme care and precision if one has to observe it. A few months after joining his lab, out of curiosity, I conducted the experiment taking considerable precaution. To my surprise, I could see the isotropic point (a dark spot which does not move or change position on varying the load), and I called Landsberg to come and see it. Landsberg, who would not believe it initially, after some persuasion came and made sure it was an isotropic point. Later on when he mentioned this to Dr. Frocht, he just remarked, “may be, may be!”

About a year prior to our graduation, Y. F. Cheng from China had joined us for his Ph.D. with Dr. Frocht. Landsberg was still there working as a “mechanician” though he had obtained his MS degree. After graduation, Thomson went back to Dayton, Ben Wang joined IBM, Betser returned to Israel to join Technion, and I returned to India. Within a few months after my return I got a telegram (no faxes in those days) from Dr. Chiarulli offering me an Asst. Professor’s post. The offer was tempting and I went back to Dr. Frocht’s laboratory. Landsberg had left the lab by then to join some paper industry. Cheng was still there. Since a part of my salary came from Dr. Frocht’s research grants, I had to work in his lab in addition to teaching. Since Landsberg was not there, the job of maintaining the workshop, ordering the chemicals, casting the models, cutting, polishing and conducting experimental investigations fell on Cheng and myself. Frocht was about 65 then and was not very energetic. He had just lost his brother which had depressed him; and Mrs. Frocht told me that Dr. Frocht was thinking of retiring and asking me to take charge of the lab But by then I had become a bit disillusioned since the relationship with Frocht had not changed from that of a student-professor to colleague-colleague. So, a day came when I decided to leave IIT and join University of Kansas-Lawrence. Mrs. Dora Frocht was unhappy to see me leave IIT, since she had maintained very cordial relationships with all Dr. Frocht’s students. Frocht and I maintained close contact for many years and we published a few papers together. At the Fourth US National Congress of Applied Mechanics in Berkeley in 1962, where I met Dr. Donnell and Dr. Sternberg (he had left IIT to join Caltech) again, Dr. Frocht was introduced by Sternberg to some foreign visitors as “Meet Dr. Frocht, father of photoelasticity,” to which Dr. Frocht replied, “I do not know much about being a father, but let us say we are related.” There were of course good laughs and smiles from many of us there. He had a great sense of humor, was a lover of music, particularly of opera. It was the indelible mark he left on us as a great teacher, a scholar and a dedicated experimentalist which made a majority of us pursue academic careers and experimental investigations. It was rather an irony of fate that after Dr. Frocht retired, it was Dr. J. W. Dally, a student of Durelli, who succeeded him as the Director of his famous experimental stress analysis laboratory, and it was W. F. Riley, another student of Durelli who replaced Durelli at IITRI. Two good friends and frequent collaborators occupied the two positions which were formerly occupied by keen rivals. Again after Dally left IIT, it was Dr. Sciammarella, another student of Durelli, who became the Director of Dr. Frocht’s laboratory.

Max Frocht died in July of 1974 at the age of 80 and Dora Frocht died in the following year also at the age of 80. They leave behind them a wonderful legacy of dedication and extraordinary achievement.