Report on 'Representing Mega Earthquakes in the Laboratory: The Discovery of Super-shear, or Intersonic, Earthquake Ruptures' *by Professor Ares J. Rosakis, California Institute of Technology, USA* under the aegis of the Indian Academy of Sciences, held at IISc Campus, 11 a.m. to 12 noon on 9th September, 2019 by P. Krishnamurthy, Geological Society of India, Bengaluru (*E: krisviji@gmail.com*) and K.R.Y. Simha, Dept. of Mechanical Engineering, IISc, Bengaluru; (*E:simha@iisc.ac.in*).

Earthquakes are one of the most challenging natural hazards that defy prediction with any reasonable warning time that may be possible in the case of hurricanes, cyclones or tsunamis. Studying earthquakes both in the field and laboratories, presents a host of challenges to the seismologist; and, the most obvious ones being the inability to trigger an earthquake in the laboratory and simulate the behaviour of slip along the fault zone at depths. In an enthralling lecture, Prof. Rosakis illuminated the concept of *Laboratory Earthquakes* as well as the experimental discovery of *super-shear* earthquake ruptures, whose speeds exceed the shear wave speed of crustal rocks.

In simplistic terms, earthquakes are akin to the *zipper* in sweaters or hand bags. The speed with which this unzipping (sudden slip of a fault and the development of rupture) takes place depends on how fast the energy is supplied to the crack front and how far the rupture has propagated from the point of initiation.

Ground shaking and rupture speed are closely related to the faster primary P wave and the slower shear (S) and surface Rayleigh (R) waves. As a mechanical engineer, Prof. Rosakis explained and linked the principles of rupture and crustal fault mechanics with engineering fracture mechanics (EFM) of jointed and layered media (akin to rock masses in the field). He also demonstrated some elegant techniques developed to produce *surrogate laboratory earthquakes* in thick plastic sheets joined together with a hair-thin wire to measure the speed of the movement after triggering an implosion. The progress of the quakes was monitored with multiple, ultra-high-speed, pulsed-laser photographic tools and detectors. The P waves came first with a speed of 2.3 km/s in the polymeric model material employed at Caltech.

Intricate fracture mechanics concepts entailing propagating crack tips at sub- Rayleigh and super-shear speeds were vividly explained and visualized through the optical techniques of photoelasticity and DIC. During later discussion it was speculated that while super-shear crack tip faces slip past each other without breaking contact, the trailing sub-Rayleigh crack tip faces may remain open *locally* as evidenced by the photoelastic fringe pattern signature of butterfly wings.

Prof. Rosakis explained through film-clips and slides, as how the *laboratory quakes* mimic the actual ones such as the devastating 1999 Izmit earthquake (1999, M 7.5) in Turkey and the 2002 Denali earthquake (2002, M 7.9) in Alaska, USA. He further demonstrated as how the ruptures transitioned to *super-shear* and how the propagating fronts, at a speed of 7.3 km/s of such *super-shear* ruptures generate a Mach-cone of impact (equivalent to 22 Mach in air) explained crisply with small film clips and slides.

The two main kinds of ground motions, namely fault-normal (Mother waves) and fault parallel (Daughter waves) as well as vertical motion were recognised and their magnitudes estimated. The effect of super-shear rupture transmission on buildings 3 km from Denali was studied. Prof. Rosakis emphasized the need for appropriately scaling-up the experiments to simulate ground motion records for sub-Rayleigh or super-slow experiments (15 cm plastic for a 13 km long fault zone in the Denali earthquake in Alaska! Albeit far from a realistic scenario these model experiments do provide some vital clues to understand earthquakes).

The lecture was followed by a lively interaction through questions from the audience comprising largely of students and faculty from the Mechanical and Aeronautical Engineering Departments besides others from Earth Science Departments and Geological organizations from Bengaluru. Questions were on a variety of topics such as the possibility and need for monitoring earthquake- prone regions of the world with a dedicated satellite by NASA and other agencies, change of experimental material to near natural types (rocks) besides others.

The discussions with Prof. Rosakis continued with the need to introduce fluids in the experiments. He was also appraised the seismic zonation of the Indian sub-continent and the seismicity of the Deccan basalt plateau and the on-going near-field earthquake observations in and around the Koyna dam with deep drilling and monitoring of the boreholes with seismometers under the aegis of the Ministry of Earth Sciences (MoES), with Dr. Harsh Gupta, President of the Geological Society of India, as a lead Geophysicist along with scientists from NGRI and other national and international groups.

Earlier, Prof. Roddam Narasimha, FASc and FRS chaired the lecture and introduced the distinguished speaker Prof. Rosakis, who is currently the Theodore von Karman Professor of Aeronautics and Prof. of Mechanical Engineering at Caltech, USA. He is a Fellow of the U.S National Academy of Sciences and European Academy of Sciences and Art beside a number of International Academies. He was elected recently as an Honorary Foreign Fellow of the Indian National Academy of Engineering. Prof. Rosakis is the recipient of several awards including Kinslake, Eringen, Von Karman and Timoshenko medals. The function ended with a presentation of memento to Prof. Rosakis.

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