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Undergraduate

Building a Bridge for the Future with Professor Abolhassan Astaneh-Asl

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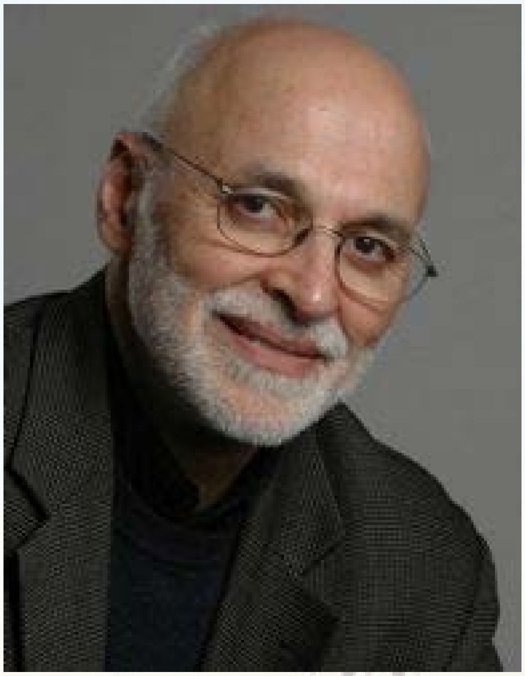
BSJ

Although stress is primarily interpreted from the psychological or biological perspective, the term stress is widely used in the realm of civil and structural engineering as well. Buildings and bridges must be able to withstand a wide variety of stressors, ranging from natural phenomena such as earthquakes to blasts and terrorist attacks. Individuals like Professor Abolhassan Astaneh-Asl, professor of civil and environmental engineering at the University of California, Berkeley, are leading the charge in making our buildings and bridges safe from whatever stressors they may face. Professor Astaneh-Asl also had the privilege of being one of the few researchers who had access to the engineering blueprints for the World Trade Centers following their tragic collapse in the 9/11 terrorist attacks. This past semester Professor Astaneh-Asl was in Turkey conducting research as a Senior Fulbright Scholar; he graciously took time out of his busy schedule to speak with us over Skype. Currently, Profession Astaneh-Asl added an additional focus on blast protection. In conjunction, he works with a large team of UC Berkeley undergraduates to create an archive of the information gathered from the collapse of the World Trade Centers.



BSJ: How did you first get interested in your line of research?

Prof. Astaneh-Asl: It goes back to how I got interested in structural engineering, specifically bridge engineering. The research you get interested in is specific to your background and your education. My background and my education are in structural engineering. My interest was sparked in the first undergraduate course I took, which was a statics course, where we looked at stresses and equilibrium and forces. When I went to this class, this was the first time that I saw buildings and bridges. I thought, "Wow, this is amazing!" Imagine, you come into a classroom and sit there with the Bay Bridge and all these wonderful structures. Everyone is fascinated with buildings and bridges. Taking that course was a defining moment where I decided, "This is it. I'm going to be a structural engineer." I got my undergraduate degree and started working. I had 10 years of practice in design of structures.

Then I came to the United States in 1978, I'm originally from Iran. I completed my Masters and Ph.D. at the University of Michigan in Structural Engineering, and of course, that was my life by then. I did design work on buildings and bridges. Then, I went to University of Oklahoma for 4 years, where I was a professor. I came to Berkeley in 1986. I was still working on buildings, but not so much on bridges. I started working on building bridges specifically in the Bay Area. My friends were in structural engineering, so I got involved. Just three years after I joined this "super group", there was a big earthquake. This earthquake collapsed a small part of the Bay Bridge. The Bay Bridge was closed for a month. As a faculty member who specialized in steel bridges, I was the only one in Berkeley working on steel, long standing bridges. Other faculty in our group were working on concrete bridges. Therefore, I was in a unique position as the only professor in California, not just Berkeley, who knew something about steel bridges. Berkeley became the center of the universe, in term of long span steel bridges, surpassing even Japan, which is known for earthquake engineering. We ended up being the leaders for many years for research into seismic studies of long span bridges.

In 1995, there was the terrorist attack on a federal building in Oklahoma. In fact, it was a little personal because that building that the terrorists, Timothy McVeigh and others, attacked was the federal building where I had my interview for US citizenship. I went to Oklahoma as a faculty and the university helped processed citizenship for me. I went to this building with my family, wife and two kids. There were federal agents there who fingerprinted us and talked to us. They were, of course, very kind. Moreover, that was a historic day in the life of any immigrant. It was like Ellis Island. That federal building collapse was like our Ellis Island collapsing. We passed through that building to become US citizens. This is our home. We are very, very proud. As any proud immigrant, we remember that day, even the faces of the federal agents. That was 5 or 6 years later, when I had seen the building collapse.

At that time, I had no interest in blast protection and terrorist protection. I was only interested in seismic activity, earthquakes. Having that sort of personal attachment to the Alfred P. Murrah building, and having this feeling that the attack was not just like any other bombing, but a personal attack, was a very defining moment. They attacked and killed people that I knew personally. During that time, I had decided to look into protection of buildings and bridges against terrorist attacks, including car bombs. I, then, got involved with the Lawrence Berkeley National Lab. I spent 3 years learning the basics -- studying, reading papers and researching results. It was a very new area for me. It wasn't earthquake engineering; it was different dynamic effect. So, I educated myself for about 3 or 4 years. Then, we started to do research on blasts and started thinking about how you can make bridges and buildings that can withstand blasts, especially car bombs.

Then in 2001 came the attacks on the World Trade Center. When Al-Qaeda attacked the World Trade Center, I was very focused on how you protect tall buildings and bridges against terrorists attacks. I ended up being the only researcher to receive a National Science Foundation (NSF) grant to go to Ground Zero in New York to investigate and

document the collapse, and do a reconnaissance. I went there one week after 9/11, on September 18, when the airplanes started flying again. It was a very fast operation, from the time I submitted the proposal, received the grant, and landed in New York at Ground Zero. I stayed there for 3 weeks and went through hundreds, probably even thousands, of tons of steel to document it, to photograph it, to inspect it, to videotape it and make comments on what I discovered, so later, other researchers can use this information when they study what happened. This was the most important structural building collapse and the toughest project of my lifetime.

Later, I testified before the Committee on Science of House of Representatives. The Committee of Science is the committee that oversees disasters, like natural disasters or any major disasters. I ended up testifying and answering questions about what I thought. The committee gave me the drawings, engineering drawings, of the World Trade Center. The engineering drawings of the World Trade Center, even today, are sealed and you cannot look at them. No one had the drawings to look at, but I was very lucky when I testified. The Chair of Committee asked me, "Astaneh, what do you want to continue to research?" I immediately jumped on the chance, "I need the drawings, I have to study the drawings and give them up". So to keep it short, the Chair ordered FEMA, the Federal Emergency Management Agency, which was in charge of drawings and everything else. They gave me the drawings in 2002 and then I did 5 years of very extensive research on the World Trade Center.

I ended up being the only researcher who was able to do the research and publish the results, as I was the only researcher to receive drawings from Congress and because of that, I did not accept any restrictions on my research at Berkeley. With this privilege, we published our results based on actual data from the field. No other researcher was allowed this unique opportunity, other than the few of us at Berkeley. The analysis that we did demonstrated a structural collapse. Last year, we had an opportunity to revisit this project. I have a few undergraduate students who organized the entire archives on the World Trade Centers. About a month ago, in October, we established World Trade Center archives at UC Berkeley. I am very proud of this work. There are many prestigious universities and UC Berkeley ended up being the only university that actually worked on this project, the archives especially, and we are adding more.

BSJ: In recent years you have co-authored a number of papers focused on blast protection of bridges. Can you explain conceptually how an explosion of blast places stress upon a bridge, and how these effects may compare to another event such as an earthquake?

Prof. Astaneh-Asl: That's a very good question. Some think that if you design a bridge for earthquakes, it will be just fine for blasts as well. However, earthquakes are dynamic forces that shake a whole structure. The dynamic forces come from the foundations all the way up; every cubic foot of bridge is affected. Earthquakes are also relatively slow: the waves come in cycles, one cycle per second so you can think of it like average. That is slow actually in terms of groundbreaking. When you look at a blast, it's just a local effect. The blast force is very large compared to an earthquake, but just at the mass that is affected. It's like taking a hammer and hitting a small piece of bridge. You are just going to damage the local area and it is one thousand times faster than an earthquake. If a blast hits a very critical member, it can be devastating, but if it doesn't hit the critical member or you have a mechanism to prevent collapse of that critical member then the effect is just local. Earthquakes affect all the members of the structure, all the connections.

BSJ: In your paper on blast protection of suspension bridges, mild steel is found to be more blast resistant than high strength steel. Can you please elaborate on how the properties of these materials may contribute to these observations, and the significance of such an observation?

Prof Astaneh-Asl: The issue comes down to what can be called "ductility". Ductility is the capacity of the material to absorb energy, the character of material that allows it to bend but not break. If you take a paper clip and bend it back and forth, it takes maybe ten or twenty bends before you break the paper clip. The reason it takes so many cycles to break it is because steel is highly ductile. Therefore, low strength steel is more ductile than high strength steel. High strength steel is very strong but is very brittle, which means it can take a lot of force, but cannot bend too much. So the difference between high strength steel and low strength is that low strength steel can yield and deform quite a lot before it breaks which is important in a blast of earthquake. Every time I've presented, I've see engineers who think you can resist a blast by making the structure stronger. That is an absolutely incorrect solution. You make your structure stronger and it becomes very brittle, like glass. Because it's very strong, it generates large dynamic forces. But it doesn't have ductility to absorb it, which causes the structure to break and fly all over the place. Low strength steel bends, but it does not break.

So the difference between high strength steel and low strength is that low strength steel can yield and deform quite a lot before it breaks which is important in a blast of earthquake.

BSJ: Many of the papers you have co-authored contain performance criteria for structures subject to specific conditions and stressors. What role do these performance criteria play in the design and construction of buildings and structures on a greater scale?

Prof Astaneh-Asl: Whenever you design something, you have to put on paper what you want this structure to do. Nevertheless, you cannot design structures to avoid all damage. Now, we have the technology to design a structure that will not take any damage during a magnitude 9.0 earthquake. But we cannot afford that. So, the performance criteria come into play. For example, if you are designing a building for earthquakes, the performance criterion focuses on life safety. During a major earthquake, there will be glass broken, doors jammed, walls cracked, this and that, but the floors should not collapse and people should not be killed. We have been very successful in the US as compared to other countries. Now when we started looking at blast protection for bridges, I realized that not much had been done. Then, the question was "What should be the performance criteria for blast protection of bridges?" We cannot just design every bridge, such that if a car bomb goes off, the bridge will not have any damage, otherwise every bridge would be like a tank. It's very important to come up with performance criteria that are economical because society can afford only certain amount of money to spend on certain risks. It's a balancing act between how much risk we should accept and how much money, accepting that risk, we will need to spend. We started to formulate this, considering one very important criterion, life safety. When there is a car bomb on a bridge, there will always be casualties. You can't do anything as engineers to stop the tragedy of cars next to the explosion. And the bridge will be damaged. What we don't want is the collapse of the whole span. If the whole span collapses, then many cars will go down; that would be catastrophe. So establishing that level is important.

BSJ: In addition to your own research, you are in charge of the undergraduate research program within the Civil and Environmental Engineering Department. What drew you to become so involved in undergraduate research?

Prof Astaneh-Asl: From the beginning, I always had undergraduates involved in my research, probably because our students are just amazing. In the undergraduate classes I teach, I have heard questions that I've never heard in my 8 years of teaching. Also, I work with all of my undergrads directly and make sure that each undergrad has a special well-defined project. They're not just helping graduate students plot curves.

This phenomenon of resonance is very important because if resonance occurs, we see really large forces.

Last year was very exciting because I had 10 undergraduates to work on the World Trade Center archives. We had a request for information, for me to submit all my World Trade Center data during that first year I was in New York. I anticipated that my undergraduates and I are going to go through a lot of storing, a lot of indexing, and a lot of paperwork, which makes it hard for an undergrad to do a self standing unit of research that can be published in a paper. So, I decided that I would hire 10 undergraduates, and they would spend half their time on the World Trade Center archives and the other half on their own projects. Each student had one building or bridge that they worked on for the semester with me, with no graduate student involvement.

The goal was to establish how these structures would respond to long distance earthquakes. In 2011, the Washington Monument in Washington D.C. was damaged by an earthquake. However, Washington D.C. is not a seismic hotspot. The earthquake was about 120 miles to the south of Washington D.C., 5.5 magnitude, and only the Washington monument was damaged. Why? It wasn't close to the epicenter; it wasn't even a big earthquake. Other things in Washington had no damage. This is a phenomenon called the "Long Distance Earthquake". Tall buildings are very flexible, like the Washington Moment, and they are very safe if the earthquake is nearby. But if an earthquake is that far away, the seismic waves traveling through the ground become longer and longer. These long waves are very weak. So usually, when they get to a city far away they don't do any damage. But, because they have a long period, they can create resonance with very flexible buildings or bridges. This phenomenon of resonance is very important because if resonance occurs, we see really large forces. So, now if the structure is very tall and very flexible - like the Washington Monument - or if it is a long span bridge that is also very flexible, - like the Golden Gate Bridge or the Bay Bridge - due to their flexibility, these structures have very long periods of vibration. The earthquake that is coming in, if it comes from very far away it creates long waves, long period waves. Those waves coming into the structure can create resonance. Those long period waves hit the tall and flexible Washington Monument and it took serious damage; it'll be under repair for three years.

We started looking into this phenomenon in 2005. That year there was an earthquake in southern Iran, which was about 100-150 kilometers from Dubai. That earthquake was magnitude 6 and for Iran, that's not that big a deal. But, the shockwaves of that earthquake traveled about 150 km through the Persian Gulf and reached Dubai, and became long period waves. Dubai is full of tall buildings and resonance occurred. In the morning at about 11 o'clock, all these tall buildings in Dubai started shaking. There was big chaos and Sheikh Zayed, the Amir of the United Arab Emirates, was panicked that all these tall buildings were going to collapse. That was when Lawrence Livermore National Lab (LLNL) and I got involved. We realized that the United Arab Emirates and Dubai are in "bad neighborhoods" as far as seismic activity, due to the seismic activity in Iran to the north.

Long distance earthquakes are phenomena that most structural engineers, almost all of them, don't look at. We don't design for it, we just design for earthquakes next door, If the San Andreas fault ruptures in San Luis Obispo, it would be worse for Los Angeles, as compared to an LA earthquake – for tall buildings at least. These ten undergrad students each had a structure, and only one parameter, long distance earthquakes. For example, one student had the Campanile, and she was comparing what would happen if the Hayward fault ruptures on campus, just next to Campanile versus if it ruptures in Santa Cruz. What she found was an earthquake in Santa Cruz could cause more damage to Campanile than earthquake right on our campus.

This research has been very successful. Our Department of Civil Engineering has started a research program that we offer certain people who are admitted called Undergraduate Research Opportunity Program, UROP. Usually we get top applicants applying, but we don't get those very top students coming to Berkeley, mostly because Stanford and MIT offer more money. So, we offered the 20-30 top applicants some money. They are also guaranteed an opportunity to do research when they get to their third or fourth year. Suddenly, the whole picture changed – we now have the brightest students coming in and registering. I ended up being in charge of this program now. We have 14 freshmen now. Next semester, when I come back from sabbatical, I will be teaching an undergraduate research seminar. Once a week, faculty from our Department of Civil Engineering will come in, lecture these students, and hold discussions with them.

Next semester, this group moves into another course, which teaches them how research is done – how you work with a team, how you discuss questions, etc. Research requires very close relationships; everyone is responsible for other people to succeed. The most important thing in research is to dispute advice, of course in a nice way. Undergrads, in my experience, sometimes are a little bit scared. But that's just natural. You're going to break that, make sure they're confident, and they feel there is no consequence asking questions. If there is some risk, and the results are not quite as expected, so what?

Then they write a proposal, and they reach out to faculty whose work they are interested in. The faculty select a few students, and that student and faculty spend a semester together. Having an undergrad as a team member is very exciting! Even though they are not as knowledgeable as graduates are, they bring in all kinds of new ideas.

I've seen for so many years that undergrad research is getting so much attention, and many faculty members are very excited. As an engineer, when I design, there is a client. Nowadays, I always tell my students that you're my client. My salary comes from tuition that he or she has paid as a student. Undergrads are very important and we need to take care of them.

BSJ: I think that's a great place to end. Thank you for everything. It was a great interview.