DR. TEDDY BOEN AND FERROCEMENT SEISMIC RETROFITS

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This article is written to honour the memory of Dr. Teddy Boen, (1934-2023) an engineer who worked for decades to improve the safety of dwellings in Indonesia.

In 1962 Dr. Boen was the first Indonesian engineer to be sent by the Indonesian government to Japan, specifically to study earthquake engineering. From 1964 onwards he published numerous papers, manuals and guidelines related to earthquake-resistant designs, empowering communities to retrofit and upgrade houses to reduce the risks from earthquakes, as well as working tirelessly to support communities to rebuild more safely after earthquakes.

Dr Boen was responsible for the development and introduction of the first formal earthquake engineering syllabus in Indonesia at the University of Indonesia and Trisakti University back in 1967, and personally lectured on earthquake-resistant design to countless civil engineering students across Indonesia. Dr. Boen served as the Director of the International Association for Earthquake Engineering (IAEE) from 1978-1986 and then continued on as the Indonesian national delegate to the IAEE through to 1992. In 2022, a year before his passing at the age of 89, DR Boen became one of only four recipients of the ACECC Asian Civil Engineering Achievement Award for his "outstanding & remarkable contribution to the advancement of civil engineering & development in Asia", in recognition to his lifelong career.

The following article highlights the use of Ferrocement reinforcement, which was one of the many technical solutions promoted by Dr Boen for improving the earthquake resilience of housing in Indonesia.

FERROCEMENT RETROFITTING AS AN AFFORDABLE MEASURE TO STRENGTHEN HOUSES IN THE PREPAREDNESS AND RECOVERY CONTEXT

There were three basic principles that Dr. Teddy Boen taught his students about retrofitting with ferrocement.

1. Civil engineering, including earthquake engineering, is a matter of respecting and following the natural flow of loads. This is the same whether these are static vertical loads or dynamic load caused by wind or an earthquake. Structures might fully or partially collapse if the structural elements cannot carry the loads.
2. People should implement civil engineering principles by following building codes. These do not need an engineering degree. If builders are trained to read the drawings, to fix rebar correctly and work with the proper admixture, they can create strong structures. For those civil engineers who produce the building codes, a combination of calculation and laboratory tests are required to validate calculations.
3. Retrofitting to improve seismic performance needs to be simple and economical. Whenever possible it should be implemented using affordable building materials easily found in local markets and hardware stores. Dr. Boen calculated that retrofitting an existing building for seismic resilience commonly costs only around 30% of the cost of building a new structure.

Dr. Boen recognised that to achieve such a societal change to building practices a combination of regulatory work, and engagement on supply and demand is required.

On the regulatory side you need to work with governments and authorities to ensure that it is within the building codes.

On the supply side you need to work with the building trades to ensure that the industry has the capacity to build using the approach.

On the demand side you need to work with vulnerable communities to ensure that they are their aware about this simple and affordable technique. You also need to encourage the understanding of the risks that they face and the importance of investment in risk reduction.

Many emerging nations throughout the world face the problem that a significant portion of the country's housing stock was built prior to the enforcement of appropriate seismic building codes and is therefore inadequate for the seismic risks they are likely to face. This leaves many communities highly vulnerable and in need of urgent support to reduce risk. Simply waiting for disaster to strike will result in unnecessary loss of life and much higher cost in recovery and reconstruction.

Retrofit solutions such as the ferrocement system developed by Dr Teddy Boen offer a practical and affordable solution for development agencies to assist local governments and communities to be better prepared.

FERROCEMENT RETROFITTING IS SAFE, ACHIEVABLE, AND AFFORDABLE

Dr. Boen was the first engineer in Indonesia to research and document retrofitting through the use of ferrocement for seismic resilience. The simplest system developed used a combination of chicken wire, steel rods, common fastenings and cement render to create a 'ferrocement' layer. This layer encased the masonry walls of a building to create an integrated earthquake resilient structure. The beauty of this methodology is that it can easily applied to existing, new or repaired brick walls. It provides an effective, low-cost seismic retrofit solution. This solution can be particularly appropriate for heritage listed masonry buildings in need of seismic upgrading or post-earthquake repairs. The low cost and relative ease of the system also makes it appropriate for a wide range of simple non-engineered community masonry structures such as houses and shops.

Dr Boen extensively tested ferrocement techniques using calculation and computer analysis to identify where forces are largest, and how ferrocement can strengthens those parts. He validated these theoretical models with full-scale shake table tests. This modelling and research showed that ferrocement renders is inexpensive compared to building a new structure and is simple to apply and can be done by anyone. During many hands-on trainings with with both men and women, builders and homeowners , people learnt to fix the wire mesh in the x-shaped cracks formed by seismic stresses on a wall.

Ferrocement retrofitting works well on houses with masonry walls and can be applied after disasters or as a preparedness measure. However, the technique is quite different to standard construction practice in Indonesia so requires time investment within a given community to raise awareness.

THE IDEA OF MASSIVE RETROFITTING FOR PREPAREDNESS MEASURES

The ferrocement retrofitting system developed by Teddy Boen is an appropriate and applicable technology for masonry houses in many parts of the world. Implementing this system will however need to be actively promoted both with government agencies and with local communities. Ideally implementation of this system should include additional local research and engineering as Dr. Boen conducted to ensure that it meets the requirements of local building codes and is appropriate to local seismic risk and construction techniques. Implementation in new contexts will also need to be accompanied by appropriate public information campaigns to create understanding and demand for this cost-effective retrofitting solution.

The gap between retrofitting ferrocement knowledge and public willingness for people to retrofit their houses can be significant. The most challenging part for the retrofitting of vulnerable houses is for homeowners with extremely low incomes. For these people additional assistance and incentives may be required along with information and communications programs.

In Indonesia, more than 70 percent of houses are built without any assistance from licensed construction professionals. As a result a large proportion of the national housing stock is suspected to be highly vulnerable to earthquakes. This is also true in many other emerging nations where poor building code enforcement and a lack of training leave many households vulnerable to seismic risks.

In these contexts improving the demand/capacity for seismic retrofitting is essential and can be done by community mobilization through sensitization of earthquake risk.

A pilot programme was conducted in 2020 in Sukabumi, West Java and Banyuwangi, East Java, both in Indonesia . This programme saw a series of local-language trainings on ferrocement retrofitting using a community-based approach. These trainings were made available, not only for local builders and tradespeople but also to local.

to local leaders, housewives and any other community members who could benefit from access to such training and help ensure improved resilience.

In Indonesia, Dr. Boen worked tirelessly to train local builders and volunteered to teach shelter agencies and their teams about recovery initiatives through ferrocement training. As recently as 2019 at the age of 84, Dr. Boen travelled to Palu to support the Indonesia National Shelter Cluster during the ongoing response to the 2018 Central Sulawesi earthquake. Shelter agencies were subsequently able to better convey important retrofitting messages to both the local government and the affected community.

Whilst Ferrocement is still far from standard in Indonesia, it is now accepted in building codes and the beginning of the work to ensure that people are aware of it and use it is well underway.

For Teddy Boen's publications, such as manuals, guidelines, posters, and drawings please visit the website:
teddyboen.com