



### **“Assessment of In-Situ Compressive Strength of Concrete in Existing Structures”**

by Ir. Lo Seng Ling

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A workshop of “Assessment of In-Situ Compressive Strength of Concrete in Existing Structures” was organised by the Civil and Structural Engineering Technical Division (CSETD) of IEM on 28th March 2019. Total of 97 participants attended the workshop.

The workshop was presented by Prof. Dr. Tam Chat Tim. Prof Dr Tam obtained his BE Hon. in Civil Engineering in 1959 and ME (Structures) from University of Adelaide, South Australia and PhD (Materials Science – Concrete) from University of Calgary, Canada during his sabbatical leave from University Malaya (1968-1972). After two years of practice as a designer at the Hydro-Electric Commission, Hobart, Tasmania, Australia and another year with a top consultancy company in Kuala Lumpur, he was with the Department of Civil Engineering University Malaya from 1963 and served as Head of Department before joining Department of Civil and Environmental Engineering at National University of Singapore (NUS) in 1979. He retired in 1996 after serving as Vice-Dean of Faculty of Engineering and continues with research activities currently as Adjunct Associate Professor. He is a Professional Engineer in Malaysia, Singapore and UK holding memberships of FIEM, FIES, FIStructE, FACI and FCS. He serves as active member of technical committees in ASTM, ACI, and Enterprise Singapore. He has received several awards for his contribution in standards development and life membership of Singapore Concrete Institute and ACI Singapore Chapter.

Prof. Dr. Tam’s research interest include the adaptation of new concrete knowledge for adoption in tropical climate covering production, construction and performance of concrete due to the higher ambient temperature and relative humidity service environment of this region. Over the past decades he has served on standards committees in the development of concrete specification and standards both in Malaysia and Singapore. He also provides technical support to the concrete construction industry. His interest in appraisal of concrete structures started in the 1960’s and further motivated after being called as the Expert Witness on concrete at the Commission of Inquiry into the collapse of Hotel New World in 1986. A series of laboratory studies were conducted in NUS on NDT methods and their relation to in-situ concrete strength based on core tests to have a fuller understanding of their usefulness and limitation in the assessment of in-situ concrete strength in existing structures. The current approach based on BS EN 13791:2007 and the complimentary standard of BS6089:2010 (and their equivalent Malaysia and Singapore standards) has firmly establish appropriate assessment approaches for in-situ concrete replacing the former less definite guidance document of BS6089: 1981.

The assessment of concrete compressive strength in the European approach is now available as EN standards. It covers the two important aspects of concrete strength, during concrete production and when it has been placed into structures. These two aspects have always been of interest to all sectors of the concrete industry. However, the latest EN standards provide specific guidance on assessing conformity with clearly stated principles and methods. The conformity control and conformity criteria in production of concrete are the responsibility of the concrete producer. Where required by

specification or by regulation, the producer's production control is to be assessed and surveyed by an approved inspection body and then certified by an approved certification body. The system based on formal BS5328 is now replaced with a more comprehensive system based on BS EN 206. However, depending on site control during execution of concrete structures, the level of workmanship, in particular curing applied, varies and the resultant as-built quality of the concrete cannot be expected to be the same as that indicated by standard specimens. A reduced quality is accepted at a specified level by national standards.

With the quality of concrete assured by the production system, and where the need arises, assessment of concrete strength in existing structure will provide the assurance of the quality of the in-place concrete which is influenced by the workmanship and construction processes on site. Previous guidance on core testing and non-destructive testing have been replaced with BS EN 13791 and BS EN 12504-1 to BS EN 12504-4. Corresponding Malaysian standards are based on these overseas standards. The new approach provides details for assessment by the various methods and for each specific method, the procedures to determine and the interpretation of the test results. In this way, a common approach can be adopted by all parties involved in planning the investigation and in the interpretation of the test results with respect to the use of cores and/or one or more of the three non-destructive testing methods considered in BS EN 13791. These are rebound number, ultrasonic pulse velocity and the pull-out force (a test not commonly adopted in this region). Additional guidance is provided in UK with the updated BS 6089: 2010 as the complimentary standard to BS EN 13791: 2007.

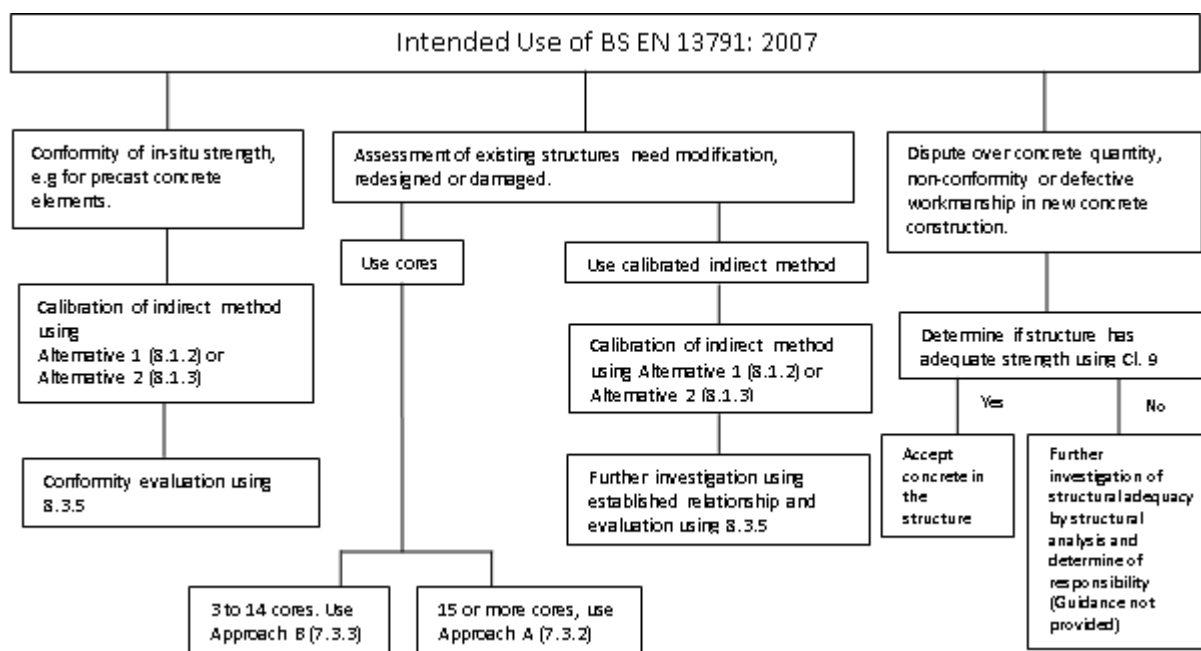
Prof. Tam started his presentation on the collapse of the 6-stories new World Hotel Singapore on 15th March 1989. This accident caused 33 people killed and 17 people were rescued. The hotel collapsed due to improper design, poor construction, over loading on the building during service, inadequate building maintenance and inspection during service. After the incident, Singapore Government amended their Building Control Act in 1989. In the revised act, all the design work shall be reviewed or checked by Independent Accredited Checker and the construction work shall be supervised by qualified engineers. Meanwhile, the inspection work shall be done by a Professional Engineers with 5 years experience for public structures and 10 years experience for private structures. Malaysia also adopted similar provisions at that time.

The estimation of the in-situ concrete strength required when:

- The existing structures need to be modified or redesigned;
- Doubt arises on the concrete compressive strength due to excessive deflection, defects, deterioration of concrete due to fire and others;
- Assessment of the in-situ concrete strength is needed during construction;
- To assess structural adequacy in the case of non-conformity of the compressive strength obtained from standard test specimens;
- Assessment of conformity of the in-situ concrete compressive strength when specified in a specification or product standard.

BS EN 13791: 2007 covered the methods and procedures for assessment of in-situ compressive strength of existing concrete structures and precast concrete components. It also provided principles and guidance for establishing relationship between test results from indirect test methods and in-situ core strength, guidance for assessment of in-situ concrete compressive strength in structures or precast components by indirect or combined methods. However, BS EN 13791: 2007 does not cover indirect methods without correlation to core strength, testing of cores less than 50mm in diameter, testing for cores less than 3 units and the use of microcores.

The different usages of BS EN 13791: 2007 shown in Flowchart below:



The criteria for assessment of in-situ compressive strength in structures adopted in BS EN 13791 are not the same as the recommendations of BS 6089: 1981. The new approach is based on the estimated the in-situ characteristic strength directly from core tests (reference method) or indirectly using semi-destructive or non-destructive methods to establish specific relationship between the compressive strength of cores and the test result by the indirect method. For specific production conditions and constituent materials development of economic design where permitted by national provisions may be possible through the assessing the partial safety factor,  $\gamma_c$  from knowledge of the in-situ compressive strength and the strength of standard test specimens. When assessing compressive strength in cases other than checking the quality of the concrete or the workmanship during execution or before the structure for use, the appropriate reduction in the partial safety factor should be determined on a case-by-case basis according to national provision.

Meanwhile, BS 6089: 2010 provides greater and more details to complement the use of BS EN 13791: 2007 including guidance on the estimation of potential strength can be found in Annex A (normative). However, the use of this approach should be with full agreement by all parties concerned as there is lack of experimental evidence to support its validity.

During the workshop, Prof. Tam presented the usefulness and limitation of core testing and non-destructive testing in assessing in-situ concrete strength as well as the factors affecting measured values and their relationship with the compressive strength. Prof. Tam also presented procedures and examples based on BS EN 13791:2007 and BS 6089:2010 on the use of the cores and NDT methods in the assessment of in-situ compressive strength in existing structures including the case where conformity of concrete based on standard tests is in doubt. Assessment of in-situ concrete compressive strength on the existing structures shall be systematically planned and ensured all the equipment used are calibrated. All the test results shall be recorded and interpreted based on appropriate methods in BS EN 13791 and BS 6089.

In the afternoon session of the workshop, all the participants were given a hand-on exercise based on selected working examples presented before. The purpose of the hand-on exercise is to provide application experience to the participants. A short quiz is also included to assess the knowledge gained by the participants from the workshop.

Later Q&A session was carried and a token of appreciation was presented to Prof. Dr Tam by Ir. Chong Chee Meng as the Chairman of IEM Civil and Structure Engineering Technical Division before the workshop ended.



Ir. Chong Chee Meng presented a token of appreciation to Prof. Dr. Tam at the end of the Workshop