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**MEMORANDUM OF UNDERSTANDING (MOU)
"PERFORMANCE EVALUATION OF CRACKED/DAMAGED
CONCRETE STRUCTURES UNDER FIRE"**

This Memorandum of Understanding (MOU) made and entered into on the 02 day of SEPTEMBER, 2014 between **Bhabha Atomic Research Centre (BARC)** situated at **Trombay, Mumbai 400 085**, (hereinafter called **BARC** which expression shall include its successors-in-interest and assigns) on the first part.

AND

Indian Institute of Technology Roorkee, Roorkee-247667 and represented by its authorised signatory **Dean, Sponsored Research & Industrial Consultancy** hereinafter referred to as **IITR** of the other part.

PREAMBLE

Whereas BARC is a premier multidisciplinary R&D organization under the Department of Atomic Energy, Govt. of India, engaged in research with the objective of generating knowledge and techniques for nuclear power production, advancement of science, use of radioisotopes in industry, health and agriculture as well as research in frontier areas of science and technology. This includes development of various types of accelerators for nuclear studies, medical applications, bio-technology, food preservation, non-destructive testing, pollution control and monitoring and other industrial applications.

The Department of Civil Engineering at Indian Institute of Technology Roorkee is quite strong in terms of standards of education, research and consultancy and has been instrumental in developing various national codes of practice. The faculty of the department has vast experience in the area of experimental and theoretical investigations of earthquake and fire effects on structures. IITR has recently developed numerous test facilities to enable testing of small-scale models and prototypes of structural members under simulated extreme loads namely, earthquake and fire. The test arrangements eg: high temperature furnaces with and without loading during heat exposure, full-scale fire compartment for testing sub-assemblages, actuators for applying cyclic loading, reaction wall, strong floor are the key facilities which make the department of civil engineering an ideal center for undertaking research in the area of structures exposed to fire.

Whereas BARC, on the basis of discussion with IITR is desirous of collaborating for Research Projects with IITR in carrying out "**PERFORMANCE EVALUATION OF CRACKED/DAMAGED CONCRETE STRUCTURES UNDER FIRE**" (hereinafter called the Projects) as per the scope of the work detailed hereunder identifying three major projects:



Now therefore in consideration of the premises and mutual covenants hereinafter contained, the parties hereto agree as follows:

1.0 SCOPE OF THE MOU:

The MoU details the terms and conditions, financial arrangements, modalities of collaborative research projects, responsibilities and obligation of BARC and IITR pertaining to the Projects. This supersedes all previous discussions, correspondence etc., on this subject matter.

2.0 PERIOD OF MOU AND ITS EXTENSIONS :

This MOU shall come into effect from the date of its signing and will remain in force for the period of 2 years. Its validity can be extended by mutual agreement between both the parties.

3.0 OBJECTIVES OF THE PROJECT:

Experimental evaluation of effect of axial restraint and cracking on behavior of Reinforced Concrete (RC) beam during fire.

The study of concrete structure under high temperature will help to understand the behavior of structure during fire and develop rational criteria for the evaluation of the safety of the structure. Experimentally the performance of RC beams shall be evaluated under three different support conditions and three different levels of loads to simulate different crack widths. RC beams shall be exposed to standard fire as per ISO 834. A total of 24 nos. of beams shall be tested for various combinations of the factors stated above.

The details of the Projects to be carried out are enumerated in 4.0 of this MoU.

4.0 SCOPE OF WORK:

The scope of the work is described henceforth

4.1 The typical RC beams with section 230 X 400 mm and length of 4 m as shown in Figure 1, shall be tested. Total 24 beams would be tested as per Cl. 4.3:

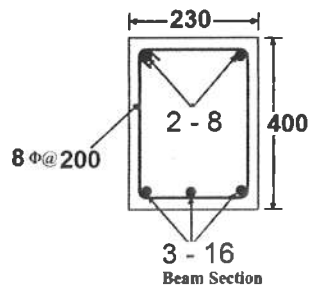


Figure 1 Details of beams

The beams would be subjected to constant load (3 different levels) during the entire duration of exposure i.e. 2.0 hrs. After the fire exposure the member will be allowed to cool naturally. The beam will be exposed to fire from three sides and the top face shall be insulated. The beams would be tested under four point bending as shown schematically in Figure 2. During entire testing temperature at various locations would be measured. Also beam deformations would be measured with the help of LVDT's. The beams which would survive the fire would be tested for its ultimate residual capacity. This will also help to develop an understanding of the residual capacity of RC beams, which again would help in estimating the level of damage caused and the level of strengthening required thereafter.

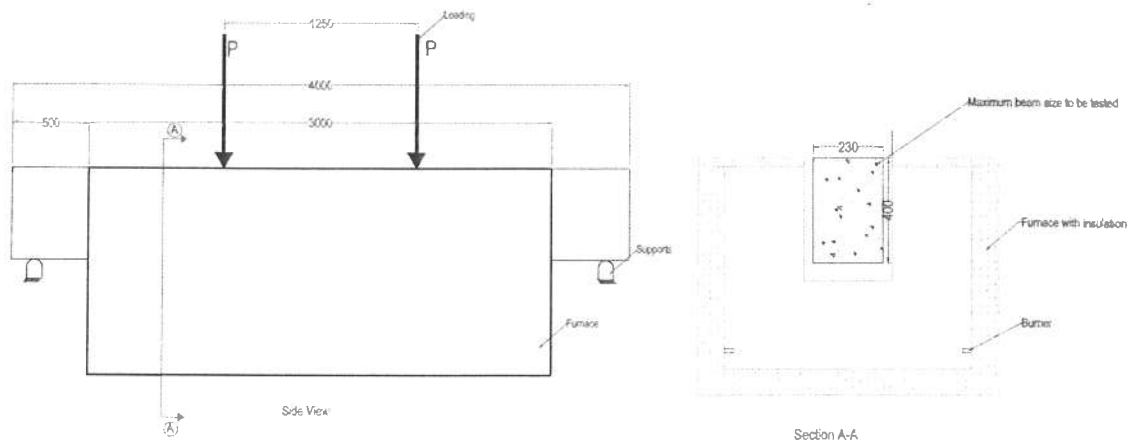


Figure 2 Schematic test setup

Three different levels of load will be so chosen, so as to induce a pre-decided crack width. Load shall be applied 30 min before the fire test so as to attain an equilibrium state and constant crack width under that load. These cracks shall be marked and measured before proceeding with fire test.

4.2 Measurements:

Before fire test: Crack width and deflection under sustained load.

During fire test: Deflections and temperatures across section at various sections.

After fire test: Load deflection characteristics.

4.3 Test Matrix:

Table 1 shows the test matrix for 24 tests to be conducted by IITR.

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Table 1 Test Matrix


Type of Testing and Nos. of specimen.	Purpose of the tests	Parameters to be measured	Remarks
6 nos	Control specimen under 3 support conditions at ambient temperatures on 2 specimens for repeatability. (3X2)=6.	Load deflection characteristics	
18 nos. of beams.	Fire tests with 3 support conditions and 3 load levels on 2 specimens for repeatability. (3X3X2) = 18.	<ol style="list-style-type: none"> 1. Temperatures 2. Deflections 3. Residual load deflection characteristics 4. Crack widths. 	Temperatures during fire test. Crack width at suitable stages of testing.

4.4 Deliverables:

- Data and evaluation of structural performance of cracked/ damaged concrete structure under fire. Recommendations/guidelines based on the above studies.
- Experimental database for validating the numerical models.
- Project report with complete experimental results and conclusions.
- Suitability of current fire resistance clause in IS codes and if necessary refinement of design method.

5.0 PROJECT REPORT:

- 5.1 Project report shall be submitted by IITR giving details of the work enumerated in section 3 Scope of work and Test Results.
- 5.2 Draft report will be prepared by IITR presenting the results and conclusions. BARC will provide comments and will be included by IITR in the final report.
- 5.3 Photographs shall be provided in Original.

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6.0 FINANCIAL ARRANGEMENTS:

IITR will take up the project as Collaborative Research Project and the fees will be borne by BARC. The total cost of the Project is Rs. 49.98 Lacs inclusive of institute overhead charges.

Since the major portion of the cost estimated is needed for procurement of materials for casting of 24 nos. of RC beam specimens, fabrication of loading frame and fixtures for support conditions, technical assistance, man-power during casting and fabrication, 30% of the fee may be paid as first installment. Second installment of 40% may be paid after the placement of order of sensors. After casting of all specimens and testing of 16 beams, 25% of fee would be paid as third installment. Remaining 5% would be paid at project completion.

The details of payment schedule are included in Table 2.

Table 2: Payment Schedule

S. No.	Deliverable	Amount
1.	Signing MoU	₹ 14,99,400/-
2.	Placement of order for sensors by IITR and submission of draft PO.	₹ 19,99,200/-
3.	Casting of specimens and testing of 16 beams and preliminary report submitted by IITR to BARC.	₹ 12,49,500/-
4.	Testing of 8 beams and submission of final report by IITR to BARC.	₹ 2,49,900/-

BARC shall release payment based on the review of the progress and certification by project review committee as per payment schedule and deliverables.

Payment will be in the form of a Demand Draft drawn in favour of "DEAN SRIC INDIAN INSTITUTE OF TECHNOLOGY ROORKEE "The Draft shall be sent at the following Address:

Dr Pradeep Bhargava
Professor in Civil Engineering
Indian Institute of Technology Roorkee, Roorkee-247667
UTTARAKHAND
e-mail: bhpdpfce@iitr.ac.in
Ph: 01332-285495, 285245



No tax shall be deducted at source since IIT Roorkee is exempted from paying income tax from its sponsored or consultancy charges and as such IITR does not file income tax return to claim refund from the Income Tax Department.

7.0 PROJECT IMPLEMENTATION COMMITTEE (PIC):

The following project implementation committee shall take responsibility for completing the project.

BARC	IITR
Shri Hitesh Lakhani, SO/D, Reactor Safety Division Tel: 022-25593548	Dr Pradeep Bhargava Professor , Civil Engineering IIT Roorkee-Roorkee Tel: 01332-285495
Shri Tarvinder Singh, SO/E, Reactor Safety Division Tel: 022-25593548	Dr Umesh K Sharma Associate Professor , Civil Engineering IIT Roorkee-Roorkee Tel: 01332-285877

8.0 PERIODIC REVIEW

It is mutually agreed that a mid term review will be held at mutually convenient place for reviewing the progress of the work. IITR shall submit a progress report for every six months to BARC. The review committee will review the project every six months. A project review committee will consist of following members:

BARC	IITR
Dr. G.R. Reddy, Head, SSES Reactor Safety Division Tel: 022-25595181 Dr. R.K. Singh, Head, Reactor Safety Division Tel: 022-25593919	Dean , Sponsored Research & Industrial Consultancy Indian Institute of Technology Roorkee, Roorkee-247677 Tel: 01332-285245





9.0 ROLE AND RESPONSIBILITIES OF BARC:

The roles and responsibilities of BARC and IITR, Roorkee mutually agreed for "PERFORMANCE EVALUATION OF CRACKED/DAMAGED CONCRETE STRUCTURES UNDER FIRE" are as follows.

During the period of this MOU, BARC will supply the structural drawings. BARC shall maintain close co-ordination and co-operation with IITR representatives during the duration of the Project.

Considering the quantum of work and nos. of RC beams, the fabrication of test sample will be taken up at IITR in discussion with BARC.

10.0 ROLE AND RESPONSIBILITIES OF IITR:

IITR will utilize their equipment, infrastructure and experts for carrying out the project work. IITR will cast the RC beams defined earlier as per the drawings supplied by BARC. IITR will carry out the tests as per the procedure explained in Section 3 and 4. IITR shall maintain close co-ordination and cooperation with BARC representatives during the duration of the project. Data of test as and when performed shall be submitted to BARC after every test.

On completion of the technical work, IITR will submit a detailed report of the Project giving the results of the investigations and data analysis. A draft report will be given to BARC for comments before finalization. Final report will be prepared by IITR with consultation of BARC.

11.0 LIABILITY:

In the event of any loss or damage to any property or injury to any person arising from the testing of the samples supplied, no liability would be incurred by BARC for such loss or damage.

12.0 ARBITRATION:

If any dispute arises between the parties to this MoU regarding implementation of the terms of the MoU, the interpretation of the terms of the MoU or any other matters incidental to or connected with the subject matter of the MoU, such dispute shall be resolved, as far as possible, amicably by mutual consultation, using the good offices of the Director IITR, and the Director, BARC or their respective nominees. Both such arbitrators shall be entitled to select a third arbitrator (i.e. Umpire) in accordance with the law, and the decision taken by such arbitrators shall be binding on both parties to this MoU. The provisions of Indian Arbitration and Conciliation Act, 1996 as modified from time to time shall apply to such arbitration proceedings.



13.0 FORCE MAJEURE:

Neither of the parties hereto shall be considered in default in performance under the contract if such performance is prevented or delayed by events such as war, civil war, (whether declared or not) civil commotion, insurgency, hostilities, revolution, riots, strikes, lockouts, conflagration, epidemics, accidents, fire, flood, droughts, earthquake or any act of God or causes beyond the reasonable control of the party affected, provided notice in writing is given within ten days, failing which, the shortest period by IITR to BARC and vice versa. Soon after the causes of force majeure has ceased, the party whose ability to perform its obligation has been affected shall notify the other of such cessation and of the actual delay occurred in the affected activity, abducting necessary evidence in support thereof. From the date of occurrence of Force majeure, the obligations of the party affected shall be suspended during the continuance of any ability resulting there from having been removed and the agreed time of completion of the respective obligation under this agreement shall stand extended by a period equal to the period of delay occasioned by such events.

Should one or both parties be prevented from fulfilling the obligations by state of force majeure lasting for a period more than one month, the two parties shall consult each other and decide on the future execution of the contract. In case of termination of work due to force majeure conditions, BARC shall pay IITR towards all work done by IITR on their part up to the date of happening of the force majeure events. IITR on their part will submit the report of the project at this stage with available data, analysis result etc.

14.0 SECURITY:

IITR shall not disclose any information furnished to them by BARC and other information prepared by IITR for the project without prior written approval of BARC, except in so far as disclosures necessary for the performance of IITR's work and services hereunder. IITR shall be subject to the provisions of the Atomic Energy Act, 1962 and the Official Secrets Act, 1923 pertaining to such information at all times.

15.0 INTELLECTUAL PROPERTY RIGHTS

Results of the study and the report thereof would be sole property of BARC. IITR will obtain specific permission from BARC for publication of technical papers based on the studies conducted.

16.0 MoU & ITS AMENDMENTS



Any amendments required will be agreed mutually and noted.



17.0 TERMINATION OF MoU

In case it is found by either parties that the desired objectives cannot be met due to what so ever reason(s) this MoU will be treated as terminated by mutually agreed procedure without any liability on either of the parties.

In witness whereof, the parties hereto have signed this Memorandum of Understanding and affixed their respective seals on the date first noted above.

FOR AND ON BEHALF OF BHABHA ATOMIC RESEARCH CENTRE	FOR AND ON BEHALF INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
<p style="text-align: center;"></p> <p>Signature Dir., RD&DG BARC, Trombay Mumbai-400 085</p> <p><i>AD, RD&DG</i> डॉ. अ. के. सिंह / Dr. R. K. SINGH अध्यक्ष, रिक्टर संरक्षा प्रभाग Date: Head, Reactor Safety Division भाभा परमाणु अनुसंधान केंद्र Bhabha Atomic Research Centre त सरकार / Government of India Witness: <i>Taruinder Singh</i> (TARUINDER SINGH) Witness: 2. <i>Hitesh</i> (HITESH LAKHANI)</p>	<p style="text-align: center;"></p> <p>Signature Dean SRIC IITR Dean Sponsored Research & Industrial Consultancy Indian Institute of Technology Roorkee Roorkee-247 667 (INDIA)</p> <p>Place: ROORKEE Date:</p> <p>Witness: 1. <i>Chandra</i> (Satish Chandra)</p> <p>Witness: 2. <i>B Anand</i> (Anand Bhusu)</p>

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