

THE MAKING OF PSUEDO-DYNAMIC TESTING FACILITY (PDTF) AT IIT KANPUR

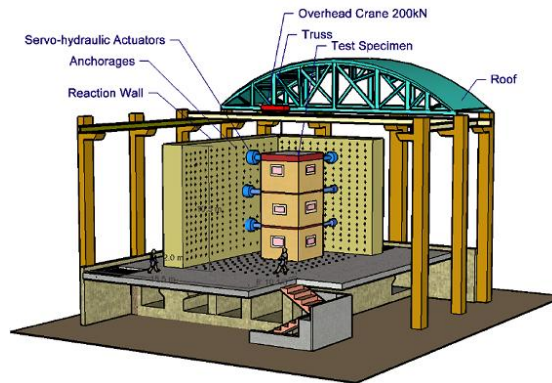
by

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Delivered at the inaugural function held on Sept 21, 2019 in the presence the chief guest, Prof. Ashutosh Sharma, Secretary, DST; Prof. Abhay Karandikar, Director, IIT Kanpur; Prof. S Ganesh, Dean, R&D; Prof. Sachhidanand Tripathi, Head, Civil Engineering; and Dr Arindam Bhattacharya, DST-FIST program, IIT Kanpur faculty and staff members and students.



The journey of the making of PDTF has been indeed a long and arduous one and many individuals have contributed to it. I would like to remember and acknowledge their contribution as I recall the milestones leading to this inauguration day.

The journey of PDTF is also a significant part of my journey at IIT Kanpur. On the last day of 2001, I moved here from IIT Roorkee where, we at Dept. of Eqk. Engg. were successful in getting a DST grant of about 104 lacs, after some 3 years of pursuance, to replace the 1985 vintage real-time PDP -11 computer as controller for the first ever bi-axial shake table in India with new digital *Instron*¹ controller and new *National Instruments*² high performance data acquisition system³. The maintenance and operational costs of the shake table facility were so high that it was difficult to maintain and operate in the university like setup with the typical project-based short term funding.

VISION & OBJECTIVE

At IIT Kanpur, we wanted something with a low running costs but versatile enough for the research related to experimental evaluation of earthquake resistance of full prototype structural systems. Strong floor and wall reaction assembly with large capacity servo-controlled actuators are the standard equipment for the psuedo-dynamic testing at most centers of Experimental Earthquake Engineering Research throughout the world and can often serve as a substitute for expensive shake table facilities.

FIRST ATTEMPT AT FIST 2002

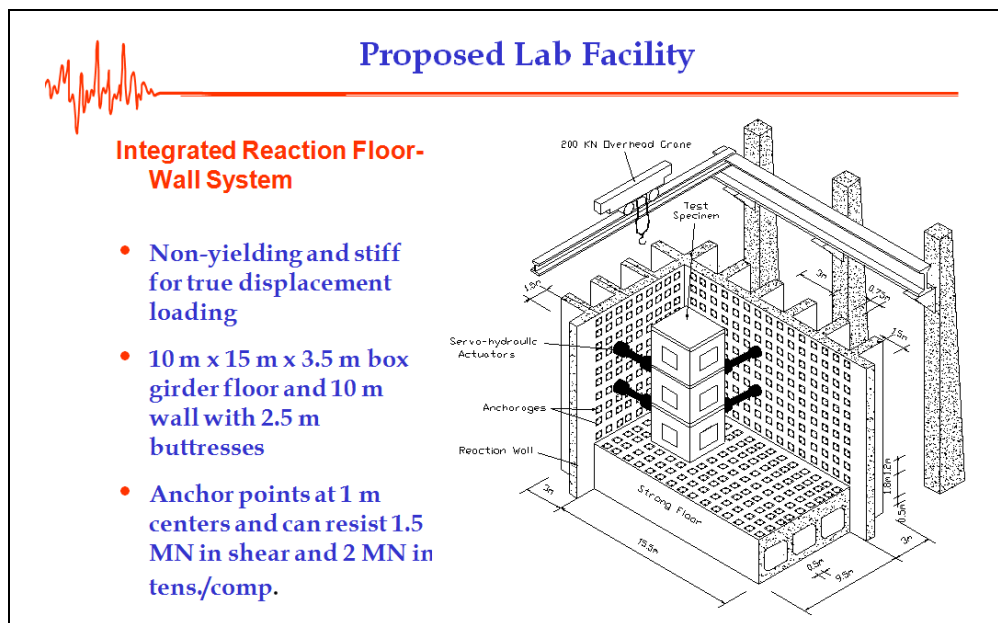
Our first attempt to find funds was through the FIST in 2002 and I was really encouraged by the positive response from **Dr TVSR Apparao**, former Director CSIR SERC Madras and Chairman **Prof SP Sukhatme**, former Director of IIT Bombay, who supported the idea and

¹ <https://www.instron.us/products/testing-systems>

² <http://www.ni.com/en-in.html>

³ Shrikhande, M., Rai, D. C., Kumar, A. and Basu, S. (2002), "Upgradation of Shake Table Facility at IIT Roorkee," *Proc. 12th Symp. on Earthquake Engineering*, Indian Institute of Technology Roorkee, Roorkee, Dec. 16-18.

funds for mechanical equipment but expressed inability to fund for the construction of reaction floor-wall assembly.



FIST 2002 presentation slide showing schematic of PDTF and key parameters of its loading capacity

SECOND ATTEMPT & SUCCESS AT FIST 2003

The next year in 2003, **Prof. Sudhir Jain**, then Head of the Dept., made a case for the facility to which we received a grant of 90 lacs for the equipment (a 100 ton actuator, a 20 ton overhead crane and hard hydraulic line) but it was conditional on getting funds for civil works of reaction floor and wall assembly from other sources. The chairman **Prof. Amitabh Ghosh** assured that he would request **Prof. S G Dhande**, then Director of IIT Kanpur for the funding from internal sources for its civil works.

IITK COMMITS FOR CIVIL WORKS AND APPOINTS CONSULTANTS

In Feb 2004 the Institute agreed to fund the civil construction of PDTF.

In Apr 2004, the Institute appointed **Mr Sanjay Kanvinde** (*M/s Kanvinde Rai and Chowdhary, New Delhi*) as Architecture Consultant and **Prof Mahesh Tandon** (*M/s Tandon Consultants Pvt. Ltd⁴, New Delhi*) as Structural Design Consultant for PDTF. This was the first time when the Institute had two separate firms for architectural and structural design for a project. The Institute favoured M/s Kanvinde for both jobs as they had earlier designed Structural Engineering Research Center (SERC), Ghaziabad laboratory but since we wanted pre-stressed reaction wall, we needed the expertise of Tandon's office. Negotiation skills of **Mr Rajeev Garg**, then Executive Engineer, IWD and **Prof Sudhir K Jain**, Head, CE Dept., made it possible.

It took almost one year (Nov 2004 -Sept 2005) to obtain formal approval for space allocation for the PDTF. It required the relocation of the transportation lab to the Workshop I Building where the canteen was working. For which a new canteen facility had to be constructed which is now known as DOAA Canteen. Most importantly, Dept. of Material Science and Metallurgy under the leadership of its HODs **Profs Sanjeev Bhargav**

⁴ <https://www.tcpl.com/>

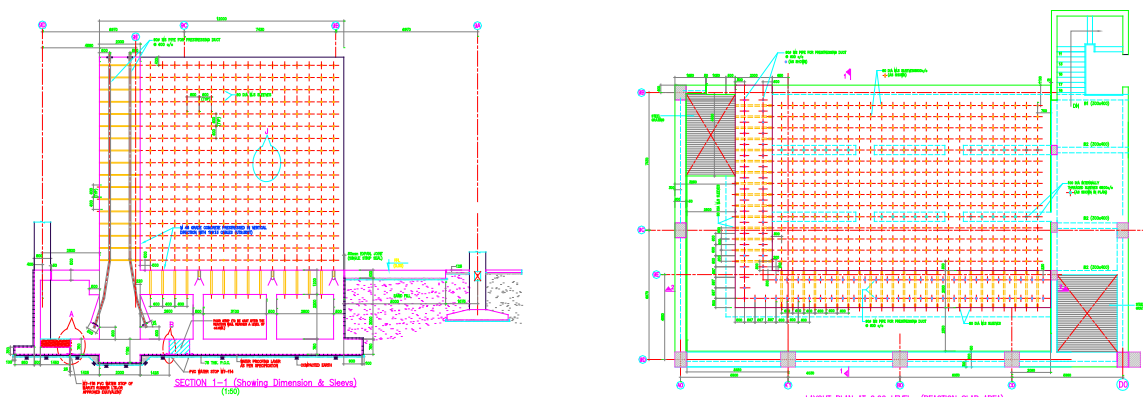
and **Rajiv Sekhar** was very generous to give away their space in the adjoining lab to PDTF which now houses its two-story control and instrumentation room and conference facilities.



Layout of the proposed PDTF adjoining existing Structures' and MSME Lab

DEVELOPMENT OF STRUCTURAL DESIGN

Prof. Tandon's office prepared the detailed good for construction drawings based on our basic parameters with its load rating comparable to the best in the world for such facilities. The pre-stressed reaction walls, the first time in India, were designed with a unique post-tensioning system as used in bridges. The 200 tons push-pull force capability at each anchor point at located at 0.5m space, 10 m high, 2 m thick and 10 and 15 m long L-shaped walls and 1.2 m thick top slab of 4 m deep box girder for the loading floor, suitable for full-size bridges or buildings of three-story tall. It needed some 1200 m³ of M45 concrete, 200 m³ of M30 concrete, (in total some 250 truckloads of ready-mix-concrete), 210 tons of pre-stressing cables and 90 tons of normal reinforcement.



Structural details of post-tensioned reaction wall and 3-cell box girder reaction floor

Of course, it was the first of a kind assignment for **Prof Mahesh Tandon** and also for **Mr Rajeev Garg**, then Executive Engineer of IWD. They visited such facilities in Singapore together and **Prof Tandon** even travelled to Japan to visit facilities at Kajima Corporation and others.

TENDERING & AWARDED CONTRACTS

In Oct 2005, the Building & Works Committee, IIT Kanpur approved the grant for civil works.

The lab grant of Rs 50 lacs from MHRD's National Program of Earthquake Engineering (NPEEE) was also allocated to this facility which was possible due to **Prof SK Jain**, the national coordinator and **Prof CVR Murty**, the Institute coordinator of the program

The tendering process began in Jan 2006, **Profs SK Jain and Mahesh Tandon** personally requested **Mr P Y Manjure** MD of the Freyssinet Pre-stressed Concrete, Mumbai (FPCC)⁵, the largest pre-stressing company to bid for such a small work which they kindly agreed. The lowest bid was substantially more than the estimated cost and negotiations failed.

Tenders were invited 2nd time as recommendation Building & Works Committee. A special Tender Review Committee was instituted under the chairmanship of **Prof Ashwani Kumar** in Aug 2006 and on its recommendation, the Finance Committee in Aug 2006, approved the project with a total outlay of about Rs. 453 lakh for the civil works

In Oct 2006, the tender was awarded to M/s Freyssinet Pre-stressed Concrete, Mumbai (FPCC).

CONSTRUCTION OF PDTF

The Groundbreaking ceremony was held in Nov 2006 and demolition of the portion housing transportation lab began.



Nov 2006 Dismantling a part of existing Lab



Dec 2006 Digging for the basement & foundn

During 2007, foundation and basement work was completed and building columns were constructed.



Nov 2007 Construction of Basement Walls



Nov 2007 Reinforcement of Reaction Wall & Basement

⁵ <http://freysinnet-india.com/>

During 2008, construction of box girder walls below the strong floor was executed. Precision alignment of steel sleeves for anchors at 0.5 m grid was achieved using robotic total station.



May 2008 Sheaths for post-tensioned walls



Oct 2008 Fixing of anchors' sleeves

In Mar 2009, the concreting of the Strong Floor of 200 cum was completed in one go in day & night operation. Such a mass concreting had challenges of controlling temperature in the hardened concrete. If the temperature increase due to heat of hydration is not controlled properly, the concrete develops cracks and loses its strength and integrity.



Mar 2009 Reinforcement of Strong Floor



Mar 2009 Concreting of Strong Floor Slab

A unique technique of passing water through steel tubes was employed to cool concrete with the measurement of temperature at regular intervals. I will like to commend, **Mr Mohit Dwivedi** who was then a project employee and now JTS even took thermocouple measurements in the morning of Holi festival!

The development of this piped water cooling scheme became a masters' thesis of **Mr Piyush Raj** a dual degree student and later published as full-length paper in *ASCE Journal of Engg Mechanics* in 2018⁶.

During 2009, precision laying of steel sleeves in the strong walls was performed, I would recall **Mr S Chaudhary** of Freyssinet who came up with a novel idea of holed steel plates to ensure that sleeves for anchor points are precisely at 0.5 m square grid. The walls were constructed in several stages and all concreting and building was completed in 2010.

⁶ Singh, P. R. and Rai, D. C. (2018). "Effect of piped water cooling on thermal stress in mass concrete at early ages," *Journal of Engineering Mechanics*, American Society of Civil Engineering, vol. 144, no. 3, 04017183, 11p.



Mar 2009 Reinforcement of Strong Floor



Mar 2009 Concreting of Strong Floor Slab

It was really complicated and challenging for the IWD to execute the contract as the Freyssinet specialized in pre-stressing while PDTF included building construction and other normal RCC construction. It was the experience and exemplary skills of **Mr Rajeev Garg**, who made it through the most difficult situations.

Mr Niranajan Dass, Mr Vinay Dwivedi, Mr Vijay Pal and Mr Virendra Singh of IWD often went well beyond the call of duty for the PDTF.

All the structures' lab staff especially **Mr Pankaj Gupta, Mr Vinay Dwivedi, and Mr Digambar Urukude** had a major role at every stage of construction.

The resourcefulness of **Prof SK Jain** came in handy whenever we faced any trouble with the construction related activities. For example, he could get the reinforcing steel directly from Tata Steel when large 32 mm dia bars which was often not available in the open market.

PURCHASE OF EQUIPMENT FROM FIST 2003 GRANT

After the completion of civil works, DST released the grant of 90 lacs in August 2010.

Hard hydraulic lines were installed by Concord Hydraulics, Mumbai in June 2011 at the cost of Rs. 14 lacs. The 100 ton MTS actuator with large 1 m stroke was received in July 2012. The 20 ton overhead crane was installed in Dec. 2012 at the cost of Rs 45 lacs with additional grant of Rs 30 lacs from the Institute, thanks to **Prof K Muralidhar**, then Dean R&D and Director, **Prof SG Dhande**.

Mr Varun Bakshi of the Universal Enterprises (Hoist Division) of Latouche Road, Kanpur took the plunge and built the 20 ton, 22 m span double girder crane on the design reviewed by us as they were constructing for the first time such a large crane. In all, we spent Rs 126 lacs against Rs 90 lacs sanctioned for these three equipment.



2010 Completion of reaction wall-floor assembly, hard hydraulic lines, EOT crane and the uilding housing PDTF

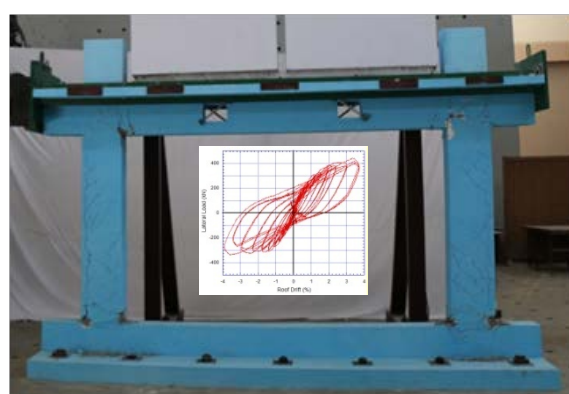
RESURFACING OF REACTION WALLS

Since the surface finish of the wall was not as good as needed, 3mm in 3m, Class 1 (F1). **Prof Bharat Lohani and Geokno's** team did a survey of undulations and it was decided to provide a micro-concrete resurfacing and thanks to the form and pour methodology worked out by our lab's staff, **Mr Pankaj Gupta, Mr Radheshyam and Mr Dhruv Kumar** to use plexiglass sheet for formwork.

On the recommendation of **Prof AK Chaturvedi**, then Dean R&D, **Prof SG Dhande** approved another Rs 40 lacs for the resurfacing work in Sept 2012 so that the facility can be inaugurated early. It was brilliantly completed under the lead of **Mr Pankaj Gupta** especially the embossing of IITK on the wall. **Prof Sudhir Misra** as lab-in-charge saw it completed in 2015.

FIRST EXPERIMENT IN THE LAB

The first test in the lab was conducted by **Mr Abhijit Gupta**, a dual degree student for his master's thesis on verification of an RC frame with beam opening in 2015, however, it was cyclic load, not a true pseudo-dynamic⁷.



2015 Cyclic testing of 1:2.5 scaled RC frame with beam openings

We also published the details of the construction in PDTF in *Current Science* in 2017 and the load rating algorithm by **Dr Dipanshu Bansal**, then UG student, now a faculty member at IIT Bombay, so that other groups will be encouraged to build such facilities⁸.

⁷ Gupta, A. (2015). *Behaviour and Design of Reinforced Concrete Frames with Beam Openings under Lateral Loads* (Master's thesis), Indian Institute of Technology Kanpur, Kanpur.

EQUIPMENT GRANT UNDER FIST 2014

While the resurfacing work undergoing in 2013, there was a move at Dept level to remove the specialty of seismic simulation of PDTF and convert it to a general Large Scale Testing Facility. Thanks to the DST-FIST program monitoring that not only it remained PDTF but qualified for more funds for 400 litre capacity hydraulic power supply (MTS, USA- Rs 100 lacs), 250 ton UTM, Seismic Controller for pseudo-dynamic as well as true dynamic testing (MTS, USA Rs 280 lacs) and high performance data acquisition system (National Instruments, Rs 60 lacs) and received a grant of 4.4 crore under FIST in 2014.

I would especially like to thank **Dr SK Joshi**, Chairman of FISTAB to allow us full freedom to configure the specs of these equipment, FIST expert committee members, **Prof Tarun Kant and Mr N Vedhachalam of VSSC, Dr A Mukhopadhyay and Dr Pratishtha Pandey from DST and Profs Rajesh Srivastava and Purnendu Bose, then HODs, and Prof Samit Ray Chaudhary**, the present lab-in-charge.

Of course, **Dr K K Bajpai**, PSO has played a critical role in the technical as well as the management side of the implementation of both FIST grants as well as the Institute grants.

I am glad that the large test that we just completed in the facility is on the brick masonry the traditional construction material for which experimental simulations are probably the best recourse until our numerical models improve with more such simulations. However, these tests were still cyclic loads and hopefully, we will do the true pseudo-dynamic tests sooner or even better, the real-time dynamic tests with **Prof Chinmoy Kolay**, the youngest faculty member of the Structures' Group.



2019 Full scale testing of a masonry building at PDTF

FUTURE DIRECTIONS

We want the facility to be available for researchers in earthquake engineering area across the country for the collaborative research program. To this end, we have developed a plan to set up a National Center of Experimental Simulation in Earthquake Engineering around this facility. We made a presentation to MHRD as well as to DST in 2007 and 2011. I think the time is right now when this proposal should be given serious consideration.

⁸ Rai, D. C., Jain, S. K., Murty, C. V. R. and Bansal, D. (2014). "Large capacity reaction floor-wall assembly for pseudo-dynamic testing at IIT Kanpur and its load rating," *Current Science*, vol. 106, no. 1, 93-100.

CONCLUDING REMARKS

This journey of making of the PDTF continued through tenure of 3 directors, 6 Dean R&Ds, 7 heads of CE Dept, and 3 lab-in-charges and a large number of individuals from the Institute, the Dept., the IWD, the consultants, and the contractor have contributed to it. It is not possible to name every individuals but their contribution is very much acknowledged.

In the end, the PDTF would not have been possible without three illustrious individuals, **Prof SK Jain** for the vision and overall leadership for earthquake engineering not only at IIT Kanpur, but also at national and international level, **Prof SG Dhande** for the commitment and generous support of the Institute and **Prof CVR Murty** for his unmatched hard work and passion for earthquake engineering. It would have been really inspiring and fitting tribute if these three gentlemen who played such a pivotal role in setting up this facility could be with us today.

Thank you very much for your attention.

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