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## IC-IMPACTS India Workshop Series December 4 and 5, 2017

Venue:

**Tata Research Development and Design Centre (TRDCC)**  
54-B, Hadapsar Industrial Estate, Pune, Maharashtra 411013, India  
TRDCC Contact: Mr. Sachin Parkhi: +97 6671 8844

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### Important information for participants

Sunday, December 3rd, 2017	
19:00 – 21:30	<b>Opening dinner reception hosted by IC-IMPACTS at Conrad Hilton</b> Please meet at 7 pm in Vivanta Taj lobby, near reception

Monday, December 4th, 2017	
7:00 – 7:30	<b>Breakfast in Latitude restaurant at Lobby level in Taj</b>
7:45 – 8:15	<b>TCS Bus will leave Taj Vivanta at 7.45am to beat traffic. ETA at TCS is 8.15 am if we start early at 7.45 am.</b>



## Agenda

Monday, December 4 <sup>th</sup> , 2017		
8:30 – 9:00	<b>Registration</b>	
9:00 – 10:00	<b>MC: Shapoor Marfatia</b> COO & Network Manager, IC-IMPACTS	
	<b>Welcome &amp; Opening Session :</b> <b>Lighting of the Lamp</b> <b>Ravindra Naik</b> <i>Delivery Center Head , TRDDC</i>	15 min
	<b>Raju Goteti</b> (over phone) <i>VP and Global Head, COIN</i>	
	<b>Overview of IC-IMPACTS &amp; Infrastructure Theme</b> <b>Nemkumar Banthia</b> <i>Civil Engineering Professor at the University of British Columbia CEO, Scientific Director, and Infrastructure Theme Lead, IC-IMPACTS</i>	15 min
	<b>Overview of Health Theme</b> <b>Stewart Aitchison</b> <i>Electrical &amp; Computer Engineering Professor, UofT Public Health Theme Lead, IC-IMPACTS</i>	10 min
	<b>Overview of Water Theme</b> <b>Madjid Mohseni</b> <i>Chemical &amp; Biological Engineering Professor, UBC Representing Water Theme Lead, IC-IMPACTS</i>	10 min
	<b>Overview of TCS Research and Innovation</b> <b>Nita Sarang</b> <i>Principal Innovation Evangelist</i>	10 min
10:00 – 10:15	<b>Coffee Break</b>	15 min



10:15 – 12:30	Public Health <b>Multiplexed Assay for Point of Care</b> Stewart Aitchison and Parama Pal University of Toronto	15 min
	Integrated Water Management <b>Biomonitoring of Water Quality in Relation to Human Health</b> Damase Khasa, Manzoor Shah, Sanjay Pal and Afreen Anwar Laval University, University of Kashmir, and University of Alberta	15 min
	<b>An overview of the Intelligent Infrastructures R&amp;I program</b> Venkatesh Sarangan TCS Research and Innovation	15 min
	Public Health <b>Development of a Hand-Held Molecular POCT Device for TB</b> James Mahony and Daman Saluja McMaster University and University of Delhi	15 min
	Integrated Water Management <b>Bioremediation-green Technology</b> Jaswinder Singh, Rameshwar Kanwar, & Neeta Raj (PI: Shiv Prasher) McGill University, Iowa State University, and LPU	15 min
	Safe and Sustainable Infrastructure <b>Smart Sensor Deployment in Buildings</b> Mark Fox and Krithi Ramamritham University of Toronto and IIT-Bombay	15 min
	Public Health <b>Development of an Affordable Point-Of-Care Diagnostic Kit</b> Anil Kumar and Aravindhan Ganesan (PI: Thomas Hobman) University of Alberta	15 min
	<b>Affordable healthcare Sensing</b> Sanjay Kimbahune TCS Research and Innovation	15 min
	Safe and Sustainable Infrastructure <b>India-Canada Initiative for Resilient Global Urban Shelter</b> Farbod Pakpour (PI: Constantin Christopoulos) University of Toronto	15 min
12:30 – 13:30	<b>Lunch Break</b>	60 min



13:30 – 15:00	Safe and Sustainable Infrastructure <b>Application of Precast Products Made using Bottom Ash &amp; Fly Ash</b> <i>Rishi Gupta</i> <i>University of Victoria</i>	15 min
	<b>Citizen Sensing and its role in Smart City services</b> <i>Venkatachari Raghavan</i> <i>TCS Research and Innovation</i>	15 min
	Integrated Water Management <b>Desalination of Brackish Water using Capacitive Deionization</b> <i>Madjid Mohseni</i> <i>University of British Columbia</i>	15 min
	Safe and Sustainable Infrastructure <b>SHM of Tall Buildings using Vibration Techniques</b> <i>S.K. Panigrahi and Timir Baran Roy (PI: Lucia Tirca)</i> <i>Concordia University</i>	15 min
	Public Health <b>Molecular Tools for Malaria Surveillance</b> <i>Ninad Mehta (PI: Stephanie Yanow)</i> <i>University of Alberta</i>	15 min
	<b>Integrated Design, Manufacturing &amp; Health Monitoring of Structures using TCS PREMAP Platform</b> <i>Amit Salvi</i> <i>TCS Research and Innovation</i>	15 min
15:00– 15:30	<b>Coffee Break</b>	30 min
15:30 – 16:45	Safe and Sustainable Infrastructure <b>Energy &amp; Water Disaggregation for Non-Intrusive Load Monitoring</b> <i>Angshul Majumdar (PI: Ivan Bajic)</i> <i>IIT-Delhi</i>	15 min
	Public Health <b>Engaging Pharmacists in Early Tuberculosis Case Detection</b> <i>Tripti Pande and Srinath Satyanarayana (PI: Madhu Pai)</i> <i>McGill University and The Union</i>	15 min



	Safe and Sustainable Infrastructure <b>Solar Energy Powered Net-Zero Energy Smart Buildings</b> Olesia Kruglov (PI: Bruno Li) Concordia University	15 min
	Integrated Water Management <b>Overview of other IC-IMPACTS Water Management Projects</b> Madjid Mohseni University of British Columbia	15 min
	<b>Microbiome Research: Towards Next-Gen Diagnostics &amp; Therapeutics</b> Anirban Dutt TCS Research and Innovation	15 min

Evening – free time



Tuesday, December 5 <sup>th</sup> , 2017		
9:00 – 10:00	<b>IC-IMPACTS Partnerships with Community and Industry</b> <b>MC: Shapoor Marfatia</b> COO & Network Manager, IC-IMPACTS	5 min
	Public Health <b>Community Health</b> <b>Vissandjee Bilkis (Guest Speaker)</b> <i>University of Montreal</i>	15 min
	Water Management <b>Drinking Water Challenges in India; Solutions for the Future</b> <b>Satish Kumar (Guest Speaker)</b> <i>Eureka Forbes</i>	15 min
	Safe and Sustainable Infrastructure <b>EDCC Retrofit of URM Walls</b> <b>Salman Soleimani-Dashtaki</b> <i>University of British Columbia</i>	15 min
10:00 – 10:15	<b>Coffee Break</b>	15 min
10:15 – 11:45	<b>Household Water Purification Solutions</b> <b>Dilshad Ahmad</b> TCS Research and Innovation	15 min
	<b>Commercialization of IC-IMPACTS Research through Partnership with Industry and Demo Projects in Communities</b> <i>Bridging Research, Practice, and Community – Panel Discussion</i>  <b>Moderator: Dr. Nemy Banthia</b>  <b>Panel: Consul General Jordan Reeves,</b> <b>Ravindra Naik (TRDDC)</b> <b>Dr. Stewart Aitchison (IC-IMPACTS),</b> <b>Dr. Madjid Mohseni (IC-IMPACTS), and</b>	60 min
	<b>Concluding Remarks</b> <b>Ravindra Naik</b> <i>Delivery Center Head, TRDDC</i> <b>Nemkumar Banthia</b> <i>Civil Engineering Professor at the University of British Columbia</i> <i>CEO, Scientific Director, and Infrastructure Theme Lead, IC-IMPACTS</i>	15 min



11:45 – 12:45	<b>Lunch Break</b>	60 min
12:45 – 14:15	<b>Action points IC – IMPACTS and TCS</b> <b>Moderator: Nemkumar Banthia</b> <i>Civil Engineering Professor at the University of British Columbia CEO, Scientific Director, and Infrastructure Theme Lead, IC-IMPACTS</i>	30 min
14:15 – 14:30	<b>Closing Ceremony</b>	10 min

**Session for IC-IMPACTS PIs to meet with COO**  
**(This special session is organized in conference room next to auditorium)**

14:30 – 15.00 TCS Conference room	<b>Tips session – Suggestions and Ideas on Operational Strategies, Social Media Strategies and Other Suggestions for IC-IMPACTS head office in Vancouver</b>  <b>Moderator : Shapoor Marfatia</b> COO & Network Manager, IC-IMPACTS	30 min
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Note:

Hotel checkout is at 12 noon.

If you don't need room on Dec 05th evening, please inform hotel that you will checkout in morning.

# Biomonitoring of water quality in relation to environmental and human health

D.P. Khasa<sup>1</sup>, S. Rimal<sup>1</sup>, M. Shah<sup>2</sup> S. Pal<sup>2</sup> ,  
G. Wani<sup>2</sup>, A. Anwar<sup>2</sup> , and Jie Chen<sup>3</sup>



<sup>1</sup>Center for Forest Research and Institute for Integrative and Systems Biology, Université Laval, Canada

<sup>2</sup>Department of Botany, University of Kashmir, India

<sup>3</sup>National Institute of Nanotechnology and Faculty of Engineering, University of Alberta, Canada

**2017 IC-IMPACTS  
workshop on  
Sustainable  
Infrastructure, Health,  
and Integrated Water  
Management  
54-B, Hadapsar  
Industrial Estate, Pune,  
Maharashtra – 411 013**



IC-IMPACTS





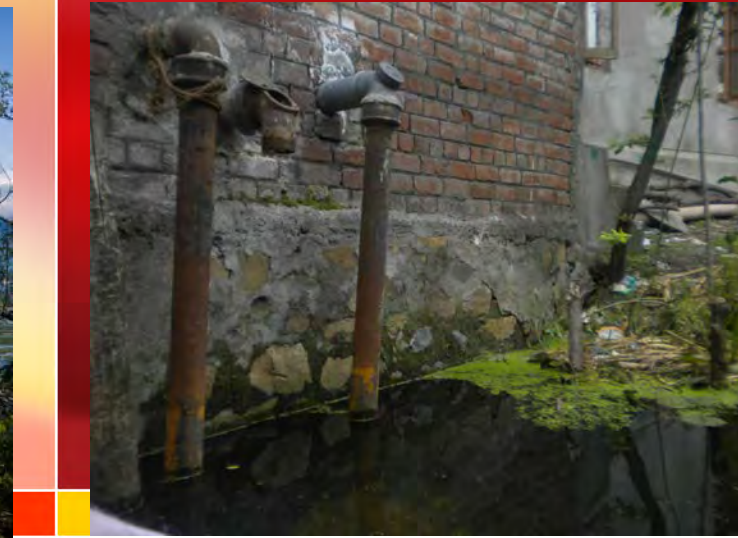
# Background and Rationale

## The problems of water contaminants in Canada



- High ion content (eg.  $\text{Na}^+$ )
- Alkaline pH
- Nutrient depleted
- Residual hydrocarbons, NAs

and India



Dal Lake in the heart of Srinagar invaded by exotics, blooms, sewerage inputs. Smart and gentle remediation technologies to ensure sustainable utilization and conservation of water resources

# Results Towards Achieving Project Objectives

## Obj1: Designing a Portable Impedance-based Point-of-Care Biosensor to monitor E. coli (Jie Chen's lab, UA)



Biosensor Housing Unit Disposable Chip  
and Biosample

Cellphone or Tablet

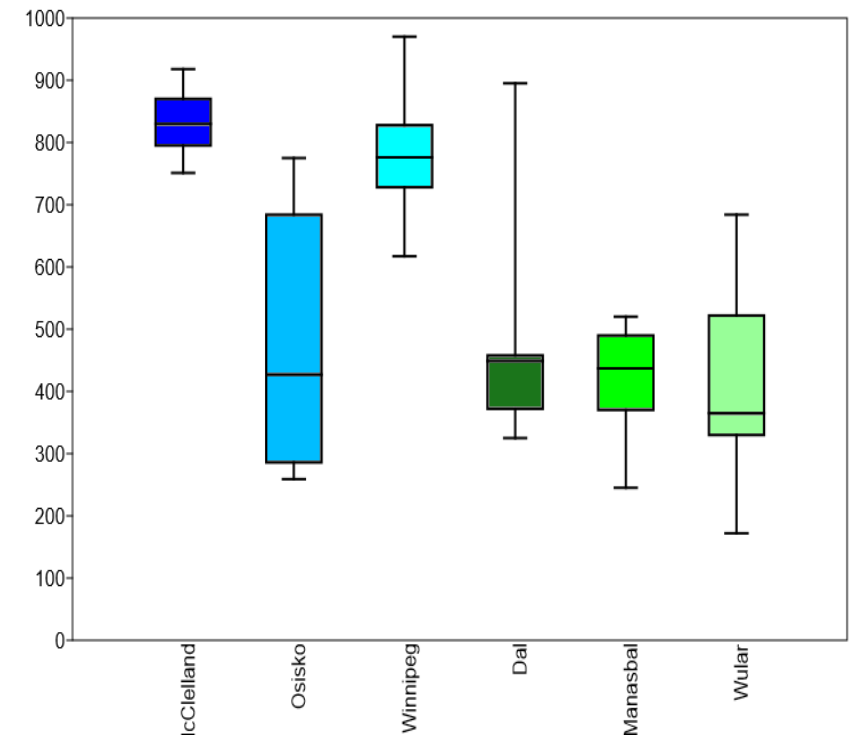
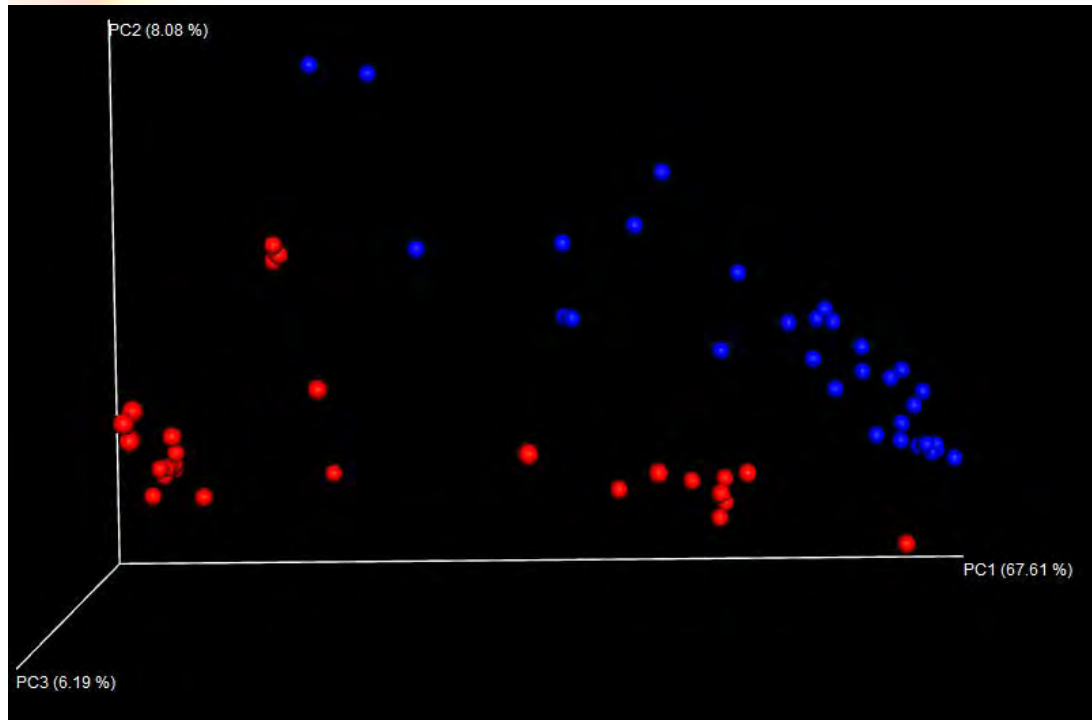


UNIVERSITÉ  
LAVAL

Inserting a chip  
into the housing  
unit

Sending measured  
data to a smartphone  
or tablet

# Obj2: Assessing bacterial communities (BC) in selected Canadian and Indian lakes through culture dependent and independent analysis in relation to water borne diseases and human health



PCOA of Ind. and Can. lakes

Chao1 diversity indices

## Table: Prevalence of different water borne diseases prevailing in and around Dal Lake in comparison Manasbal Lake

Sites	Gastroenteritis (Count % within Sites taken)	Jaundice (Count % within Sites taken)	Typhoid fever (Count % within Sites taken)	Hepatitis B (Count % within Sites taken)	Diarrhea (Count % within Sites taken)
Dal Lake	17.2%	4.7%	42.2%	1.6%	14.1%
Manasbal lake	9.9%	2.5%	23.5%	0.0%	11.1%

Typhoid fever was seen to have highest incidence among all diseases in both the lakes while Jaundice was seen to have least prevalence. However, Hepatitis-B was reported only in Dal lake.

Obj3: Development of a nanoparticle-based water treatment system to eliminate toxins and microorganisms in water

Table. Bioassay of AgNPs-coated activated carbon against *Pseudomonas* and *Fusarium* treated for one or 24 hours, and also counted three days after plating and incubating at 25°C.

Microbe	Treatment	Mean CFU per Plate (n = 4)	
		1 hour	24 hours
<i>Pseudomonas</i>	20 g L-1 AgNO3	0	0
	23 g L-1 AgNO3	0	0
	0 g (CK)	102.3	95
<i>Fusarium</i>	20 g L-1	12.5	0.5
	23 g L-1	66.8	0
	0 g (CK)	500	472.8

AgNPs-coated AC and then put into the housing unit. A cartridge filled with uncoated AC was used as a control. Savchenko et al. 2016. [Journal of Plant Pathology & Microbiology](#). 7:10 DOI: 10.4172/2157-7471.1000381

**Obj4: Evaluating gentle bioremediation technologies for wastewater treatment and contaminant sequestration of some invasive species**

*Phragmites australis*



*Typha latifolia*



*Potamogeton crispus*

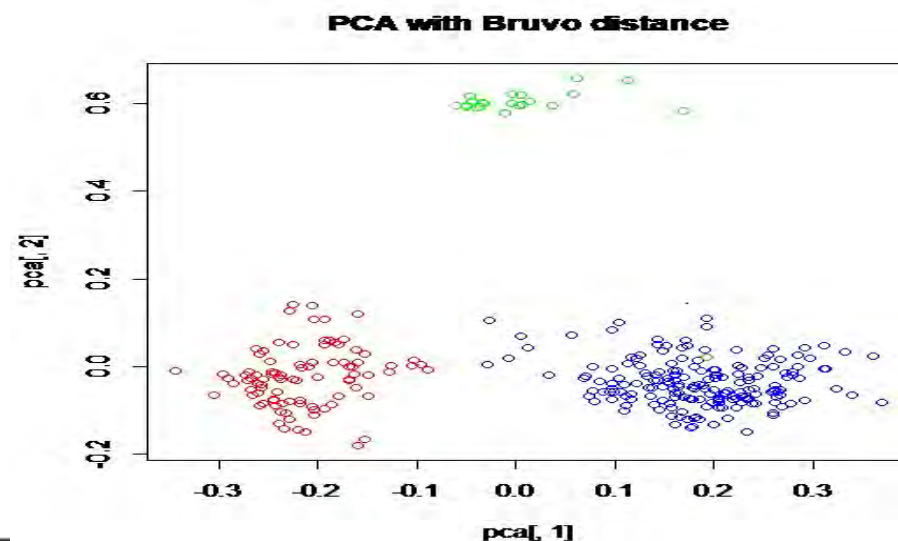


*Salvinia natans*



**Table. Population genetic diversity parameters and genetic structure estimated in 19 *Phragmites australis* populations and one native population of the species, based on 10 microsatellite markers.**

Region	<i>n</i>	<i>P</i>	<i>A</i>	<i>A<sub>p</sub></i>	<i>A<sub>R</sub></i>	<i>H<sub>O</sub></i>	<i>H<sub>E</sub></i>
Mean Kashmir	24	92.69	3.33	2.61	2.16	0.6973	0.5413
Mean Quebec	24	92.93	2.65	1.93	1.86	0.427	0.396
Overall mean	24	92.98	8.56	4.16	2.73	0.548	0.693



*n* = sample size; *P* = percentage of polymorphic loci; *A* = mean number of alleles per locus; *A<sub>p</sub>* = mean number of alleles per polymorphic locus; *A<sub>R</sub>* = Allelic richness; *H<sub>O</sub>* = observed heterozygosity; *H<sub>E</sub>* = expected heterozygosity (under Hardy-Weinberg equilibrium. PCA 1 and PCA 2 (Blue and Green - Canadian invasive and native populations, respectively; Red- Kashmir invasive populations). Wani et al. 2017. Mol. Ecology (submitted)

# Biochar Production



Ongoing chemical



## **Obj5: Outreaching stakeholders and communities for awareness and participation in addressing the water quality related issues**

to explore the perceptions of local communities to agricultural and industrial activities and the social acceptance of gentle bioremediation technologies through semi-structured interviews using a questionnaire administered to the communities, focus group.

# Refereed Contributions (Refereed Articles)

1. **X. Li**, J. Yang, Y. Hao, X. Yang and J. Chen, “A Potential Biosensor for Early Detection of *Sclerotinia Sclerotiorum* and *Leptosphaeria Maculans* in Canola”, *Plant Diseases*, (under revision)
  2. **Xiaojian Yu**, Mihai Esanu, Scott MacKay, Jie Chen, Mohamad Sawan, David Wishart and Wayne Hiebert, “An Impedance Detection Circuit for Applications in a Portable Biosensor System”, *IEEE Symposium on Circuits and Systems*, May 23-25, 2016 Montreal, Canada
  3. **Xiaojian Yu**, Kambiz Moez, I-Chyn Wey and Jie Chen, “Fully-Integrated Multiple-Stage Cross-Coupled Voltage Multiplier for Lab-on-chip Biosensors”, *38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, August 16-20, Orlando, US
  4. **Gowher. A.Wani**, M.A. Shah, Z.A. Reshi, M. E. Beaulieu, A.R. Atangana and D.P. Khasa. 2017. Phenotypic and genetic diversity of *Phragmites australis* populations in native and non-native ranges: a phylogeographic comparison. *Molecular ecology* (to be submitted)
  5. **Oleksandra Savchenko**, Jie Chen, Yuzhi Hao, Xiaoyan Yang, Susie Li, and Jian Yang. 2016. Three-dimensional Coating of Porous Activated Carbons with Silver Nanoparticles and its Scale-up Design for Plant Disease Management in Greenhouses. [Journal of Plant Pathology & Microbiology](#). 7:10 DOI: 10.4172/2157-7471.1000381
  6. **Scott MacKay**, Gaser N. Abdelrasoul, Marcus Tamura, Donghai Lin, Zhimin Yan and **Jie Chen**, “Using Impedance Measurements to Characterize Surface Modified with Gold Nanoparticles” *Scientific Reports-Nature* (under review)
- +6 in preparation**
- Dr. Jie Chen's group filed US provisional patent in Sept 2016. The title "NANOPARTICLE ENHANCED IMPEDANCE-BASED MOLECULAR SENSING"

# ◆ Acknowledgements



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# Development of a POCT device for Tuberculosis

Dr. James Mahony

Professor Emeritus

McMaster University

Director, Regional Virology Laboratory

St. Joseph's Healthcare

Hamilton, Canada

Dr. Daman Saluja

Professor

Dr. B.R. Ambedkar Center for Biomedical Research

University of Delhi, India

# Tuberculosis among top 10 causes of death worldwide last year

**10.4 million** people  
**FELL ILL FROM TB**



That's 28,500 people every day

**1.8 million** people  
**DIED FROM TB**

including 400,000  
**WITH HIV + TB**

That's over 4,900 people every day

**6.1 million** people had  
**ACCESS TO QUALITY TB CARE**

**4.3 million** people  
**MISSED OUT**

Source: Global Tuberculosis Report 2016, WHO

## Burden of tuberculosis in India according to annual status report of Central TB Division, 2016

TB Burden	Number in millions (95% CI)	Rate per 100,000 persons (95% CI)
Incidence	2.2 (2.0-2.3)	167 (156-179)
Prevalence	2.5 (1.7-3.5)	195 (131-271)
Mortality	0.22 (0.15-0.35)	17 (12-27)



**480 000**  
people developed  
**MDR-TB**

# Tuberculosis epidemiology

- One third of world's population is thought to be infected by Mtb
- 80% of people in many Asian and African countries test positive compared with 5% in developed countries
- 10 million active cases worldwide in 2016 resulting in 1.3 M deaths (number 2 behind HIV) with 95% of deaths in developing countries (50% in India, China, Indonesia and Pakistan)
- India had the highest number of new cases in 2016 at 2 million
- Risk factors for infection include overcrowding, malnutrition, close contact of children, HIV, health care providers, diabetes, smoking and lung disease
- Immunity from BCG vaccine wanes over time – need for improved vaccine for TB (some currently in phase I and II trials)

# Transmission and resistance

- Spread by aerosol droplets coughing, sneezing, spiting (one sneeze can contain 40,000 droplets) – infectious dose can be 10 bacteria
- Close contact associated with infection rates of 20-25%
- One untreated infected person can infect 10-15 people per year
- Treatment requires several months with isoniazid and rifampicin however multi-drug resistance (MRD-TB) is becoming a major problem – new treatments consist of combination with pyrazinamide and ethambutol
- WHO estimates that there will be more than 2 million new cases of MDR-TB between 2011 and 2015

# Tuberculosis pathophysiology

- After exposure 90% develop latent infection with only 10% chance of developing lifetime overt TB
- Lung infection produces prolonged cough with sputum and chest pain and is characterized by macrophage infection in pulmonary alveoli
- Tuberculosis infects many parts of the body including CNS, lymphatics, genitourinary tract, bones and joints – extrapulmonary cases are increasing
- Mycolic acid in membrane helps Mtb resist reactive oxygen species and allows bacteria to kill macrophages resulting in granuloma formation which interferes with immune response and contributes to entry into vasculature



# Diagnosis of Tuberculosis

- Diagnosis of active TB using only s/s is difficult
- Routine diagnosis of active TB employs smear microscopy, culture of MTB bacilli, and detection of MTB nucleic acid (NAATs)
- Chest X-ray and multiple sputum cultures for acid-fast bacilli are used for initial workup
- Definitive diagnosis consists of Mtb identification in sputum, pus or tissue biopsy – culture can take 6 weeks
- Interferon release assay and tuberculin skin tests (screening) not used in developing countries
- NAATs including GeneXpert MTB/RIF (Cepheid), Inno-Lipa (Innogenetics), Amplicor MTB (Roche), Applied Mycobacterium tuberculosis direct test (Gen-Probe) and line-probe assays for point mutations can provide a rapid and sensitive result but they are restricted to centralized laboratories but require power source, instrument and are expensive (\$10/cartridge) for developing countries

# Diagnosis of Tuberculosis In India

## **DIRECT** DETECTION OF *M. tuberculosis*

- Microscopy
- Culture
- Nucleic acid amplification techniques (NAAT)



## **IN-DIRECT** DETECTION OF *M. tuberculosis*

- Immunoassays
- Tuberculin Skin Test
- ELISA
- IFN  $\gamma$  release assays

## **Scenario in high incidence settings**

- Passive case finding
- Diagnosis based on clinical symptoms or laboratory diagnosis using sputum smear microscopy : Low sensitivity (<70%)
- Culture : more sensitive but time consuming, requires infrastructure

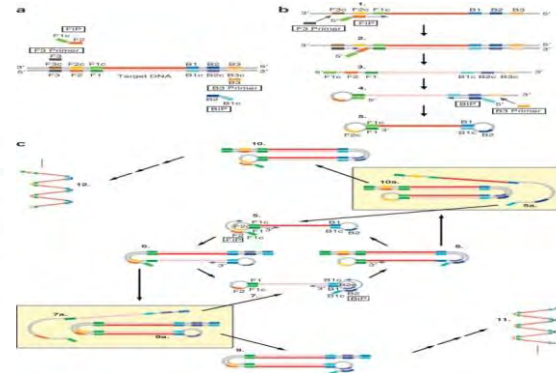
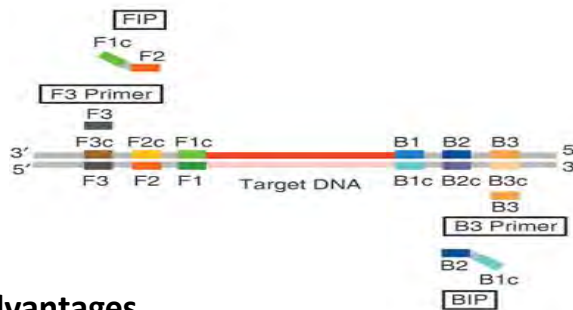
# Challenges:

- Tuberculosis (TB) is a public health problem worldwide, but more so in **developing and under developed countries**.
- The major challenge in fight against TB is lack of rapid, reliable and **inexpensive diagnostic test** for detection of *M. tuberculosis*.
- **Loop mediated isothermal amplification (LAMP) is a promising technique for the effective and reliable diagnosis of infectious disease even in resource limited settings.**
- It is sensitive, specific, fast and most importantly, does not require expensive instruments like thermocycler and complicated methods of detection.

## Loop-mediated isothermal amplification of DNA

Tsugunori Notomi<sup>1,3,\*</sup>, Hiroto Okayama<sup>2</sup>, Harumi Masubuchi<sup>1</sup>, Toshihiro Yonekawa<sup>1</sup>, Keiko Watanabe<sup>1</sup>, Nobuyuki Amino<sup>3</sup> and Tetsu Hase<sup>1</sup>

- Novel nucleic acid amplification method in which reagents react under isothermal conditions with high specificity, efficiency, and rapidity
- DNA polymerase i.e. *Bst* polymerase and a set of four specially designed primers that recognize a total of six distinct sequences on the target DNA



### Advantages

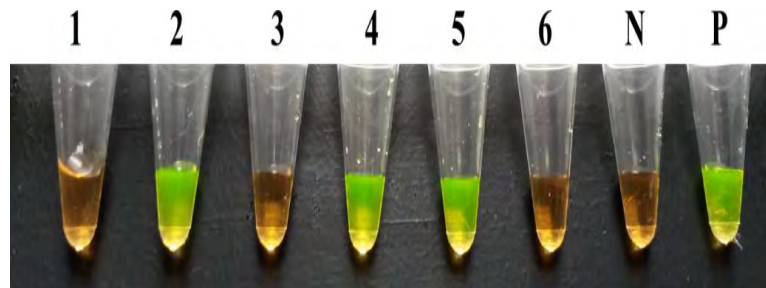
1. **Isothermal** (63 to 65°C)
2. **Sensitive**
3. **Specific** amplification (primers to recognize 6 distinct regions on the target)
4. **Cost effective**
5. Point of care
6. Different methods of visualization (agarose gel, turbidity, SYBR Green, fluorescence, LFD)

# Comparison of various parameters to check the quality and accuracy of inhouse developed assay and accuracy of different methods calculated with 95% Confidence intervals (CI)

Can we print in panoramic view. This will help.

	Smear Microscopy		devR PCR		IS6110 PCR		MPT64 PCR		rpoB PCR		sdaA PCR	
Result for specimen (n=412)	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive	Negative
TB Positive	91	58	135	14	95	54	124	25	129	20	143	6
TB Negative	18	244	10	253	2	261	13	250	29	234	9	254
Sensitivity (95% CI)	61.0 (52.7-68.8)		90.6 (84.4-94.6)		63.7 (55.4-71.3)		83.2 (76.0-88.6)		86.5 (79.7-91.4)		95.9 (91.0-98.3)	
Specificity (95% CI)	93.1 (89.1-95.8)		96.2 (92.9-98.0)		99.2 (96.9-99.8)		95.0 (91.4-97.2)		88.9 (84.3-92.3)		96.5 (93.3-98.3)	
PPV (95% CI)	83.4 (74.8-89.6)		93.1 (87.3-96.4)		97.9 (92.0-99.6)		90.5 (84.0-94.6)		81.6 (74.5-87.1)		94.0 (88.7-97.0)	
NPV (95% CI)	80.7 (75.7-84.9)		94.8 (91.2-96.9)		82.5 (78.1-86.7)		90.9 (86.7-93.9)		92.1 (87.9-95.0)		97.6 (94.8-99.0)	
LR + (95% CI)	8.8 (5.5-14.1)		23.8 (12.9-43.9)		83.8 (20.9-335.2)		16.8 (9.8-28.7)		7.8 (5.5-11.1)		28.0 (14.7-53.3)	
LR - (95% CI)	0.41 (0.34-0.51)		0.09 (0.05-0.16)		0.36 (0.29-0.45)		0.17 (0.12-0.25)		0.15 (0.1-0.22)		0.04 (0.01-0.09)	
Accuracy %	81.3		94.1		86.4		90.7		88.1		96.3	

## Evaluation of *sdaA* LAMP Assay for diagnosis of tuberculosis



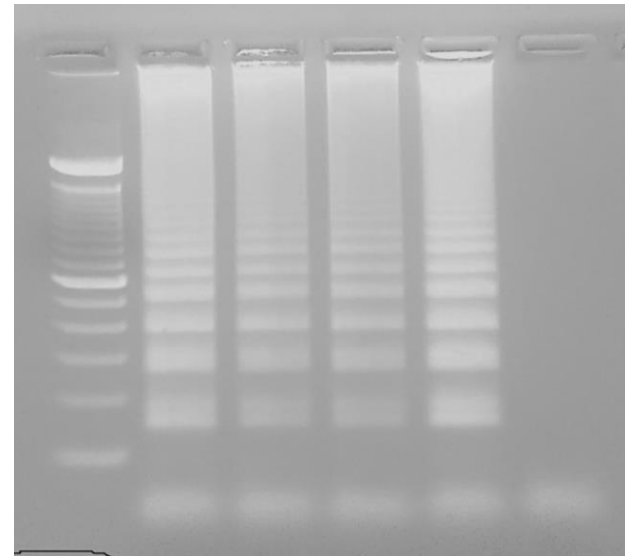
**Visual LAMP results for specimens with negative and positive control**

# Drawbacks of current LAMP assay

- **DNA extraction from clinical samples is required.**
  - Tedious method
  - Require special facility
  - Involves several centrifugation steps
- **Cause of variation**
- **Expertise required**

# CENTRIFUGATION FREE PROTOCOL FOR DNA EXTRACTION

- Solubilization of sputum
- Lysis of bacteria ←
- Extraction of DNA ←
- Partial purification of DNA ←



LAMP assay using MTB positive sputum



# Need for new point-of-care tests

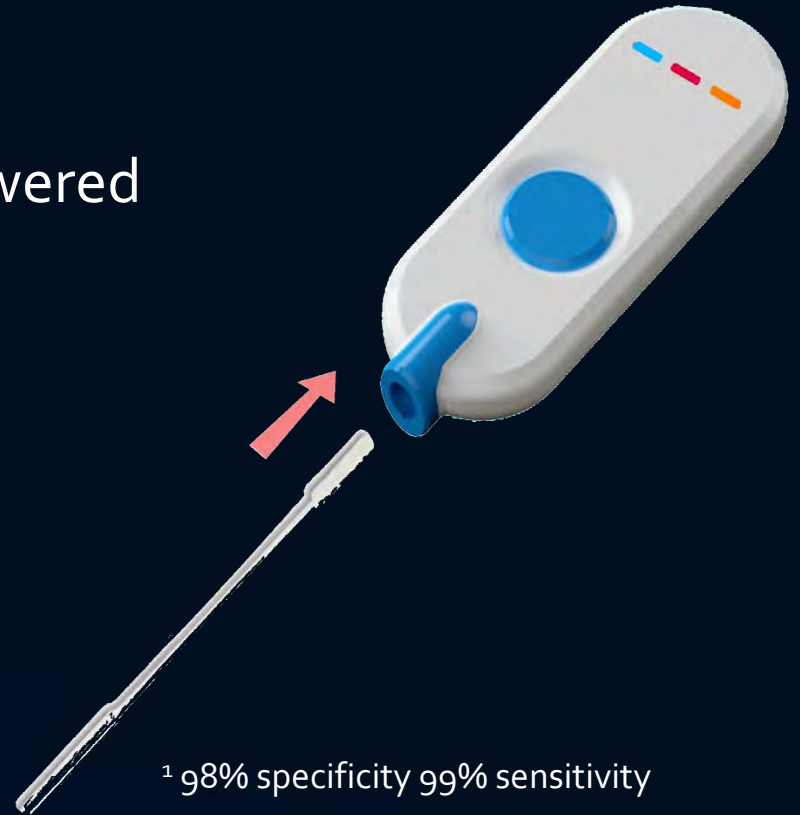
- Some POCT platforms exist but they are expensive and only semi-portable and do not lend themselves to field use
- Cepheid X-pert for TB and rifampicin resistance (GeneXpert MTB/RIF)
- Urine based lateral flow antigen test, Determine TB lipoarabinomannan antigen test, has been developed (Alere) and provides a rapid result at low cost (\$3-5/test) but it is only 28% sensitive (Lawn et al. 2012) in culture positive individuals (higher in HIV patients) and still investigation
- Renewed interest in POCT using microfluidics, biosensors and nanotechnology
- Despite considerable improvements in diagnostics for the last few decades, a simple and effective POCT for TB is not yet available

# POCT molecular device

- Swab in and answer with rapid results (20 minutes)
- Use isothermal amplification (no thermal cycling)
- Three steps including lysis and release of nucleic acid, amplification and detection
- Fully integrated, no instrument and no training required

# Point of use requirements

- Single use, totally disposable
- Fully self contained / Self-powered
- No training needed
- Highly accurate<sup>1</sup>
- Rapid swab to result
- Highly economical

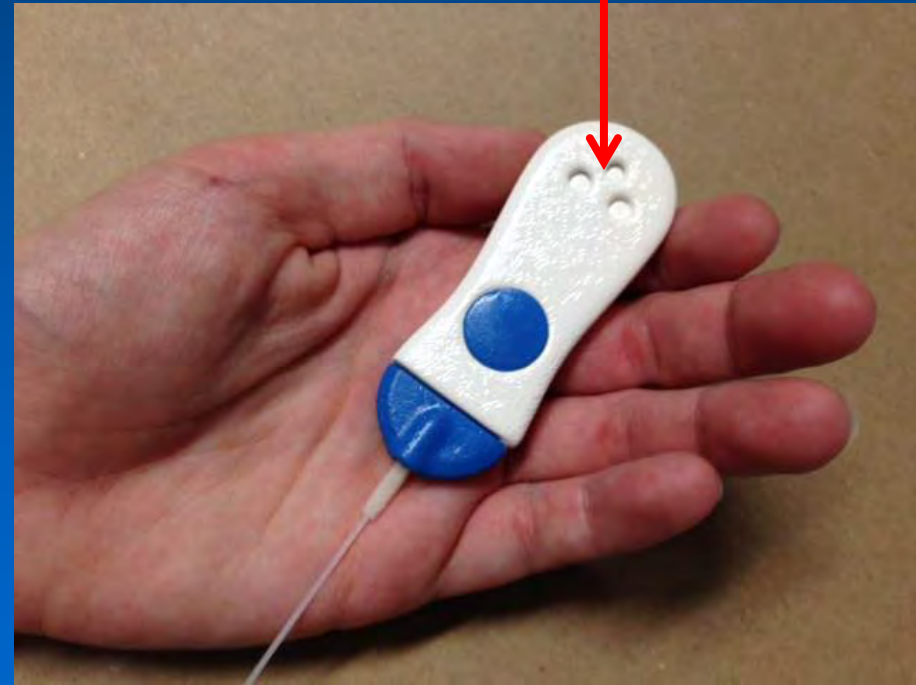


# Industrial design of POCT device

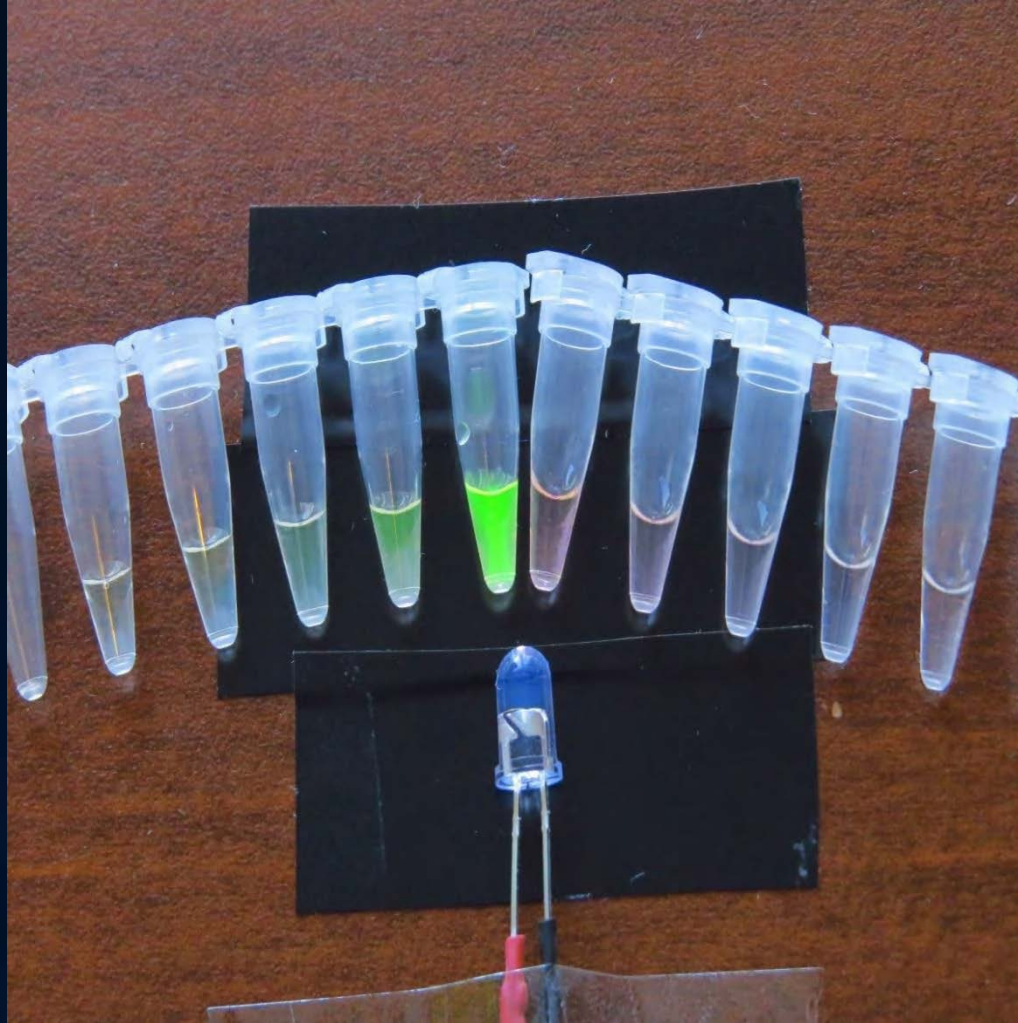
Swab entry

20 minutes

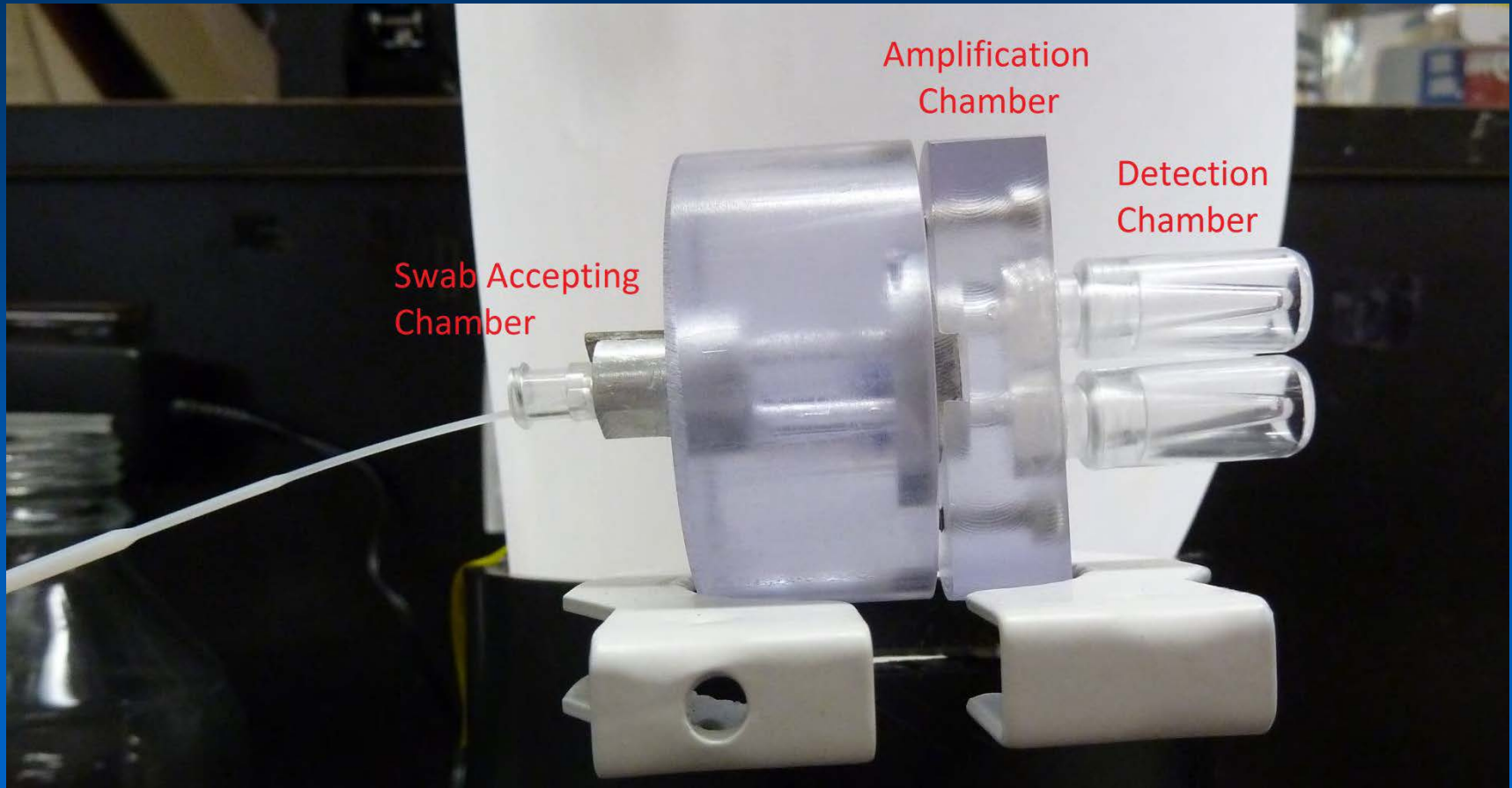
Read out windows



# Detection using LED for visual readout



# Working prototype device



Self-regulated heaters 93o C for lysis and 65o C for amplification

# Proof of Concept device results

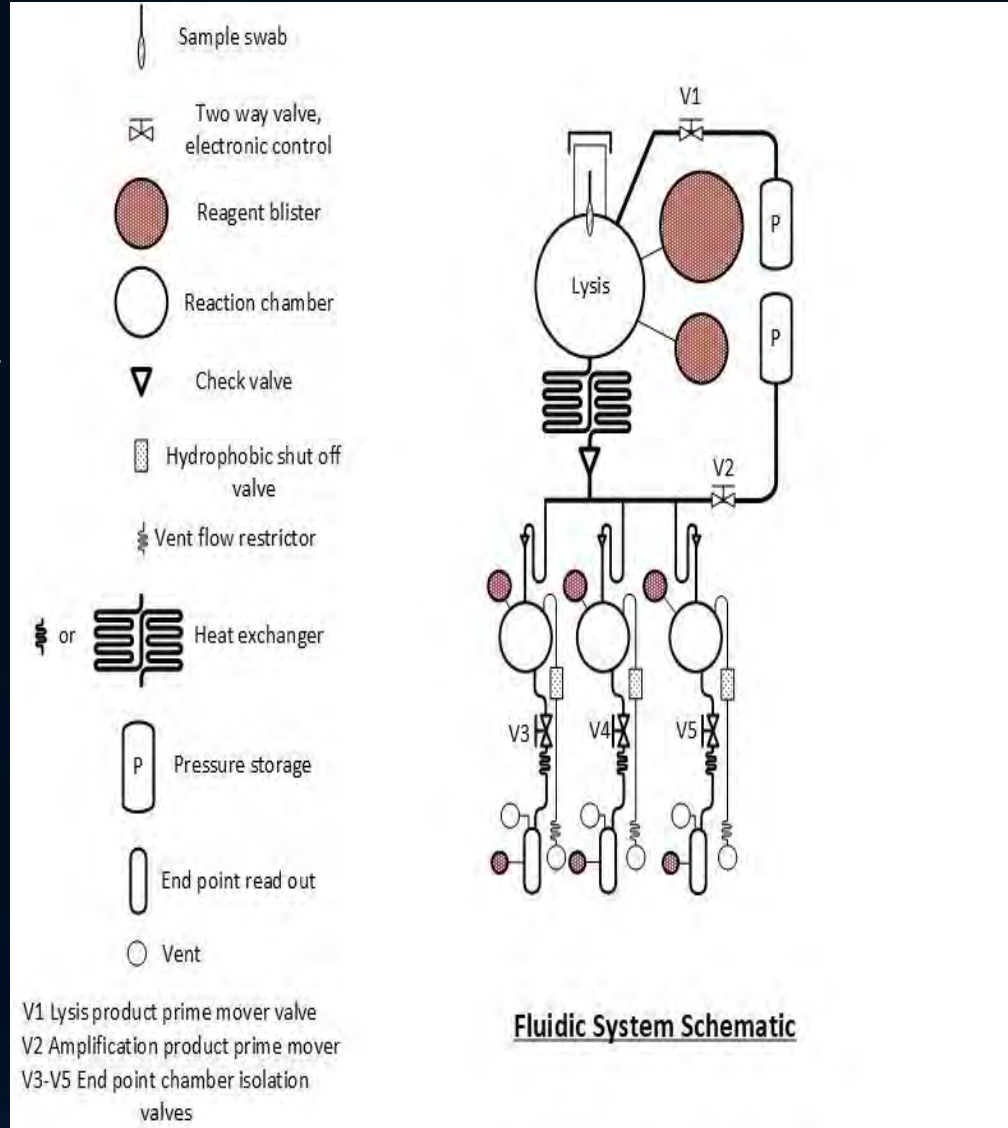
Test Type	Number of tests	Concordance with <sup>1</sup> standard methods (%)
Influenza	63	100
Chlamydia	17	100
Strep A	4	100
RSV	11	100
Patient Negative	47	100

<sup>1</sup>Influenza, RSV: RT-PCR, Chlamydia: PCR, Strep A: culture

# Fluidic System Schematic

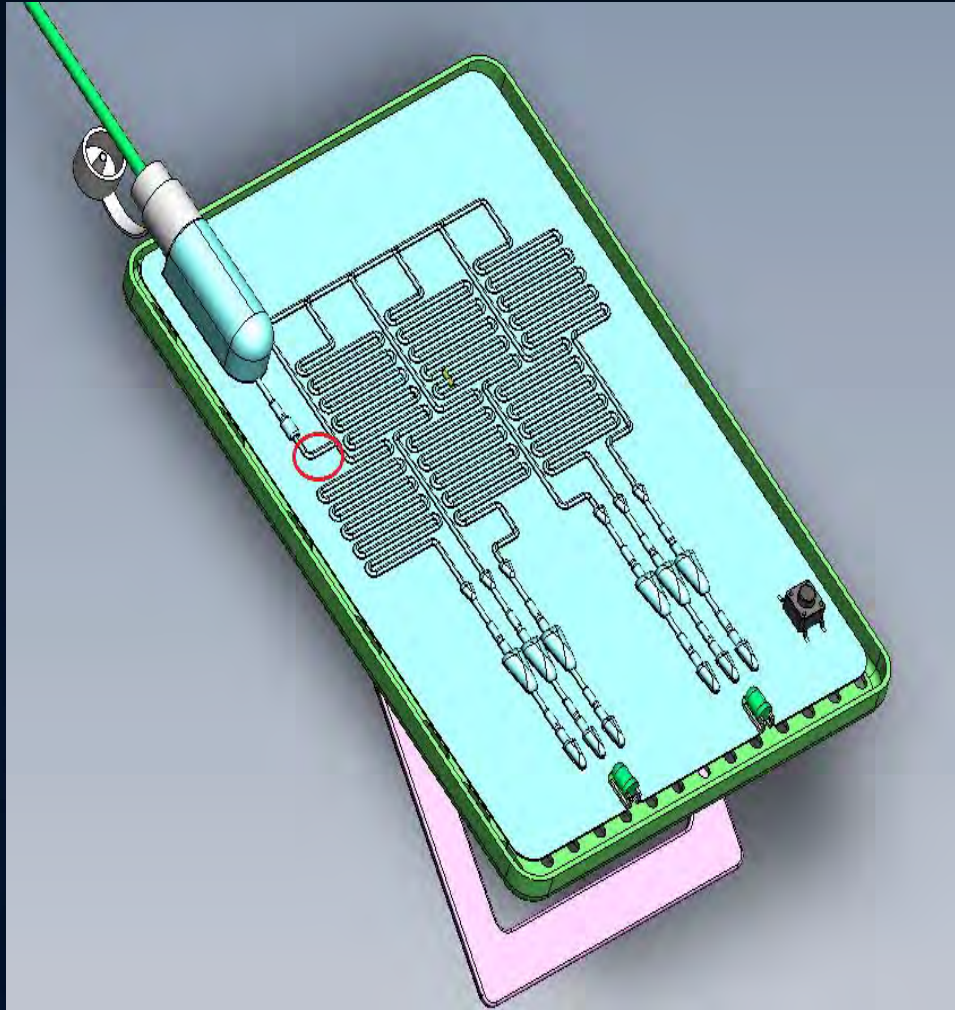
Fluid movement options (pressure, vacuum, capillary action)

Self-regulated heaters below lysis and amplification chambers not shown



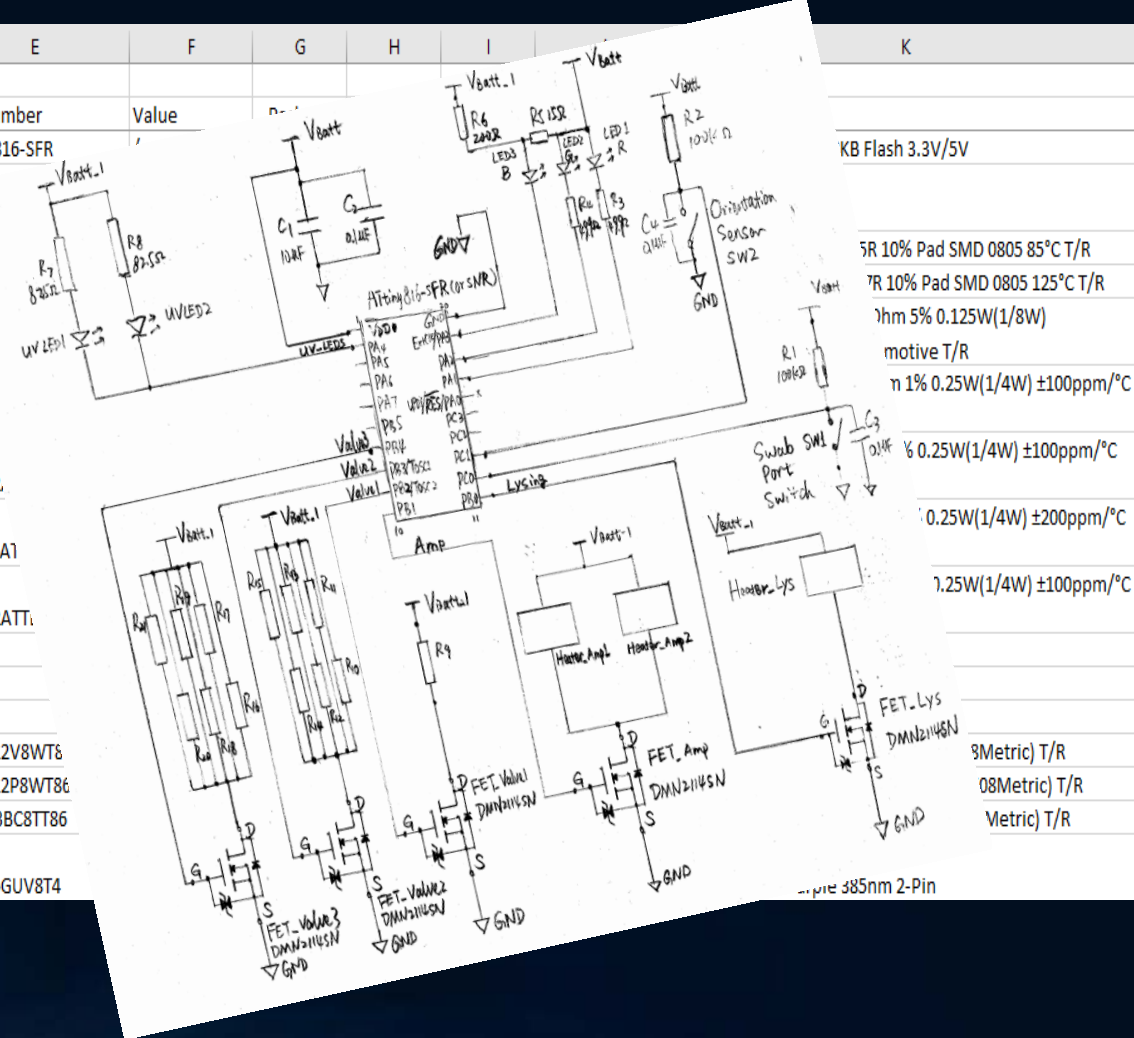


# Early microfluidics design stage with 6 channels



# PRODUCT DEVELOPMENT - ELECTRONICS

No.	Type	Quantity	Designation	Part Number	Value
1	MCU	1	U1	ATtiny816-SFR	
2	Capacitor	C1, C2, C3, C4	C		
3	Resistor	2 R1, R2	ERJ-		
4		2 R3, R4	RK73H		
5		1 R5	RK73H2		
6		1 R6	RK73B2A1		
7		2 R7, R8	RK73H2ATT		
8	Switch	1 SW1			
9		1 SW2-Orient			
10	LED	1 LED1	SML-D12V8WT8		
11		1 LED2	SML-D12P8WT86		
12		1 LED3	SMLA13BC8TT86		
13		UVLED1, UVLED2	VAOL-5GUV8T4		



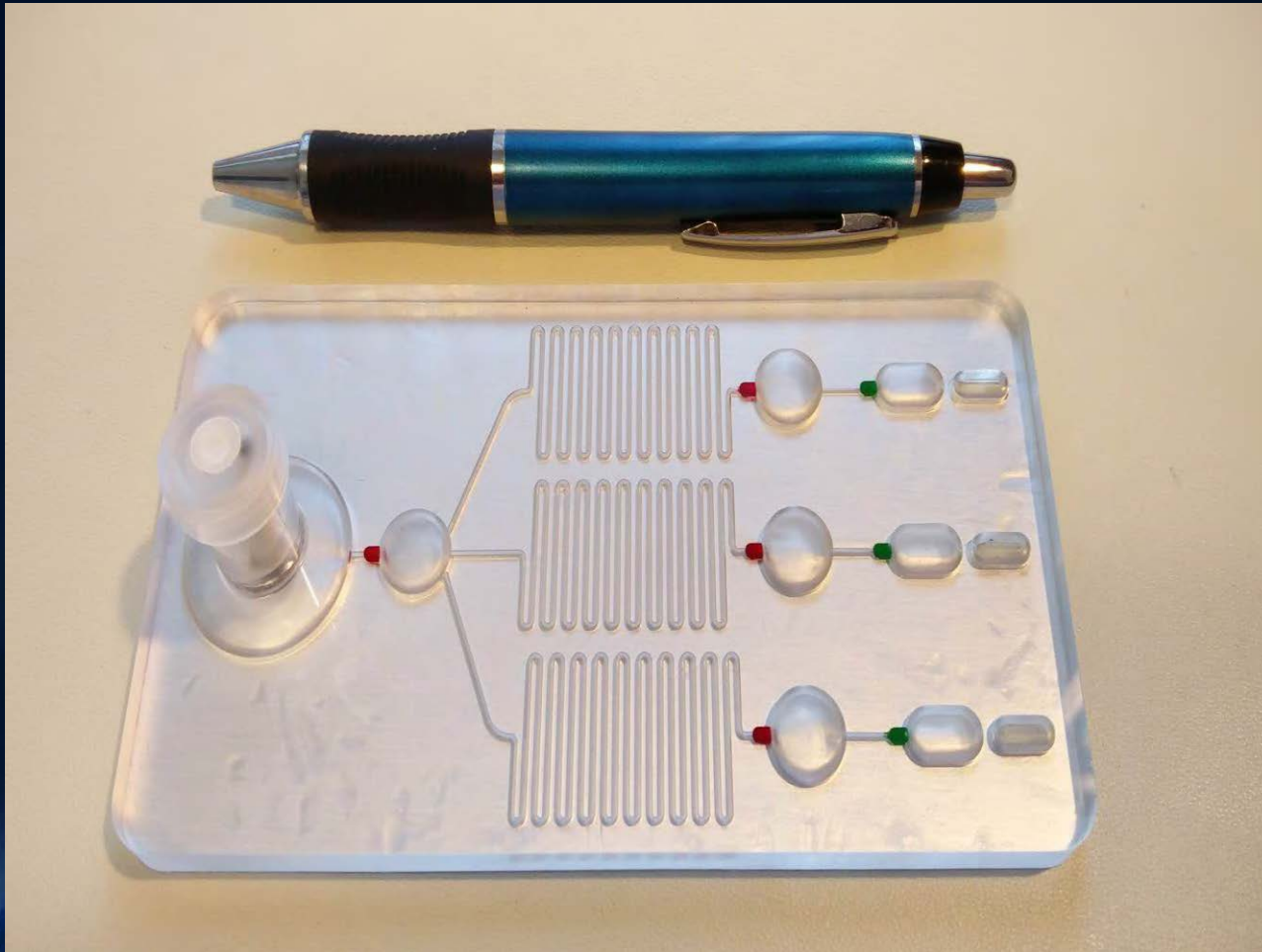
- KB Flash 3.3V/5V
- 5R 10% Pad SMD 0805 85°C T/R
- 7R 10% Pad SMD 0805 125°C T/R
- 1hm 5% 0.125W(1/8W) motive T/R
- n 1% 0.25W(1/4W) ±100ppm/°C
- % 0.25W(1/4W) ±100ppm/°C
- 0.25W(1/4W) ±200ppm/°C
- 1.25W(1/4W) ±100ppm/°C
- 8Metric) T/R
- 08Metric) T/R
- Metric) T/R

# Sputum processing challenges

- Inhibitors of amplification present in sputum, blood, urine and fecal specimens
- Amplification also inhibited by reagents used to remove specimen inhibitors
- Inhibitor removal will be essential for POCT device
- Experiments ongoing to liquify sputum and remove inhibitory substance with a Specimen Processing Adaptor (SPA) that will connect with swab entry chamber

# COMPLETELY INTEGRATED AND FULLY FUNCTIONAL (MVP) - DEVELOPMENT STAGE PHYSICAL PROTOTYPE, 3-6 CHANNELS

Swab  
acceptor  
and/or  
SPA



Result  
windows

# Summary

1. TB is difficult to diagnose and a rapid, sensitive POCT device for use in the field would be beneficial for developing countries
2. We have designed a working proof of concept POCT device for detecting infectious agents that provides a swab in and result out answer in 20 minutes
3. This POCT device performs pathogen lysis, isothermal amplification and detection without any instrumentation or user training
4. A fully integrated prototype (MVP) is being engineered with self-regulated heaters and microfluidics to provide devices for pre-clinical and clinical trials (Q4/2018)
5. Once approved for clinical use this POCT device may help with global control of TB infections

# BIOREMEDIATION

## *A GREEN TECHNOLOGY*



- PROF. RAMESH KANWAR, LOVELY PROFESSIONAL UNIVERSITY**  
**PROF. NEETA RAJ SHARMA, LOVELY PROFESSIONAL UNIVERSITY**  
**PROF. JOGINDER SINGH, LOVELY PROFESSIONAL UNIVERSITY**  
**PROF. SANJAY PAL, AMRITA UNIVERSITY**  
**DR. K. KHAJANCHI, INDIAN AGRICULTURAL RESEARCH INSTITUTE**  
**PROF. SHIV PRASHAR, MCGILL UNIVERSITY**  
**PROF. JASWINDER SINGH, MCGILL UNIVERSITY**  
**PROF. RAMESH RUDRA, UNIVERSITY OF GUELPH**





# BIOREMEDIATION

*A GREEN TECHNOLOGY*

## The Team



Lovely Professional University (LPU), Phagwara, Punjab, India

McGill University, Canada

Indian Agriculture Research Institute (IARI), Pusa, New Delhi, India

Amrita Vishwa Vidyapeetham, Kollam, Kerala, India

University of Guelph, Ontario, Canada



श्रद्धावान् लभते ज्ञानम्

**AMRITA**  
VISHWA VIDYAPEETHAM  
UNIVERSITY



भाकृअनुप  
ICAR



**McGill** 2



# BIOREMEDIATION

## A GREEN TECHNOLOGY



### **IC-Impact Project Title:** An Innovative green technology for treating municipal and industrial wastewater entering rivers and streams

#### **Key Objectives:**

- 1. To characterize Budda Nala Drain Wastewater (most polluted in northern India) Draining into Sutlej River in Northern India**
- 2. To convert agricultural biological waste material (rice straw/rice husk) into biochar, characterize bochar, and use for wastewater clean up**
- 3. To isolate microbes from Budda Nala drain that are capable of cleaning contaminants (heavy metals, textile dyes etc.) from wastewater.**
- 4. To develop “innovative green technology for cleaning municipal and industrial wastewater entering streams using microbial biofilm concept to develop bioreactors or floating wetlands**



## Accomplishments of this project to this point?

1. Six bacteria capable of removing contaminants from Budda Nala were isolated and metabolites from this treatment process were to be safe to the aquatic environment
2. Biochar was prepared from rice husk and rice straw at different temperatures, characterized, and was successful in removing heavy metals, BOD, textile dyes etc.
3. 1Mx1M Biofilter consisting of biochar and other biological materials was tested in wastewater drain and was found to remove significant amount of contaminants
4. Amrita university has developed a technique to prepare biofilm around biochar leading to the development of biofilter (a green technology) to remove in-situ water contaminants from rivers and streams
5. An International Conference was organized on Wastewater Cleaning Technologies jointly by project partners (LPU, McGill, Amrita U, IARI, and Guelph U) on Nov. 17-18, 2017 at LPU which was attended by 473 people with 100% participation of PIs.

A close-up photograph of fresh green tea leaves on the left side of the slide, with a soft-focus background of more tea plants. The text is overlaid on the right side of the image.

**Prof. Neeta Raj**  
**Lovely Professional University**  
**Phagwara, Punjab, India**

## The Background and Problem Stated...



**Site 1**  
Rich in industrial waste



**Site 2**  
Rich in dairy waste



**Site 3**  
Rich in industrial and domestic waste



**Site 4**  
Green Bridge



## Wastewater scenario

### In India:

✓ **Wastewater generation (Major cities): 38,354 MLD**

- Treatment capacity of 11,786 MLD only

✓ **Industrial wastewater :13,468 MLD**

- Treatment capacity of 8,081 MLD (Kaur et al., 2012)

### In Punjab:

✓ Sewage class generation I: 1,528 MLD

✓ Sewage treatment capacity of only 411 MLD (CPCB Report 2009 – 10)

Waste water restrains various pathogenic organisms which are interfaced to severe infectious & fatal diseases



## Different Technologies for Wastewater Management

- Coagulation-flocculation
- Activated carbon adsorption
- Ozonation and advanced oxidation processes
- Membrane processes
- Membrane bioreactor

- Above stated methods are incapable of removing endocrine disruptor chemicals.
- Need to develop an eco-friendly method which covers all the limitations of poor waste water management systems.

# Green Technology to Remove Pollutants



Industries disposing effluent into drain.



Buddha Nallah carries the industrial effluent, organic contaminants, domestic waste



Disperse Red 167  
(Dark red 2B)

**Disperse Red  
167.1  
(Rubine BL)**

Disperse Blue 60  
(Blue BG)

Disperse Red 54  
(Scarlet RR)



# Dye degradation assay and pathway elucidation

## 1. Collection of textile effluent and dye

## 2. Isolation of bacteria from textile effluent

- Synergistic activity of dye degrading bacteria
- Development of consortium

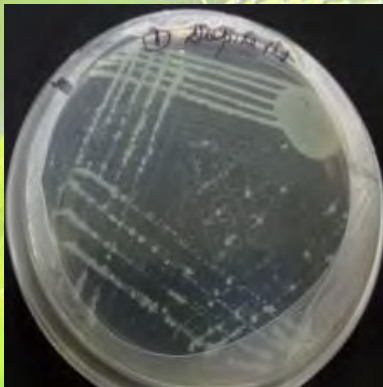
## 3. Dye decolorization assay

- Analysis of degraded products of dye

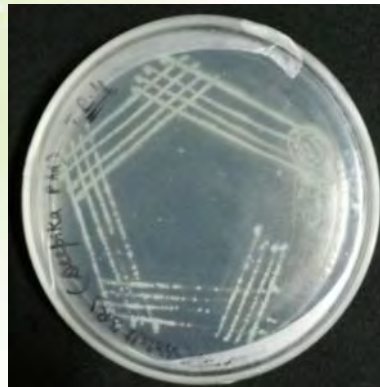
## 4. Molecular characterization of bacterial isolates

## 5. Extraction of metabolites after decolorization and pathway elucidation

## Six Efficient Dye Degrading Bacterial Isolates



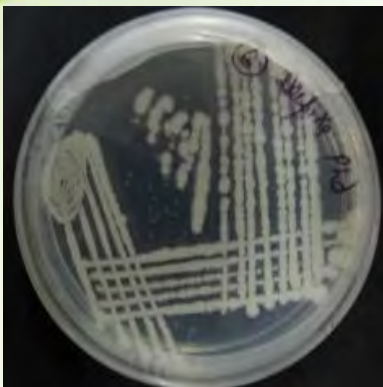
Isolate 1



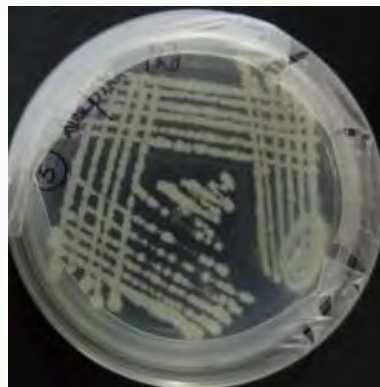
Isolate 2



Isolate 3



Isolate 4



Isolate 5



Isolate 6



# Dye Decolorization Assay obtained with respective Seven Isolates After 24 hrs. at 50 ppm



Disperse red 167



Disperse red 54



Disperse red 167.1

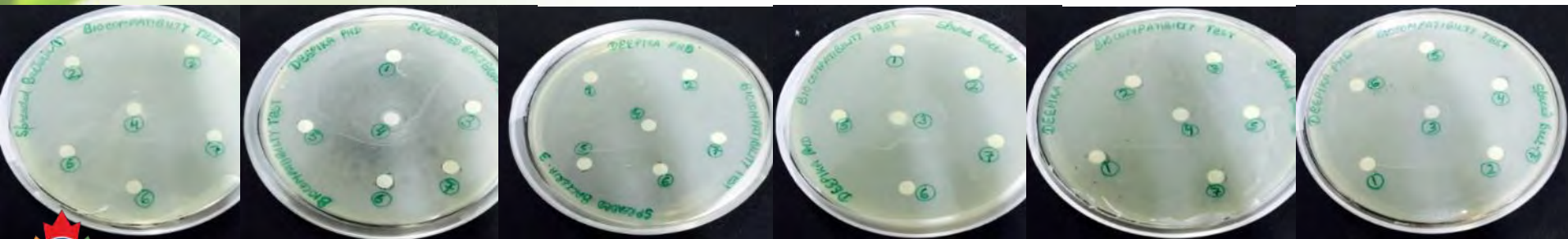


Disperse blue 60

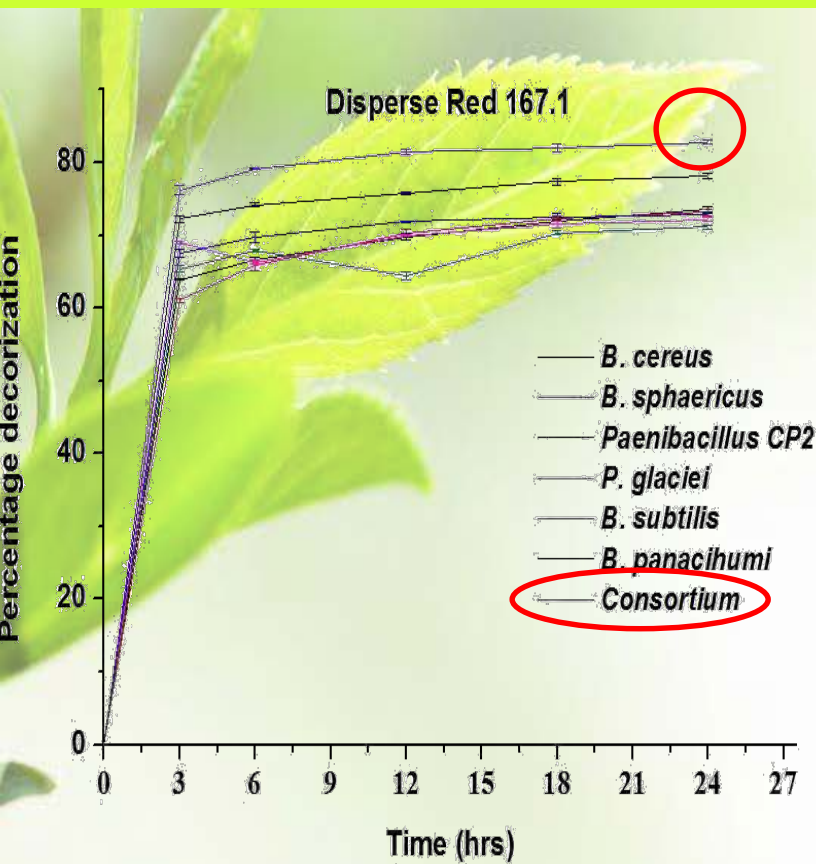
## Molecular identification of bacterial isolates

S.no	Bacterial sample	Molecular characterization	NCBI accession number
1	Isolate 1	<i>Bacillus cereus</i> strain AU50	KX034566
2	Isolate 2	<i>Bacillus sphaericus</i>	KX034564
3	Isolate 3	<i>Paenibacillus</i> sp. C-2	KX034565
4	Isolate 6 (4)	<i>Paenochrobactrum glaciei</i>	KX034561
5	Isolate 11 (5)	<i>Bacillus subtilis</i>	KX034562
6	Isolate 15 (6)	<i>Brevibacillus panacihumi</i>	KX034559

## Biocompatibility Test (Nikam et al. 2007)



## Enzyme Activities

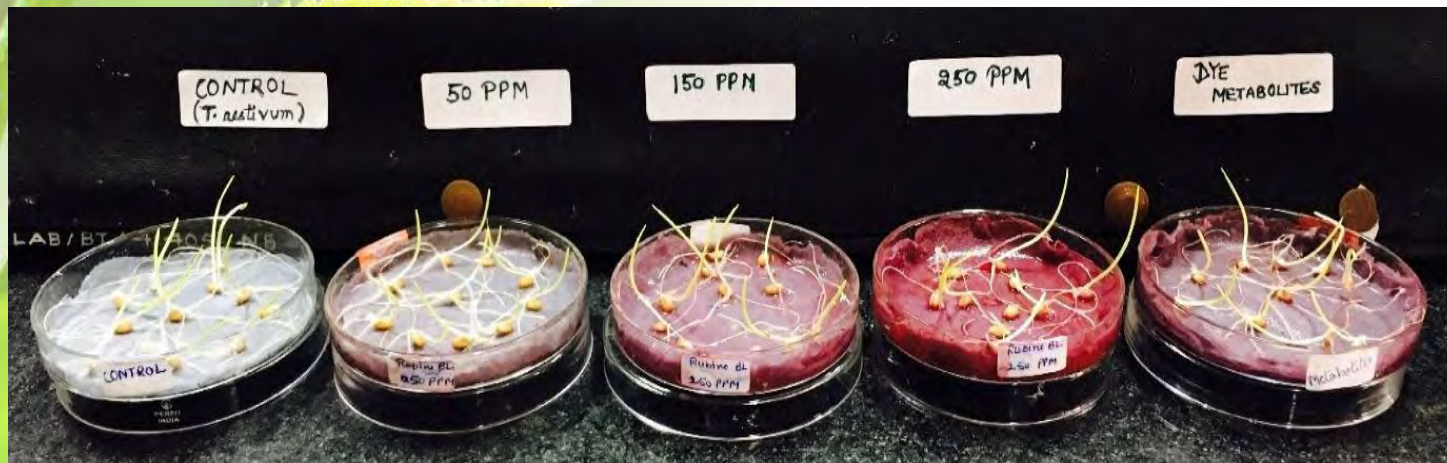


S.No	Micro-organisms	Laccase activity x	Azo reductase activity y
1.	<i>B.cereus</i>	0.94	3.81
2.	<i>B.sphaericus</i>	1.17	3.13
3.	<i>Paenibacillus</i>	1.94	4.76
4.	<i>P.glaciei</i>	2.03	6.12
5.	<i>B.subtilis</i>	0.76	0.91
6.	<i>B.panacihumi</i>	1.84	4.92
7.	<i>Consortium</i>	2.83	6.83

x  $\mu\text{M}$  of ABTS oxidized  $\text{mL}^{-1} \text{min}^{-1}$

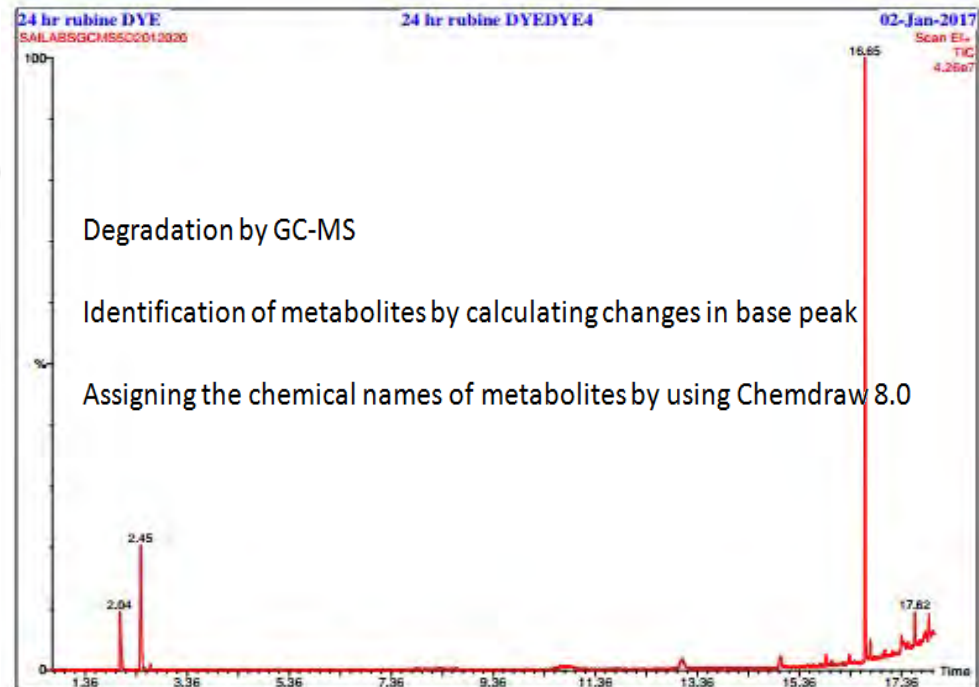
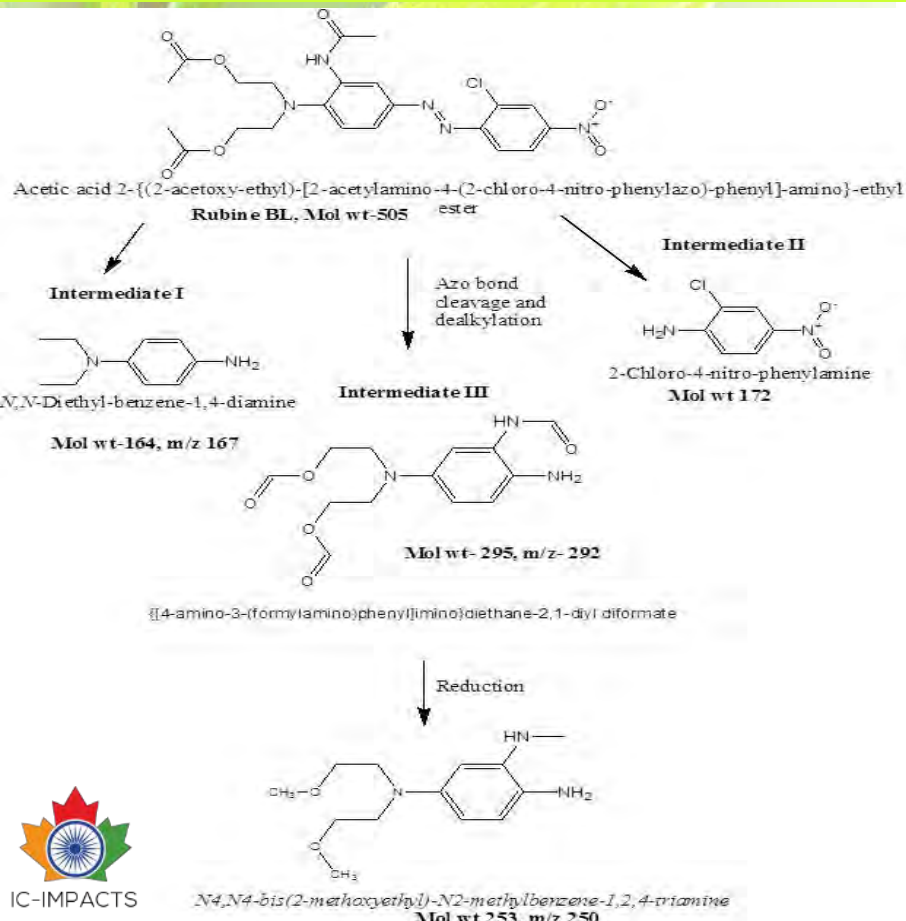
y  $\mu\text{M}$  of azo dye reduced  $\text{mL}^{-1} \text{min}^{-1}$

# Phyto-toxicity of Dye with Seed Germination Assay



Plant species	Treatment	Concentration	Germination (%)	Shoot length (cm)	Root length (cm)
<i>Triticum aestivum</i> (Wheat)	Disperse red 167.1 (Rubine BL)	50 mg/L	100	3	4.7
		150 mg/L	70	2.5	3.03
		250 mg/L	60	1.83	2.4
	Metabolites		90	3.2	4.03

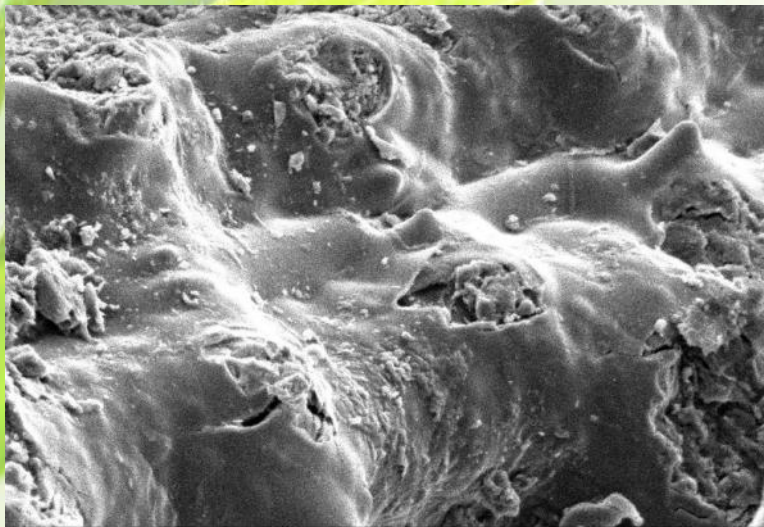
# Proposed Degradation Pathway for Disperse Red 167.1 (Rubine BL)



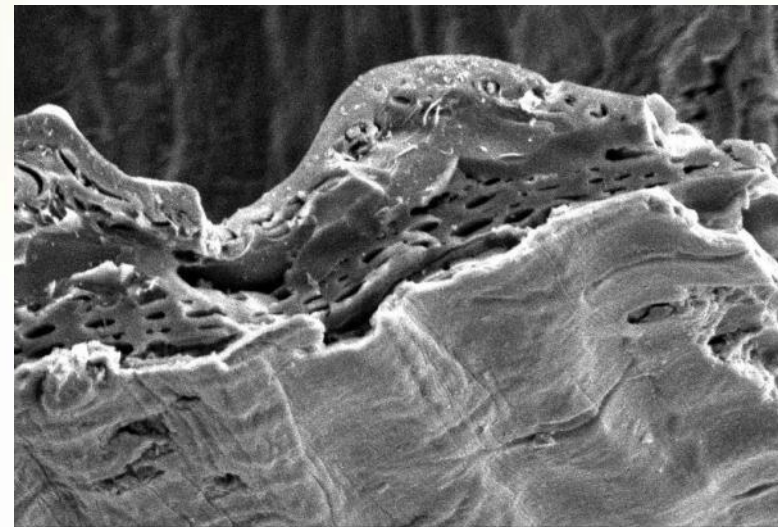
## Conclusion:

# Technology Development in the form of Bio-Filters

Immobilized rice husk biochar (consortium) and raw rice husk biochar



SEI 10kV WD10mm SS37 x1,000 10µm  
SAI Labs, Thapar Univ, Patiala G.Mourya 07 Aug 2017



SEI 10kV WD10mm SS37 x1,000 10µm  
SAI Labs, Thapar Univ, Patiala G.Mourya 07 Aug 2017

## Outcome:

Published article on “Biological methods for textile dye removal from wastewater: A review,  
In Critical Reviews in Environmental Science and Technology [Impact Factor=5.790]  
(DOI:-<https://doi.org/10.1080/10643389.2017.1393263>)

# In-situ Green Technology



## Onsite filtration set up

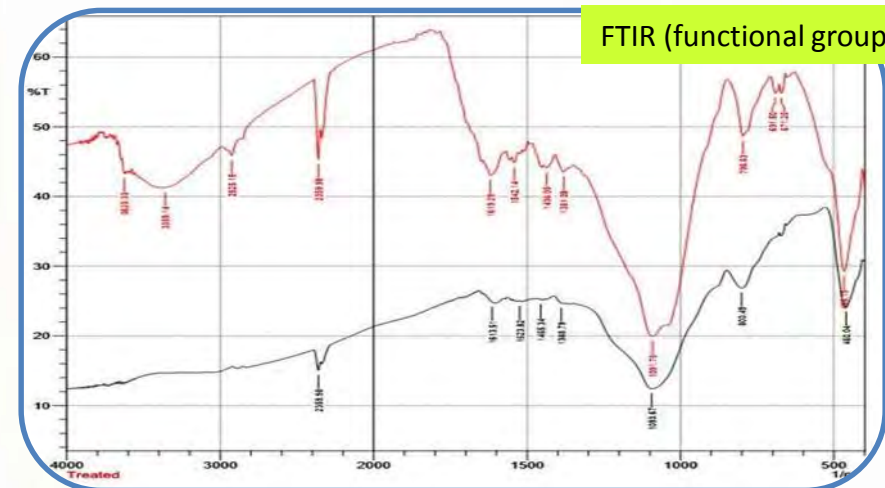


## Experimental Design

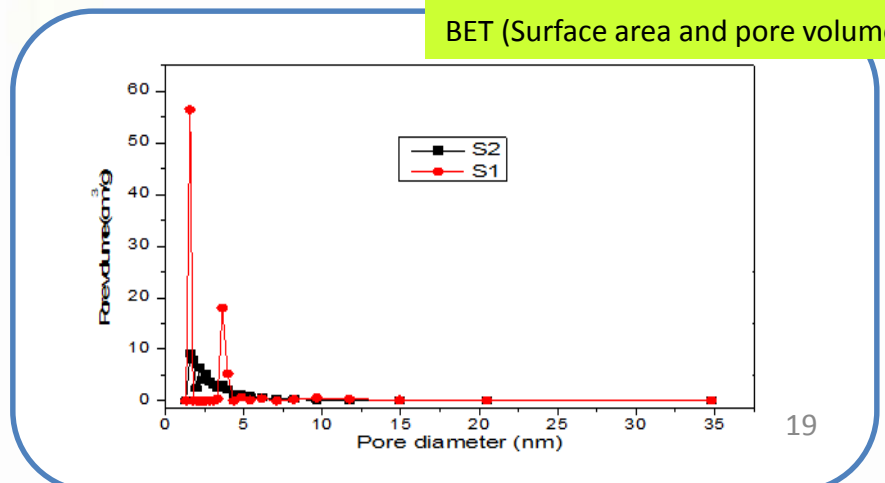
Metals	Adsorption Efficiency (%)
Zinc	80.86%
Lead	78.30%
Nickel	86.74%
Barium	21.79%
Iron	82.04%
Manganese	53.42%
Chromium	61.32%
Magnesium	5.52%
Calcium	17.80%
Copper	85.88%
Titanium	90.76%
Aluminium	77.92%

# Characterization of Biochar after Onsite Filtration Setup

FTIR (functional groups)



BET (Surface area and pore volume)

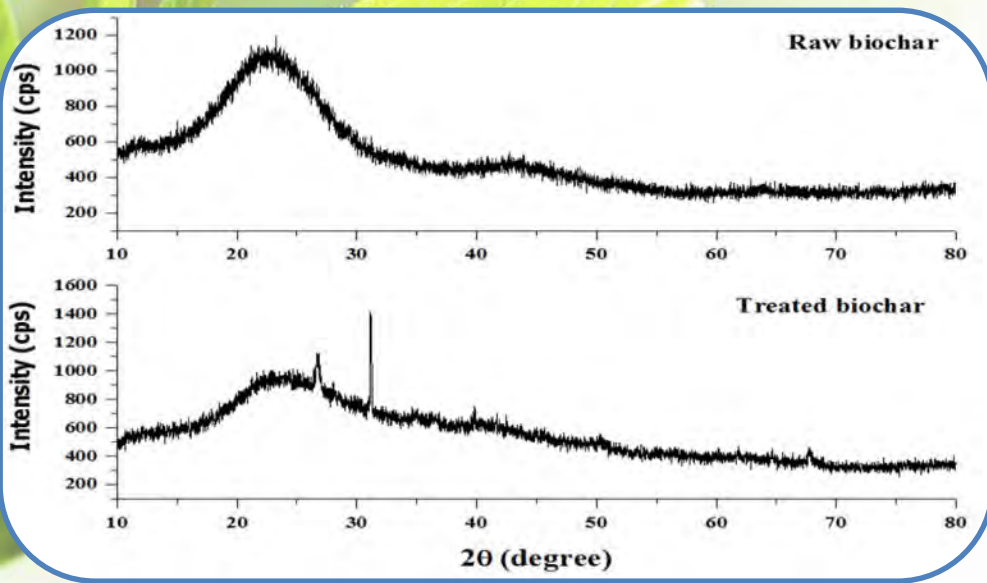


CHNS (Elemental analysis)

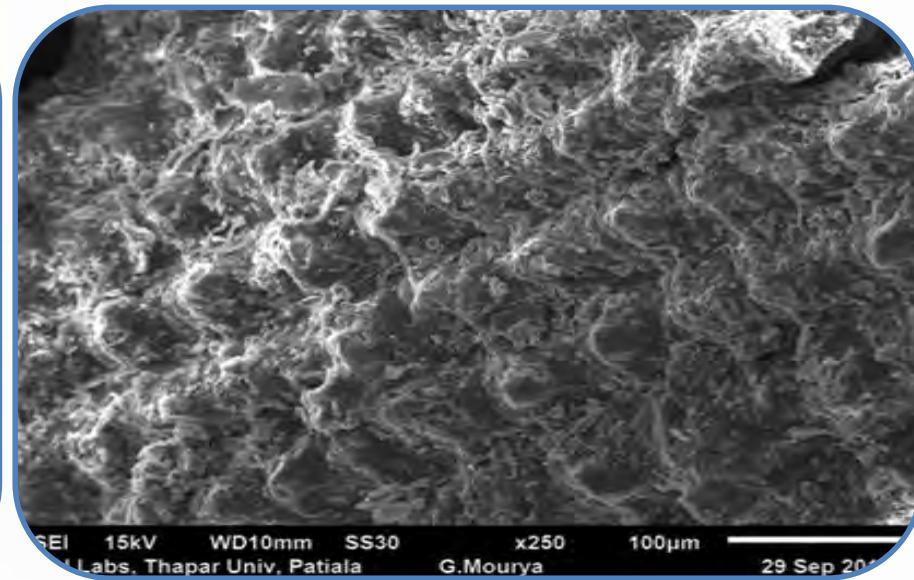
Elements	Raw biochar		Treated biochar	
	Element	Percentage/Mass	Element	Percentage/Mass
Carbon	53.61	4.467	47.60	3.96
Hydrogen	1.35	1.35	2.10	2.10
Sulphur	-----	-----	0.83	0.025
Oxygen	45.05	3.81	49.47	3.09
C/O ratio	1.19	-----	0.96	-----
C/H ratio	39.71	-----	22.66	-----



## Characterization of Biochar after Onsite Filtration Setup



XRD ( Structural properties)



SEM (Surface morphology)

# Removal of Ni by Rice Husk Biochar

## Characterization of Rice Husk Biochar

	pH (1:20)	EC (dS m <sup>-1</sup> ) (1:20)	CEC (Cmol(p <sup>+</sup> )kg <sup>-1</sup> )	C (%)	H (%)	N (%)
400°C	6.7	0.12	10.7	44.2	2.5	0.67
500°C	7.5	0.12	9.2	45.1	1.2	0.42
600°C	7.8	0.14	8.6	47.1	0.8	0.36

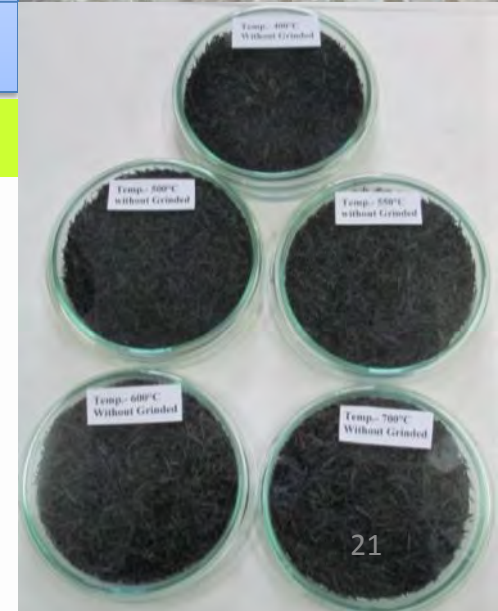


## Functional groups in biochar (FTIR)

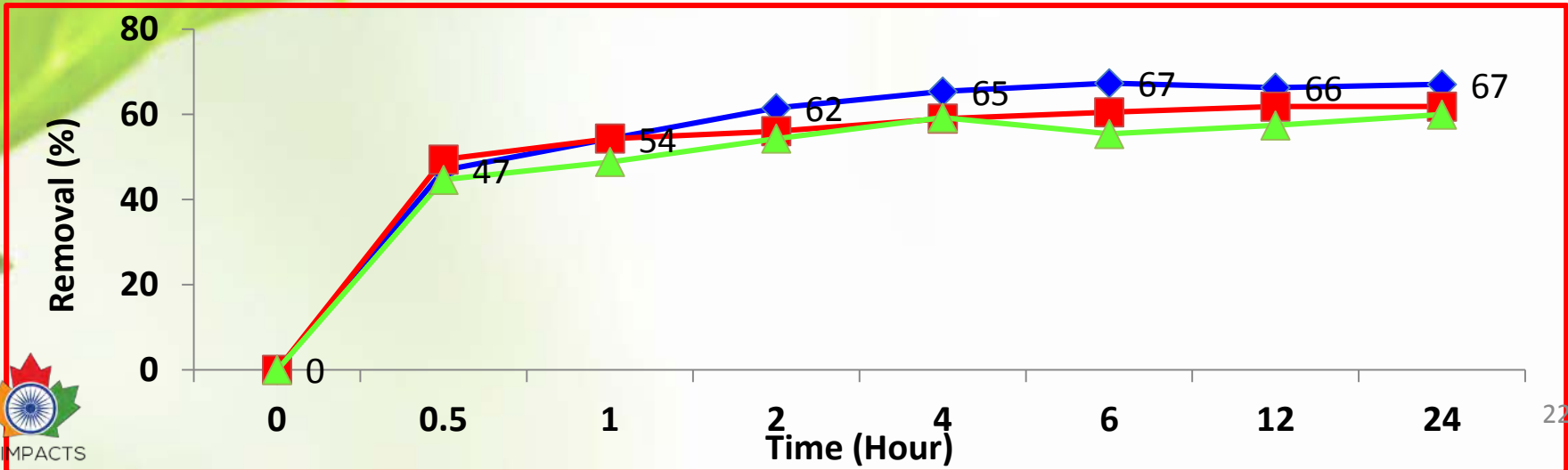
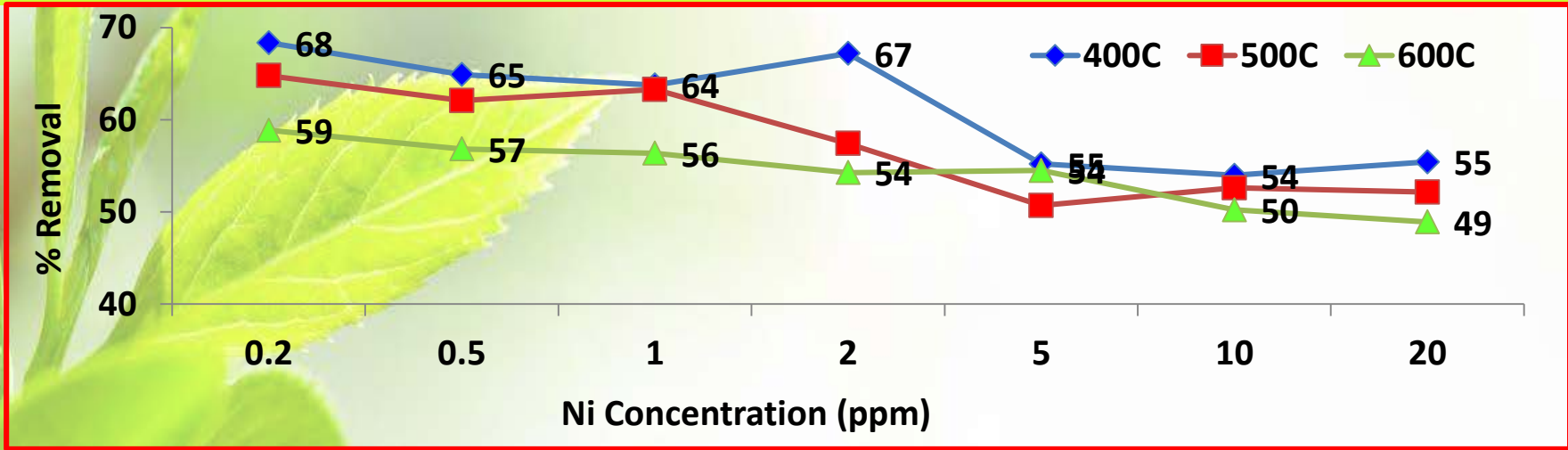
By Attenuated total reflection spectroscopy

- Peaks : 1421 - 1428 cm<sup>-1</sup>, phenolic OH
- Peaks: 1578 - 1617 cm<sup>-1</sup>, COOH, C=O and C=C plane aromatic vibrations.
- Peaks: 1105 - 800 cm<sup>-1</sup>, CO<sub>3</sub>

The peak (2923-3045 cm<sup>-1</sup>) corresponding to C-H disappeared with increase in temperature.



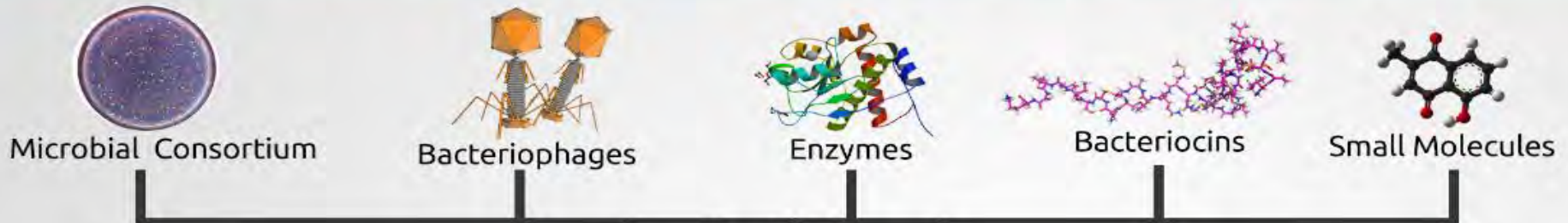
### Effect of Conc. and Contact Period on Ni removal by Biochar



A close-up photograph of fresh green tea leaves on the left side of the frame, with a soft, out-of-focus background of more tea plants. The text is overlaid on the right side of the image.

**Prof. Sanjay Pal**  
**Amrita University, India**

### BIO-CONTROL OF INFECTION & SMELL

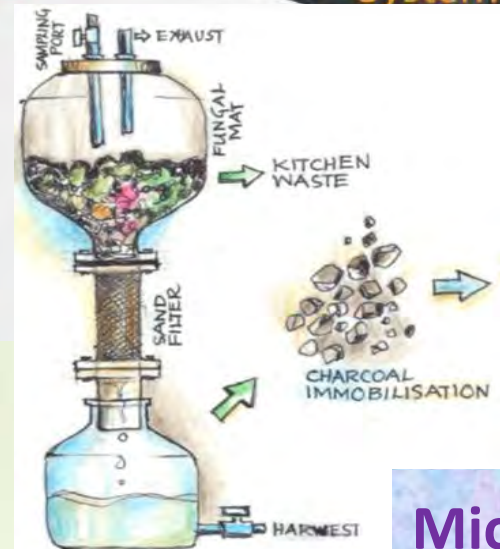


**INFECTION**

**Lytic Broadcasting System**

**MALODOUR**  
Sulfur Reducing Bacteria

- Bacteria**  
*V. cholerae*  
*E. coli, Shigella*
- Parasites**  
*Ascaris*



Phages filtered from fermenter



**Microbiome Engineering of Wastewater**

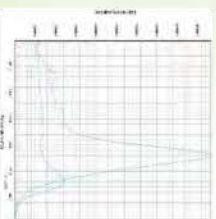
# Phage Stock Library



**Plaque morphology;  
Burst size**



**DNA/RNA**  
(lane 1-1kb marker  
DNA; lane 2 phage  
DNA)



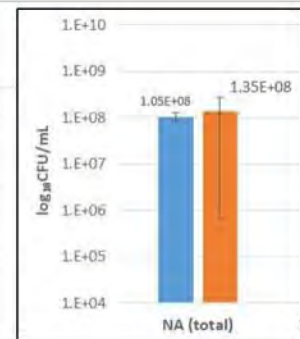
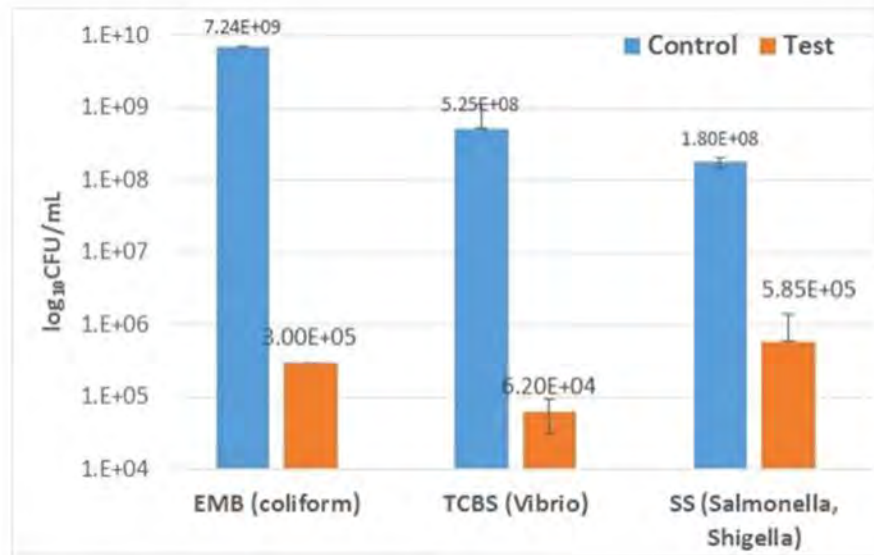
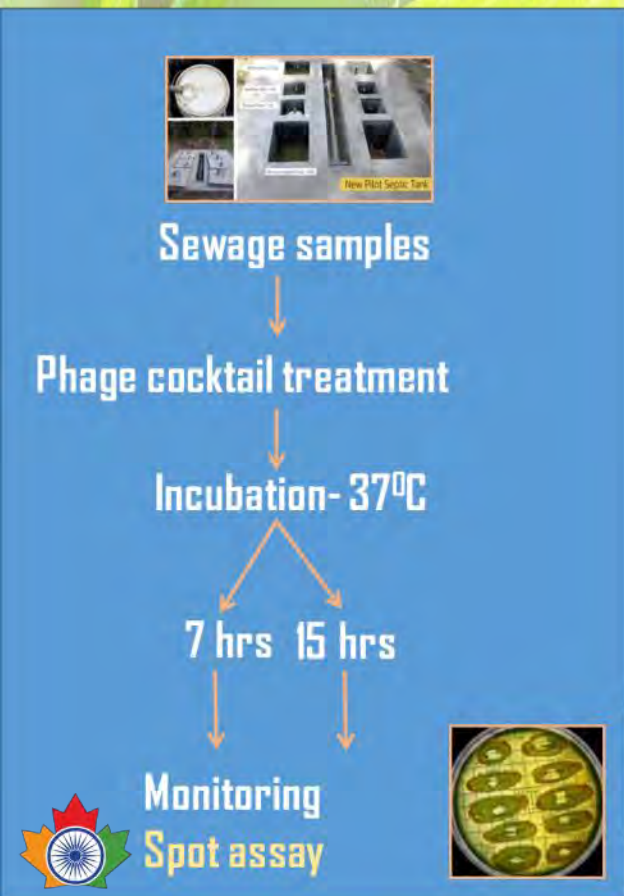
**Melting curve**



**Tropism:  
Narrow/broad  
spectrum**

Phages	Isolates	Best Titre (PFU/mL)
<i>E. coli (clinical)</i>	10	2x10 <sup>6</sup>
<i>E. coli (sewage isolate)</i>	02	2x10 <sup>3</sup>
<i>Shigella sp (clinical)</i>	10	5x10 <sup>8</sup>
<i>Ecoli-pBAD</i>	02	N.D.
<i>Salmonella (clinical)</i>	02	3.8x10 <sup>6</sup>
<i>Salmonella (sewage isolate)</i>	01	2x10 <sup>7</sup>
<i>Vibrio (sewage isolate)</i>	01	2x10 <sup>3</sup>
<i>Citrobacter braakii (SI)</i>	01	2x10 <sup>4</sup>
<i>Shigella flexneri (Ec)</i>	01	5x10 <sup>5</sup>
<i>Klebsiella pneumoniae (Zh)</i>	01	7x10 <sup>4</sup>
<i>Urease positive isolate</i>	01	2.6x10 <sup>9</sup>

# Application: Disinfection with phages



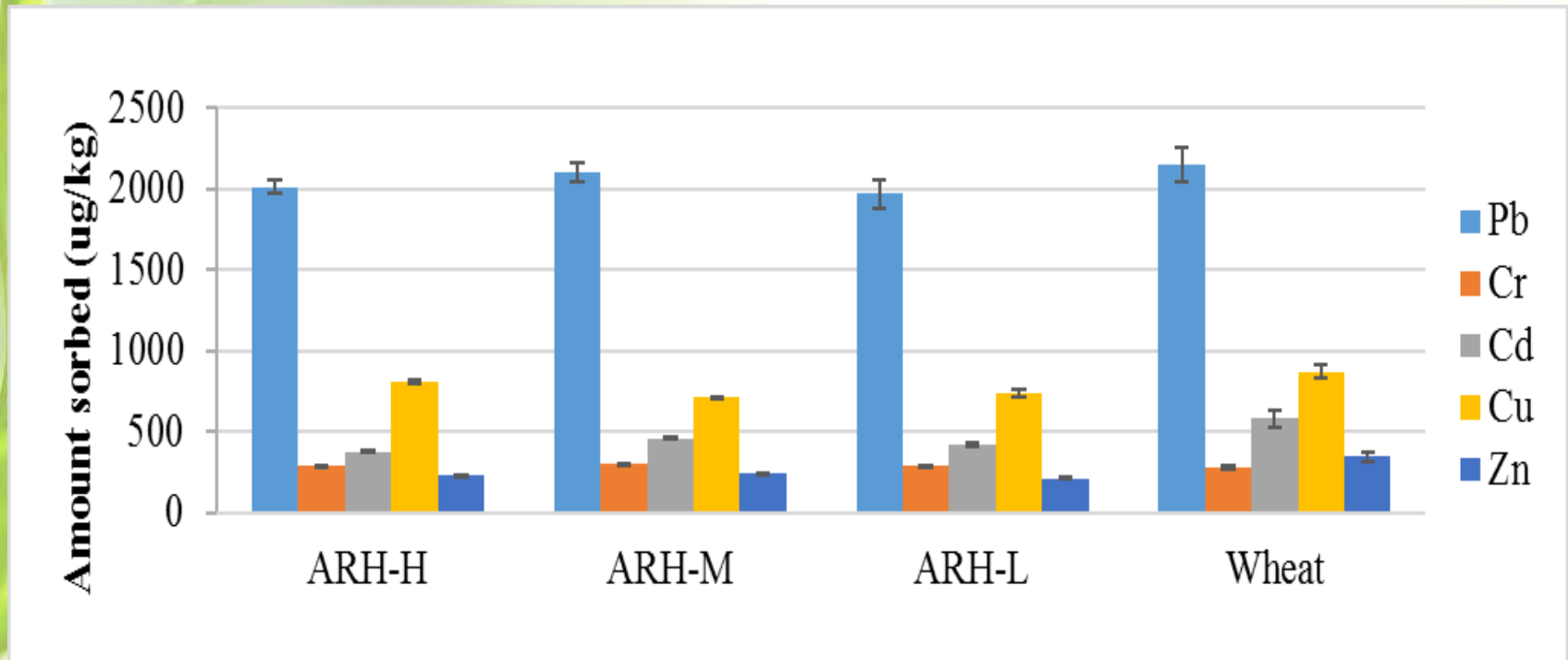
- **3-5 log reduction** with liquid formulation of phage cocktail (of 4 phages types)
- Experiment conducted **on sewage samples**

A close-up photograph of fresh green tea leaves on the left side of the slide, with a soft, out-of-focus background of more tea plants. The text is overlaid on the right side of the image.

**Shiv Prashar, McGill University**



# Heavy Metal Sorption by Rice Husk Biochar



**ARH-H** : activated rice husk, high temperature at 400 °C; **ARH-M**: activated rice husk, medium temperature at 340 °C; **ARH-L**: activated rice husk, low temperature at 280 °C; **WT**: Wheat straw, temperature at 550 °C

# Irrigation, Soil Sampling and other Measurements



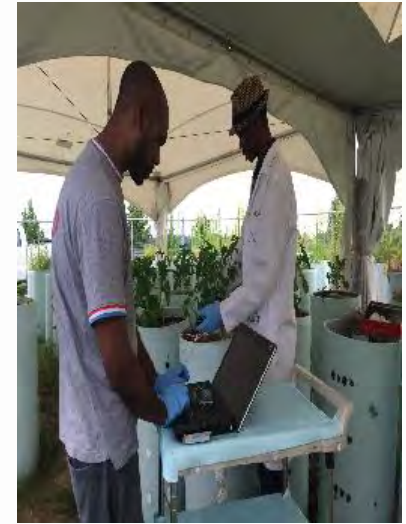
Wastewater  
Irrigation



Soil Sampling

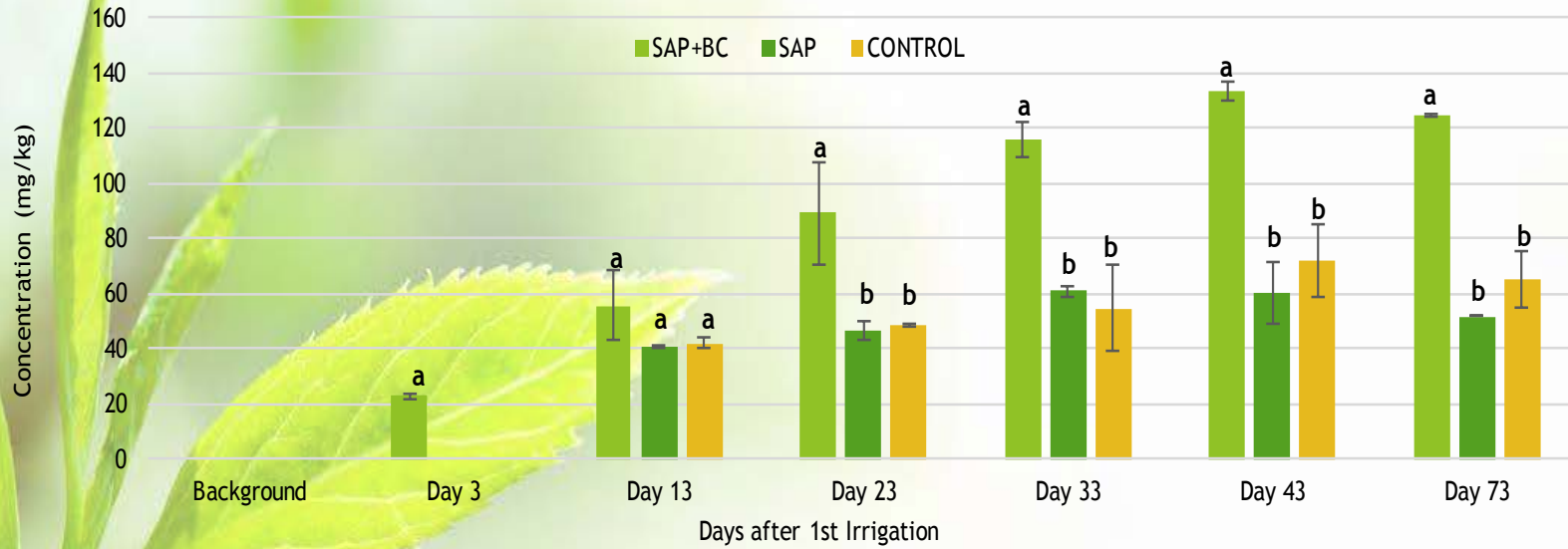


Moisture Content



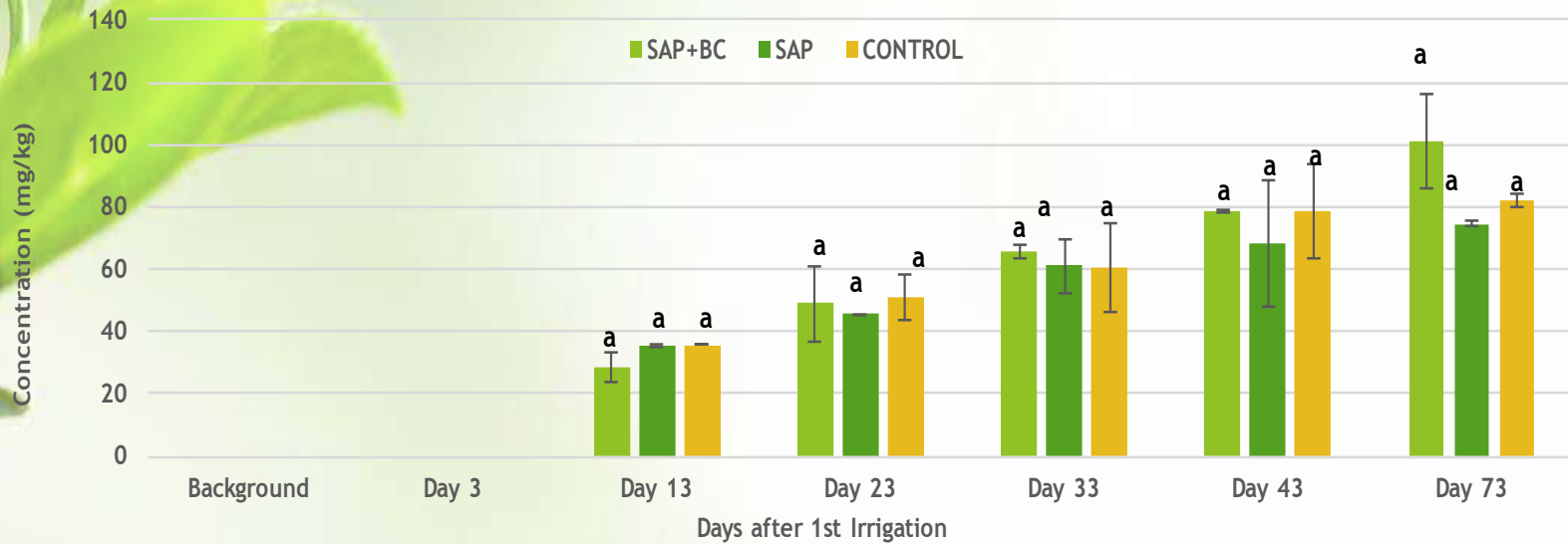
CO<sub>2</sub> Measurement

# Heavy Metals in Soil



**Cd**

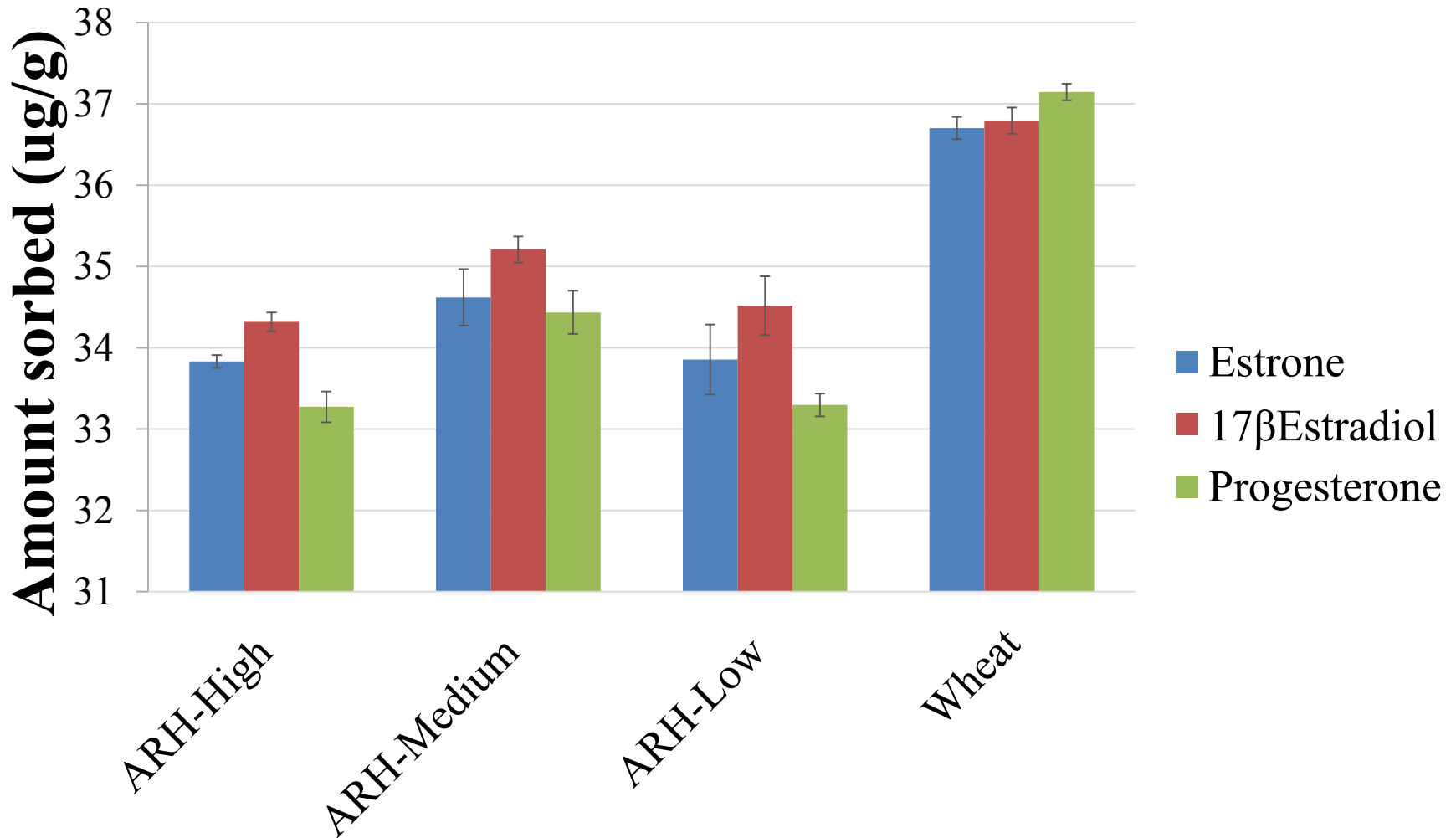
Not detected  
in depth 10 cm



**Cr**

Not detected  
in depth 10 cm

# Female Sex Hormone Sorption Laboratory Study

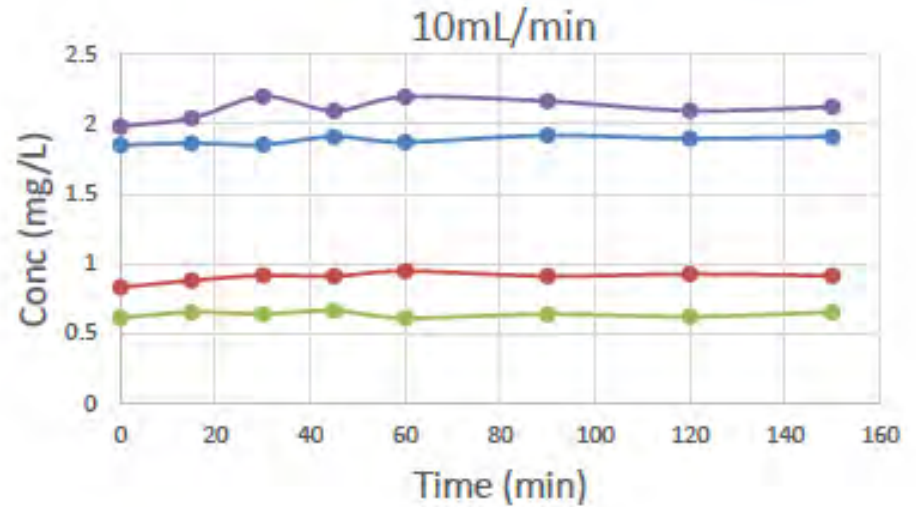
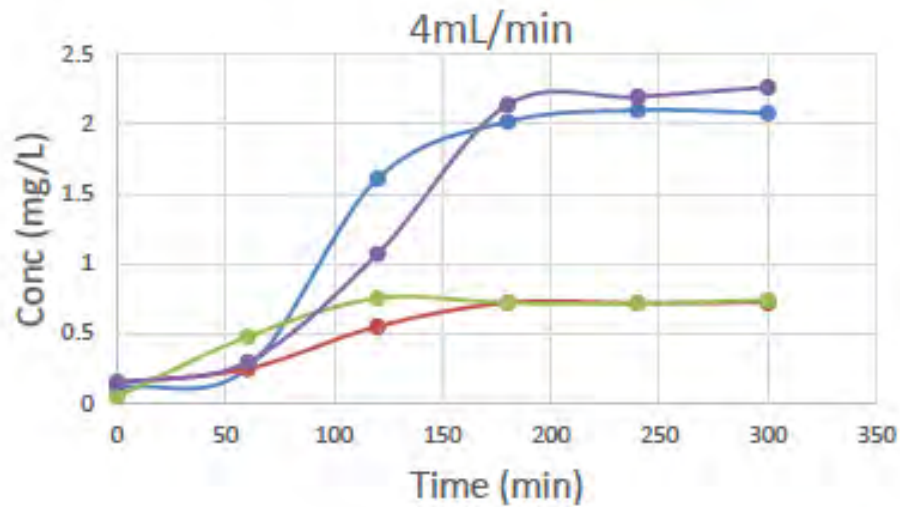
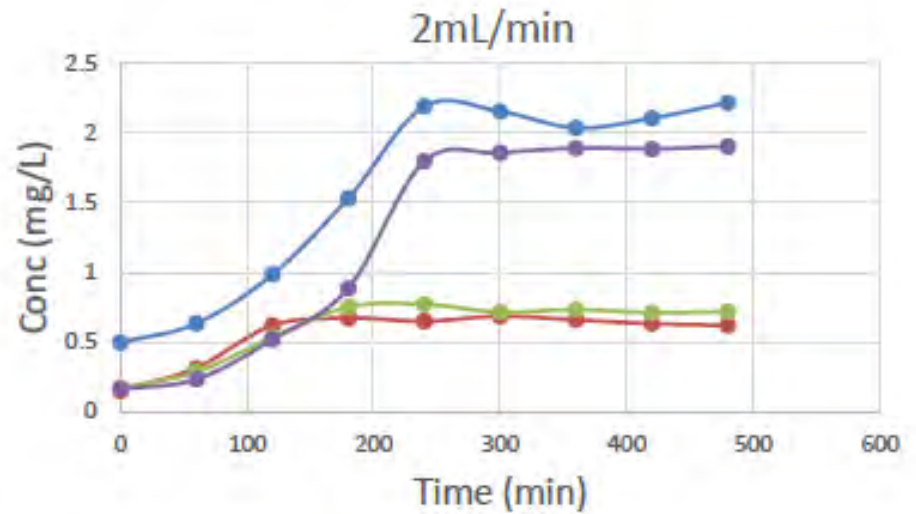
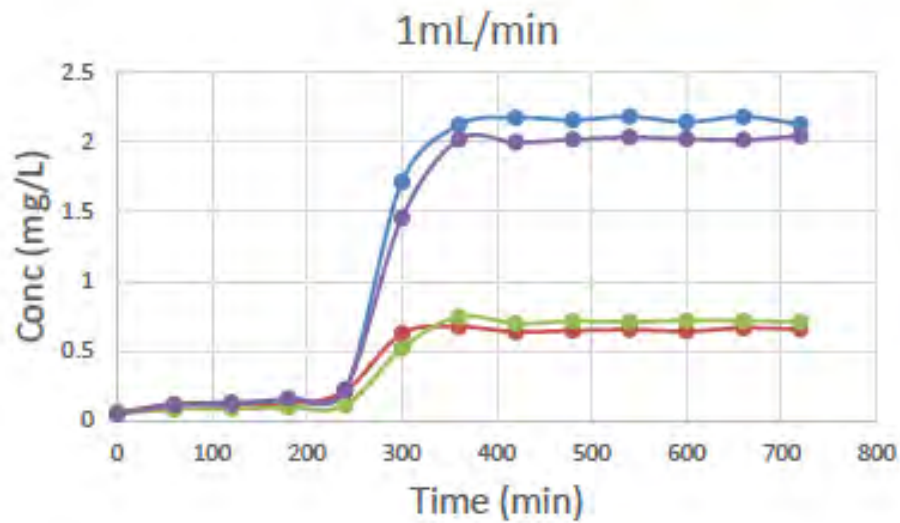


# Adsorption of Environmental Contaminants onto Rice Husk and Rice Straw Biochar

- Three columns
- Length = 15 cm
- Packed bed = 10 cm
- Biochar bed = 4 cm
- Diameter = 5/8 inch or 1.54 cm



# Results-Rice Straw



—●— Cadmium    —●— Chromium    —●— Zinc    —●— Copper



# BIOREMEDIATION

*A GREEN TECHNOLOGY*

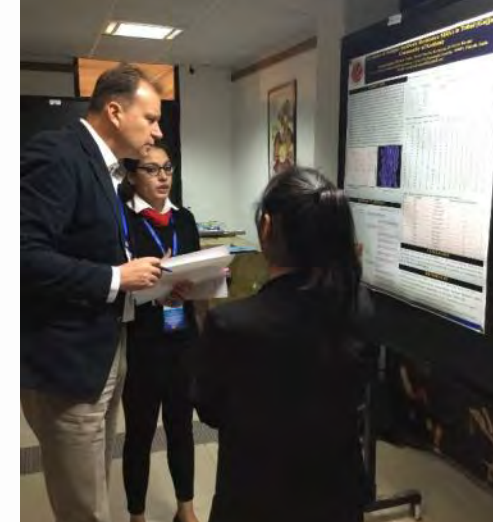


## PROJECT OUTCOME – Hosted ISSWM 2017 at LPU in November 17-18, 2017

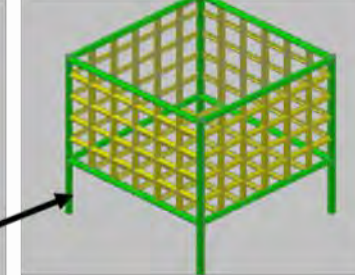
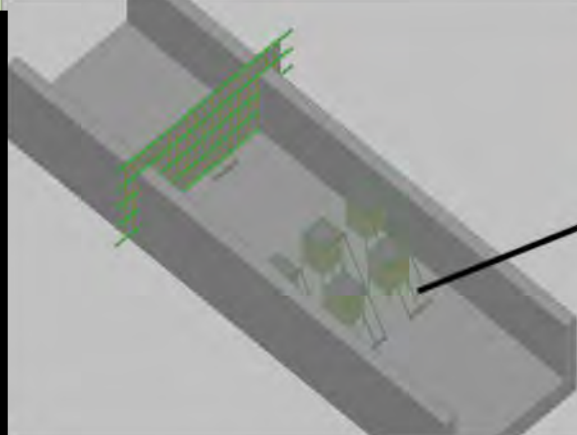
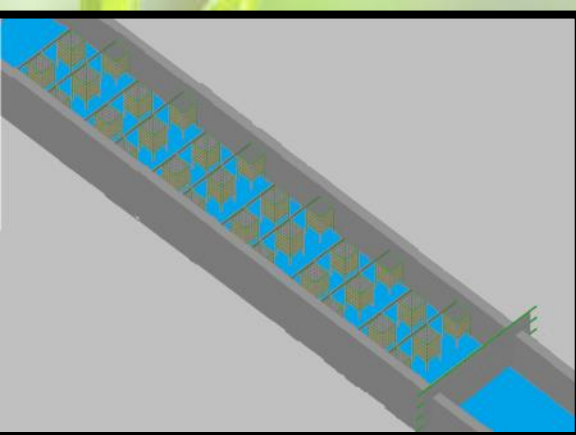


### ISSWM 2017

- 500+ Participants
- One day PhD symposium
- Delegates from 7 countries
  - 130 Abstracts

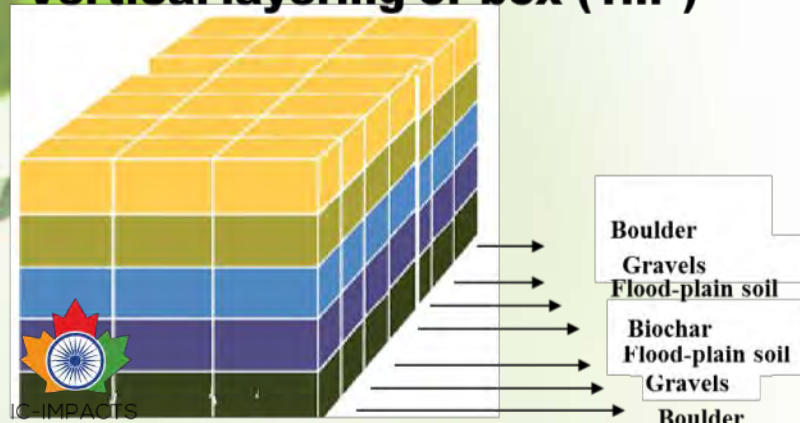


## Future Experimental Plan

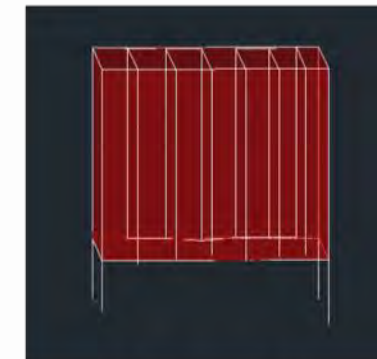
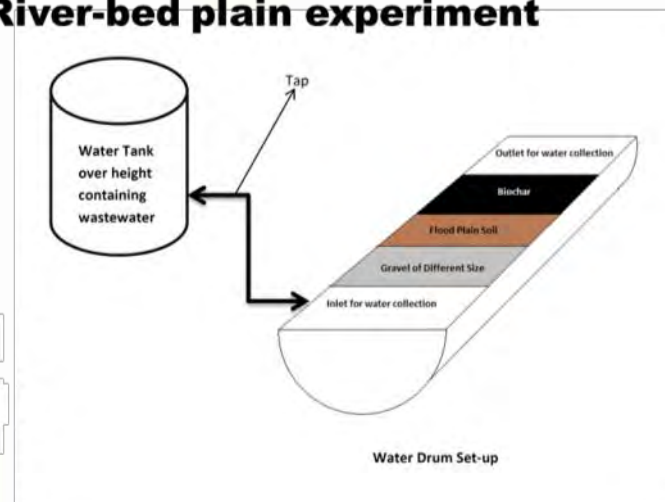


Front View

### Vertical layering of box (1m<sup>3</sup>)



### River-bed plain experiment



Side View





# BIOREMEDIATION

*A GREEN TECHNOLOGY*



# Thank You



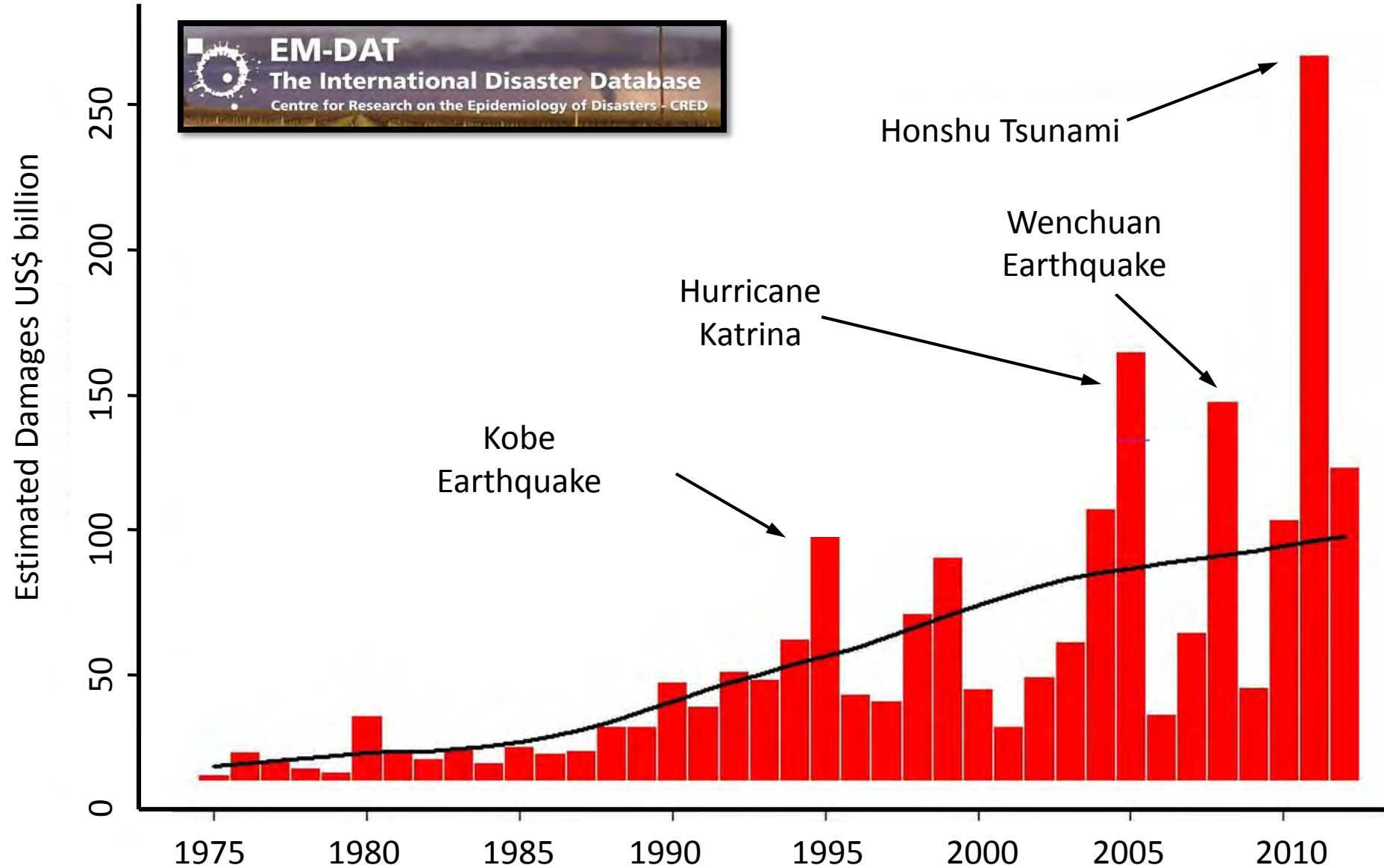
# **India – Canada Initiative for Resilient Global Urban Shelter**

Farbod Pakpour, PhD candidate  
Dr. Hossein Agha Beigi, Post Doctorate Fellow  
Supervisor: Professor Constantin Christopoulos

# Outline

- 1. Background on worldwide natural disasters and need for resilient shelter**
- 2. Research objective**
- 3. Development approach and ideas being explored**
- 4. Accomplishments**
- 5. Next Steps**

# Damage Trend from Natural Disasters



# Seismic loses in developed & developing regions

Nepal (2015)



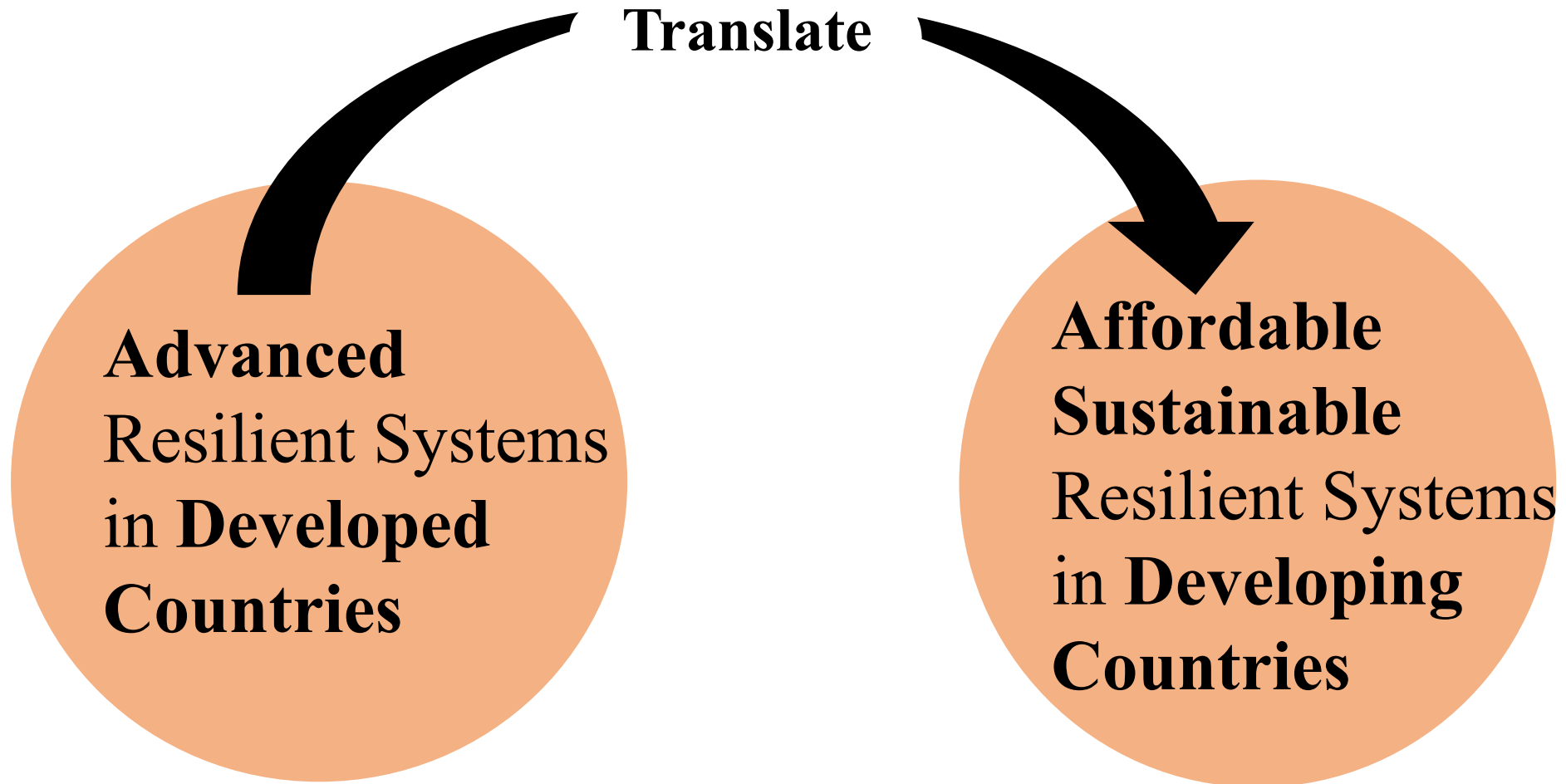
- **Magnitude: 7.8 Mw**
- **9500 death and 16800 critically injured**
- **Structural damage: US\$ 5.2 bill.**
- **1-in-5 homes were severely damaged**

Baja, California (2010)



- **Magnitude: 7.2 Mw**
- **4 death and 233 injured**
- **Total damage: \$1.15 billion**

# Research Objective



# Safety Vs. Resilience



**Intent of the Seismic design code:**  
**Safely Resists earthquake**  
**(No loss of life)**  
**but **not** resilient**



**Resilient:** Immediate functionality  
even after Earthquakes

# Objective

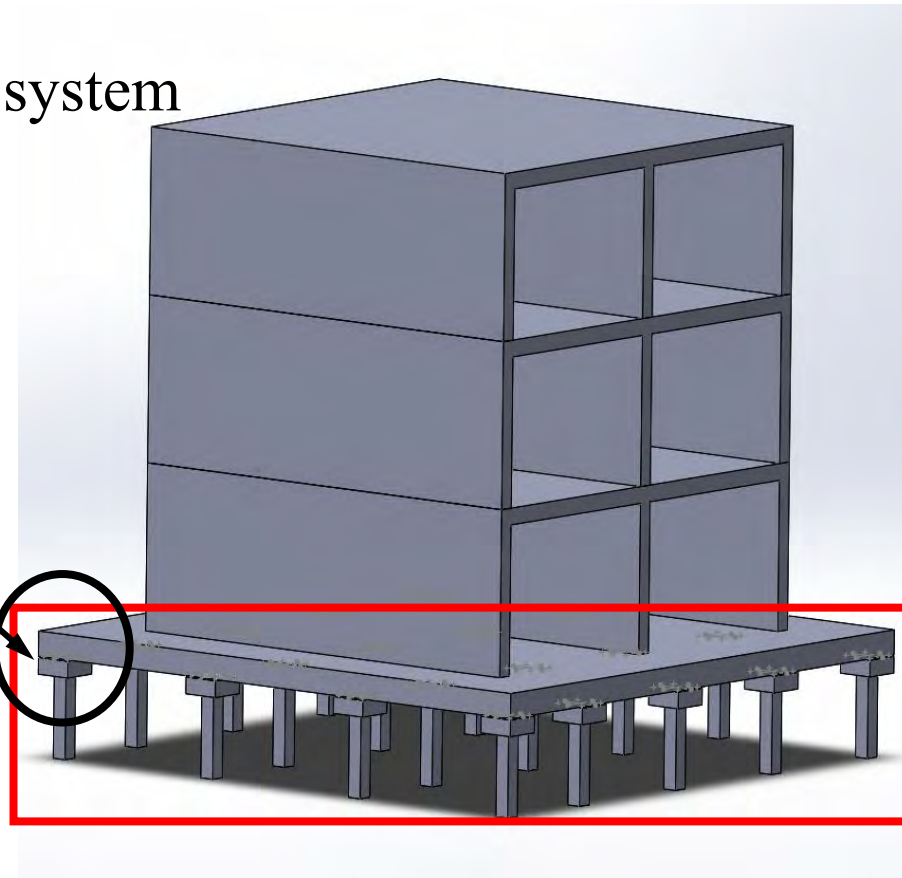
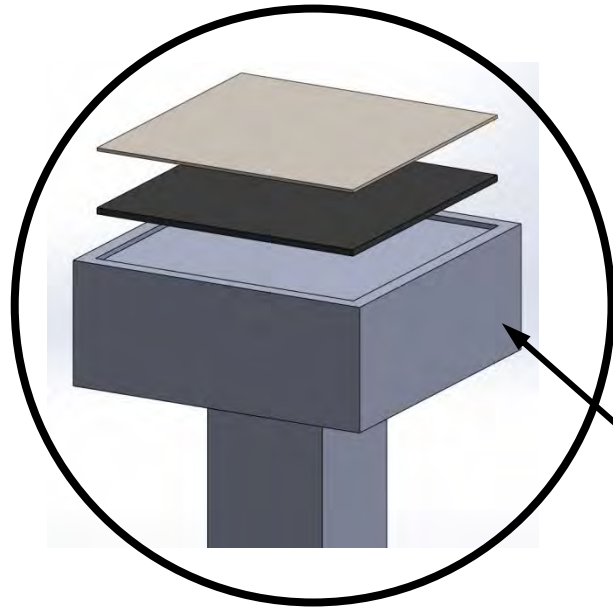
- Development of affordable seismic isolation platforms (SIPs) in urban settings of developing countries
- Engineering the proposed “frugalized” SIP to provide protection to floods
- Mass implementation of the developed isolation system
- Not changing current construction practice in India



# Effectiveness of the Seismic Isolation Platform

- Provides resiliency to the current construction in India **without changing current construction practices**

“Frugalized” seismic isolation system

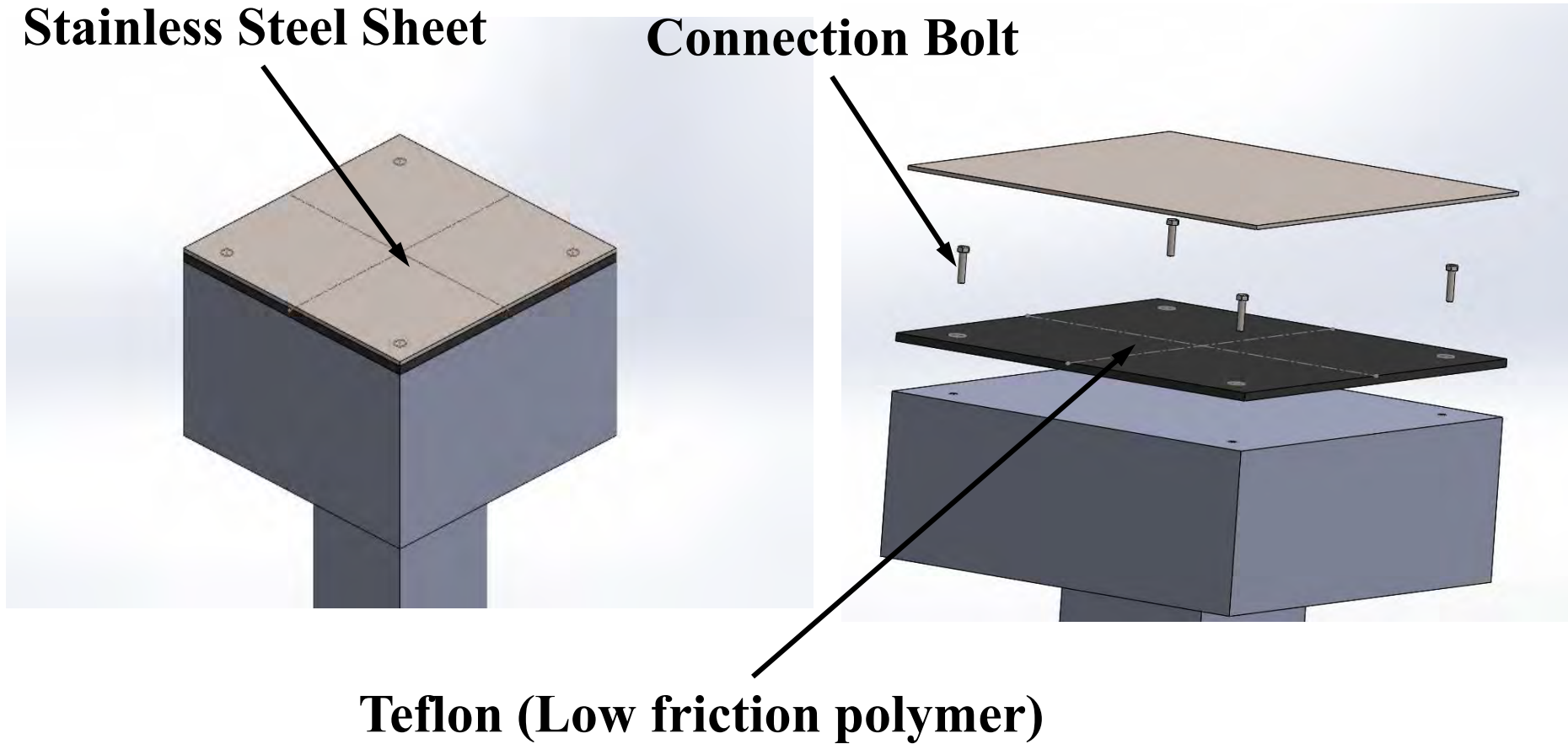


Seismic isolation platform

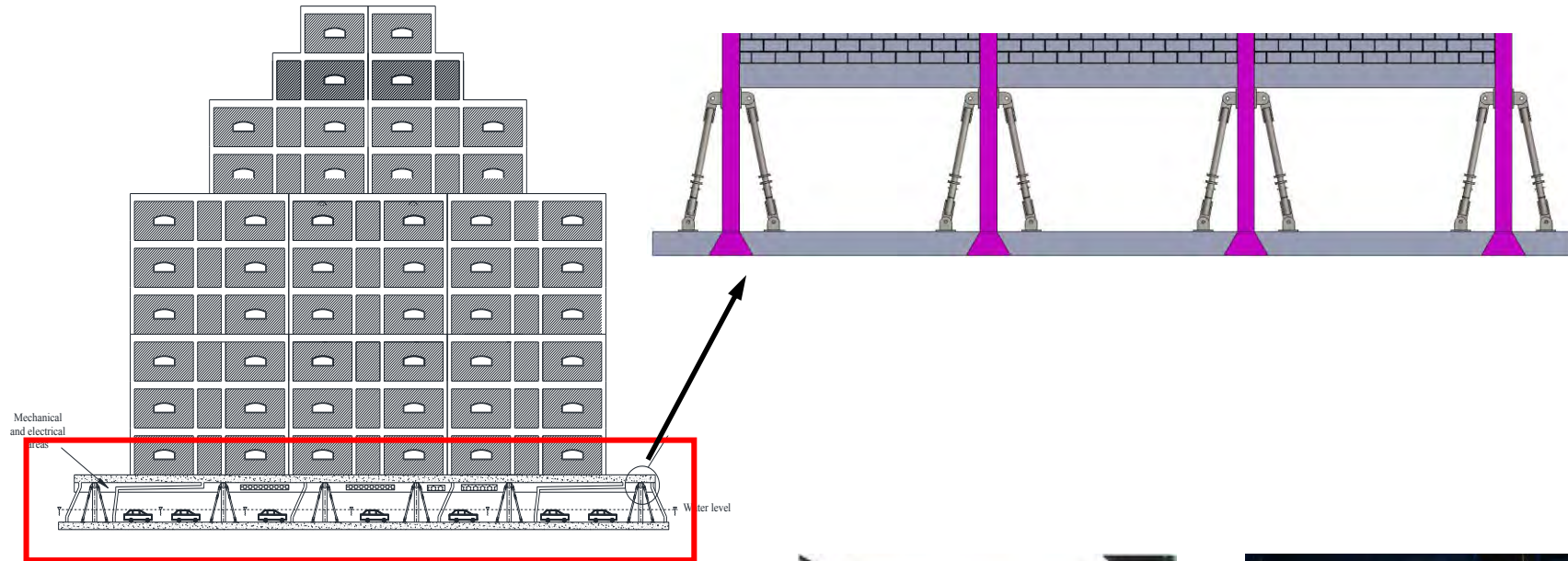
# Ideas for Resilient layer are Being Investigated

- **Low cost sliding isolators**
- **Low cost pivoting brace systems (GIB System)**
- **Self centering rocking (SCR) system**

# Low Cost Sliding system



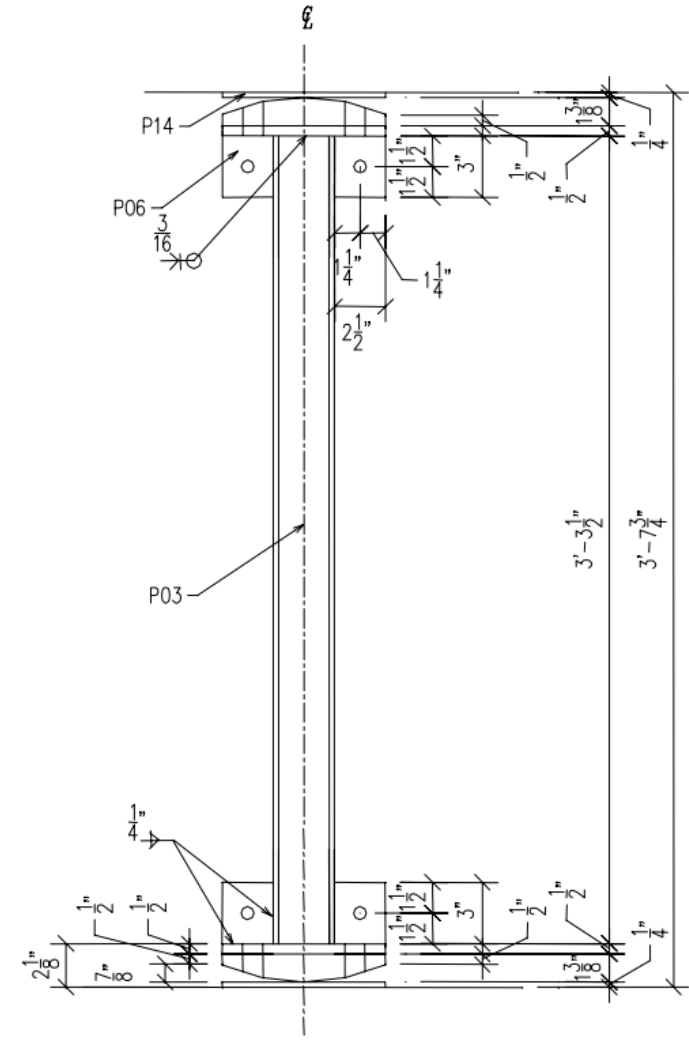
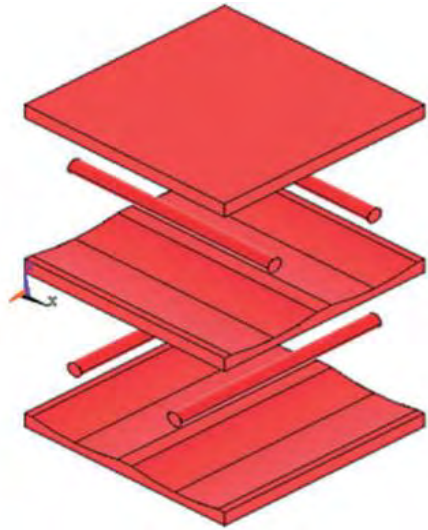
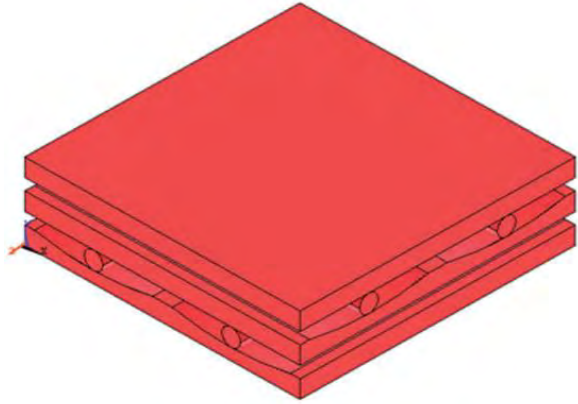
# Gapped Inclined Braced (GIB) System



- **Prevents soft-storey collapse mechanism**
- **Allows the soft storey to sway while protecting upper floors**
- **Currently being tested at University of Toronto's structural research Laboratory**

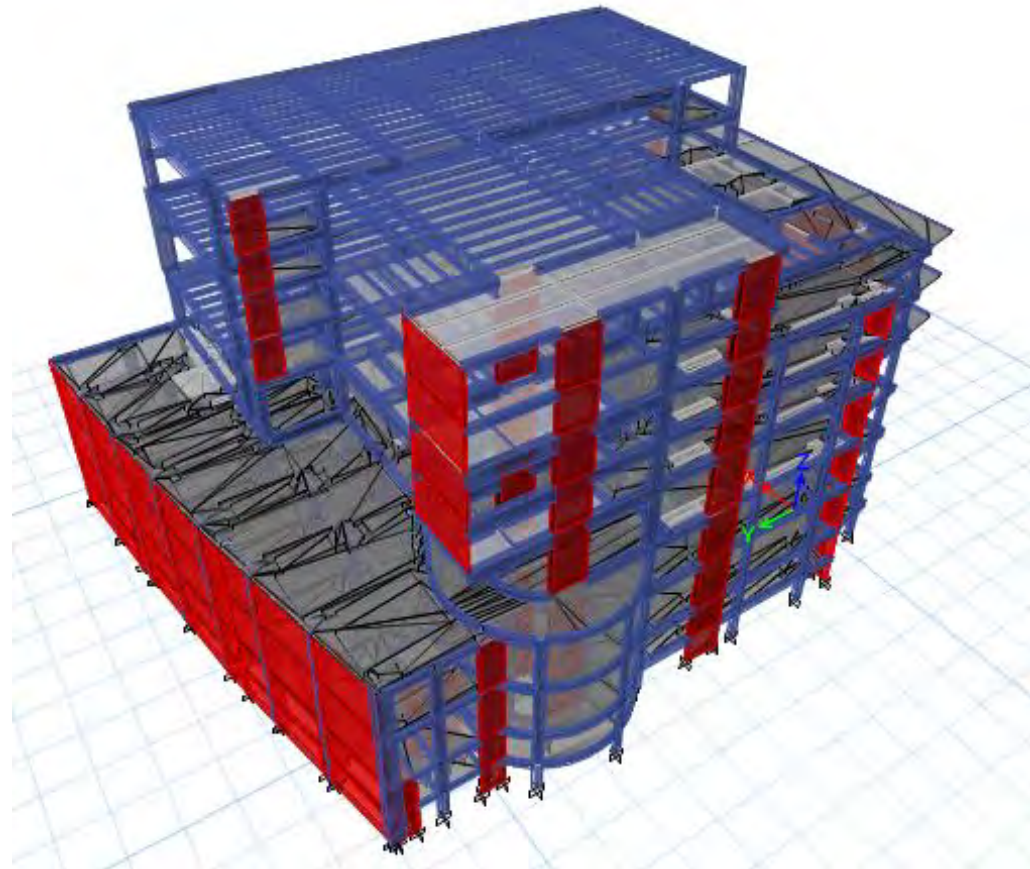


# Summary of Rolling and rocking systems

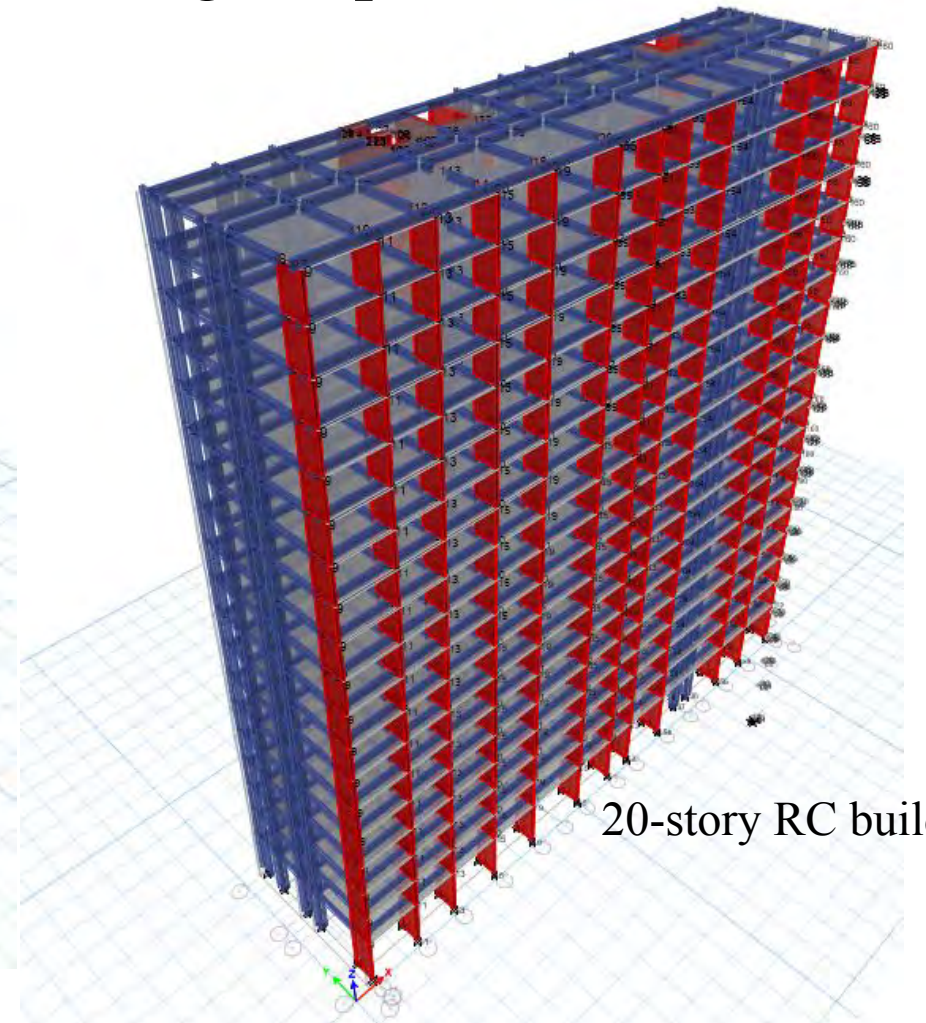


# Accomplishments

a) Over a period of 12 months we did an extensive numerical analysis of a 8-story and 20-story RC building in India and assessing the performance with and without any base isolation



8-story RC building



20-story RC building

# Summary of main modeling aspects

## 1. Beam/Column elements:

- beamWithHinges elements

## 2. Shear wall elements:

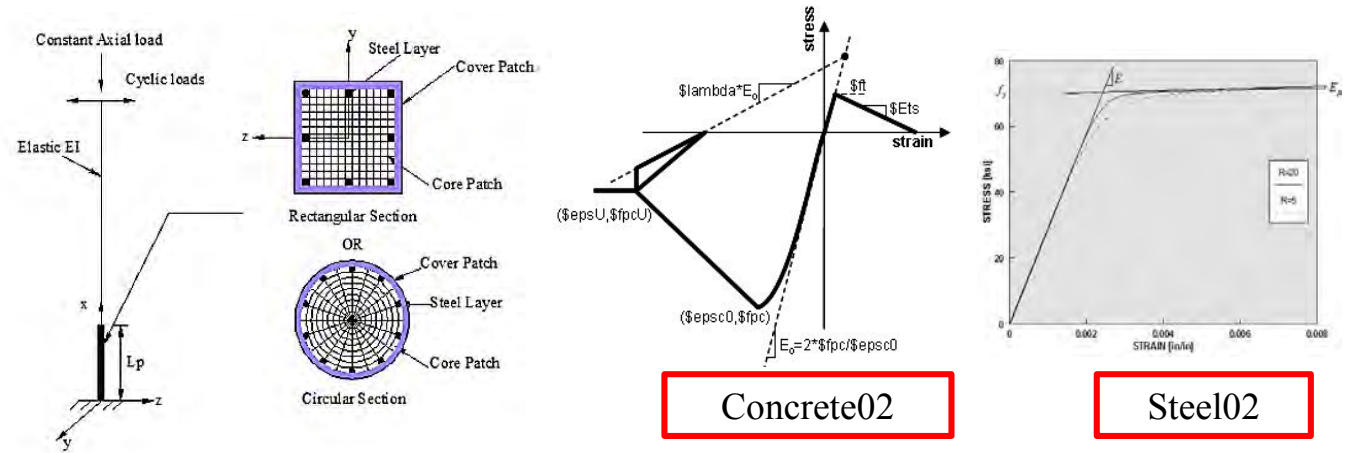
- Equivalent Frame Method + Rigid Links

## 3. Joints are not modelled

## 4. Masonry walls are not modelled

## 5. Isolation:

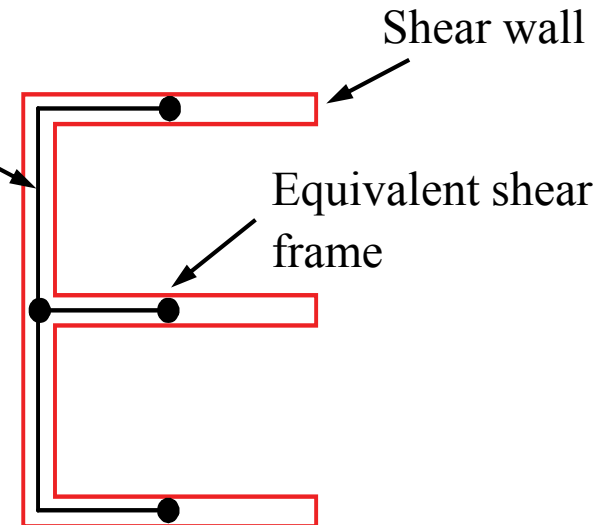
- Sliding isolation bearing
- Coulomb friction
- $\mu = 0.03$



Rigid links:

$$E_{Rigid} = 10 * E$$

$$A_{Rigid} = 10 * A_g$$



# Scaled ground motions

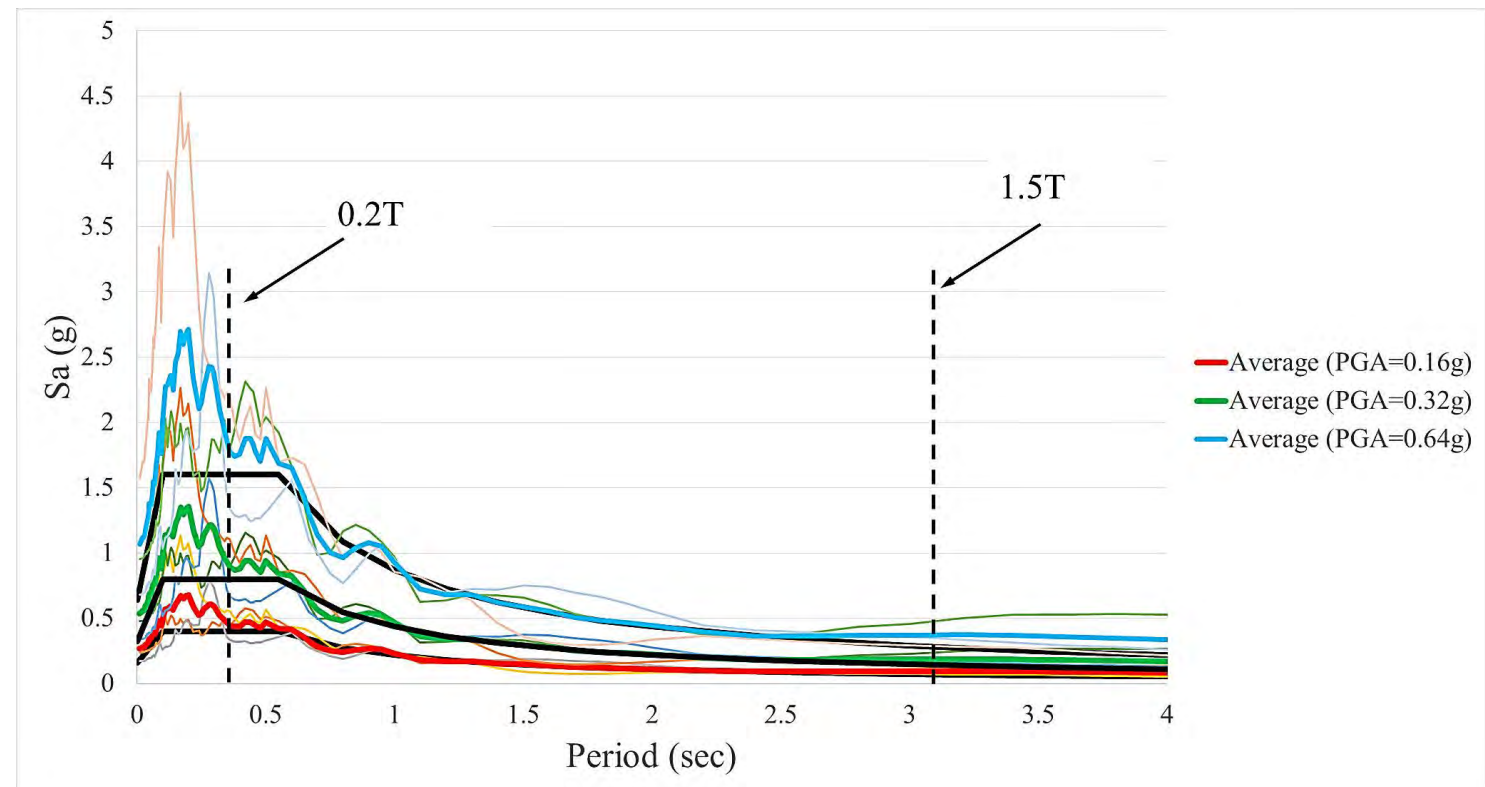
EQ no	Event	Year	Magnitude	PGA [g]	Duration (sec)	Scale Factor
EQ1	Kocaeli_Turkey	1999	7.51	0.2	28	0.8
EQ2	Kocaeli_Turkey	1999	7.51	0.17	30	0.6
EQ3	Darfield_New Zealand	2010	7	0.4	54	0.9

- 3 intensity levels are considered:

Intensity 1: PGA = 0.16g

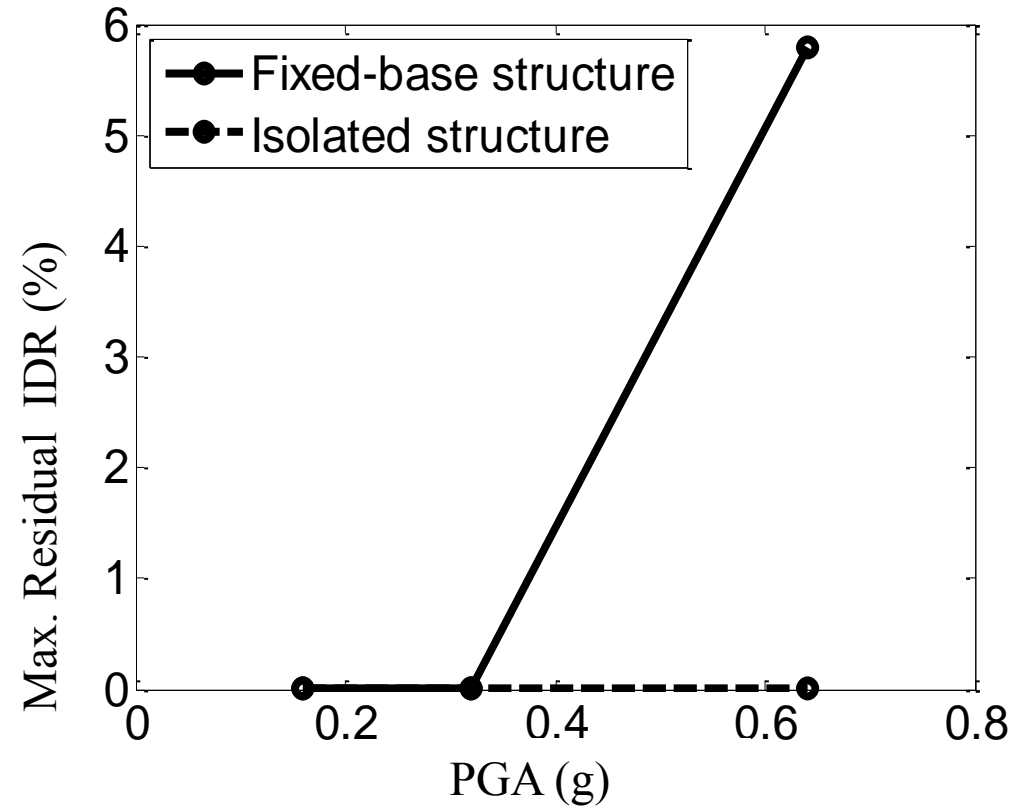
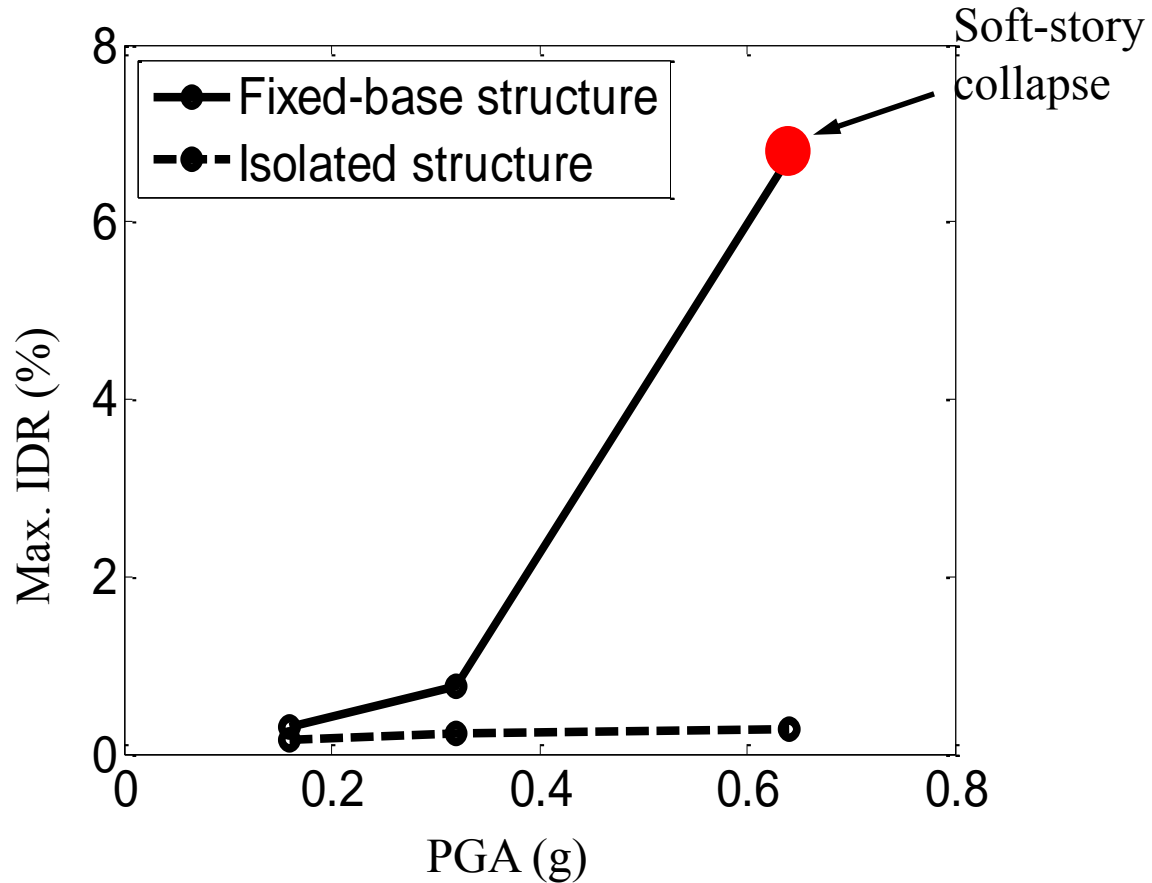
Intensity 2: PGA = 0.32g

Intensity 3: PGA = 0.64g

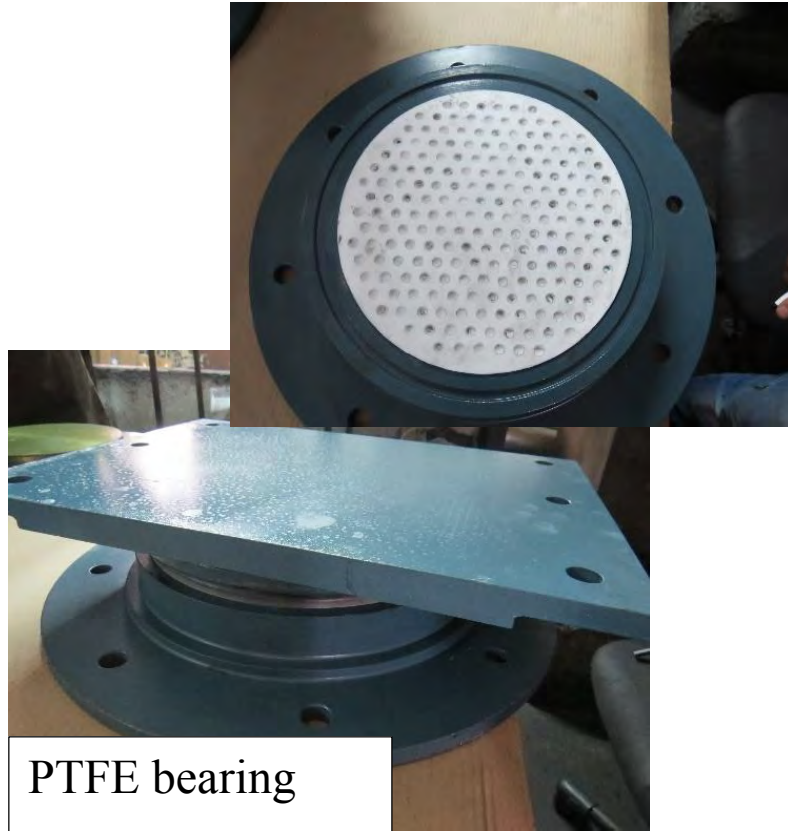




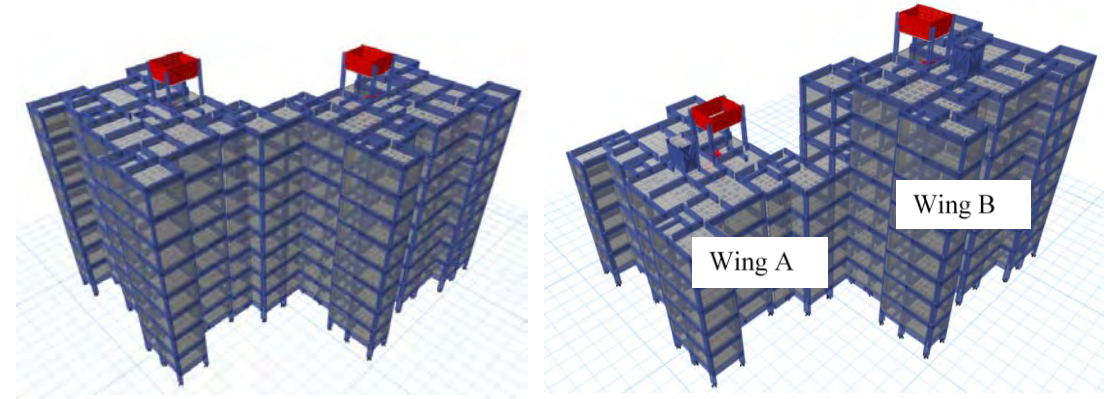
# Intensity measures of the Sion Building



# Accomplishments from collaboration with IITB

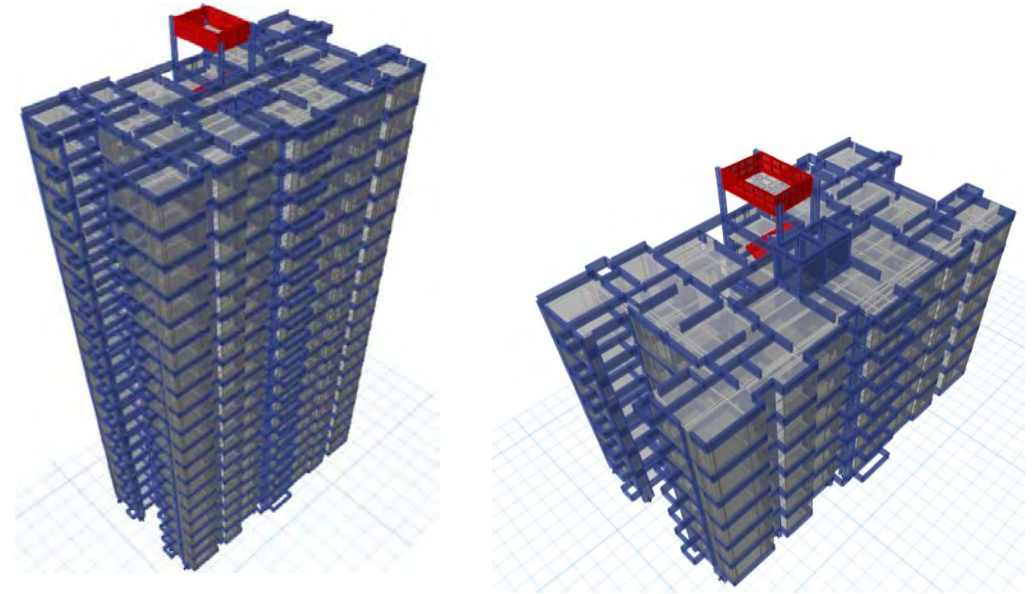


Investigate the availability and cost of low-cost materials



(c) Building #9: As Built

(d) Building #9: As Approved



(a) Building #11: As Built

(b) Building #11: As Approved

Access to a few more target buildings

# Accomplishments from collaboration with IITB



Visited a few manufacturing Sliding bearing companies to investigate the cost of production of low cost sliding isolation bearings

# Accomplishments from collaboration with IITB



Investigating the  
quality construction



Constructions Safety



Affordable housing site  
visit

# Accomplishments from collaboration with IITB

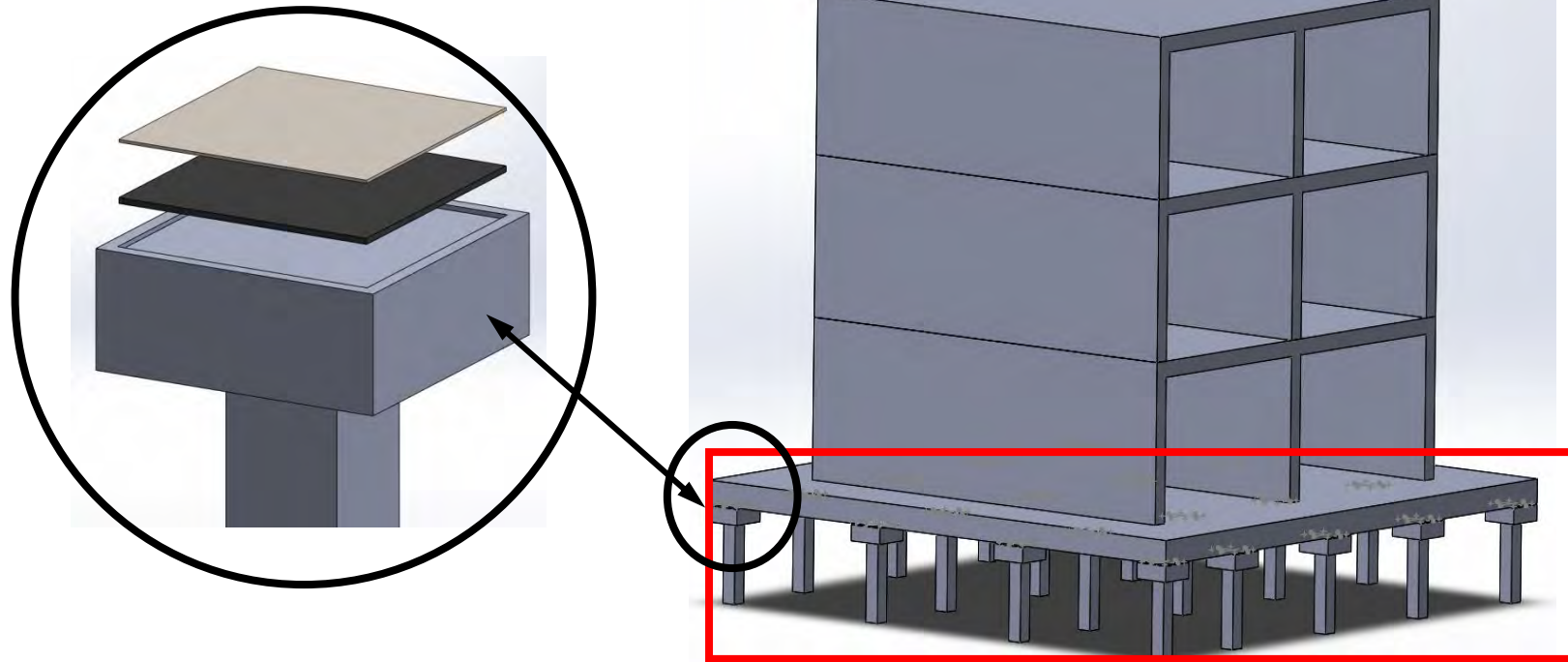
## Visiting Scholar from IITB

- Mr. Aditya Jhunjhunwala, MASc student visited University of Toronto last summer
- His major focus in this collaboration:
  - Extensive numerical analysis of SIP
  - Design of rigid base slab
  - Study the sequential construction of buildings on the base slab



# Phase 1A : Unidirectional low cost sliding isolation systems

“Frugalized” seismic isolation system

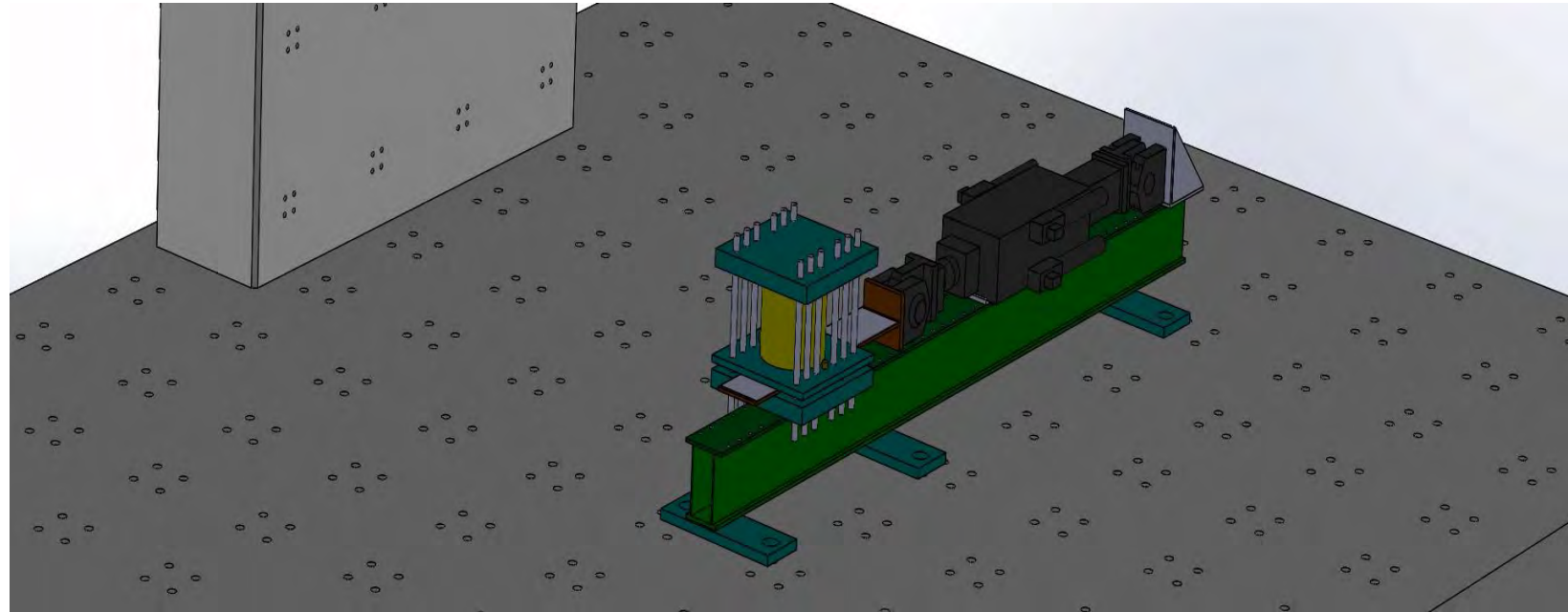


Seismic isolation platform



# Phase 1A : Unidirectional low cost sliding isolation systems

- Full scale component-level experiment
- Vertical load capacity: 6000 kN
- Lateral displacement Capacity: +/-380 mm
- Actuator Velocity :
  - $\text{Velocity}_{\text{Capacity}} = 466 \text{ mm/s}$



# Future Plans

- a) Full scale component-level experiments on other “frugalized” seismic isolation systems (Rolling and rocking)
- b) Performance assessment of benchmark building models with and without the developed seismic isolation systems
- c) Full design and mass implementation plan of the developed isolation system
- d) Cost analysis and quality control plans



# ***Development and implementation of alkali-activated concrete & UAV-based infrastructure monitoring protocols***

**Rishi Gupta, Ph.D., FEC, P.Eng.**

**Department of Civil Engineering  
University of Victoria (CANADA)**

**Sunday-Wednesday, December 3-6, 2017  
(IC-IMPACTS Workshop, Pune, India)**



University  
of Victoria



# Topics of presentation

- Updates on two projects
- Application of Precast Products Made Using Bottom Ash and Fly Ash for Rural Pavements and Other Infrastructure in India
- Full Field Non-Contact SHM Protocols for Long Span Railway Bridges and Heritage Structures



# Application of Fly ash and Bottom ash based Alkali Activated Concrete Paver Blocks for Design and Construction of Rural Pavements



University  
of Victoria



# Alkali Activated Concrete



# Mix Design

<b>Final Mix Design Parameters</b>	
Proportion of fly ash and bottom ash	50:50
Aggregate content (%)	75%
Source of Bottom ash	Gandhinagar Thermal Power Plant
Contents of source material (kg/m <sup>3</sup> )	429
Ratio of alkaline liquid to source material, by mass	0.4
Ratio of sodium silicate solution to sodium hydroxide solution, by mass	2.5
Addition of super plasticizer(%)	0%
Rest period (day)	1-2 days
Water content of mixture(%)	10%

<b>Mix Constituents (kg/m<sup>3</sup>)</b>	
Fly ash	215
Bottom ash	215
Fine Aggregate	630
Coarse Aggregate	1170
NaOH Solution	48.98
Na <sub>2</sub> SiO <sub>3</sub>	122.44
Water	42.85

**Compressive strength of pavers**  
**Flexural strength**  
**Split tensile strength**  
**Abrasion**  
**Water absorption**  
**Acid attack**  
**Alkali attack**  
**Sulphate attack**



# Application of Alkali Activated Concrete Paver Blocks for Construction of Rural Pavement



# Model Pavement Stretch of Alkali Activated Concrete Paver Blocks at Nirma University

Size of Pavement	2.5 m × 4 m
Site of Pavement	Behind “C” Block , Nirma University
No. of Paver Blocks Used	340





# Construction Process of Model Pavement Stretch





(a) Casting at Nirma



(b) Marking of Required



(c) Excavation having depth of



(d) Levelling for kerbing around (e) laying



(e) laying of 9 inch depth Ker



(f) laying of PCC having depth



University of Victoria



(g) Laying of 40 mm sand



(h) Levelled



(i) Laying of Pavers in



(j) Mortar filling near edges



(k) Paver block  
Pavement Stretch



(l) Compaction on paver  
blocks



# COMPLETED STRETCH- January 2017



# Rural Pavement of Alkali Activated Concrete Paver Blocks

Size of Pavement	2.5 m × 16 m
Site of Pavement	“Jashpur” Village, Ta. Kalol, District. Gandhinagar
No. of Paver Blocks Used	1200



# Construction Process of Rural Pavement at Jashpur Village





Alkali Activated Concrete Paver Blocks casted in Casting yard at Nirma University



University of Victoria



Marking of Required Excavation having Size of 2.5 m × 16 m on Proposed Pavement



Excavation of size 2.5 m × 16 m having depth of 200 mm using Backhoe



Transportation of Alkali Activated Concrete Paver Blocks to Jaspur Village Site







Storage of Alkali Activated Concrete Paver Blocks at Pavement Site



Compaction & Levelling of Earth in Progress at Pavement Site





Preparing of Plain Cement Concrete



Laying of PCC of depth 100 mm





View of Pavement after completion of the PCC work



Laying of 12 inch kerbing around edges of rural pavement





Laying of 40 mm depth sand bedding & levelling



Laying of Paver blocks having depth of 60 mm in Herringbone Pattern





Mortar filling between boundary of paver blocks & kerbing



Joint sealing between paver blocks using compactor



# Rural Pavement of Alkali Activated Concrete Paver Blocks- April 2017

Size of Pavement	2.5 m × 16 m
Site of Pavement	“Jaspur” Village, Ta. Kalol, District. Gandhinagar
No. of Paver Blocks Used	1200



Actual image of Rural Pavement at Jaspur Site



# Nov 24, 2017



**Pavement of Alkali Activated Concrete Paver Blocks**  
Location : Jaspur Village, Ta. Kalol, Dist. Gandhinagar  
Length : 16 Meter  
Width : 2.5 Meter  
  
Designed & Constructed by  
Civil Engineering Department,  
Institute of Technology, Nirma University, India  
In Association With  
University Of Victoria, Canada  
&  
IC-IMPACTS

જાસપુર  
Jashpur

# What's planned ahead...

- Cast-in-place (funding dependant)
- Monitoring



University  
of Victoria





# In Canada



University  
of Victoria



2017  
RESEARCH  
CONFERENCE



# Application of Precast Products Made Using Bottom and Fly Ash

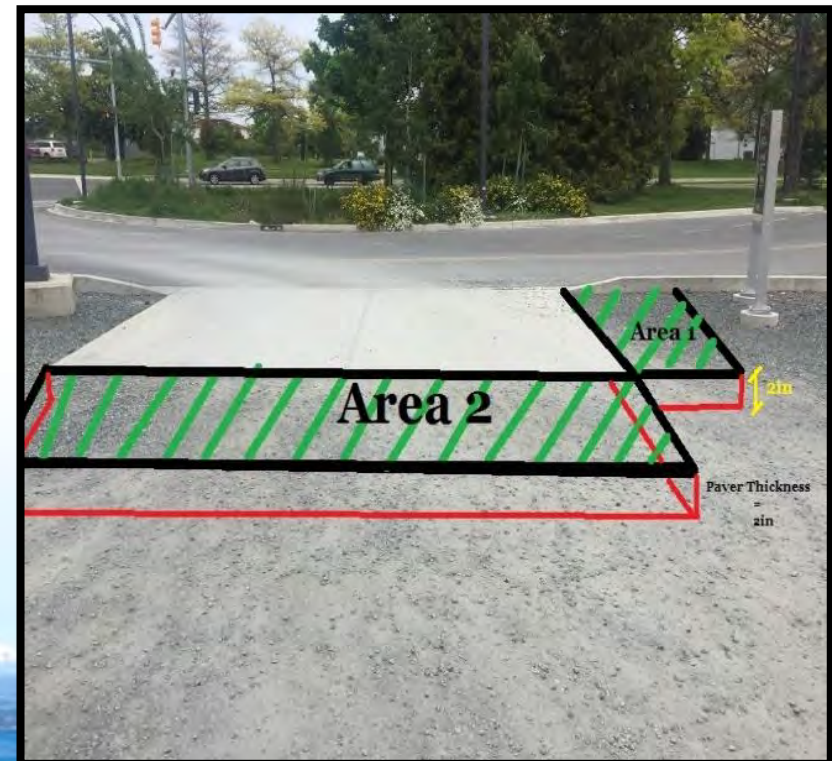






## Mock-implementation of Geopolymer concrete

- Stretch of pavement using K-based geopolymer concrete paver blocks
  - Carsa parking lot at university of Victoria
  - Freeze-Thaw
  - Leaching Test
  - Traffic load parameters





# Execution



**Excavation**



**Soil  
Compaction**



**Gravel  
Placement**





# Execution



University of Victoria

**Gravel  
Compaction**

**Bedding Soil  
Placement**

**Paver block  
placement**





# Execution completed Nov, 2017



**Final Compaction**



**Final Placement**



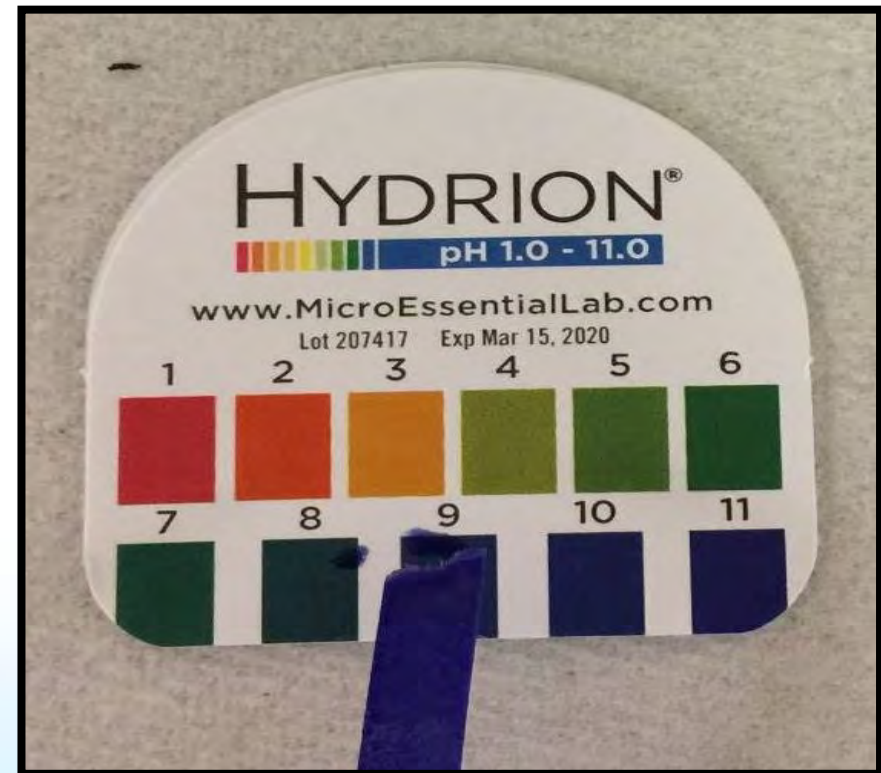






# On going work: Leachate Test

- Hach Strips
- pH, Total Alkalinity, Copper, Total Hardness, Phosphate, Total Iron, Nitrate & Nitrite



# TCLP (Toxicity characteristic leaching procedure)



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**Attention: Peiman Azarsa**

UNIVERSITY OF VICTORIA  
PO BOX 1700 STN CSC  
VICTORIA, BC  
Canada V8W 2Y2

**Report Date: 2017/11/17**  
Report #: R2478785  
Version: 1 - Final

## CERTIFICATE OF ANALYSIS

**MAXXAM JOB #: B7A0691**

**Received: 2017/11/10, 15:22**

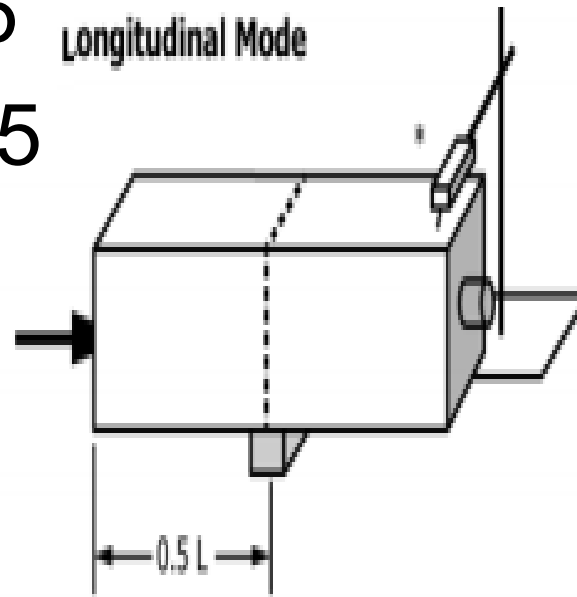
Sample Matrix: Bulk  
# Samples Received: 1

Analyses	Quantity	Date	Date	Laboratory Method	Analytical Method
		Extracted	Analyzed		
Metals - TCLP	1	2017/11/16	2017/11/17	BBY7SOP-00005,	EPA 1311, 6020bR2 m
TCLP pH Measurements	1	N/A	2017/11/17	BBY7SOP-00005	EPA 1311 R1992

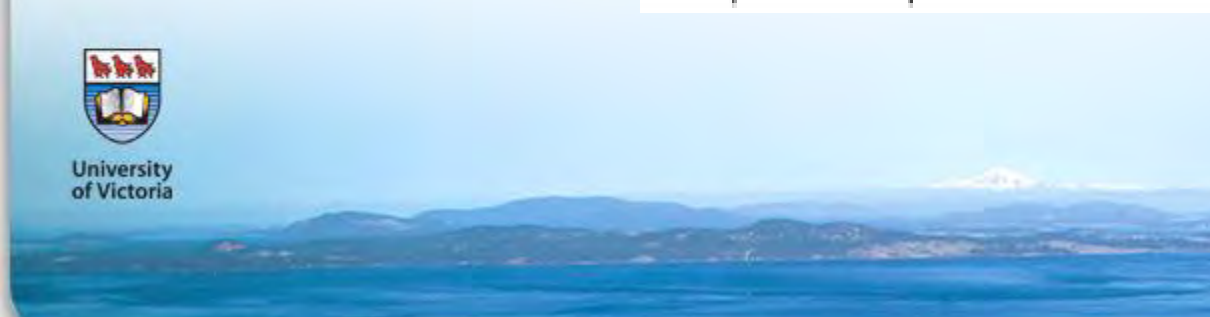
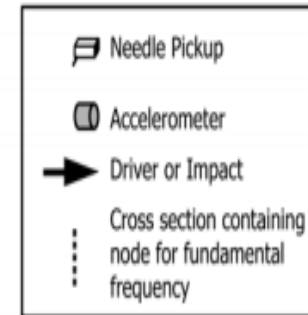
# Freeze-thaw and Resonant Frequency Test



- ASTM C666
- ASTM C 215



## LEGEND



# What's next?

---

- City of Victoria/ Saanich



# Future industry involvement

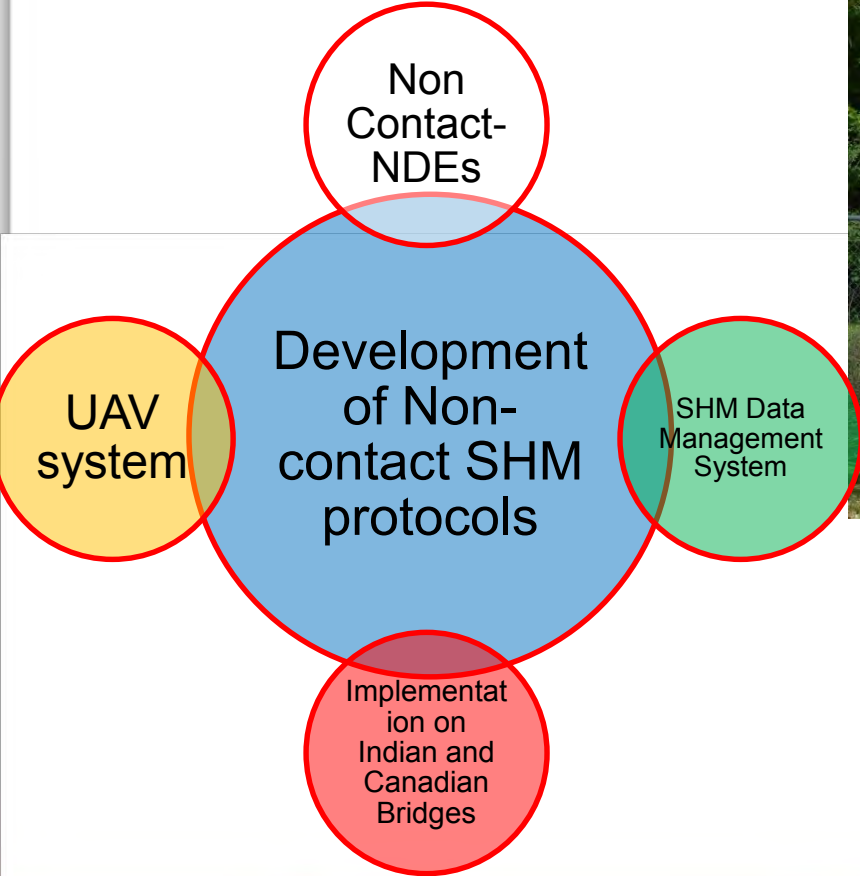
- In India
  - Patent filed ~July 2016
  - Universal Enterprises (Paver manufacturer), Cuttack, Bhubhaneshwar
  - Devansh Enterprise (Concrete Precast Manufacturers), Vallabh Vidyanagar, Gujarat
  - Yash Khandol (HQP), Parshwanath Tileworld (Tiles and marble product manufacturer), Gandhidham, Gujarat
  - Formation of a University spin-off
- In Canada
  - RJC
  - PQ Corporation, Toronto, Canada

# FULL FIELD NON-CONTACT SHM PROTOCOLS FOR LONG SPAN RAILWAY BRIDGES AND HERITAGE STRUCTURES

- Project Principal Investigators:  
Dr. Rishi Gupta, University of Victoria  
Dr. Balasubramanian Esakki, VelTech Unive

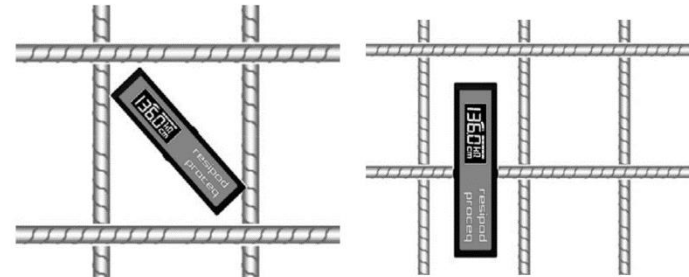
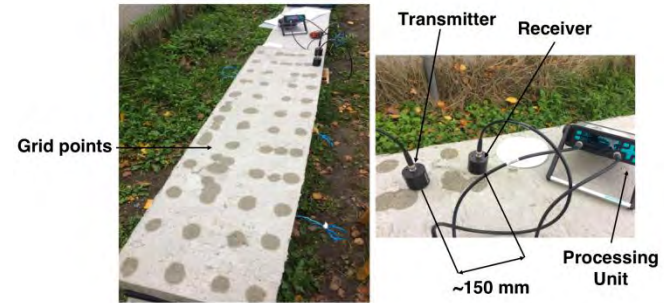


# PROJECT UPDATE IN CANADA:



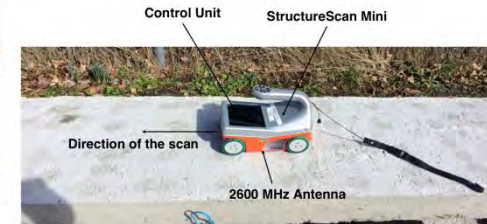
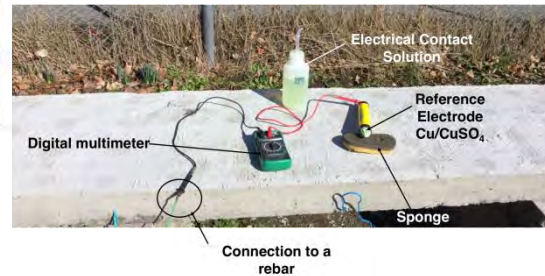
# Data Collection using Contact NDEs:

- Monitoring for 2 years
- Proceq-UPV
- Electrical resistivity-Resipod- Wenner probe
- GSSI Structure Scan Mini- 2600 MHz – GPR
- Half –Cell on the Rebar Grid



CN = Control  
 D = with induced defects  
 CR = with induced chloride ions

100 = 100 mm  
 150 = 150 mm  
 200 = 200 mm





# Data Collection using Non-Contact NDEs:

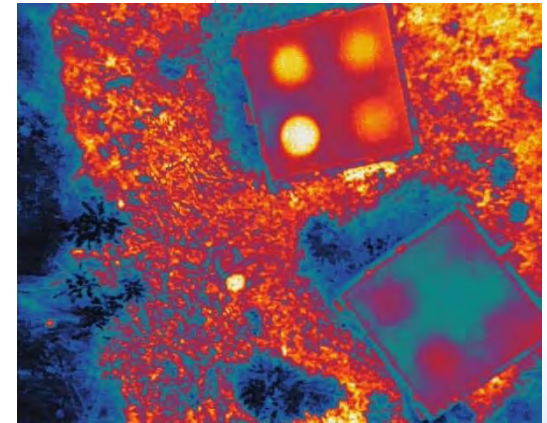
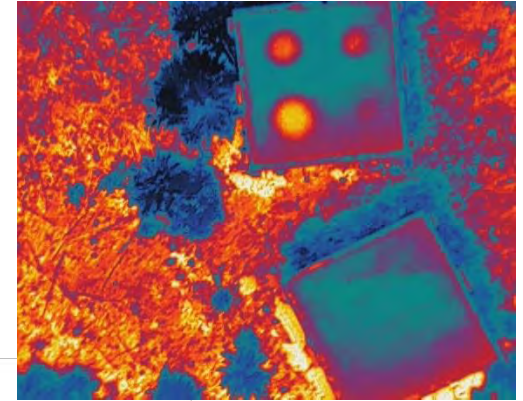


- Thermal payload integrated into airframe
- Thermal payload testing underway



Scientific payload design, prototype, and airframe integration complete  
Scientific payload testing in

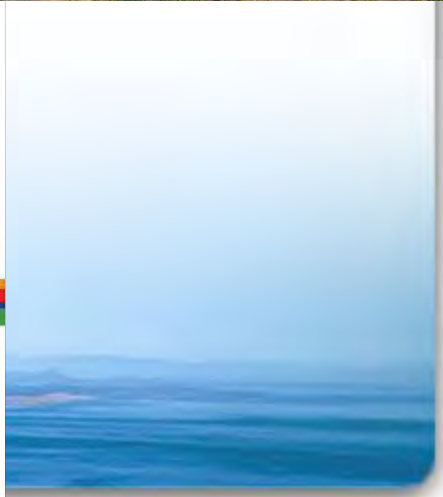
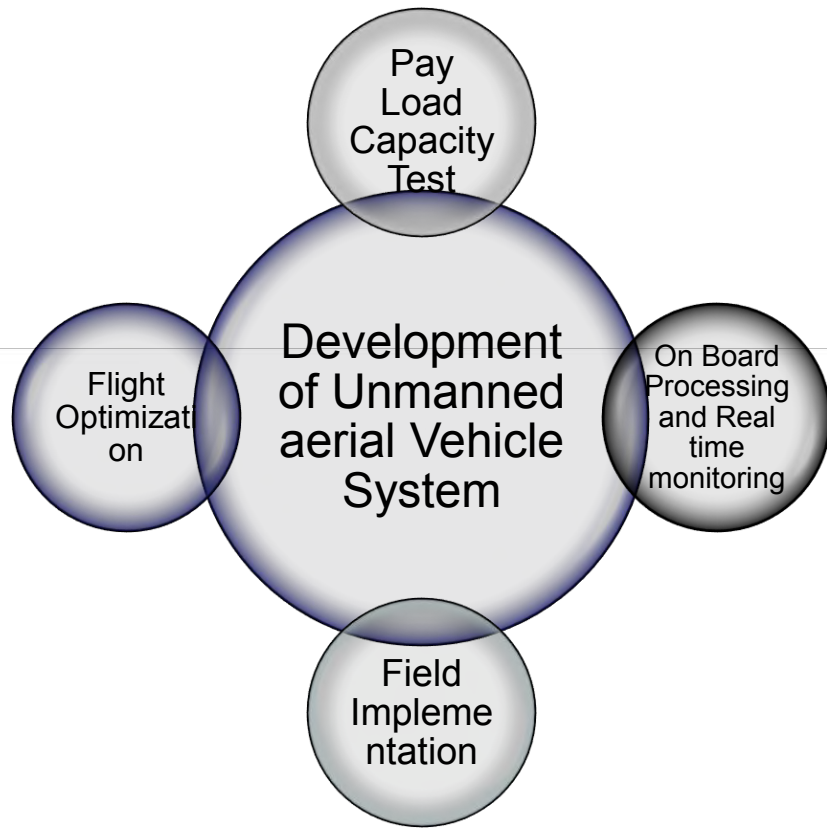
# RECENT TEST FLIGHTS IN 2017



# FIELD IMPLEMENTATION (2017).....



# PROJECT UPDATE IN INDIA:



# DEVELOPMENT OF UNMANNED AERIAL SYSTEM



# IMPLEMENTATION ON BRIDGES



Nagari Railway Bridge, India



Renigunta Railway Bridge,  
India



Ponnier Railway Bridge, India



Ambur Railway Bridge, India

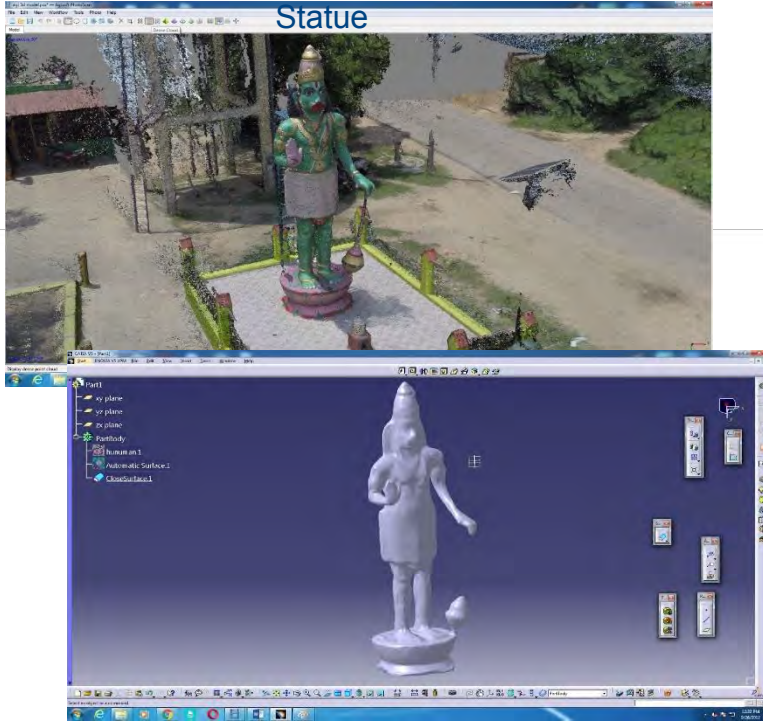


Ambur Railway Bridge, India

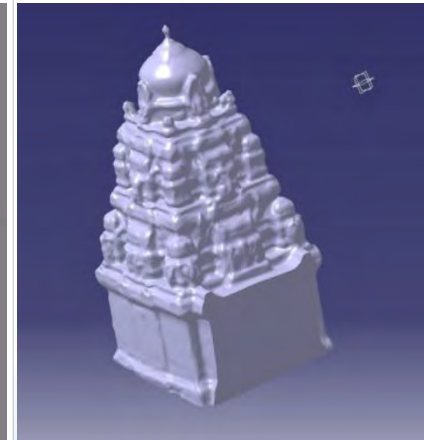
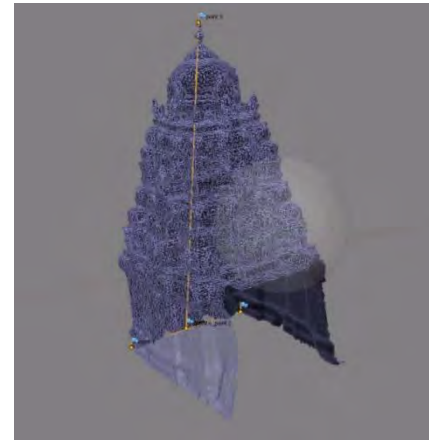


# MOCK IMPLEMENTATION ON HERITAGE STRUCTURES- 2017

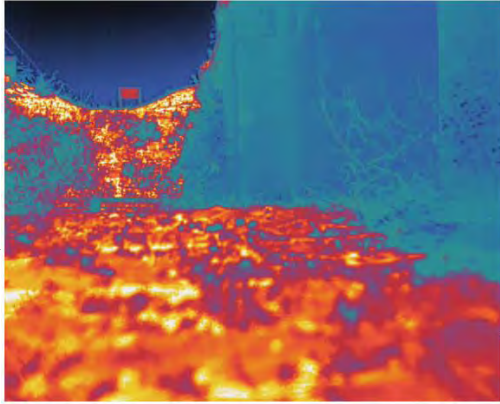
- Anuman Statue



- Perumal Temple



# SOME GLIMPSES OF UAV BASED INSPECTION.....



Ponnier River Bridge – Infrared Thermography

- Ponnier River Bridge – Digital



Ambur Railway Bridge





# NEXT STEPS.....

▪





University  
of Victoria



Department of Science and Technology (DST)  
DST





# The team!

- Dr. Urmil Dave (Co-PI, India)
- Peiman Azarsa, Chen Yang, Fernanda Belforti, Milan Patel, Yash Khandol, Sonal Thakkar
- Dr. Essaki Bala (Co-PI, India)
- Dr. Haran Pragalath, Dr. Mohit Garg, Harsh Rathod, Sean Blaney



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+1 (250)721-7033



University  
of Victoria





# Structural Health Monitoring of Tall buildings using Vibration-based Techniques



Department of  
Science and Technology



IC-IMPACTS

Collaborating Institutes

CSIR – Central Building Research Institute  
Roorkee, India

&

Department of Building, Civil and Environmental Engineering, Concordia  
University, Montreal, Canada

*Jointly Presented by:*

Dr. Soraj Kumar Panigrahi, PI (India)  
Timir Baran Roy, PhD Scholar (Canada)

Pune Dec. 04-05, 2017

# PROJECT LEAD

## India

**CSIR-CBRI,  
Roorkee**

Soraj Kumar Panigrahi, PI  
Ajay Chourasia, Co-PI

## Canada

**Concordia University,  
Montreal**

Lucia Tirca, PI  
Ashutosh Bagchi, Co-PI



# Why SHM of Buildings ?

*It is known that building and bridge structures are getting damage/deteriorate over time...*



... but how much?

This research program put-forward efforts in structural monitoring area, to increase the knowledge of damage identification of buildings.

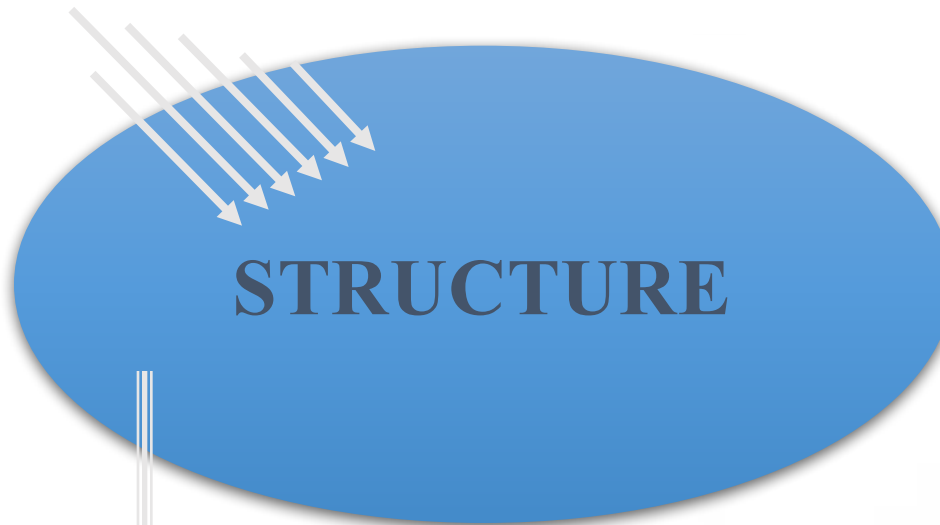


# Problem Statement

**Given Sensor Measurement Data,  
Determine External and/or Internal Parameters.**

## External:

- Load
- Temperature
- Moisture
- Etc.



## Internal:

- Damage Location
- Damage Size/Type
- Material Properties
- Etc.

- Develop an **easy to deploy, low maintenance** and **long-term** structural health monitoring system for buildings

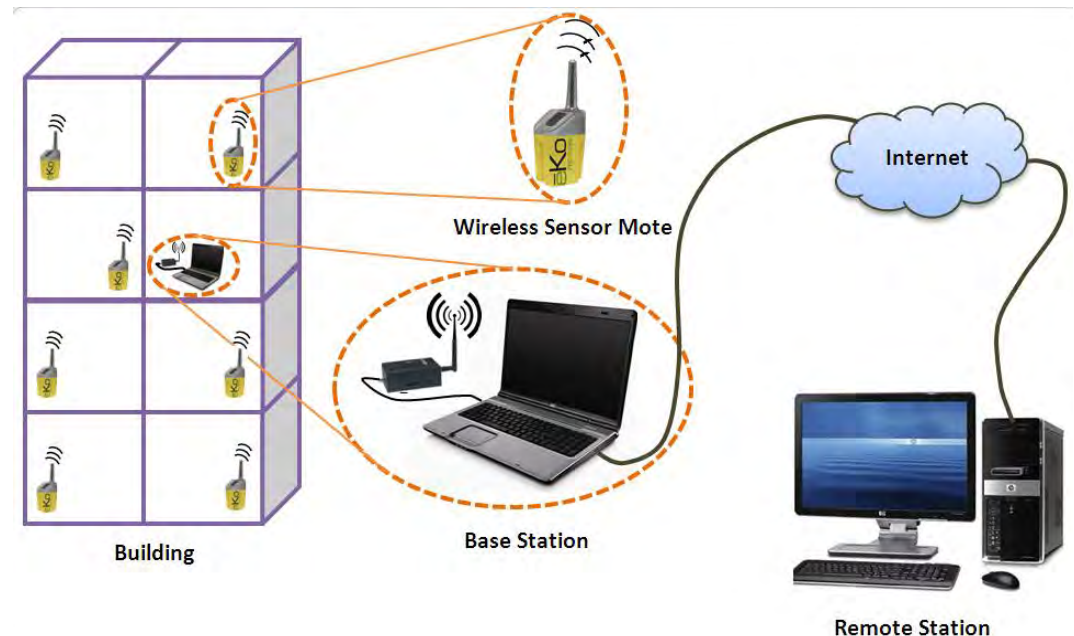
**Easy to deploy:** Cost effective and faster deployment

**Low maintenance:** Technical expertise is difficult to get

**Long-term:** Useful to monitor a structure's health over time

# Objectives

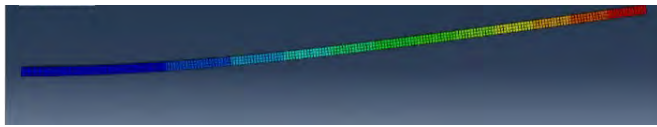
- To develop a robust instrumentation strategy for SHM of multi-storey buildings to monitor their behavior for condition monitoring.
- To develop numerical models for damage identification from experimentally obtained noisy and sparse modal information.
- To develop even efficient model capable of health monitoring of existing buildings without baseline data.



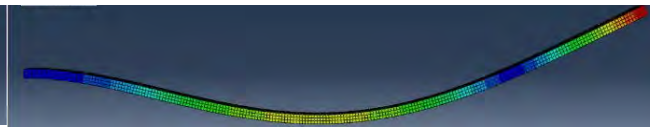
# Mild Steel Cantilever Beam

Beam: length 1020 mm, width 65 mm and depth 8 mm

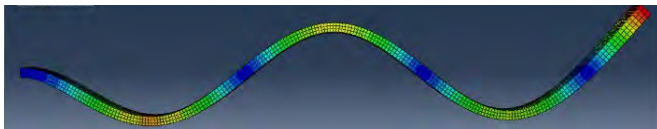
Mode Number	Numerically obtained Modal Frequency (Hz)	Experimentally obtained Modal Frequency (Hz)
1	8.3331	6.202
2	52.174	39.62
3	145.91	127.7
4	285.47	213.29
5	470.96	-



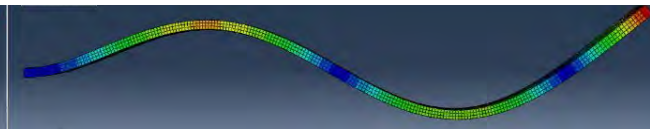
(a) First Mode



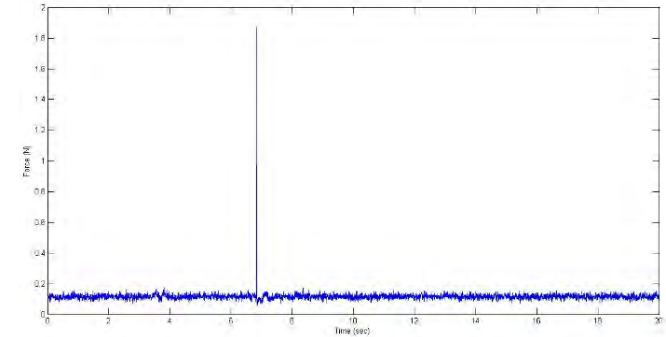
(b) Second Mode



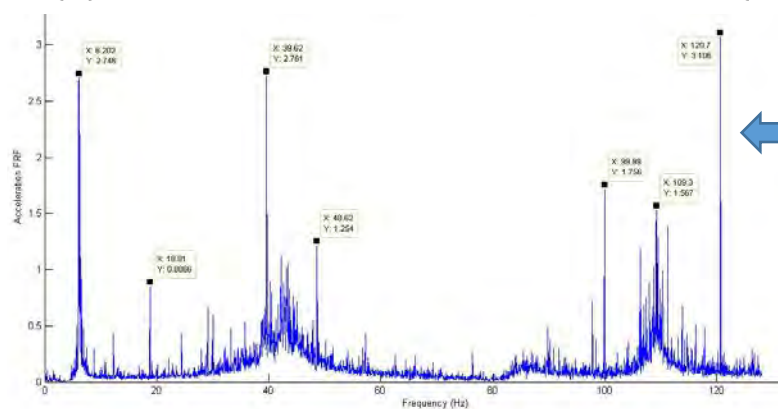
(a) Third Mode



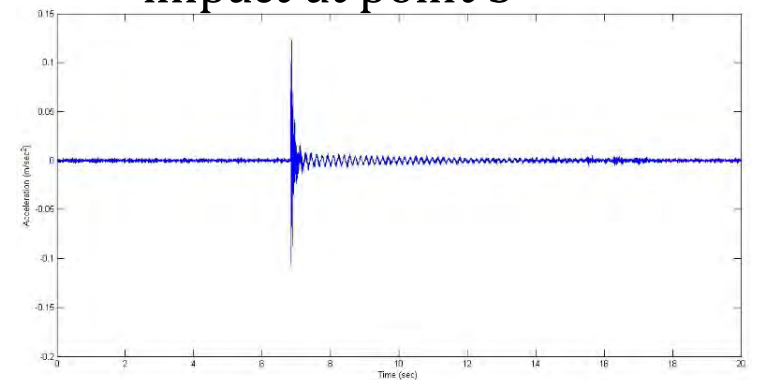
(d) Fourth Mode



Load-time signature for the impact at point 5



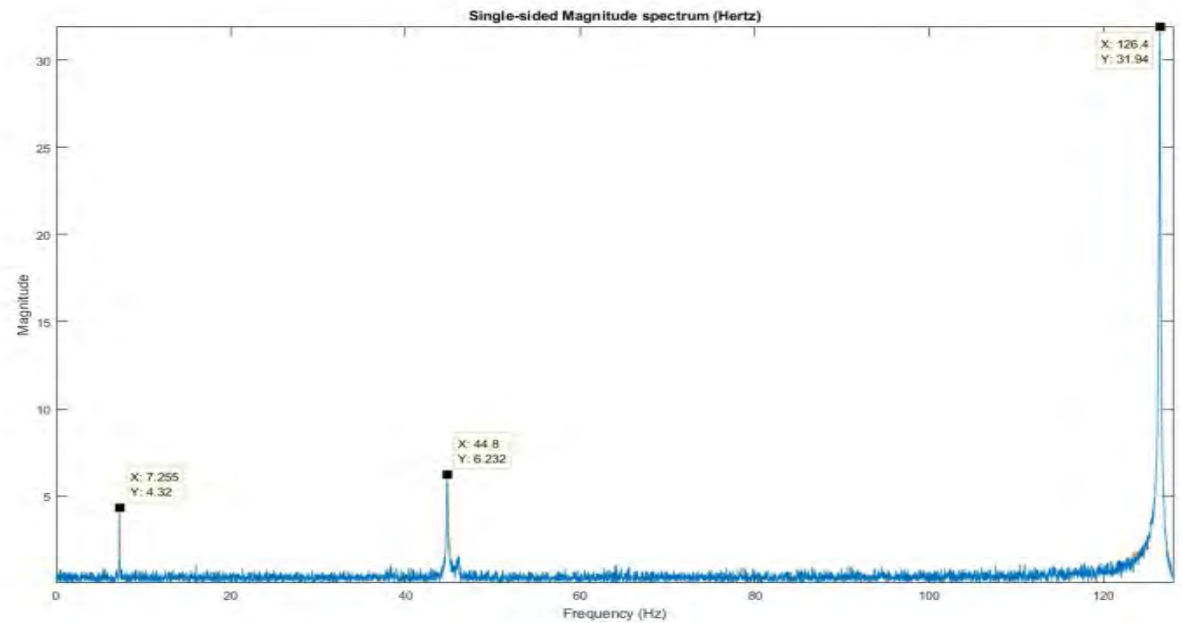
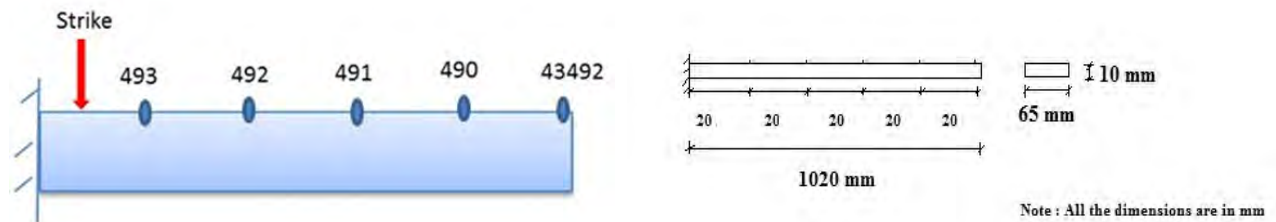
← Frequency Response Function of cantilever beam



Acceleration-time history from point no. 3 on the beam

# Steel Beam

## Health Assessment of Steel Beam Prototype



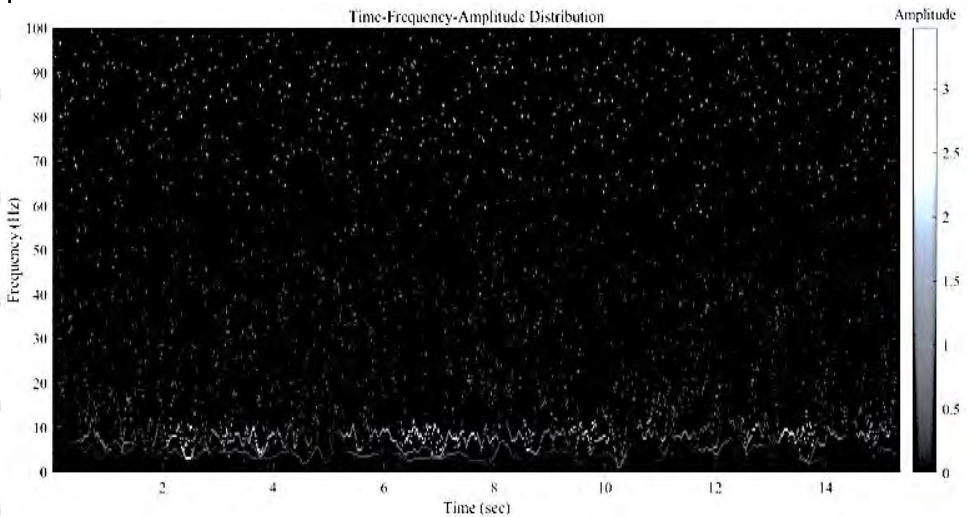
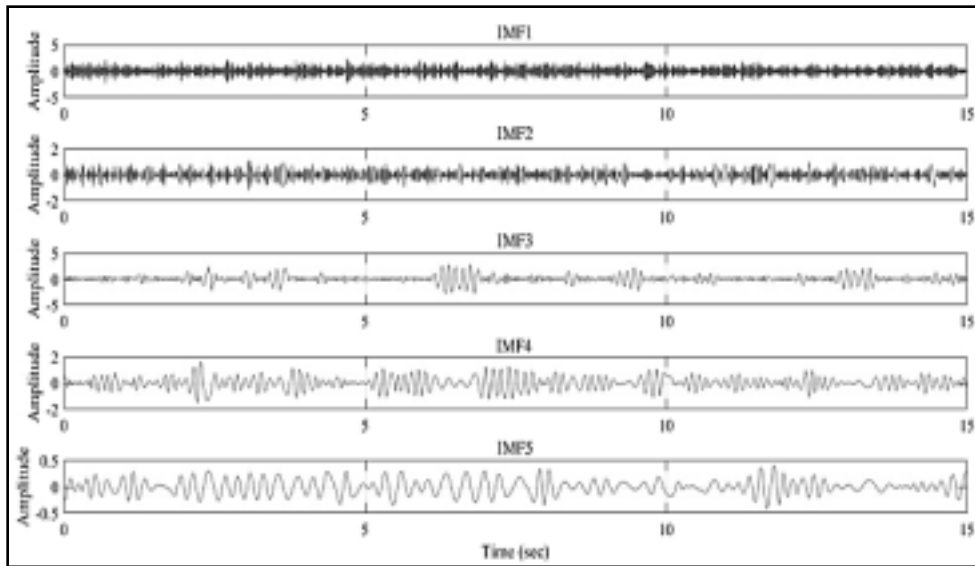
**MS Cantilever Beam:** 1.02 m long, 65 mm wide and thickness of 10 mm

**5 Wireless Tri-axial Accelerometers**

Sampling rate of the sensors: 256 Hz

# Steel Beam

## Health Assessment of Steel Beam Prototype

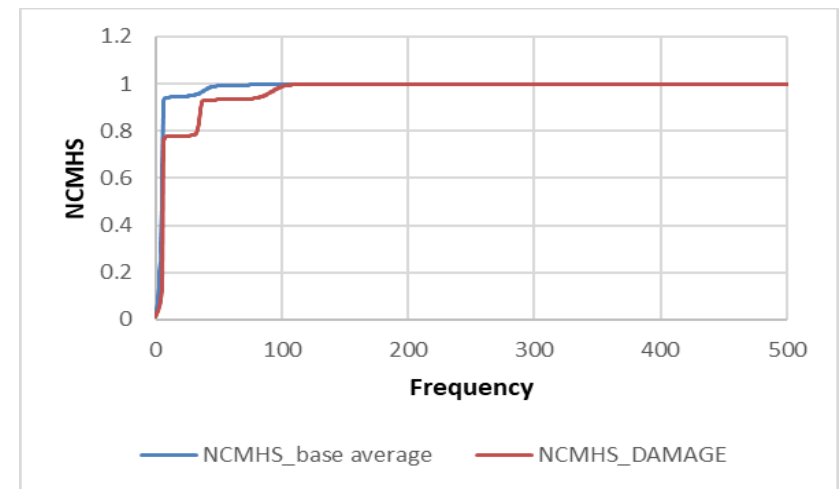


HHT plot for beam

IMFs of sensor data for intact structure for beam

**Case I**, the damage was simulated by assigning 50gm mass at 0.75m from the fixed end

**Case II**, the damage was simulated by using 50gm mass at 0.415m from the fixed end



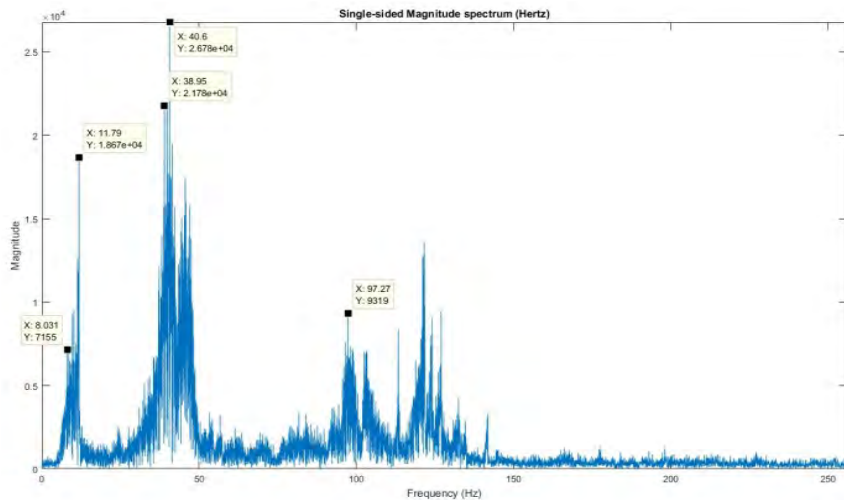
NCMHS comparison for beam prototype

# Steel Frame Prototypes

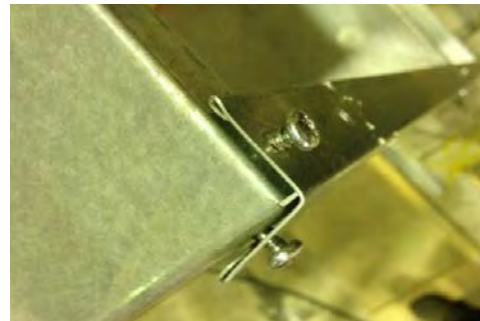
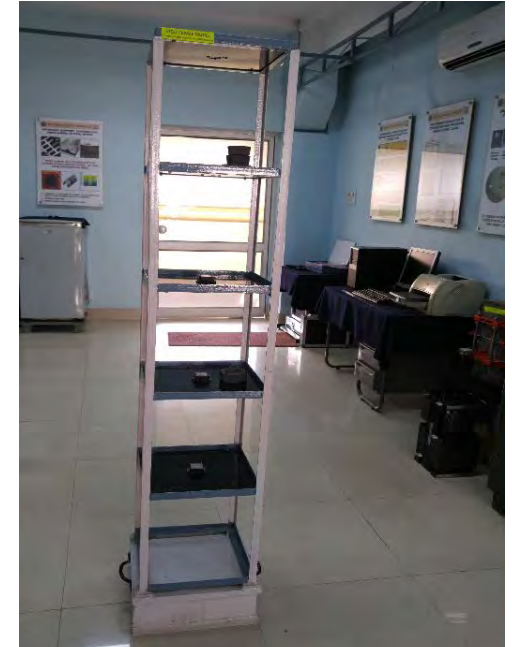
**Impact hammer** was used to impart impact at top floor

**To induce damage** at a level, all the eight bolts were loosened

**Wireless Tri-axial accelerometers** were used with sampling rate of 512 Hz



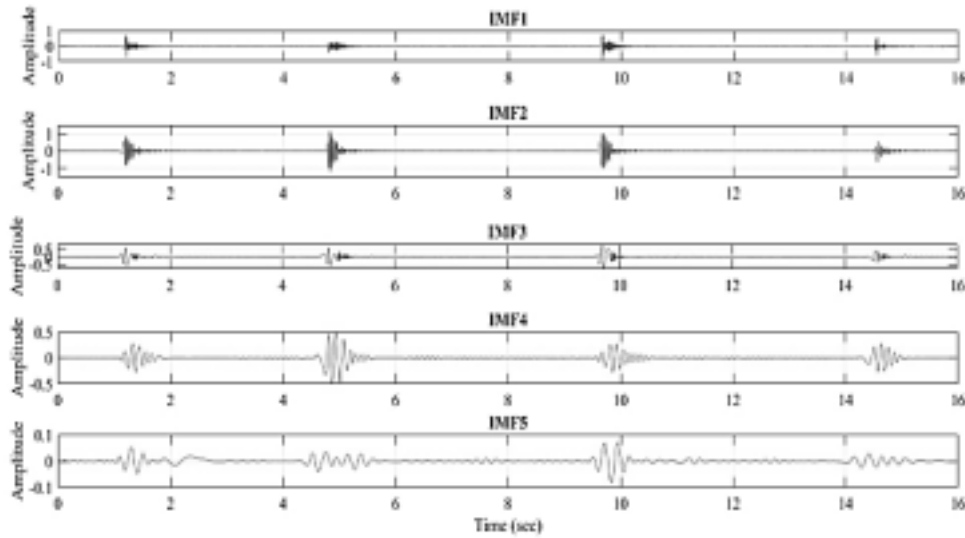
FFT diagram of a frame prototype



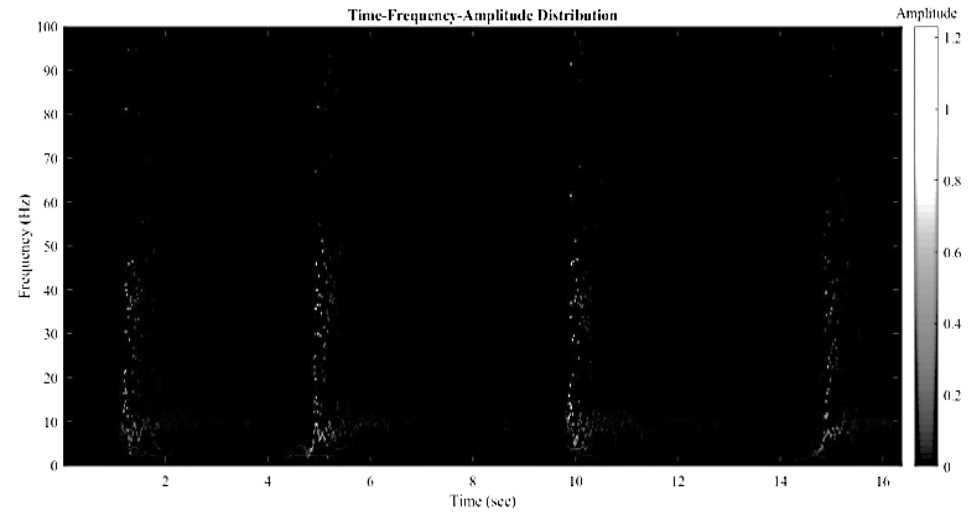
Damage scenario

Damage case:  
additional mass

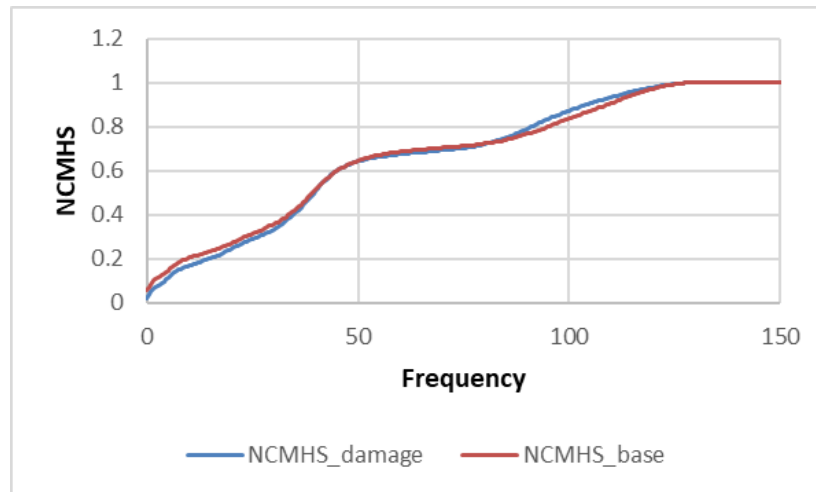
# Steel Frame Prototypes



IMFs of sensor data for intact structure for a frame



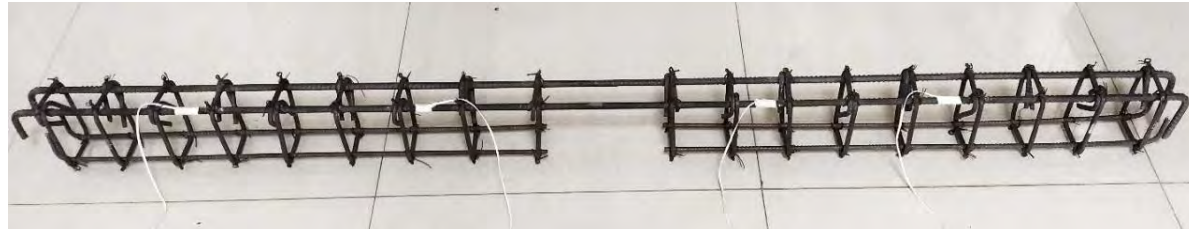
HHT plot for frame



NCMHS comparison for the frame

# Reinforced Concrete Beam

3 reinforced concrete, M30, beams with cross-section of 100\*150 mm & length 1800 mm



Strain gauges installed on tensile reinforcement



Reinforced Concrete beams casted with M30 concrete

**Testing Condition: Four-point flexural loading**



# Reinforced Concrete Structure

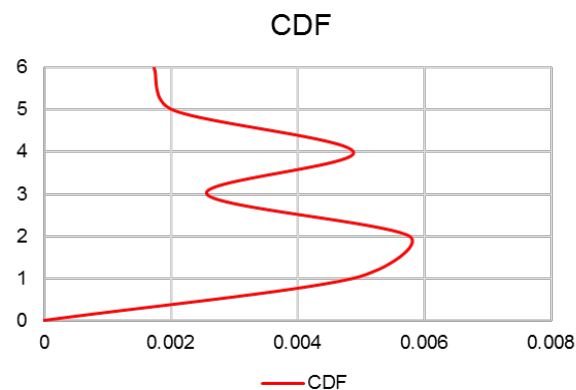
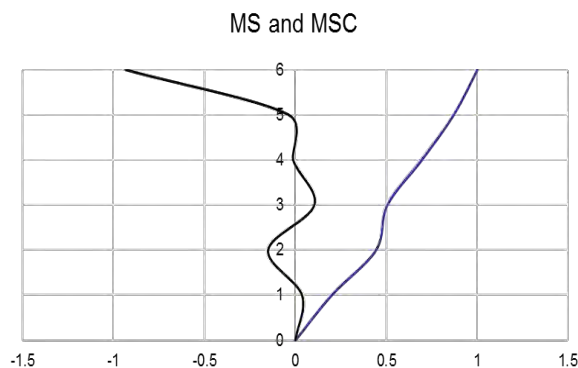
## Reinforced concrete six-storey frame structure

- Height of building: 6.6 m, Plan: 2 x 1.5 m
- Floor to floor height: 1.1 m
- Beam dimension: 175 \* 100 mm, Column dimension: 150 \* 150 mm.
- Sensors used: Wireless Tri-axial Accelerometers

## Damage Detection techniques :

- Curvature Damage Factor (CDF) method
- Marginal Hilbert Spectrum (MHS) method

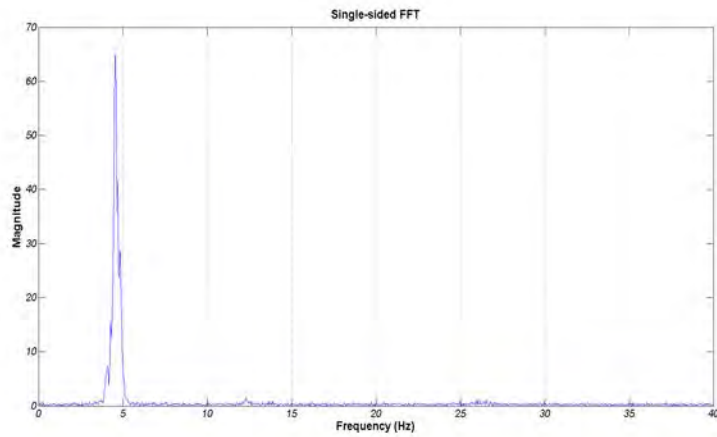
Damage detection: case study – 48 kg masses on 2<sup>nd</sup> and 4<sup>th</sup> floor



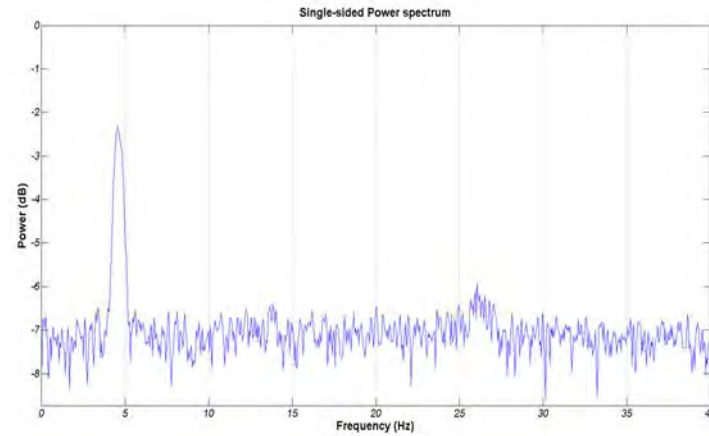
Six-storey RC frame structure

# Reinforced Concrete Structure

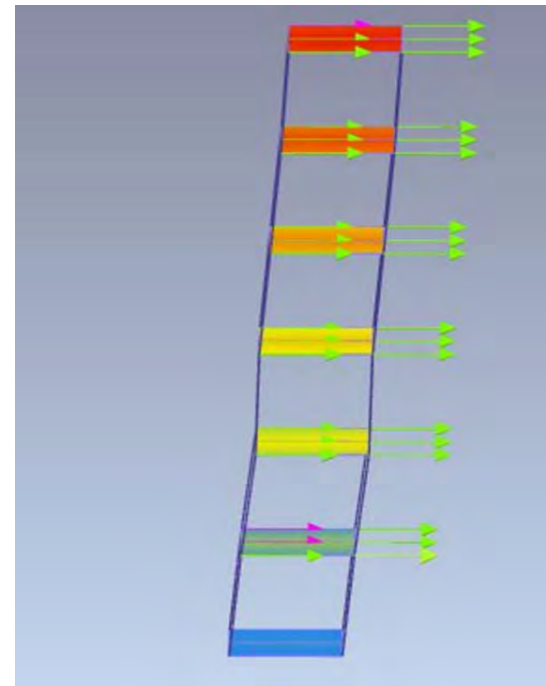
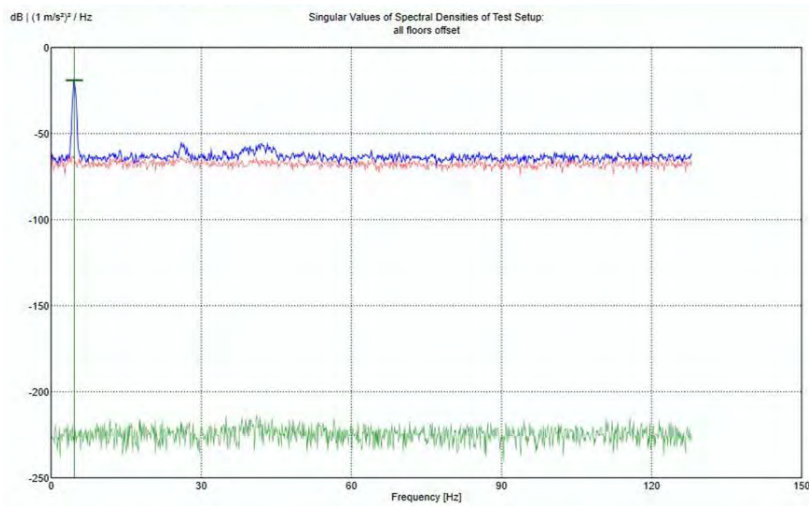
FFT diagram



PSD diagram



SVD digram



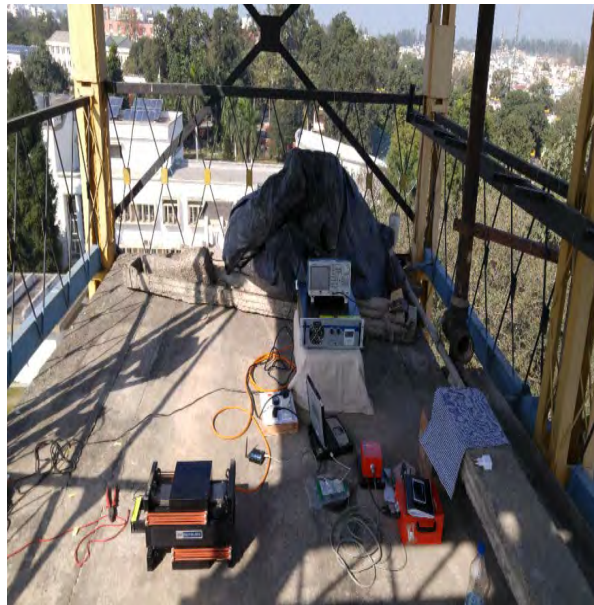
ARTEMIS  
model for  
the six-  
storey RC  
structure

# 8-storey Steel Building

**Building:** 8-storey Steel Building at CSIR-CBRI Roorkee

**Sensors:** Wired velocity sensor and wireless Tri-axial Accelerometers

**Excitation Mechanism:** Long stroke shaker and harmonic signal generator

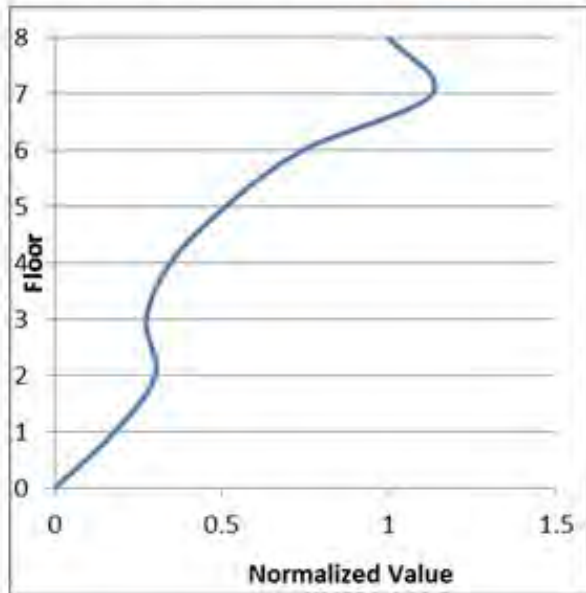


Instrumentation

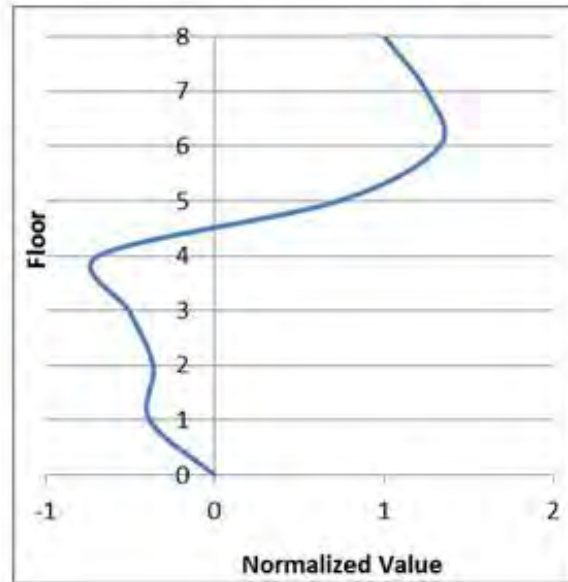


**Eight Story Steel Building in CSIR-CBRI Roorkee**

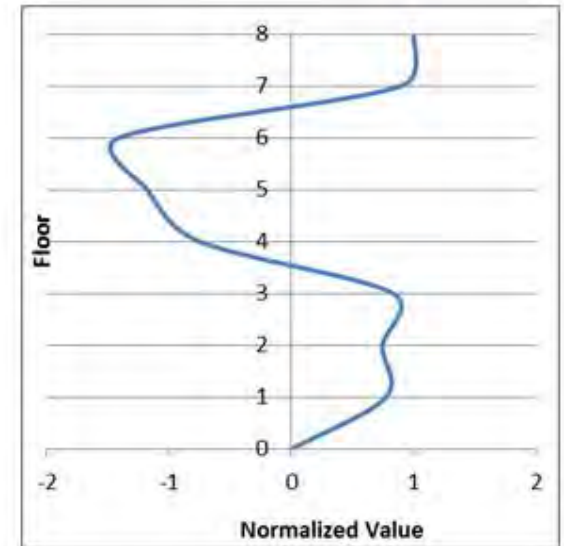
# 8-storey Steel Building



Mode 1<sup>st</sup> (2.0625 Hz)



Mode 2<sup>nd</sup> (6.3594 Hz)



Mode 3<sup>rd</sup> (11.094 Hz)

Case study: 320 kg on 7<sup>th</sup> floor and 310 kg on 5<sup>th</sup> Floor

# Health Assessment of Concordia University EV Building

**Objective of the work** is to verify the algorithms developed so far for the health monitoring of a real operational multi-story structure



Ambient vibration data from the structure will be collected using Fibre Optic Sensors.

**Challenge:** To reduce the effect of noise from the signal to process it using MATLAB and ARTeMIS software

Sixteen storied fully operational EV building of Concordia University, Montreal, Canada



# Thank you

Any Question?



Department of  
Science and Technology



IC-IMPACTS

# Uniqueness

- A robust damage identification methodology for SHM of buildings using noisy and sparse modal information.
- Development of energy efficient wireless sensors for SHM.
- Development of in-built data processing sensors
- To overcome interference losses in data transmission
- An even efficient sensor placement optimization technique
- A modern signal processing and data driven technique for health assessment of buildings without baseline data

# Methodology

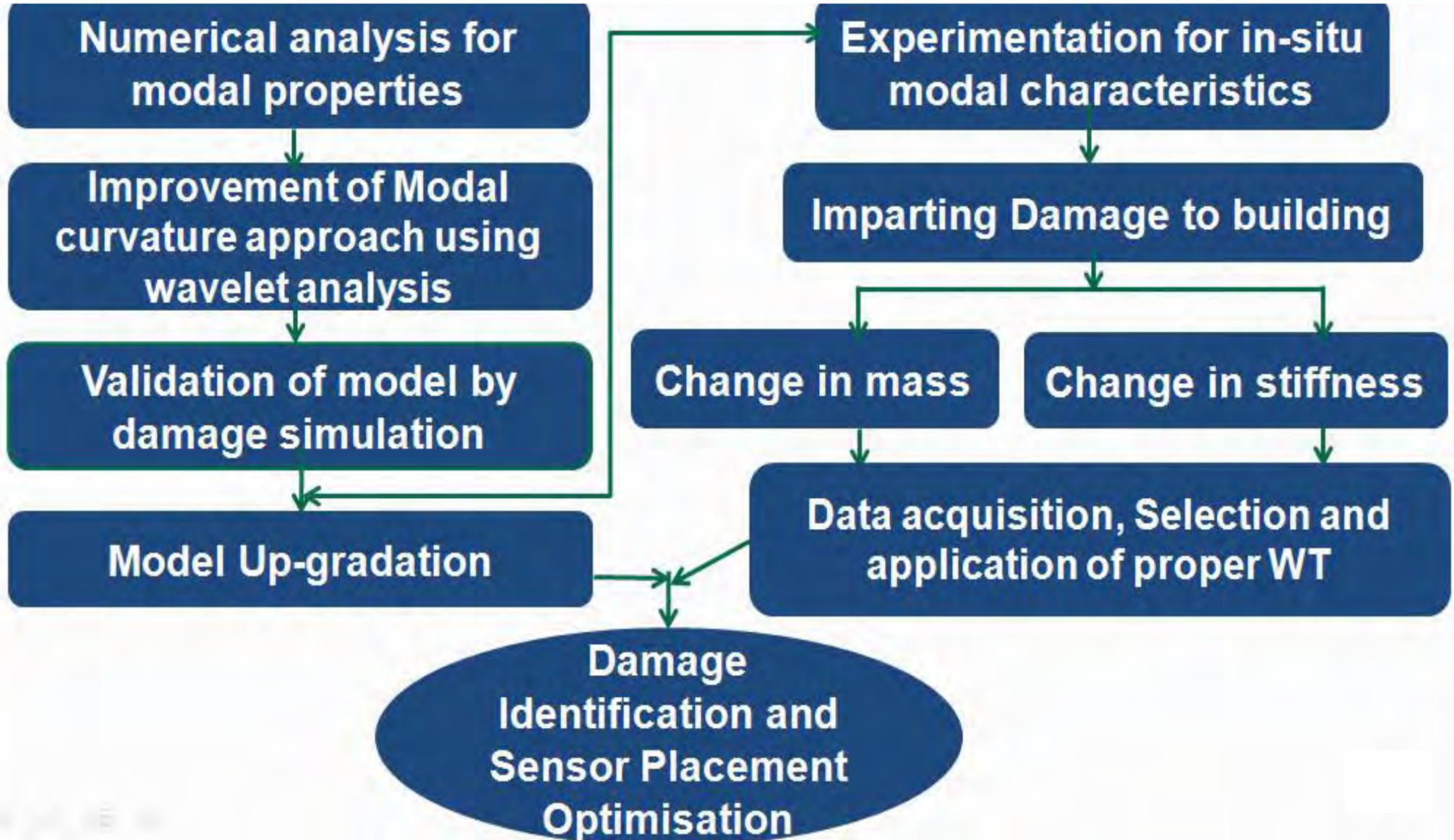
- SHM for **prototype 8-storey steel & 6-storey RC buildings**
- **Development of numerical models & validation**
- Model update of the **prototype buildings**, extraction of dynamic characteristics of the structure, and identification of damage
- Optimization of sensor placement
- **Improvement of wireless sensor network**
- Developing method for interrelationship of data patterns from the sensors
- **Monitoring real-life buildings in India and Canada**



# Methodology

## Numerical

## Experimental



# SHM- Steel Structure

By varying mass  
(M)

No loading

630 kg load

Variable loading  
(346kg,202kg,80kg)

By varying stiffness  
(K)

Case 1: one cut, 4<sup>th</sup>  
floor, west brace

Case 2: second cut , 4<sup>th</sup>  
floor west brace

Case 3: third cut, 4<sup>th</sup>  
floor, west brace

Case 4: one cut,4<sup>th</sup>  
floor, east brace with  
complete west brace

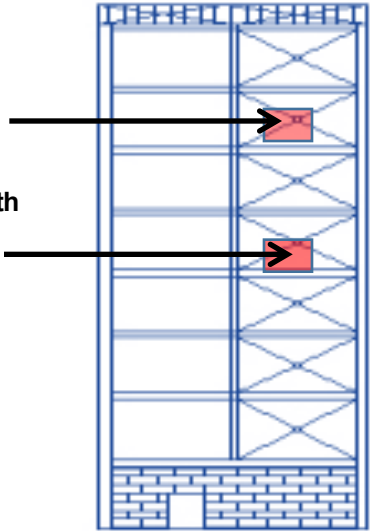
Case 8: second cut,4<sup>th</sup> floor,  
east brace with complete  
west brace

Case 6: : third cut,4<sup>th</sup> floor,  
east brace with complete  
west brace

Case 7: second cut,6<sup>th</sup> floor,  
west brace with complete 4<sup>th</sup>  
floor braces

Case 8: third cut,6<sup>th</sup> floor,  
west brace with complete 4<sup>th</sup>  
floor braces

By cutting  
braces on 4<sup>th</sup>  
& 6<sup>th</sup> floor



# SHM- RC Structure

Ambient state response for load on 3<sup>rd</sup> floor

- Case 1.1: 9kg
- Case 1.2: 13kg
- Case 1.3: 19.5kg
- Case 1.4: 22kg
- Case 1.5: 26kg
- Case 1.6: 32.5kg
- Case 1.7: 45kg
- Case 1.8: 64.5 kg at 4<sup>th</sup> floor
- Case 1.9: 77.5 kg at 4<sup>th</sup> floor

4-5 Hz Sine sweep excitation response for load on 3<sup>rd</sup> floor

- Case 2.1: 9kg
- Case 2.2: 13kg
- Case 2.3: 19.5kg
- Case 2.4: 25kg
- Case 2.5: 35kg
- Case 2.6: 52kg
- Case 2.7: 65kg
- Case 2.8: 78kg
- Case 2.9: 91kg

Sine continuous 4 Hz excitation response for load on 3<sup>rd</sup> floor

- Case 3.1: 9kg
- Case 3.2: 20kg
- Case 3.3: 25kg
- Case 3.4: 34kg
- Case 3.5: 43kg
- Case 3.6: 52kg
- Case 3.7: 65kg
- Case 3.8: 78kg

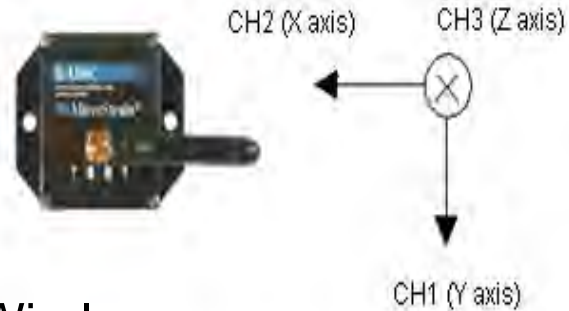
Sine continuous 3 Hz excitation response for load on 3<sup>rd</sup> floor

- Case 4.1: 9kg
- Case 4.2: 13kg
- Case 4.3: 20kg
- Case 4.4: 25kg
- Case 4.5: 34kg
- Case 4.6: 43kg
- Case 4.7: 52kg
- Case 4.8: 65kg
- Case 4.9: 78kg
- Case 4.10: 91kg

# INNOVATIVE SENSORS



Fibre Optic sensor



Wireless sensor



Accelerometer



FOS Interrogator  
(e.g. Micron Optics)



Wireless Base Station  
(e.g. MicroStrain)



Dynamic Data  
Acquisition (e.g.  
NI Compact Rio)

# NDE TECHNIQUES



3D Laser  
Scanner



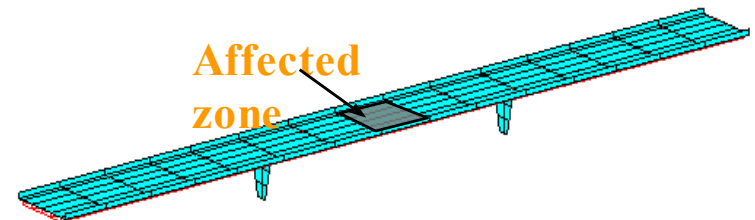
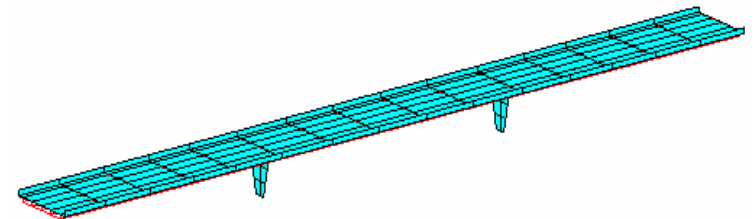
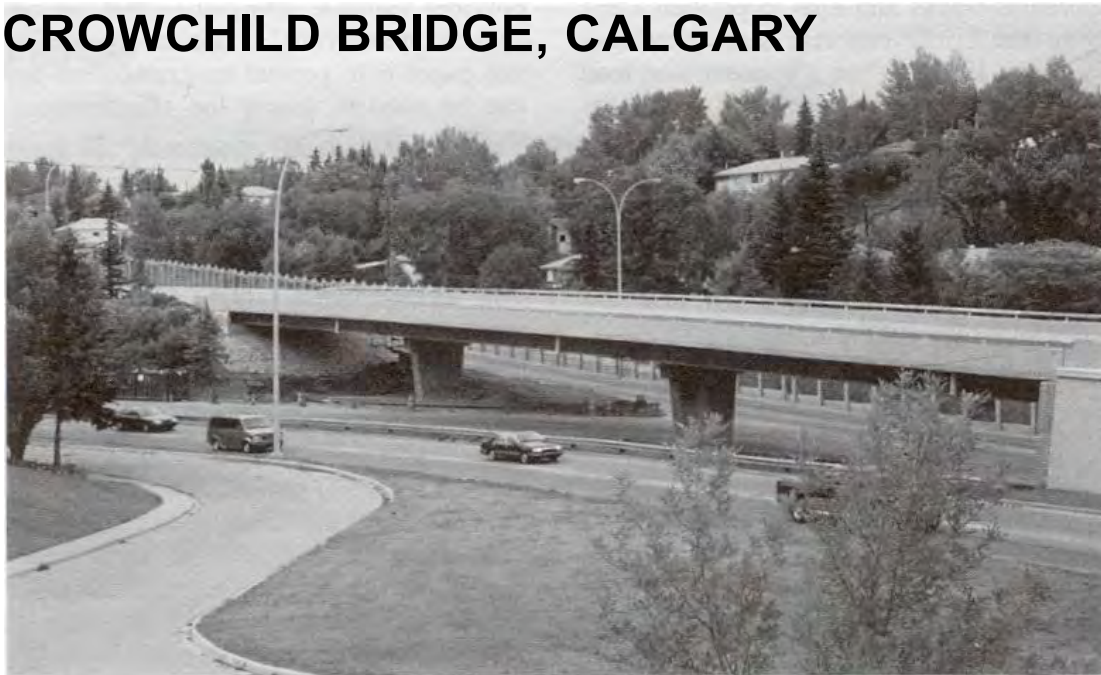
Ground  
Penetrating  
Radre



Thermography  
Camera

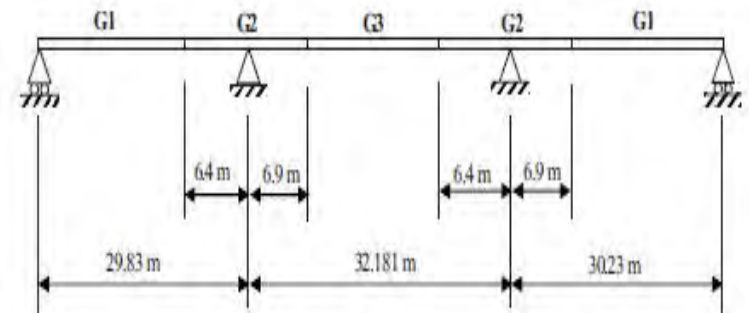
# MODEL UPDATING & DAMAGE DETECTION

## CROWCHILD BRIDGE, CALGARY



Natural Frequencies of the Crowchild Bridge

Mode	Measured frequencies			Description
	1997	1998	2004	
1	2.78	2.60	2.80	First vertical mode
2	3.13	2.90	3.16	First torsional mode
3	3.76	3.63	3.78	Second vertical mode
4	4.05	3.85	4.19	Second torsional mode
5	4.64	2.43	4.66	Third vertical mode
6	5.18	5.00	5.36	Third torsional mode
7	7.13	6.85	6.89	Fourth torsional mode
8	9.13	8.60	8.29	Fourth vertical mode

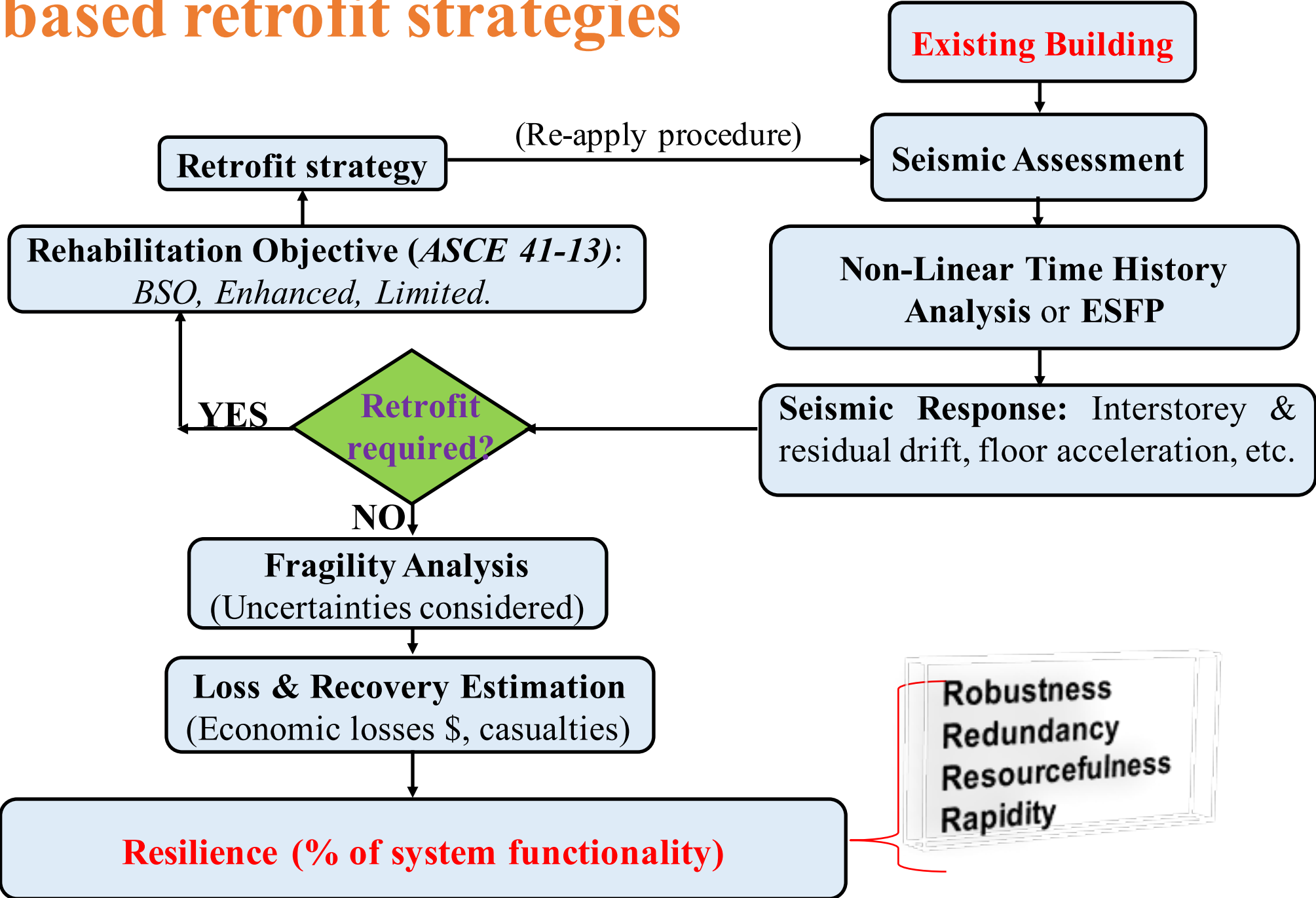


# DATA DRIVEN TECHNIQUES FOR SHM

- Statistical pattern recognition
- Neural Networks
- Wavelet Transform
- Machine Learning Techniques
- Data mining and cloud computing
  
- System ID, Damage Detection, Sensor Reliability



# Seismic Monitoring & Resilience based retrofit strategies





# POTENTIAL CANDIDATES FOR FIELD STUDIES



**Concordia JMSB Building**



**Concordia Biology Building**

# ROAD MAP...

- Experimental Program**
  - Prototype steel building**
  - Prototype RC building**
  - Real-life buildings**
- Numerical analysis of models**
- Analytical modelling & simulation**
- Model-based & data-driven techniques**
- Sensor placement optimization**
- Field implementation**
- Wired & wireless hybrid sensor system**

# Structural Failures in India and Canada



## Building collapse in India

- Korba, Chhattisgarh Korba chimney collapse, 41 died, 23 September 2009
- Thane building collapse, 74 people died, 4 April 2013
- "Mumbai building collapse: 61 people died, 27 September 2013.
- Chennai building collapse, 11 died, 28<sup>th</sup> June 2014.



## Building collapse in Canada

- CKVR Television Tower, Barrie, Ontario, Canada, 1978
- Cape Race LORAN-C Mast Collapse Cape Race, Newfoundland and Labrador, Canada, 1993
- Downsview Park stage collapse Toronto, Canada, 2012
- Algo Centre Mall Elliot Lake, Ontario, Canada, 2012

# Expertise of the Indian Team

## ❑ Experimentation on lab scale models

- MS cantilever beam
- MS 5-storey model
- 8 -storey steel structure
- Reinforced Concrete beam
- Reinforced concrete building

## ❑ Numerical analysis of models

## ❑ Analytical modelling and simulation



IC-IMPACTS India Workshop Series

December 4-5, 2017

# SOLAR ENERGY POWERED NET-ZERO ENERGY SMART BUILDINGS

Aditya Nibandhe, Olesia Kruglov, Efstratios Rounis, Ahmed Noman  
Professors Bruno Lee, Ashutosh Bagchi, Andreas Athienitis



# OBJECTIVES

- Define building details and geometry
- Consider building envelope properties for building location
- Perform energy modeling
- Design a building integrated photovoltaic/thermal (BIPV/T) system for rooftop and façade applications

Concept rendering of a BIPV/T cladding



# BUILDING CASE STUDY 1

- Typical low-rise building consisting of 4 stories (Fig. 1)
- Each floor comprises of two 60 m<sup>2</sup> and two 50 m<sup>2</sup> apartments (Fig. 2 and 3)
- Ground floor contains retail stores (in the urban setting) and parking (in the suburban setting)
- Available rooftop area is approximately 220 m<sup>2</sup>
- Building geometry is defined based on statistical data



Figure 3: A typical low-rise building in India

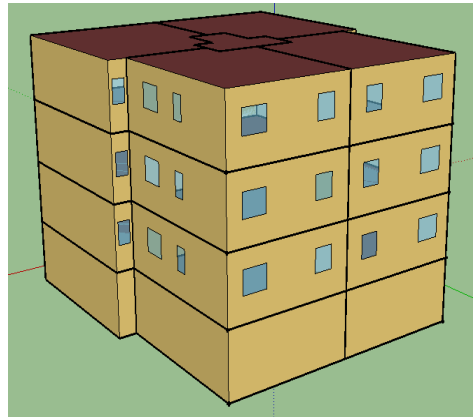


Figure 2: Building model, left rear view

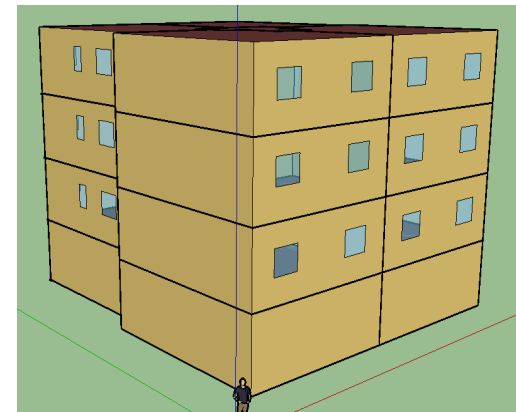
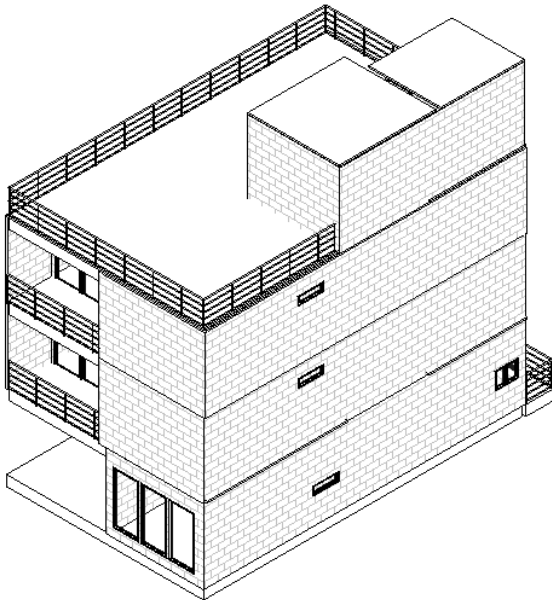


Figure 3: Building model, front right view

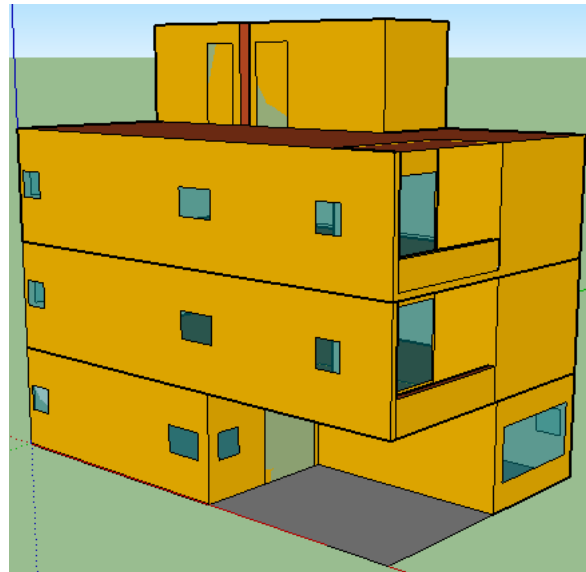


# BUILDING CASE STUDY 2

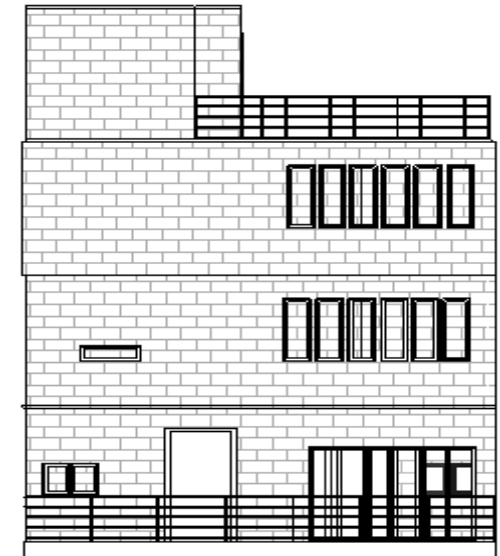
- Building consists of a single family home
- Includes 3 stories with parking on the ground floor
- Total floor area is 3276 ft<sup>2</sup>



Isometric view



3D rendering



West view





# BUILDING ENVELOPE PROPERTIES

- Energy modeling is performed for Chennai, India
  - Climate type is warm and humid
- Selected building envelope properties are as follows:

Envelope Properties	
<b>Wall</b>	230 mm brick wall U-value=1.722 W/m <sup>2</sup> -K
<b>Roof</b>	150 mm concrete roof U-value=2.942 W/m <sup>2</sup> -K
<b>Window</b>	U-value=5.8 W/m <sup>2</sup> -K SHGC=0.82 VLT=0.8
<b>Floor</b>	U-value=2.942 W/m <sup>2</sup> -K

Envelope properties based on thermal conductivity/resistance

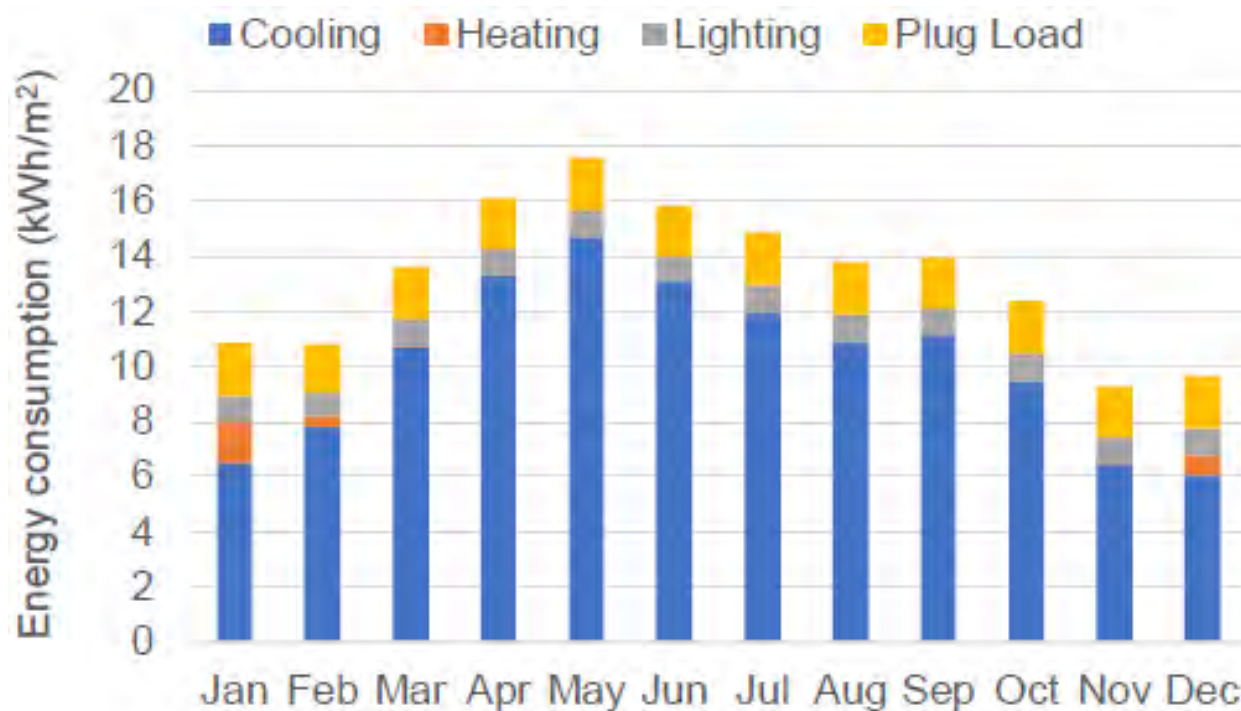
Parameter	Values
<i>Wall</i>	
External wall: 230-mm brick wall	U-value <sup>a</sup> : 2.0 W/m <sup>2</sup> .K; surface absorptivity: 0.65
Internal wall: 115-mm brick wall	U-value: 3.2 W/m <sup>2</sup> .K; adiabatic
Glazing: 6-mm single clear glass	U-value: 6.1 W/m <sup>2</sup> .K; SHGC <sup>b</sup> : 0.85; VLT <sup>c</sup> : 0.9
Shading on the window	500-mm horizontal static overhang at lintel level
Intermediate floor: 150-mm RCC slab	U-value: 3.0 W/m <sup>2</sup> .K; Adiabatic
Window-to-floor area ratio	27%
External wall-to-floor area ratio	181%
Window-to-wall area ratio	15%
Occupancy load and schedule	<i>Schedule for weekdays:</i> 2 persons (21:00–07:00 hours) <i>Schedule for weekend:</i> 2 persons (23:00–07:00 hours and 14:00–17:00 hours)
Set-point temperature	26 °C
Locations	Mumbai and Chennai

Parameters taken from residential building guidelines



# BUILDING ENERGY ANALYSIS

- Energy modeling is conducted for Case Study 1
- 13 thermal zones were used (12 Apartments & 1 retail store)
- Result shows an average annual energy use intensity of 173 kWh/m<sup>2</sup>



Monthly energy consumption profile for a mid-level south facing residential zone



# NET-ZERO ENERGY BUILDINGS

- To harness the vastly available solar energy, modular rooftop BIPV/T systems are proposed.
- The IC-IMPACTS project will feature a low-sloped roof ( $\sim 8^\circ$ ) integrated into a modular system.
- A low slope is optimal for near equatorial latitudes.
- The BIPV/T system incorporates the production of electricity and useful heat, while considering the building envelope requirements for both wall and roof applications.



Modular BIPV/T prototype

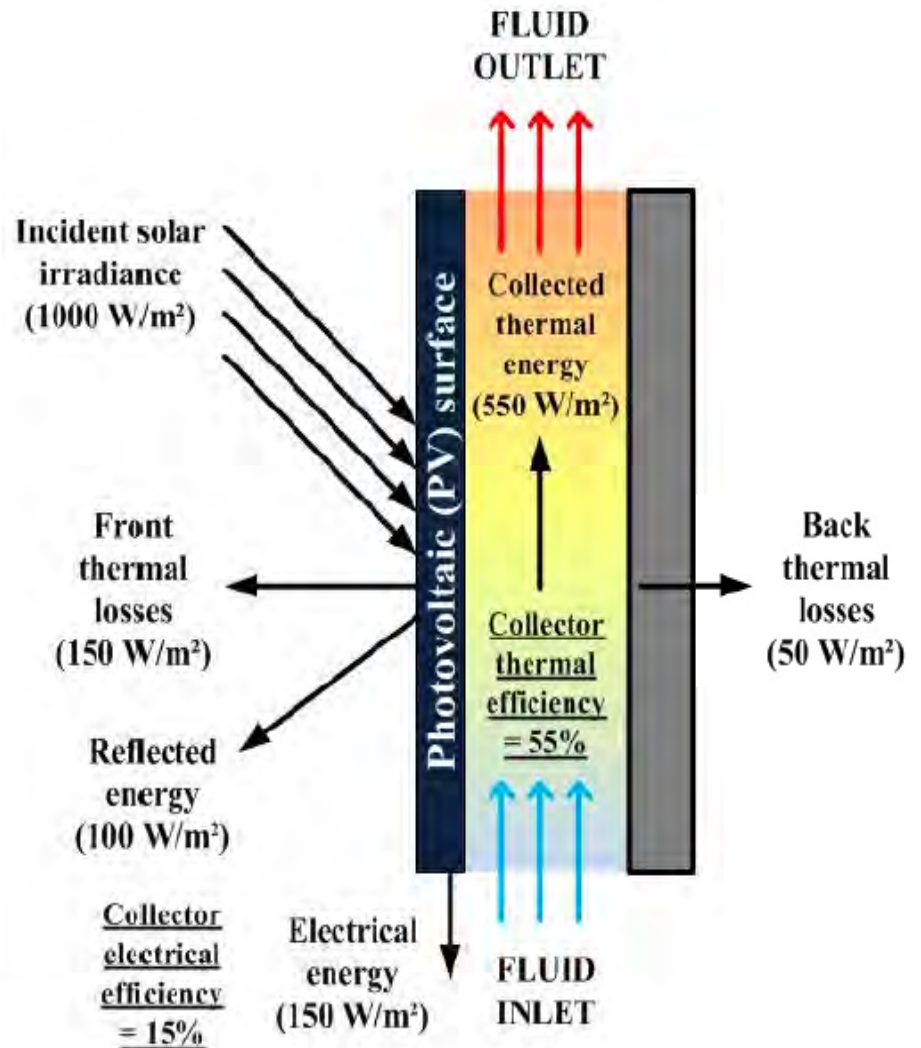


BIPV/T roof on Varennes Library



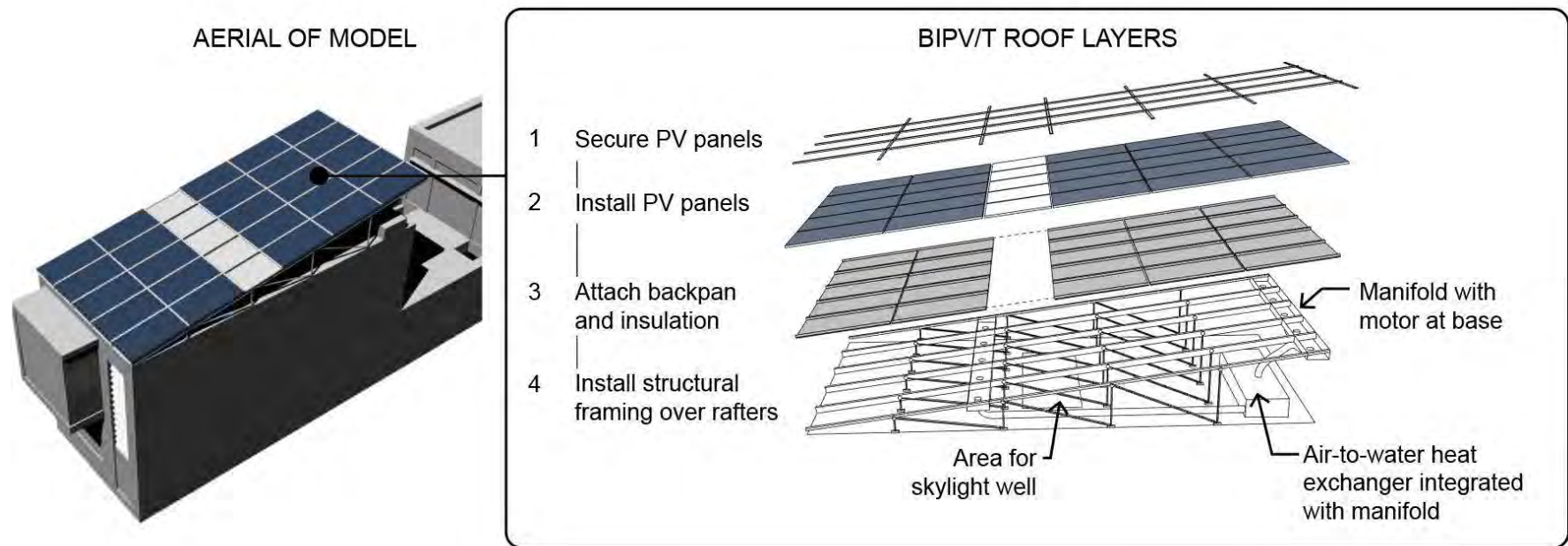
# WHAT IS BIPV/T?

- Current practices for solar panel or photovoltaic (PV) technologies on buildings are mainly **racked systems**
- **Building-integrated photovoltaic/thermal (BIPV/T)** systems as alternatives to traditional cladding
- Retrofits can **turn unused or semi-conditioned spaces into fully enclosed conditioned spaces**
- Heat generated from the **PV panels can be collected and utilized**



# ROOFTOP APPLICATION

- A **curtain wall (CW) framing assembly** is a good solution for large scale, air-based BIPV/T systems
- **Manifold collects preheated air from the system and passes it to an air-to-water heat exchanger**
- For a roof coverage of 180m<sup>2</sup> and typical summer day conditions in Chennai, India, a typical system would have an electrical output of 147 kWh and a thermal output of 228 kWh



# CONCLUSIONS

- Building energy analysis shows an average annual EUI of 173 kWh/m<sup>2</sup> for a low-rise 4 story building as in Case Study 1
- BIPV/T modular rooftop system as practical application for delivering energy to the building
- Focus on **common building practices** and **previous lack of true integration** between façade and PV/T system design
- Potential for **modular and unitized designs**, primarily for **large scale applications, as well as architectural and visual continuity**
- For Indian climate, BIPV/T application can utilize heat driven cooling systems such as absorption cooling systems.



THANK YOU!

Olesia Kruglov

olesia.kruglov@gmail.com



**Community engagement  
Gender and Equity**

**Bilkis Vissandjée, PhD**  
Faculté des sciences infirmières, School of Nursing, Université de Montréal  
Institut de recherche en santé publique de l'Université de Montréal











Highlights of Success	4
Safe and Sustainable Infrastructure Projects	6
Featured Innovations	8
Integrated Water Management Projects	10
Featured Innovations	12
Public Health Projects	14
Featured Innovations	16
Training Programs	18

*"Since its humble beginnings in 2013, IC-IMPACTS is now recognized as a very successful model for international research collaborations, innovative HQP training, respectful community engagement and creation of technologies that promote international trade."*

- Dr. Nemy Banthia  
CEO and Scientific Director, ICIMPACTS









**IC-IMPACTS HIGHLIGHTS**

<p><b>PROJECTS</b></p>  <p>16 TECHNOLOGY DEPLOYMENTS</p>	<p><b>PUBLICATIONS</b></p>  <p>584 SCIENTIFIC PUBLICATIONS</p> <p>↓</p>  <p>22 PATENTS &amp; LICENSES</p>
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<p><b>JOBS</b></p>  <p>630 INNOVATORS TRAINED</p> <p>↓</p>  <p>98% STUDENTS EMPLOYED</p>	<p><b>PARTNERSHIPS</b></p>  <p>250 MULTI-SECTOR PARTNERSHIPS</p> <p>↓</p>  <p>\$11M FUNDING LEVERAGED*</p>
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\* As of March 31st, 2017



### SAFE & SUSTAINABLE INFRASTRUCTURE

#### PROJECTS

- Assessment of Infrastructure Energy Demand (M2)**  
Assessment of the energy demand of buildings, roads, and infrastructure. Led by Dr. David Hens, Ghent University.
- Performance-based design of infrastructure for fire and explosion safety**  
Development of performance-based design methods for fire and explosion safety. Led by Dr. David Hens, Ghent University.
- Modeling and Assessment of Traffic and Air Quality in Urban Areas**  
Modeling and assessment of traffic and air quality in urban areas. Led by Dr. David Hens, Ghent University.
- Development of Energy Efficient Buildings for Smart Cities**  
Development of energy efficient buildings for smart cities. Led by Dr. David Hens, Ghent University.
- Energy Efficient Buildings for Smart Cities**  
Energy efficient buildings for smart cities. Led by Dr. David Hens, Ghent University.
- Assessing the Energy Use of Building Infrastructure in Cities and Countries with Smart Grids and Renewable Energy**  
Assessing the energy use of building infrastructure in cities and countries with smart grids and renewable energy. Led by Dr. David Hens, Ghent University.
- Application of Smart Grids in Building Energy Systems: A Case Study of the Netherlands & China**  
Application of smart grids in building energy systems: a case study of the Netherlands & China. Led by Dr. David Hens, Ghent University.

#### 8 CANADIAN PROJECTS

#### 584 SCIENTIFIC PUBLICATIONS

#### 22 PATENTS & LICENSES

### HIGHLIGHTS

#### PROJECTS

- Water Energy Potential and Low Energy Green Buildings**  
Water energy potential and low energy green buildings. Led by Dr. David Hens, Ghent University.
- Water Energy Potential for Building Water Heating**  
Water energy potential for building water heating. Led by Dr. David Hens, Ghent University.
- Energy and Water Requirements for Residential Low-Mid-Rising Buildings**  
Energy and water requirements for residential low-mid-rising buildings. Led by Dr. David Hens, Ghent University.
- Smart Sensor Equipment for Building Envelope Monitoring and Energy Management**  
Smart sensor equipment for building envelope monitoring and energy management. Led by Dr. David Hens, Ghent University.
- Water Heat Load Effect and Building Energy Demand: College Experimental Testing, Low-Cost Sensor Network**  
Water heat load effect and building energy demand: college experimental testing, low-cost sensor network. Led by Dr. David Hens, Ghent University.

#### 38 CANADIAN PROJECTS

#### 584 SCIENTIFIC PUBLICATIONS

#### 22 PATENTS & LICENSES

### IC-IMPACTS HIGHLIGHTS

#### RECYCLING TIRE FIBRES INTO PAVEMENTS

Dr. Henry Sautter and Dr. Christel Chagnacoff (University of Sherbrooke) have developed a more sustainable type of concrete using recycled tires that could be used for roadways and other building materials. Their work is being funded by the Natural Sciences and Engineering Research Council of Canada.

The team experimented with different proportions of recycled tires and concrete. They found that the best mix was 10% recycled tires and 90% concrete. This mix was stronger and more durable than traditional concrete.

The new concrete was used to build the base of a road in the city of Sherbrooke. The road is now open to traffic and has been used for several months. The team is now working on building a full-scale road to test the concrete in real-world conditions.

The team's research is being funded by the Natural Sciences and Engineering Research Council of Canada. The team is also working on developing a commercial process for recycling tires into concrete.

#### 584 SCIENTIFIC PUBLICATIONS

#### 22 PATENTS & LICENSES

### IC-IMPACTS HIGHLIGHTS

#### USING BACTERIA TO PURIFY WATER

Dr. David Hens and Dr. Christel Chagnacoff (University of Sherbrooke) have developed a more sustainable type of concrete using recycled tires that could be used for roadways and other building materials. Their work is being funded by the Natural Sciences and Engineering Research Council of Canada.

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#### 38 CANADIAN PROJECTS

#### 584 SCIENTIFIC PUBLICATIONS

#### 16 TECHNOLOGY EMPLOYMENTS

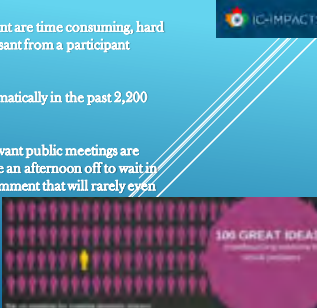
#### 22 PATENTS & LICENSES



The existing vehicles for public comment are time consuming, hard to find, difficult to navigate, and unpleasant from a participant perspective.

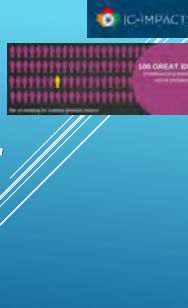
Access to information has changed dramatically in the past 2,200 years

Most people are unaware of where relevant public meetings are taking place, and most people can't take an afternoon off to wait in line for hours to make a two-minute comment that will rarely even garner a response.



Because forums for public engagement are often woefully underutilized, people might interpret a community's lack of engagement as a lack of interest.

*Public spaces don't exist where people from all backgrounds can engage in meaningful idea-sharing and collaborative community problem-solving in a user-friendly, free, convenient, welcoming way, where their ideas will actually be heard and considered by decision-makers.*



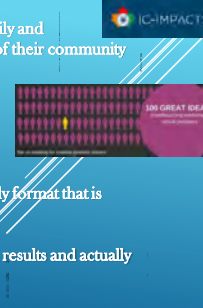
What would a "public space" where people could easily and collaboratively brainstorm ways to address the issues of their community look like for IC IMPACTS ?

Would that space be utilized by the end-users?

Would good ideas come from it?

And if those ideas were synthesized into a user-friendly format that is intuitive and clear to understand ....

Would local leadership take the time to engage in the results and actually take action based on the voices of their constituents?



What would a "public space" where people could easily and collaboratively brainstorm ways to address the issues of their community look like for IC IMPACTS ?

People want to engage ....

Women, men, boys and girls need better and differential access points...

Differential .... Gender and Equity sensitive ....




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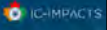
Women, men, boys and girls need better and differential access points...

Differential .... Gender and Equity sensitive ....

To foster an ongoing culture of engagement ... What does that mean for engineers engaged in ... building healthy concrete for healthy buildings and roads ...





Gender, the Environment and Sustainable Development in Asia and the Pacific


ADB Asian Development Bank

IC-IMPACTS

Good Practice Paper in Water: Closing the Gender Gap: Punjab Water Supply and Sanitation Project



ADB Asian Development Bank

IC-IMPACTS

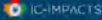


**C. Setting the Gender Agenda**

As a part of ADB's way of doing business—business that results in sustainable poverty reduction, economic growth and environmental protection—it has a gender and set of goals to guide projects toward development results. ADB's Policy on Gender and Development (GAD) brings gender issues into the mainstream of project work, showing the cross-cutting effect women's participation can have on the social, economic and environmental impacts of a project. To bring the GAD policy from paper into practice, ADB suggests three main opportunities to identify and address gender issues in the project cycle:


- **Gender analysis:** A systematic assessment of the potential impact of the proposed project on both women and men and the social and economic relations between them. A gender analysis is essential to a proposed project to determine whether women's empowerment and overall changes in gender relations, if it is a specific objective within the overall social empowerment component in the project. Empowering women. The gender analysis informs the project design.
- **Policy dialogue:** Discussions with government agencies and the project's executing agency should be ongoing throughout the project cycle. Results of the gender analysis should be shared and agreements made on how the project will be designed and implemented.
- **Project design:** Project components that are designed based on the gender analysis and to specifically benefit women.

The gender analysis commissioned for the Punjab project is notably strong for two reasons:

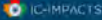

- The analysis is specific to the water sector and includes a concrete analysis of both the time women and girls spend in fetching water as well as an attempt to estimate the monetary value of that time.

**Good Practice Paper in Water: Closing the Gender Gap: Rural Water Supply and Sanitation Project**



Area of Development	Project Benefits
Health	<ul style="list-style-type: none"> <li>Reduced incidence of reduced incidence of diarrhea, malaria, and typhoid.</li> <li>Reduced incidence of meningitis, pneumonia, typhoid, and cholera, as a result of safe water and hygiene improvement.</li> <li>Reduced mortality medical expenditure (between one third and one-half level).</li> <li>Reduced incidence of wet pants, backache, and joint and muscle pains in women as a result of no longer carrying water.</li> <li>Improved health care and income as a result of reduced illness, typhoid and medical expenses.</li> </ul>
Environment	<ul style="list-style-type: none"> <li>Improved equality, particularly for women and elderly and during the wet season, as a result of improved drains and nearby paved streets.</li> </ul>
Education	<ul style="list-style-type: none"> <li>School enrollment, especially among girls has increased and water systems were installed. Primary school enrollment in one village increased by 30% in another area, primary enrollment more than tripled among girls and increased by 40% among boys.</li> </ul>
Economic	<ul style="list-style-type: none"> <li>Women have increased and diversified their income as a result of time saving from the new water system and access to nearby roads. They are using for larger numbers of livestock and poultry and avoid long hours in the field. Many women have also turned to more sewing, weaving, handicrafts.</li> <li>The project had provided technical support and opportunities for women and all other people in the area. As a result, the region is economically more resilient to natural disasters.</li> </ul>

**The 2030 Agenda and the two international frameworks represent a collective call for environmental sustainability that integrates the importance of livelihoods, well-being and sustainable economic development.**

**Features of the 2030 Agenda and the prominence of gender equality and environmental sustainability**

- 1. Prioritize development, funding, dissemination and the adoption of new gender-responsive technologies.
  - Promote strategies that realize time and energy saving technologies.
  - Leverage innovative and communication technologies to facilitate and maximize the opportunities for women engagement in digital technologies, mobile telephony, and internet data businesses and other opportunities to get more in the economy.
  - Foster the development of mobile payment technologies for less cashless.
- 2. Integrate gender analyses into policymaking and strategies for environmental sustainability and...
  - Request support of the development institutions for new concepts based on innovative models.
  - Recognize women's rights through equal work.
  - Reduce gender inequality across the world to be equal with men.
  - Develop programs especially for women's welfare and social progress.
  - Improve cross-sectoral collaboration of the gender and climate sectors.







**TRANSFORMING OUR WORLD:**



**THE 2030 AGENDA FOR SUSTAINABLE DEVELOPMENT**

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**Goal 10: Reduced Inequalities**

**Target 10.2: Empower and promote the social, economic and political inclusion of all**

**Target 10.4: Adopt and strengthen sound institutional frameworks, policies and laws to support fair competition and enhance resilience to shocks and disasters**

**Target 10.5: Upgrade infrastructure and expand high-quality public services for all, in particular for the poor and vulnerable**

**Target 10.6: Develop and operationalize gender equality and women's empowerment legislation**

**Target 10.7: Ensure that the voices of the poor and vulnerable are heard and promoted in global, national and local decision-making**

**Target 10.8: Reduce the social and economic impact of disasters and climate change on the poor and vulnerable**

**Target 10.9: Develop and operationalize gender equality and women's empowerment legislation**

**Target 10.10: Ensure that the voices of the poor and vulnerable are heard and promoted in global, national and local decision-making**

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Sustainable Development Goals and targets

Goal 1. End poverty in all its forms everywhere	17
Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture	17
Goal 3. Ensure healthy lives and promote well-being for all at all ages	18
Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	19
Goal 5. Achieve gender equality and empower all women and girls	20
Goal 6. Ensure availability and sustainable management of water and sanitation for all	20
Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all	21
Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	21
Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	22
Goal 10. Reduce inequality within and among countries	23
Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable	24

Goal 12. Ensure sustainable consumption and production patterns	24
Goal 13. Take urgent action to combat climate change and its impacts	25
Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development	26
Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	27
Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels	28
Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	28

### FOCUS: GROWING PARTNERSHIPS WITH COMMUNITIES & INDUSTRIES

**CANADA 100**

ICIMFACTS is partnering research from UBC students to develop communities and find solutions for working in partnership developing cultural and environmental and addressing transportation projects with 10 students and local residents.

75% of first females in making science careers are at high risk of underachievement. Over 70% communication and leadership practices.

70% of first female engineers, over 70% graduate and reports.



ICIMFACTS students with youth from the 7Aqam community in Cranbrook, BC.

### What Is Compassion in Healthcare?

Beth R. Forest, PhD, EdD | May 04, 2016

Compassion in Health Care: An Empirical Model

## GENDER INDICATORS FOR SCIENCE, ENGINEERING AND TECHNOLOGY

Chapter 1

### Overview: Gender indicators for science, engineering

Chapter 2

### The leaky pipeline: Gender issues in science, engineering and technology

**MEMBERS & COMMITTEES**

IC-IMPACTS

**Improve patient care and outcomes:  
Adding a Clinical Nurse Specialist to your team  
A Guide for Successful Integration**

**DEVELOPING FUTURE WATER LEADERS**

**Lessons learnt**

IC-IMPACTS

1. Engaging consumers & communities and sustaining reciprocal relationships
2. Leadership and accountability for sustained change
3. Building on strengths: know the community, know what works
4. A shared responsibility: creating partnerships and sustainability
5. Be sensitive to diversity

**“People know what they do; frequently they know why they do what they do; but what they don’t know is what what they do does.”**

**Michel Foucault, *Madness and Civilization: A History of Insanity in the Age of Reason***

- ▶ Thank you
- ▶ Merci
- ▶ Dhanyawad



Good Practice Paper in Water  
Closing the Gender Gap:  
Punjab Water Supply and Sanitation Project

*WATER for ALL*





## A. Introduction

“Women are change agents.” We hear it said all the time in development work. But are women naturally change agents, or do they need coaxing into being these change agents? What must projects do to take advantage of the benefits of these change agents? As capable as women are, they can also be reluctant to participate in change. Deeply engrained gender inequalities in traditional societies, as well as modern societies in different ways, limit not just what women can accomplish, but also what they think they can accomplish. With a bit of realization, though, women find a new will and accomplish more than imagined, including shifts in the very gender structure of their households and communities.

This good practice paper<sup>1</sup> looks at how one ADB water supply project developed female beneficiaries into change agents. The paper summarizes the planning, design, and implementation of gender-specific components that made the water supply project the success that it is. The benefits that the women are receiving, and passing on to their households and communities, are not just project bi-products. The benefits were carefully planned and designed for. As a result, it wasn't just their improved access to water that is improving women's quality of life. Water is just a means to a much larger end—an end that is the beginning of more balanced gender relations and higher levels of health, income, and education. With the chance to be change agents, the project women have become leaders and are making their communities a better, more promising place. And the men in their families and communities are starting to give them credit for their role in that change.

## B. Potential in Punjab

The focus of this case study is the [Punjab Water Supply and Sanitation Sector Loan](#). Punjab province is the largest province in Pakistan and is home to 84 million people, with 60% of them living in rural areas. ADB worked with the Government of Punjab's Housing, Urban Development and Public Health Engineering Department as the implementing unit. Half of this large rural population depends on uncovered wells, filthy rivers, and stagnant ponds for drinking water. Only a quarter of Punjab's rural population has access to household latrines, leaving most of them to defecate in open areas, which contributes to the polluted drainage system and environmental health problems.



To address water and sanitation problems in rural Punjab, the Asian Development Bank (ADB) provided the full cost of the project: loans amounting to \$46 million in 1995<sup>2</sup> and \$50 million in 2002 to improve the water supplies and drainage facilities in 1,085 rural communities. The project took special consideration of a significant cultural and social norm in the communities: water collection is considered women's work. The project's holistic, community-based approach and its gender-targeted design caught the attention of the [Gender in Water Partnership](#)<sup>3</sup> for a case study. The methodology for the case study naturally involved a review of secondary data from ADB documents and reports, but the case study writer also visited more than 10 project sites to interview project beneficiaries, project staff and local stakeholders.<sup>4</sup>

*“By fetching water three to four hours a day, carrying pitchers on our heads, we became bald! We carried water even when we were pregnant! Pregnant women carrying water became ill. This has now reduced. We used to bathe once every week or once every 10 days using canal water. The males were enjoying, but we were forced to bring water, cook, look after the children. All the burden was on us.”*

— Bashiran Bibi, Chairperson of Women's CBO DZ Khan

## C. Setting the Gender Agenda

As a part of ADB's way of doing business—business that results in sustainable poverty reduction, economic growth and environmental protection—it has a process and set of policies to guide projects toward development results. [ADB's Policy on Gender and Development \(GAD\)](#) brings gender issues into the mainstream of project work, showing the crosscutting effect women's participation can have on the social, economic and environmental impacts of a project. To bring the GAD policy from paper into practice, ADB suggests three major opportunities to identify and address gender issues in the project cycle:

- **Gender analysis:** A systematic assessment of the potential impact of the proposed project on both women and men and the social and economic relations between them. A gender analysis assesses how a proposed project could contribute to women's empowerment and overall changes in gender relations. It is a specific exercise within the overall social assessment conducted in the project preparatory stage. The gender analysis informs the project design.
- **Policy dialogue:** Discussions with government agencies and the project's executing agency should be ongoing throughout the project cycle. Results of the gender analysis should be shared and agreements made on how the project will be designed and implemented.
- **Project design:** Project components that are designed based on the gender analysis and to specifically benefit women.

The gender analysis accomplished for the Punjab project is notably strong for two reasons:

- The analysis is specific to the water sector and includes a concrete analysis of both the time women and girls spend in fetching water as well as an attempt to estimate the monetary value of that time.

<sup>1</sup> This good practice paper is a summary version of a more detail case study prepared by Reihana Mohideen. The full case study, “Gender Equality Results in the Punjab Community Water Supply and Sanitation Sector Project” is available.

<sup>2</sup> The interest-free loan, from the Bank's concessional Asian Development Fund, has a repayment term of 35 years, with a grace period of 10 years, and carries an annual service charge of one per cent. The project was developed as a sector loan under the Government's Social Action Program.

<sup>3</sup> ADB and the Gender and Water Alliance teamed up in 2003 to undertake various research and training activities to improve good gender practices in ADB projects.

<sup>4</sup> The full version of the case study provides a list of people met during the field visit (Appendix 2) and a field study checklist that guided the interviews with stakeholders (Appendix 3).

<sup>5</sup> For further information on methodologies employed for each activity, see ADB's [Gender Checklist for Water Supply and Sanitation](#).

- The analysis extended to the lessons documented from other water supply and sanitation projects in Pakistan. The lessons learned generated information that was directly incorporated into the components designed for the proposed project, such as the knowledge that providing safe drinking water generates a demand for credit and technical assistance for income-generating activities among women due to their time saved by no longer fetching water.

*"For collecting / fetching water, women on average spend three hours a day. The normal wage for women is about PRs60 per day. Assuming 50% of the available time is used in productive employment and applying a shadow wage rate of 0.7%, the value of time saved in a year is estimated as PRs 2,874"*

— Report and Recommendation of the President, November 2002, Appendix 12, pp. 56.

Both the GAD policy and ADB's water policy provided the framework for policy dialogue with the government through the project cycle. Prior to the design, ADB and the government agreed on the general directions the project should pursue, such as using a community-based approach for selecting subprojects and participatory methods and consultations for developing need-based projects.

Based on the results of the gender analysis and policy dialogue, the project was designed with four components that would directly impact women's lives. Table 1 summarizes the advantages of each component for female beneficiaries.

**Table 1.** Female benefits per project component

Project Component	Benefits for Female Beneficiaries
1. Construction of water supply and drainage facilities	Lift the burden of fetching water that women and girls bear. Women would have more free time for income generating activities to augment the family income, and girls would be able to devote more time to their education.
2. Institutional strengthening	Community groups established by the project would have female representation and interface with local governments

*After the project, I started school for the first time. I like school. I don't feel ashamed even if I am sitting in class with small girls. My mother and I were involved in fetching water. We used to make two visits daily—one in the morning and the other in the evening, spending 5–6 hours daily in fetching water from a distance of 2 kilometers one way, which means one woman has to travel 8 kilometers per day to fetch water. I started to fetch water from the age of 5 years. It was a vicious circle of 10 years. I did not think that I could get rid of fetching water. It was a sore aspect of my daily tasks. I used to idealize my brothers and wished that I was a boy. At times, when I refused to go with my mother, my grandmother would abuse me for that and would tell my father that I am disobedient. I cannot forget those words of my grandmother. Sometimes, I insisted that my brother accompany me, but my mother would tell me that my brother does an important job of getting an education, and if he would go with me it would affect his education. It was a laborious job, and I use to live under mental stress, especially to go again in the evening for fetching water ... Better off families in our village either buy water or had donkeys, donkey carts, bull carts or bicycles to carry water. I felt harassed when some boys on bicycles use to laugh at girls in my group and pass comments, but other girls or even my mother never paid attention to them. I will take my education to the highest level and will become a teacher in the village school."*

— Shakeela, 15 years old

To tie together the efforts and intentions of the gender analysis, policy dialogues and design, an action plan is needed. It is one step further in ensuring the GAD policy will be implemented. The gender action plan for the Punjab project was included in the policy dialogue with the government. Table 2 summarizes four strategies and their accompanying gender-specific indicators that make up the action plan.

**Table 2.** Female benefits per project component

Gender Strategy	Gender-Specific Indicators
1. Gender-Sensitive Participatory Processes	Female community-based organizations are established to promote, encourage and contribute to women's empowerment, and to make small but significant changes in gender relations.
2. Concrete Targets for Women's Participation	Women's participation in community meetings reaches 50%; women benefiting from micro-credit programs reaches 60%; at least 50% of all community-based mobilizers are women
3. Monitoring and Evaluation	Important sex-segregated data for monitoring and evaluation purposes are collected
4. Use of Specialists Services	Organizing gender-related activities are included in the terms of reference of specialists for social development, community needs assessment, and micro-enterprise development

Getting communities to participate was critical from the very early stages of the project because agreements with the government in policy dialogue required that the project be demand driven, with communities deciding on their needs. The work began with recruiting community-based mobilizers (CBMs), which was required by project design, to employ 50% women. The primary task of the CBMs was to travel to project villages and mobilize both men and women into community-based organizations (CBOs).

*"We might start with motivating the men in the village, but we prefer to work with women because the project is about water. Men don't see the importance of it. It's not their first need, unlike for women. It's the women who also motivate the men. Women know the technical problems with pipes, leakages, etc. They monitor this and tell us the problems. Men don't care so much about this. Without female participation no scheme can be sustained."*

— Rabia Kauser, CBM, Bahawal Pur

The job of building CBOs was a challenge: there was resistance by both women and men. Women did not believe outsiders could help them or that they could help themselves get water. They believed providing water was the job of politicians. Unconvinced of their capabilities to solve their own water problems, they did not think they had the time to be involved in the project or that their husbands would allow it. Women also believed that community meetings and decisions were for men. True enough, the women are busy as laborers working long, hard days before coming home to hours of domestic chores. Men in many project households opposed their involvement fearing that their wives would become rebellious and stop doing their housework.

### Village Contrasts in Dera Ghazi Khan and Ramdani

Azeema Bibi, in her mid-40s, does not have a household water connection because she simply cannot afford the connection fee. So instead of tapped water, she and her daughter-in-law spend two hours every morning and two hours every evening collecting water. The daily chore takes even longer sometimes hours longer if there is a long queue. It's not uncommon for them to have to transport water after dark.

CBO Chair Gulab Mai, nearly the same age as Ms. Bibi, has a recent home water connection. "I now spend more time weaving mats," she said. "I get cash for my mats in the market. I now complete weaving a mat in 2 to 3 days. Before I had the water connected, it took me about one week. I now have more energy to do my work. I now manage to do everything on time. Next March, when school enrollments begin, I will send my daughter to school."

What a difference a home connection makes.

So how did the CBM's overcome resistance?

- **Gender analysis:** A systematic assessment of the potential impact of the proposed project on both women and men and the social and economic relations between them. A gender analysis assesses how a proposed project could contribute to women's empowerment and overall changes in gender relations. It is a specific exercise within the overall social assessment conducted in the project preparatory stage. The gender analysis informs the project design.
- **Persistence.** Women and project beneficiaries said that CBM persistence in returning to their villages to discuss the project with them demonstrated their seriousness and commitment.
- **Time sensitivity.** CBMs explored several different options to make the CBO meetings more flexible and conducive to women's schedules.
- **Mobilizing men.** Where women lacked the support of men, CBM's held exclusive male meetings to explain the benefits of allowing women to participate in the projects.
- **Creativity.** Where men remained adamant against female involvement in the project, mostly in the northern areas, CBMs had to work much harder in motivating the women and winning their confidence, which led to their insistence that they be allowed to participate in the project. In some instances, such as in a village in Attak, women withdrew from their domestic chores until men relented and allowed their participation.



- **Activists.** CBMs found it critical to identify both male and female local activists who had the trust and respect of the project communities, and could therefore help effectively deliver messages from the CBM and mobilize community support. The activists proved to be usually from the villages, were outspoken and hard working. Male activists were particularly helpful in persuading men who were opposed to the project.

### D. The Benefits of Doing the Gender Homework

With the proper groundwork, the Punjab rural water supply project offered women more than just improved access to water. The community's overall health was improved through reduced incidence of dysentery, cholera, and typhoid. Through the project, the women earned for themselves and their community more time for productive activities, such as sending their children to school and livelihood projects. They gained a more influential political voice in their communities. And they no longer have to fear the same health risks that were once so common. Table 3 summarizes the benefits reported by women as a result of the project.

**Table 3.** Reported Project Benefits

Areas of Development	Project Benefits
Health	<ul style="list-style-type: none"> <li>• Reduced incidence of reduced incidences of dysentery, cholera, and typhoid.</li> <li>• Reduced incidence of miscarriages, premature births and abortions as a result of safe water and hygienic environment</li> <li>• Reduced monthly medical expenses (between one-third and one-half less)</li> <li>• Reduced incidence of neck pains, backaches, and joint and muscular pains in women as a result of no longer transporting water</li> <li>• Increased available time and money as a result of reduced illnesses, injuries and medical expenses.</li> </ul>
Environment	<ul style="list-style-type: none"> <li>• Improved mobility, particularly for women and elderly and during the wet season, as a result of improved drains and newly paved streets.</li> </ul>
Education	<ul style="list-style-type: none"> <li>• School enrollment, especially among girls has increased since water systems were installed. Primary school enrollment in one village increased by 30%; in another area, primary enrollment more than tripled among girls and increased by 40% among boys.</li> </ul>
Economic	<ul style="list-style-type: none"> <li>• Women have increased and diversified their income as a result of time saving from the new water system and access to micro credit. They are caring for larger numbers of livestock and poultry and work more hours in the field. More women have also turned to more weaving, sewing, embroidery.</li> <li>• The project itself provided increased employment opportunities for women and at pay rates equal to men. As a result, the number of economically active females has increased by 50%.</li> </ul>

**Table 3.** Reported Project Benefits (continued)

Areas of Development	Project Benefits
Leadership	<ul style="list-style-type: none"> <li>• Women play a more active role in community activities, decision making and conflict resolution as a result of their involvement in the CBO's established by the project</li> <li>• Female CBOs lead the hygiene education and training program, maintain pipes and check water quality and collect water revenues from users.</li> <li>• Female and male CBOs work together to construct latrines and settle community and family disputes regarding the water system.</li> </ul>

*In Faisalabad, there was evidence of women's strengthened voice and negotiating power in the community being reflected in women's successful participation in the Union Council elections. Two women candidates from the village were elected to the Union Council. One on a farmers' ticket and the other on a laborers' ticket. Women CBO members organized house-to-house door knocking in support of their candidates and also staffed the polling booths on election day to encourage people to vote for these candidates.*

*According to a woman CBO member: "After the formation of the female CBO, we are in a better position to solve the problems on our own. Now we also contribute politically. Some women have been elected as councilors. We negotiated with the men: 'If you give us the vote we will give you the vote.' Before only men solved the problems of the village. Now women CBOs are also involved. We also solve disputes within and between houses. The female CBO decided the candidates. These women won uncontested."*

### E. Remaining Challenges in Closing the Gender Gap

Two major challenges remain to closing the gender gap in Punjab. The first is the number of women not taking advantage of the microcredit program. The project has not achieved its 60% target for women as beneficiaries of microcredit, yet this is a covenant of the loan document. This is largely because of two reasons: the restricted mobility of women and the cultural practice of men making financial decisions. Men also deal with local banks. The demand for the project's microcredit access has come more from men than women. It is understandable then, why more must be strategically done to draw women into the microcredit program.

The second challenge is the sustainability of some of the CBOs, particularly the smaller ones. In establishing and building these CBOs, CBMs must also ensure that the CBOs become increasingly independent of them and the project staff in order to continue to sustain the project's benefits. The ability of some CBOs to be self-sustainable is of concern, yet CBMs are under time pressure to move into new project communities and startup new CBOs.

One emerging solution, though, is developing strong partnerships between female CBOs and female nongovernment organizations at community, district and provincial levels. Registration of these CBOs with the local government and providing support for dispute resolution is essential for the sustainability of CBOs and community-based schemes.

### F. Hopeful Future for Rural Punjab

Women in the project communities are determined to sustain the project, which also represents a form of increased confidence and empowerment. As an example, when their own connections to the new water system were threatened with being disconnected because their husbands had failed to pay the bill, women reportedly refused to clean or cook until the men paid the bill. In village after village, the case study reports women pledging to raise funds through their own resources not only to sustain the projects schemes but also to do other social development works using the CBO platform.

Interestingly, in one village in Gahawl Pur, the female CBO drew up a chart of project benefits, listing each benefit in order of priority. At the top of their list, ahead of increased income and improved health benefits, were their sense of increased confidence and awareness. Men also attested for the benefits of increased female confidence and empowerment. Male CBO members repeatedly said women's participation in the project had been important to the improvements seen in their community since the project started. The attitudes of young men toward female empowerment also registered change.

*"Once the female CBO was formed, we realized that women can do better work and can participate in the elections. Our elders did not like women to participate in the elections. But with the help of the younger generation of males in the CBOs, the elders started to realize that this was possible."*

— Munawar Hussain, Chair of a male CBO in Faisalabad

Through the Punjab rural water project, it should be clearly evident what has happened. Both men and women are realizing and unlocking the hidden potential of women to be change agents.

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