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IN THIS ISSUE

SILICON SENSORS FOR THE COMPACT MUON SOLENOID EXPERIMENT AT THE LARGE HADRON COLLIDER, CERN

STUDIES ON RESPONSE OF STRUCTURES, EQUIPMENT AND PIPING SYSTEMS TO EARTHQUAKE AND ITS MITIGATION

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SILICON SENSORS FOR THE COMPACT MUON SOLENOID EXPERIMENT AT THE LARGE HADRON COLLIDER, CERN

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Introduction

A specific research and development programme was undertaken by BARC, to develop the technology for 32-strip silicon sensors, for the Compact Muon Solenoid (CMS) experiment at the Large Hadron Collider (LHC), CERN. These sensors will be used as Preshower sensors in the Electromagnetic Calorimeter of CMS for π^o/γ rejection and will cover an area of ~40,000 cm^2 in the CMS. Developing silicon sensors with very stringent electrical specifications and uniformity over a large area of ~ 40 cm^2 has been a challenging task, as such technology did not exist in our country. This R&D has been carried out in various phases such as prototype development, preproduction and production. Figs.1, 2 and 3 show wafers fabricated during various phases ofthis project.

In view of expected radiation damage, the technology development was targeted to produce sensors with high breakdown voltage and low leakage currents, for ensuring ten years of operation without failure, in the high neutron and gamma radiation environment of LHC. The production of a thousand sensors has been recently completed and these sensors in the form of micromodules have been delivered to CERN. Fig. 4 and Fig. 5 show the silicon sensor after wafer dicing and the silicon sensor micromodule. The micromodule has the front end hybrid bonded to the 32 strips. The front end hybrid incorporates the PACE chip which has a 32-channel preamplifier, amplifier, shaper, 192-channel analog memory along with control logic. This chip is a radiation hard chip developed by CERN and has been fabricated by CERN in a 0.25 micron technology at IBM.

The micromodules are assembled in the form of ladders which comprise of 7-10 micromodules and

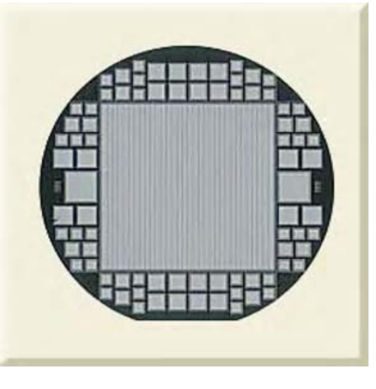


Fig. 1: Prototype

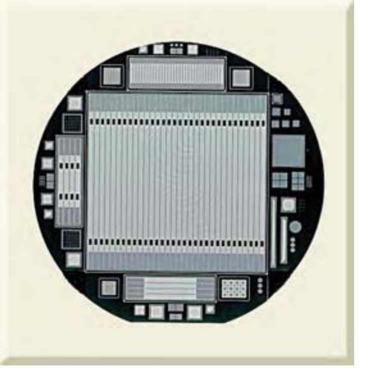


Fig. 2: Seven guard-ring design (Preproduction)

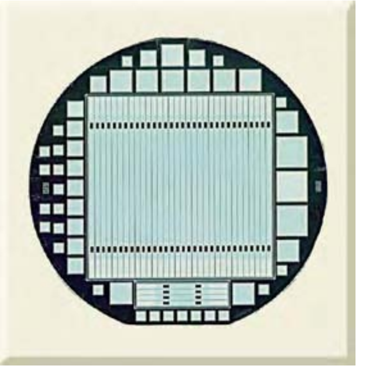


Fig. 3: Four guard-ring design (Preproduction & production)

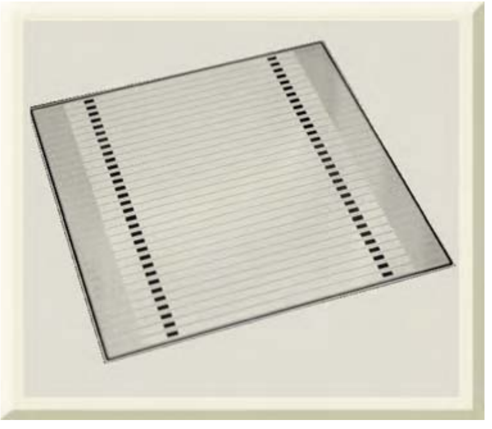


Fig. 4: Diced 32-strip silicon sensor

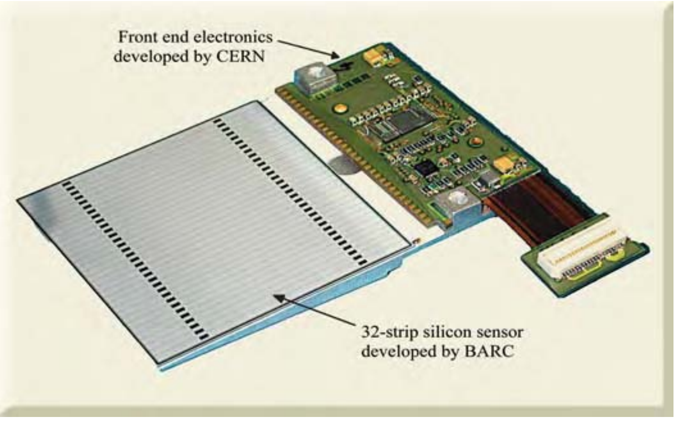


Fig. 5: Silicon sensor micromodule along with front end hybrid

these are then connected to a system motherboard which controls the micromodules and also acquires the signals from the micromodules. Fig. 6 & Fig. 7 show the ladder before and after integration of system motherboard.

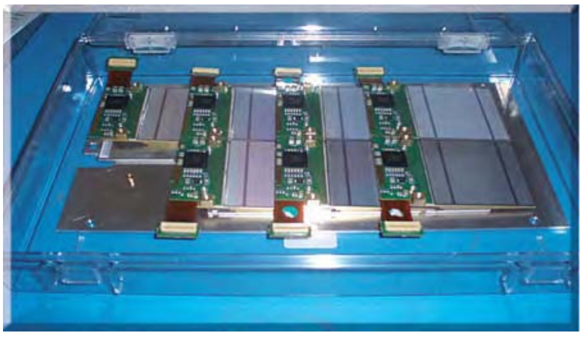


Fig. 6: Assembled ladder of seven micromodules

Fig. 7: Ladder along with system motherboard of seven micromodules

The technology development of the silicon sensors and their production involved several important activities such as detector design and layout, process and device simulations for optimization, development of characterization setups and performance evaluation, fabrication process development and optimization, quality control during production and assembly of sensors into micromodules. The prototype development for the silicon sensors was carried out with a sensor geometry of 60 mm x 60 mm using standard silicon technology. The 4" integrated circuit fabrication facility of Bharat Electronics Limited (BEL), Bangalore was used for the development of the technology for fabrication of the sensors. Several batches of silicon wafers were fabricated at BEL for optimizing the fabrication process so as to meet the required specifications. After successful development of prototype sensors and demonstration of technological capability, BARC was qualified for the production of 1000 sensors and micromodules for the CMS experiment. A set of common specifications were decided in a meeting held at CERN during May 2000, in which all the countries (India, Greece, Taiwan and Russia) involved in the production of preshower silicon sensor, participated. As per the specifications finalized in this meeting, the production of the silicon sensors was carried out for the modified geometry of 63 mm x 63 mm. In order to evaluate the performance of the sensors, a great deal of effort was also taken to develop various automated setups for characterization of sensors and probe-jigs for making simultaneous contacts to the 32 strips. A test and assembly facility was setup at the production center (BEL) for carrying out all specified sensor qualification tests during the production phase. The present document describes in detail various aspects such as the design of the sensors, processing issues and sensor characterization. The results of various tests performed during the technology development and production phase, are also presented. In order to qualify the sensors for radiation hardness, the sensors were irradiated at CERN using the 24 Gev proton beam and in a nuclear reactor at BARC and Dubna, Russia. The results of these irradiation tests have also been presented.

Specifications and design of the sensor

The technology for sensor fabrication and its design were targeted to meet the following electrical and geometrical specifications:

- Full depletion voltage of the strips (V_{FD}): $55 < V_{FD} < 150V$
- Breakdown voltage (V_{BD}) of each strip: $> 300V/500V$
- Total leakage current of the sensor: $< 5\ \mu A$ at V_{FD} and $< 10\ \mu A$ at 300V/500V
- Uniformity of leakage current for the strips: at most one strip with leakage current $> 1\ \mu A$ at V_{FD} and $> 5\ \mu A$ at 300V
- Length of sensor: 63 mm $\pm 100\ \mu m$
- Width of the sensor: 63 mm -100 μm

As shown in Figs.1-3, three types of mask layouts incorporating 32-strip silicon sensor along with other test structures were designed during various phases of technology development, preproduction and production. Test structures such as PIN diodes of various geometries, MOS capacitors, gated diodes, etc. have been incorporated in the mask design, for carrying out process diagnosis and process optimization during fabrication. In addition to this, several other types of detectors such as PIN diodes of various geometries, pixel detectors, virtual pixel detectors, small area strip detectors, photodiodes, etc. were incorporated, to utilize the space around the silicon sensor. These detectors were designed for applications involving physics experiments and radiation monitoring instrumentation applications involving measurement of α, β and other charged particles, γ radiation, X-rays and neutrons.

The first version of the design used during the prototype development phase, incorporated a silicon sensor with a geometry of 60 mm x 60 mm (Fig.1). The sensor comprised of 32 P^+ strips having a width and pitch of 1.69 mm and 1.81mm respectively. The strips were enclosed in seven P^+ guard-rings and an N^+ guard band was used in the scribe line region. However, it was later removed as it was found to deteriorate the performance of the sensor. The geometric design parameters of the sensor were the same as specified by the Preshower group, CERN. The sensor is passivated and has windows in the passivation for the purpose of bonding. A four layer mask was used for fabricating the sensors. In the initial batches, the performance of the sensors fabricated using this design, was quite poor. However, after continuous modifications of the process parameters, in subsequent batches, sensors having very low leakage, high breakdown voltage and uniformity could be realized.

As the sensor geometry was modified later from 60 mm x 60 mm to 63 mm x 63 mm, the mask was redesigned during the pre-production phase (Fig. 2 and Fig. 3). The main design considerations for the design of the silicon sensors for production are as follows:

- Not only performance, but yield also was an important issue for production of sensors.

- Due to radiation damage, the operating voltage of the sensors would progressively increase with time, during the operation in the LHC environment. The sensors would be operated at a much higher voltage after a period of 7-8 years requiring the breakdown voltage of the sensors to exceed 300V/500V .

In order to realize sensors with high breakdown voltage, the following design strategy was incorporated in the final design of the sensor:

- Floating field guard rings to reduce the peak electric fields at the surface via punch through mechanism. As shown in Fig. 2 and Fig. 3, two types of guard ring designs with seven and four guard rings were designed.

- Since the breakdown field in the oxide is higher than avalanche breakdown field in the silicon, metal overhangs were incorporated over the P^{+} strips to distribute the voltage droping across silicon and oxide so as to increase breakdown voltage of the strips.

Process and device simulations were carried out to finalize the design parameters such as width of the guard rings, spacing, length of the metal over hang, etc. As shown in Fig. 2 and Fig. 3, wafers with two types of guard ring designs i.e. four and seven guard rings, were fabricated during the preproduction phase and the yield of the batches were compared. Since the four guard ring design gave better yield, this design was used for the production of sensors. The same mask is being used for the production of sensors. The schematic cross section of the sensor showing various layers and geometric dimensions is as shown in Fig. 8. The magnified view of the layout of the sensor showing guard rings is seen in Fig. 9.

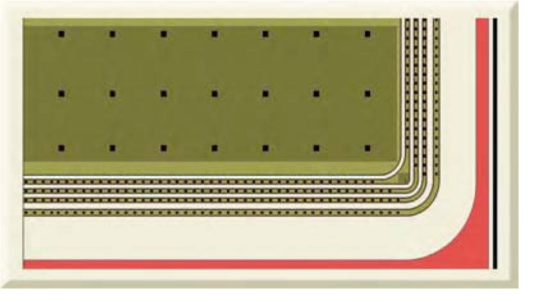


Fig. 9: Magnified view of the corner of the sensor

Characterization setups and sensor test facility at BEL

During technology development phase, static current vs voltage (I-V) and capacitance vs voltage

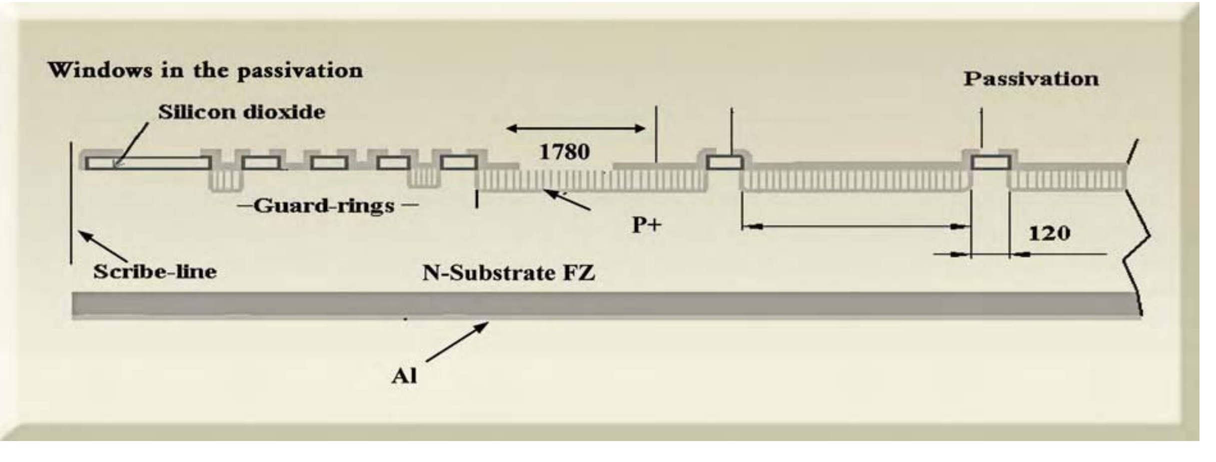


Fig. 8: Cross section of the preshower silicon sensor (all dimensions are in microns)

(C-V) measurements were used to evaluate the performance of the sensor i.e. leakage current, breakdown voltage and full depletion voltage. A great deal of effort was taken to develop characterization setups in order to carry out automated and simultaneous measurements of all 32 strips of the sensors. Probe jigs with microscopic X-Y-Z positioning to simultaneously probe all 32 strips of the unpassivated/passivated sensor were designed and fabricated at BARC.

A complete test facility for carrying out sensor qualification tests was setup at the production center (BEL), so as to avoid transport of sensors and also because further assembly of sensors in to micromodules was to be carried out at BEL. The test facility was setup in a class 10,000 clean room environment and included the equipment for I-V and CV characterization as described above. In addition to electrical characterization setups, measurement jigs for measurement of geometric parameters such as length, width and thickness were used to verify that the dimensions of the sensors were within the specified tolerance. The sensors were visually inspected from front and back using high magnification microscope for checking the dicing quality at the edges and mechanical defects on the surface, as these are important factors determining the long-term reliability of sensors. The data of all measurements was entered in to the CRISTAL data base at CERN.

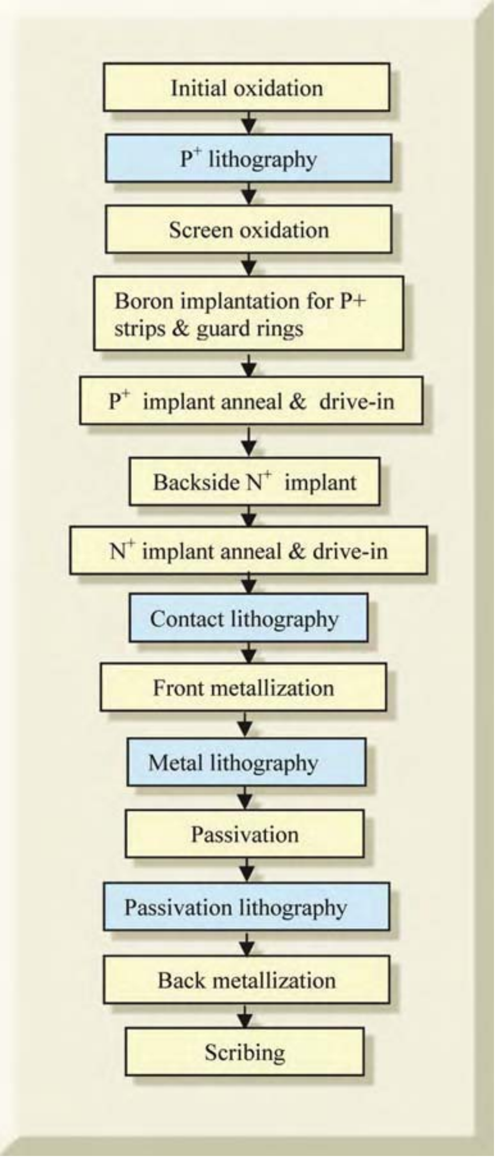
Fabrication technology for sensors

The sensors were fabricated by the silicon IC fabrication facility of BEL, Bangalore as per the process outline provided by BARC. The development for the preshower silicon sensors was challenging as compared to the standard ICs or ASICs because of the following reasons:

- The sensor fabrication required a custom process to be developed starting from virgin silicon wafer, while ICs/ASICs mostly use a standard well established process available at the foundry.
- The geometry of the sensor is very large as compared to the silicon ICs/ASICs. Hence realizing an acceptable yield of 50% was much more difficult as yield decreases sharply with increase in the die size.
- The preshower sensor required very low leakage currents of the order of nAs at high voltages of the order of few hundred volts, while usually ICs have low current at low operating voltages and high current at high operating voltages.
- The process uniformity over a large area of the order of few hundred mm^2 was required for silicon sensors while in the case of standard ICs the die size is quite small and is of the order of few mm^2.

Considering the specifications of sensors such as full depletion voltage, total capacitance of the strips, breakdown voltage, etc., high purity silicon wafers were used as the starting material for fabrication of sensors. The sensor technology was developed using N-type, FZ, <111>, 3-5 kΩ-cm or 5-10 kΩ-cm wafers supplied by TOPSIL and WACKER. These wafers had specified zero defect density and high life time of the order of a few milliseconds. This is an important specification as the quality of the wafers is a critical factor for sensor fabrication and even a single defect occurring over the sensor area, which is quite large, would result in a bad strip giving non-acceptable performance. Fabrication of sensor was carried out using a complex process sequence involving more than 25 process steps. The process used for fabricating the sensors at BEL is shown schematically in process flowchart 1.

The process parameters used for the above processes were optimized so that, there is no degradation of the wafer quality and there is no generation of defects during processing, which could increase leakage and reduce breakdown voltage. Extensive process simulations were carried out to finalize the process



Flowchart 1 : Sensor fabrication process

parameters such as implantation energy and dose for boron and phosphorus, temperature and time for drive in cycles, intrinsic and extrinsic gettering cycles, etc. High temperature cycles were properly optimized and the contamination was strictly controlled during fabrication. The process optimization for meeting the desired specifications, carried out in several batches, has been discussed in detail in the subsequent section of this note.

Process optimization

The technology development was carried out in a short span of about one year, by systematically optimizing various processes involved in sensor fabrication. During the initial fabrication runs, the sensors were fabricated without surface passivation and scribing. After realizing sensors with acceptable performance, surface passivation and scribing were introduced and optimized in the later phase. The following important points were considered to decide the initial process parameters such as quality of the oxide, boron and phosphorous implant dose and energy, the screen oxide thickness, the drive-in temperatures and time subsequent to implantation:

- Excess positive oxide charge would give rise to low breakdown voltages at the junction edges at the surface, due to accumulation of negative charge; better quality oxide with a lower defect density is required.
- Junction curvature effects strongly affect the breakdown voltages. Process parameters for ion implantation and drive-in need to be selected, to tailor the junction curvature and reduce the thermal budget, which cause defect generation.
- The temperature cycles should be optimum so that the thermal budget is low and also problems related to the warping of wafer should be prevented as the wafer is thinner i.e. 300 μm instead of 500 μm which is the standard thickness for a 4" wafer.

The technology development for the Preshower sensor was initiated using a process which involved a few process steps such as initial oxidation, metallization, etc. The dose and energy of boron implantation was varied. The performance of the sensors was evaluated using IV measurements to see the leakage currents and breakdown voltage. The typical IV characteristics of the sensor fabricated in the second batch is as shown in Fig.10. As can be seen, the sensors have higher leakage currents of the order of few microamps and breakdown voltages for most of the strips are as low as 10-50 V. Though the silicon sensor performance was poor, the diodes on the same wafer could withstand high voltage up to 1000 V without breakdown and the leakage currents were low of the orders of nAs (Fig.11). This indicated that the main cause for the poor performance of the sensor could be generation of bulk and surface defects over the sensor area and which could be prevented by tuning critical process steps.

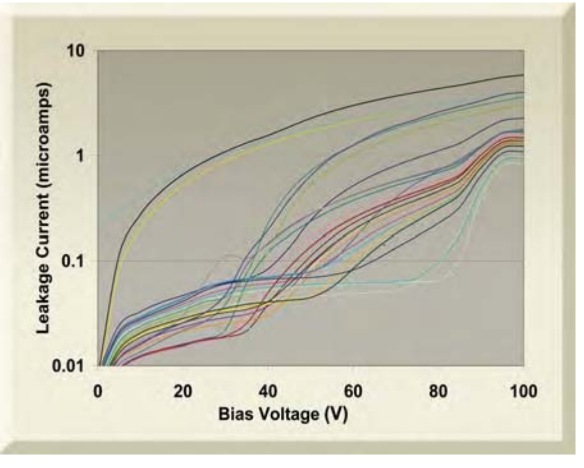


Fig.10: IV characteristics of a sensor fabricated in the second batch

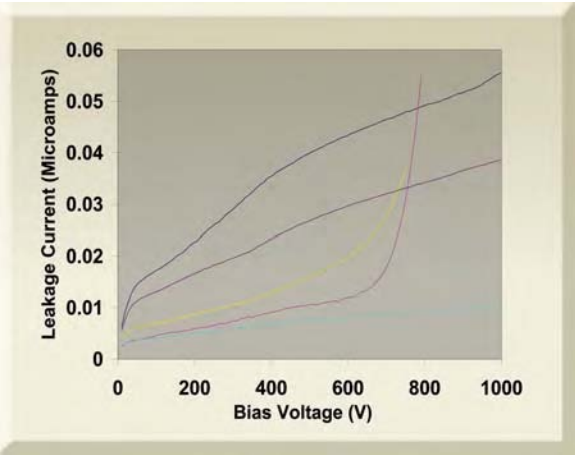


Fig.11: Leakage current characteristics of diodes of area 5 x 5 mm^2

Test structures for process diagnosis

The fabrication process for the sensor was monitored during various stages using dummy wafers. The parameters like oxide thickness, sheet resistivity of P$^+$ and N$^+$, metal thickness, junction depth, etc. were measured, to ensure that each process step was carried out consistently and there were no problems during fabrication of a particular process step. The layout of the sensor incorporated various test structures in order to measure surface and bulk defects. These structures incorporated MOS capacitors, gated diodes, diodes with different perimeter to area (P/A) ratio, diodes with different guard ring designs, etc. Baby strip detectors were also incorporated to test the radiation hardness of sensors in fast neutron and gamma background. To debug the problems causing lower breakdown/ higher leakage currents, PIN diodes of different geometries were tested to find out their leakage and breakdown voltage. MOS capacitors were fabricated separately to check the quality of the oxide at various stages of processing e.g. initial oxidation, drive-in of P$^+$ after implantation, etc. by inserting test wafers. These capacitors were characterized to obtain the fixed oxide charge and interface state density to ensure that these parameters were within reasonable limits.

Process modifications for improvement of the performance of sensor

During initial batches, sensors with desired specifications could not be produced by only varying process parameters such as implant dose and energy. Three types of processes having various combination of process steps were used to identify a set of process parameters for obtaining desired performance of the sensor. These processes were targeted to see the effect of the following parameters:

- Starting material or wafer quality
- Quality of the surface of the wafer
- Effect of implantation in the scribe-line region
- Reduction in defect generation due to gettering
- Independent control of N$^+$ and P$^+$ doping.

Wafers from two manufacturers (WACKER and TOPSIL) with two ranges of resistivities (3-5 kΩcm and 5-10 kΩ-cm were used, to see the effect of starting material. A number of wafers were fabricated using various combination of process steps such as sacrificial oxide, Argon implant for extrinsic gettering, combined or separate drive in cycles for N^+ and P^+ implantations, with/without implant in scribe line, etc. Best results were obtained for wafers which were processed with sacrificial oxidation, argon implant on the back side, separate drive-in cycles for N^+ and P^+ implantations and no implant in the scribe-line region.

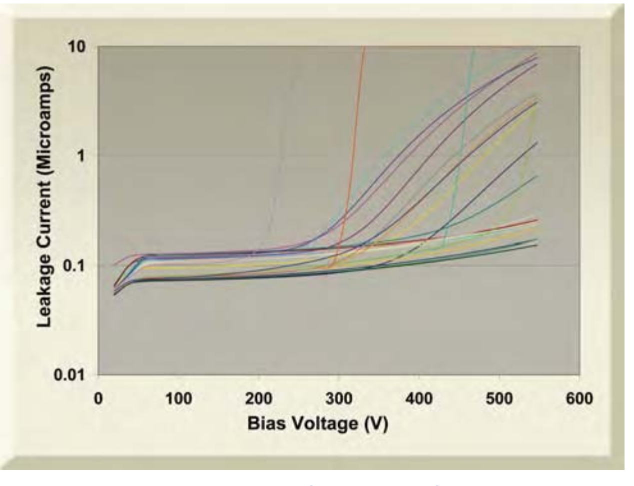


Fig.12: IV characteristics of a sensor fabricated in the fourth batch

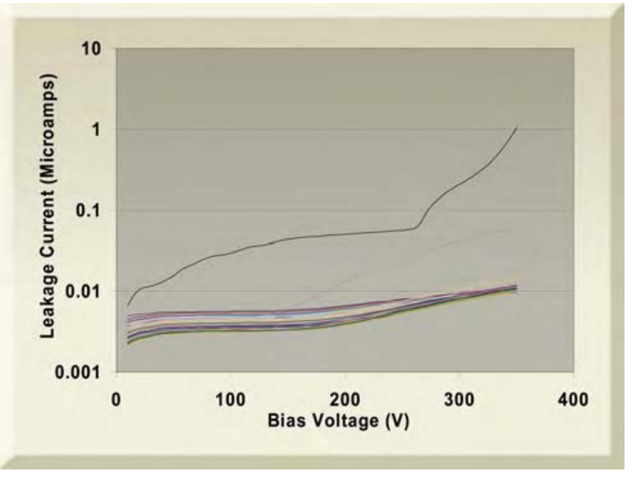


Fig.13: IV characteristics of a sensor fabricated in the sixth batch

Fig. 11 shows the reverse IV characteristics of a sensor fabricated in the fourth batch using this optimized process. Comparison of Fig.10 and Fig.12 clearly show the remarkable improvement in the performance of sensor in terms of leakage and break down voltage. The leakage currents have become very uniform and except for two, all strips could withstand 300V without breakdown. After optimizing the basic process for sensor fabrication in four batches, in the fifth batch, passivation was carried out on the front-side of the sensor. The best results were obtained for a PSG passivation layer. During this batch, measurements were carried out on all wafers after successive process steps such as after front metallization, after front passivation, after back metallization and after scribing. These measurements were carried out to check whether the process of passivation and scribing degrades the performance of the sensor or not. The leakage current per strip was significantly reduced by an order due to passivation from about 100 nAs to about 5-10nAs and it was confirmed that there is no degradation of sensor quality due to passivation and scribing. Using the optimized process of batch 5, a few sensors meeting CERN specifications of leakage and breakdown (no strip with break down for < 300 V) could be fabricated in the sixth batch (Fig.13).

Though about 70% of the sensors fabricated in batch 6 were found to have more than 90% good strips (≤ 2 bad strips out of 32 strips), the yield of the process was less than 30%. The problem was thought to be related to the injection of the carriers from the back side as several sensors showed the increase of strip currents around full depletion voltage. A double N^+ implant was incorporated at the back side of the wafer in the seventh batch to reduce back injection. The implantation dose, energy and drive-in temperature and time were decided, based on the simulations carried out to obtain a thick N^+ layer at the back side. By incorporating this process, the yield of the process improved significantly to about 50%. The typical CV and IV characteristics of all 32 strips of the sensor fabricated using the final optimized process are as shown in Fig.14 and Fig.15 respectively. As can be seen from the plots, sensors with very low leakage currents, high breakdown voltage and uniformity have been realized using the optimized process.

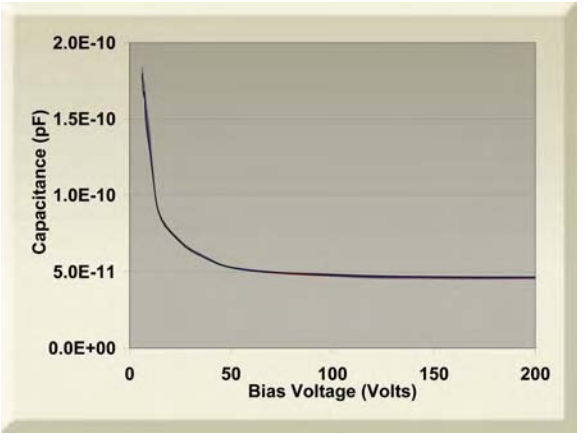


Fig.14: CV characteristics of all 32 strips of a sensor fabricated after process optimization

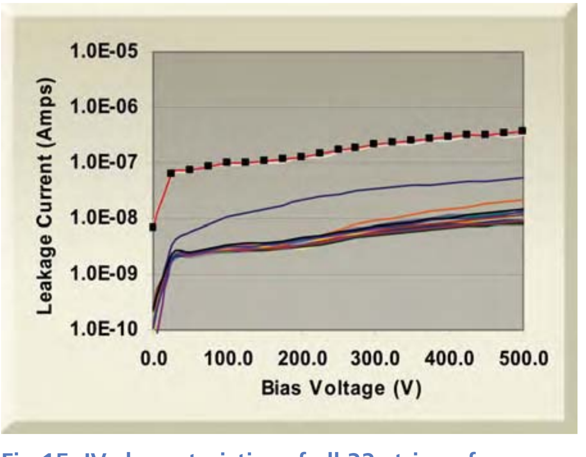


Fig.15: IV characteristics of all 32 strips of a sensor fabricated after process optimization, squares show total current

Electrical specifications of the prototype sensors

After optimizing the process for sensor fabrication and obtaining reasonable yield, twenty prototype sensors were delivered to CERN for demonstrating their performance. The data of IV and CV measurements was analyzed to obtain the parameters such as full depletion voltage of the strips, total leakage current, breakdown voltage, etc. The summary of these parameters obtained for twenty prototype sensors is plotted in Fig. 16. As can be seen, the sensors have very low leakage and the total leakage current at 300 V is by one order less than the required total leakage current specification of 10 μA. The full depletion voltage of sensors is also quite uniform and is as expected considering the substrate resistivity of 3-5 kΩ-cm.

Production of sensors and quality control

Sensors with very good uniformity and at a production yield of 50% were produced at BEL and the production of a thousand sensors was completed using the optimized process as discussed earlier. The production was carried out using 300 μm thick, <111>, FZ, 2-4 kΩ-cm wafers manufactured by WACKER. During the production of silicon sensors, a test facility was setup at BEL for carrying out all tests in a class 10,000 environment with controlled humidity and temperature. The sensors were subjected to several quality control tests as outlined by CERN. These tests mainly involved electrical (IV and CV) and mechanical measurements (length, width and thickness). Each sensor was subjected to visual inspection from the front and backside for ensuring that the surface was free of any defects such as scratches and chipping at the edges. The breakdown voltages, leakage current and capacitance of individual strips, full depletion voltage, mechanical dimensions of the sensor (thickness, length and width), dicing quality, etc. were some of the main parameters which were monitored during quality control. The data of measurement was analyzed using a LabView programme to find various parameters for individual strips of each sensor. As shown in Fig.17, this data is plotted in LabView and was used to qualify or reject the sensors.

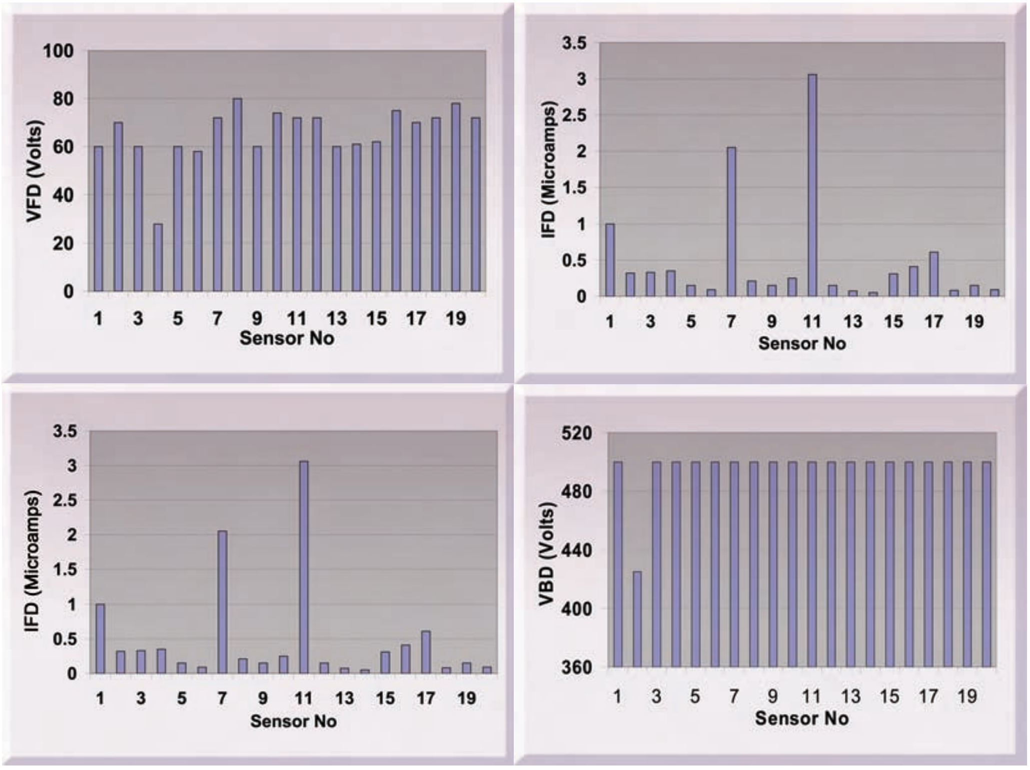


Fig. 16: Electrical specifications of the prototype sensors

The stability of the sensor was tested by measuring the total leakage current of the sensor at different stages such as after fabrication, before micromodule assembly, after micromodule assembly, etc. The statistical distribution of various parameters such as V_{BD}, V_{FD}, total leakage current at V_{FD} and at 300 V for thousand sensors are plotted in Fig. 18 a-d. As can be seen, the breakdown voltage exceeds 500 V for majority of the sensors. The total leakage current of the sensor is of the order of 200 nA at V_{FD} and is less than 1.0 μA at 300 V for most of the sensors though this tolerance is 10.0 μA.

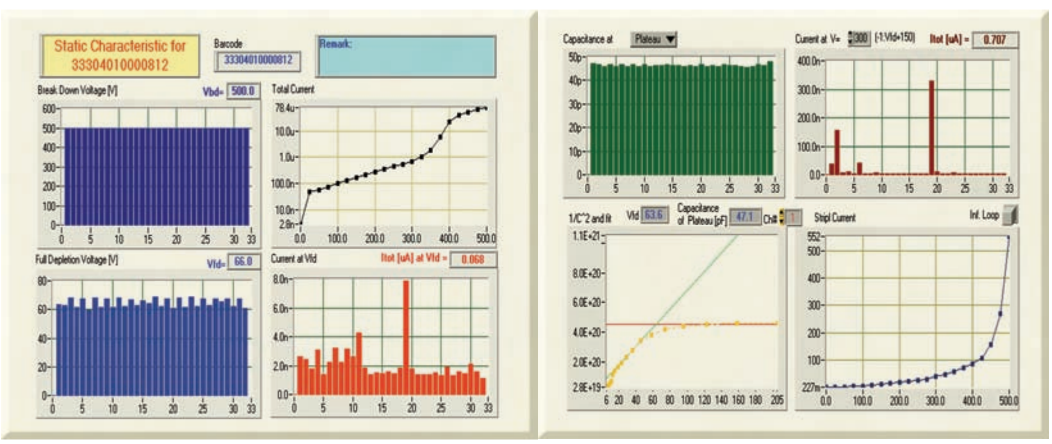


Fig.17: Electrical parameters obtained for 32 strips of a sensor using IV & CV data

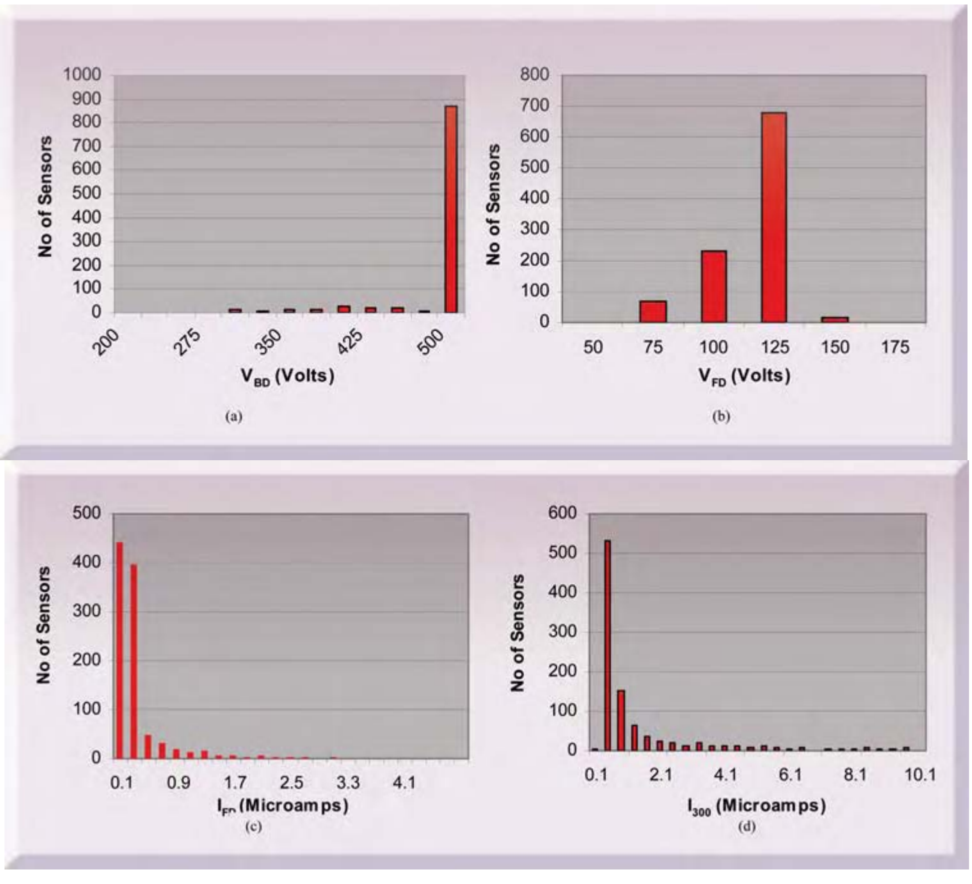


Fig.18: Distribution of (a) V_{BD}, (b) V_{FD}, (c) I_{FD} and (d) I_{300} for 1000 sensors. The tolerance for I_{FD} is 5.0 µA and for I_{300} is 10.0 µA

Reliability of sensors

Considering the operation of LHC for ten years in high radiation background, reliability requirements were very stringent, as the sensors are expected to operate without failure, once the LHC is commissioned. In view of the fact that the sensor production was started in the year 2002 and the actual commissioning of the sensors in the LHC will be done in 2008, it was also necessary to have a high shelf life. The stability of the sensors with time was verified by measuring the total leakage of the sensors with time at no bias conditions. In order to test the stability under bias condition, few sensors were kept at 300 V and the total leakage current was monitored with time. In order to test the radiation hardness of sensors, a few sensors were irradiated using the 24 GeV proton beam at CERN and in the nuclear reactors at BARC and Dubna, Russia. The variation of V_{FD} to neutron damage was investigated by irradiating sensors in APSARA reactor at BARC. As can be seen, after irradiation to a neutron fluence of $2x10^{14}$ n/cm^2, V_{FD} increases to about 300 V which is as expected (Fig. 19). Fig. 20 shows the total leakage current variation with time for four sensors after irradiation to a proton beam at CERN. The variation of temperature at the time of measurement is also indicated in the same plot. This plot shows that sensors have a stable behavior even after a long time of more than 300 days after irradiation and the leakage current increase due to irradiation, is within the limit of 1 mA.

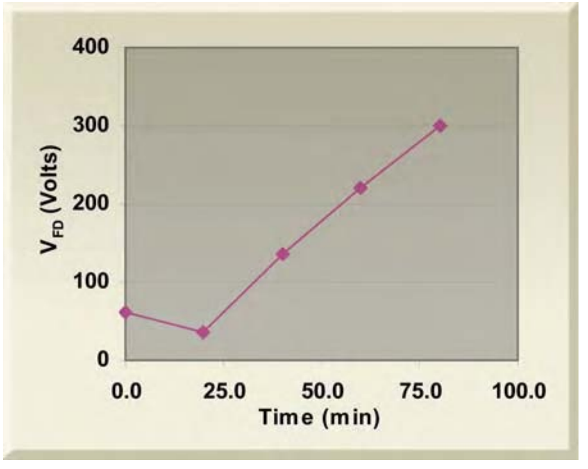


Fig. 19: Effect of neutron irradiation on V_{FD} (the neutron flux is (2.5×10^{12}) n/cm^2 min)

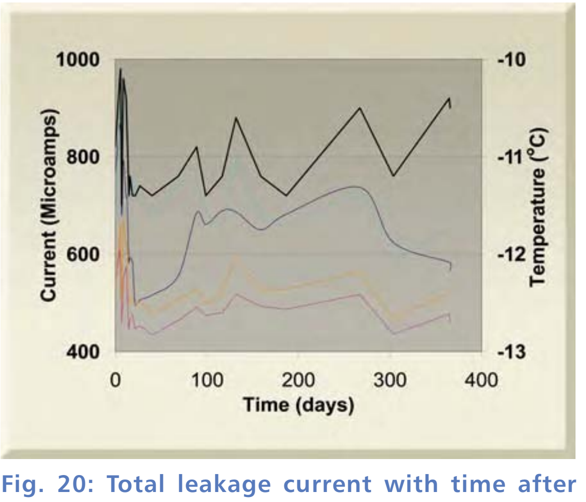


Fig. 20: Total leakage current with time after irradiation with proton beam

Summary

Demanding technology and the capability for large scale production of silicon sensors with good uniformity, low leakage currents and high breakdown voltage has been demonstrated and developed by BARC, for the first time in our country. The sensors produced have very good uniformity in terms of parameters such as full depletion voltage, breakdown voltage and leakage current of strips. The individual strip leakage is of the order of few nA/cm^2 and the strip and total leakage currents are quite well below the specified limits. Irradiation tests carried out have shown that the sensors meet the stringent specifications for reliable operation in the high radiation environment of LHC. Subsequent to the development of technology, the production of a thousand sensors has been recently completed. The sensors assembled in the form of modules are being installed in the CMS preshower at LHC, CERN. The R&D carried out over the past few years has given us the technological capability for large scale production of large area sensors. Though the R&D was targeted for the development of sensors for the international experiment at CERN, this R&D triggered the indigenous development of a wide variety of high performance sensors, for nuclear instrumentation and radiation monitoring instrumentation applications at BARC.

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Publications

1. Anita Topkar et al, "The CMS preshower silicon sensors: Technology development and production in India", accepted for publication in *Nuclear Inst. and Methods in Physics Research A*, Vol. 585 (2008), 121-127.

2. Anita Topkar, Praveenkumar S, Bharti Agarwal, S.K. Kataria & M.D. Ghodgaonkar, "Silicon detector technology development in India for the participation in international experiments", Presented in the International Linear Collider Workshop, March 9-13, 2006, IISC Bangalore.

3. Anita Topkar, Praveenkumar S, Bharti Agarwal & S.K. Kataria, "Preshower silicon strip detectors for the CMS Experiment at LHC" Presented at the 9th International Conference on Advanced Technology and Particle Physics, Como, Italy 2005.

4. Anita Topkar, Bharti Aggarwal & M.D. Ghodgaonkar et al , "Indigenous development of high performance silicon detectors", National Conference on Microelectronics and VLSI, IIT, Bombay, 2005.

5. Anita Topkar, "Development of radiation detectors at BARC", Proceedings of DAE-BRNS Symposium on Compact Nuclear Instrumentation and Radiation Detectors CNIRD, March, 2005.

6. Anita Topkar, Praveenkumar S., Bharti Agrawal, & S.K. Kataria , "CMS preshower silicon strip detector for the LHC, CERN: Reliability of detectors and trials for assembly" , Proceedings of the DAE-BRNS Symposium on Nuclear Physics, Vol 46B, December, 2003.

7. S. K. Kataria, M. D. Ghodgaonkar, Anita Topkar et al, "Silicon strip detectors under India CMS collaboration", Proceedings of DAE-BRNS symposium on Intelligent Nuclear Instrumentation, INIT 2001.

8. S.K. Kataria, Anita Topkar et al, "Development of technology at BEL for 32 strip silicon strip detectors and diode detectors", Proceedings of DAE-BRNS symposium on Intelligent Nuclear Instrumentation, INIT 2001.

9. A. Das, V. Mishra, M.Y. Dixit, S.K. Singh, Anita Topkar, S.P. Chaganti & M.D. Ghodgaonkar, "Automated and multichannel characterization systems for silicon strip detectors", Proceedings of DAE-BRNS symposium on Intelligent Nuclear Instrumentation, INIT 2001.

ANNOUNCEMENT

Forthcoming Symposium

National Symposium on Electrical Science & Technology (NSET 2008)

The Electrochemical Society of India and the Indian Institute of Science, Bangalore have organized a two day symposium on 18th & 19th July 2008, at the IISc., Bangalore. It is jointly sponsored by ISRO, CSIR, DST, BRNS & DRDO. This annual meeting will provide a platform to those in the field of Electro chemical industry. The scientific programme of the symposium comprises plenary and invited lectures, contributed papers and poster presentations. Papers and posters are invited on the following topics : Electroplating, anodizing and allied processes; Trace elements contamination of the environment; Electrochemistry: all aspects; Newer methods in surface engineering; Trends in automobile finishes; Corrosion and protection; Painting and powder coatings; Electroanalytical techniques; Batteries; Appln. of Advanced anaerobic process for the treatment of complex industrial waste water; Electroforming; PCB fabrication; Electrochemical instrumentation.

An abstract of the proposed paper (not more than 300 words) is to be submitted to the convener, NSET 2008, alongwith the registration form and registration fee.

For further details one may contact

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STUDIES ON RESPONSE OF STRUCTURES, EQUIPMENT AND PIPING SYSTEMS TO EARTHQUAKE AND ITS MITIGATION

G.R. Reddy, Y. M. Parulekar, P.N. Dubey, A. Sharma, K.N. Vaity, A. Ravi Kiran, M.K. Agrawal, K.K. Vaze , A.K. Ghosh and H.S. Kushwaha

Reactor Safety Division

Earthquake Engineering has gained the attention of many researchers throughout the world and extensive research work is being done. Linear behaviour of structures, systems and components (SSCs) subjected to earthquake loading is well understood. However, nonlinear behaviour of SSCs subjected to earthquake loading needs to be clearly understood and appropriate design methods need to be validated experimentally.

In view of this, three major areas in earthquake engineering, identified for research, include: design and development of passive devices to control the seismic response of SSCs, nonlinear behaviour of piping systems subjected to earthquake loading and nonlinear behavior of RCC structures under seismic excitation. The Reactor Safety Division has performed extensive work in the above identified areas. The work performed has given a clearer understanding of nonlinear behavior of SSCs as well as in developing new schemes, methodologies and devices, to control the earthquake response of SSCs.

A brief overview of the work is given below.

Seismic Response Control in Structure Systems and Components

Controlling of seismic responses in Structures, Systems and Components can be performed using active, semi-active, passive dampers and Seismic Base Isolators. In the first stage, work was taken up to understand and validate experimentally the performances of Elasto-Plastic Dampers (EPD), Lead Extrusion Dampers (LED), Tuned Liquid Dampers, Tuned Mass Friction Dampers and Seismic Base Isolators such as Laminated Rubbers Bearings and Lead bearings. Also under the BRNS project, Shape Memory Alloy Dampers are being designed and tested. Some details of these devices and applications are described below.

Passive devices for seismic response control of Structures, Equipment and piping systems

Elasto-Plastic Dampers (EPDs)

EPDs, based on plastic deforming steel plates, consist of X-shaped plates. These plates sustain many cycles of stable yielding deformation, resulting in high levels of energy dissipation or damping. The force displacement loop of the X- plate is shown in Fig. 1.

The area of this force displacement relationship gives the energy dissipated by the damper plate. Elasto-plastic dampers were fabricated in BARC (Fig. 2) and tested for their force-displacement characteristics. X-shaped plate in elasto-plastic energy absorber, facilitates a constant strain over the height of the device, thus ensuring that yielding occurs simultaneously and uniformly over the full

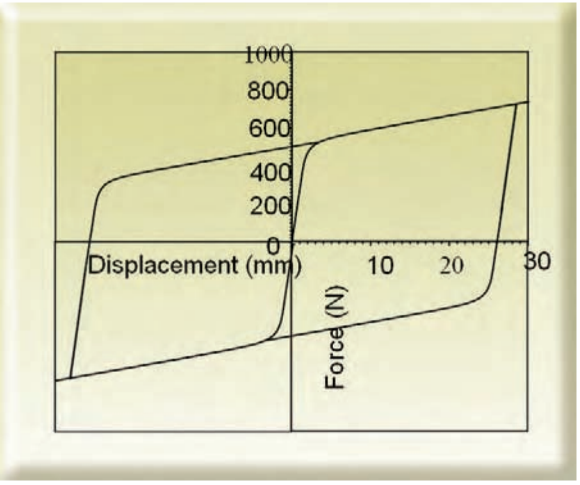

Fig. 1: Force displacement characteristics of EPD

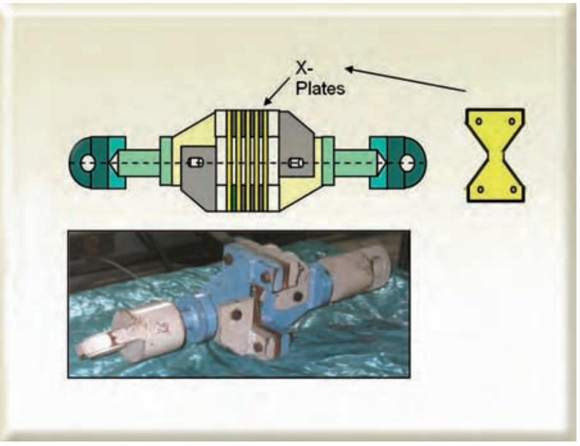

Fig. 2: Elasto-Plastic Damper

height of the damper. Cantilever (Fig. 3) and 3-dimensional piping systems (Fig. 4) were tested with and without EPD on shaker table in SERC (Chennai). The fabrication of EPD and shake table testing was done under the 9th plan project. Using a finite element model of the piping systems, linear and nonlinear time history analysis was carried out using Newmark's time integration technique. The analytical maximum response displacement obtained at the Elasto-Plastic Damper support for the two piping systems was in good comparison with experimental values as shown in Fig. 5 and Fig. 6.

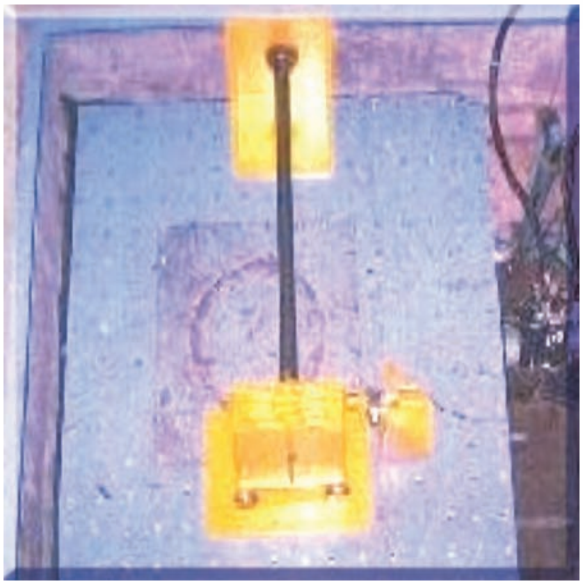

Fig. 3: Cantilever piping system

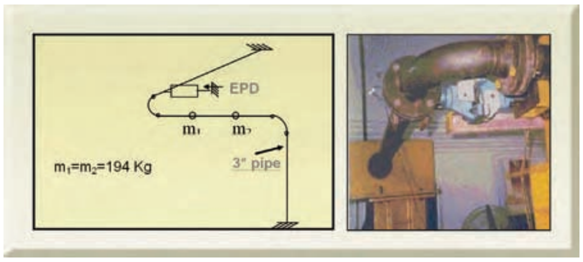

Fig. 4: 3-D piping system

Shake table tests under 10th plan project were also conducted on complex piping system (Fig. 7) in CPRI,

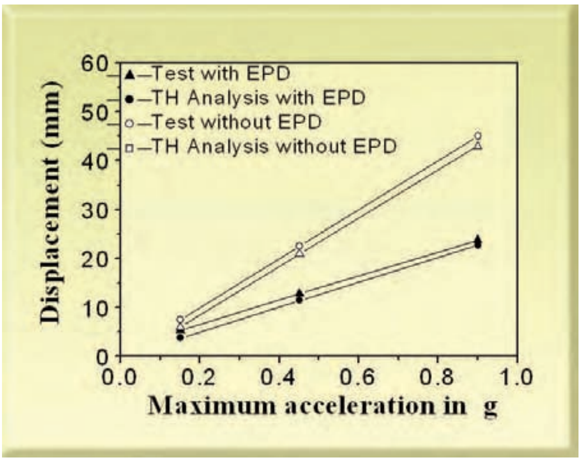

Fig. 5: Comparison of experimental and analytical response of cantilever piping with and without EPD

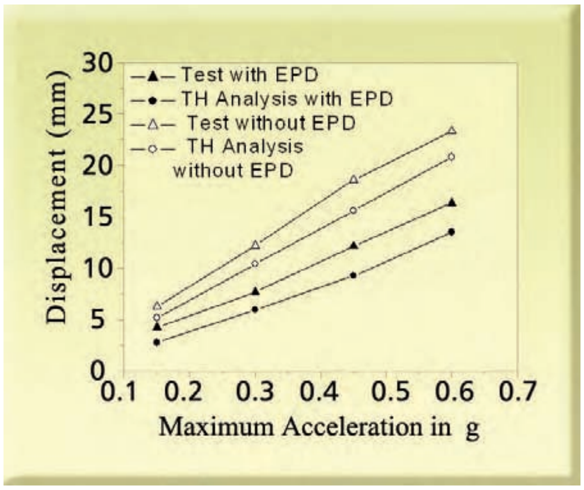

Fig. 6: Comparison of experimental and analytical response of 3-D piping with and without EPD

Bangalore with two EPDs and significant reduction in response was observed (Fig. 8). Thus piping supported on multiple EPDs and subjected to earthquake will give significant response reduction.

Applications of Elasto-Plastic Damper

Seismic retrofitting of APSARA Reactor Building

Seismic re-evaluation of APSARA reactor building (Fig. 9) was performed and it was found necessary to improve the capacity of the building, especially in footings. To meet this, it was proposed that the building should be retrofitted with Elasto-Plastic Dampers (Fig. 10). Elastoplastic dampers consisting of fifteen SS-316 6mm thick plates would be provided in the frames of the RCC building and the connections of the dampers with the beams and columns of the structure were to be made using ISMC 125 box sections. To prove the efficiency of dampers in reducing seismic response of RCC

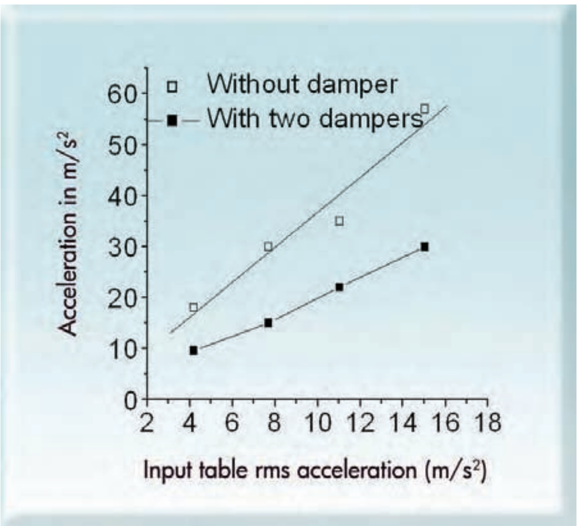

Fig. 8: Response of complex piping system with dampers

Fig. 7: Complex piping system with dampers

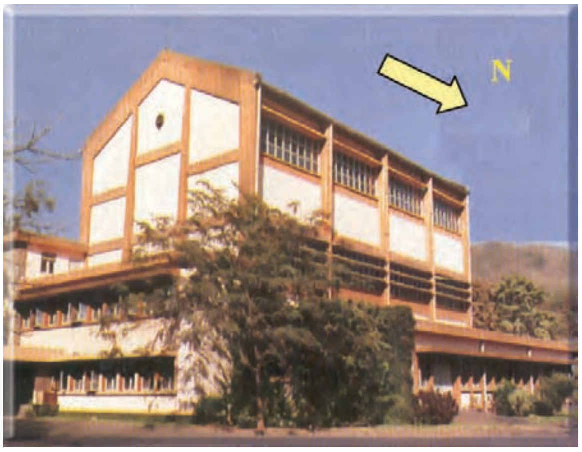

Fig. 9: View of APSARA reactor building

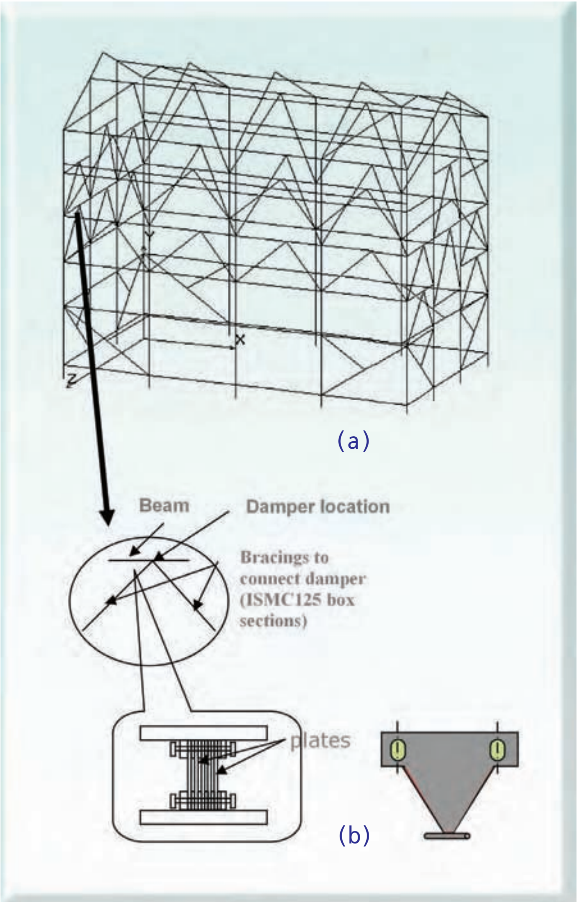

Fig. 10: (a) APSARA building model; (b) Location of dampers

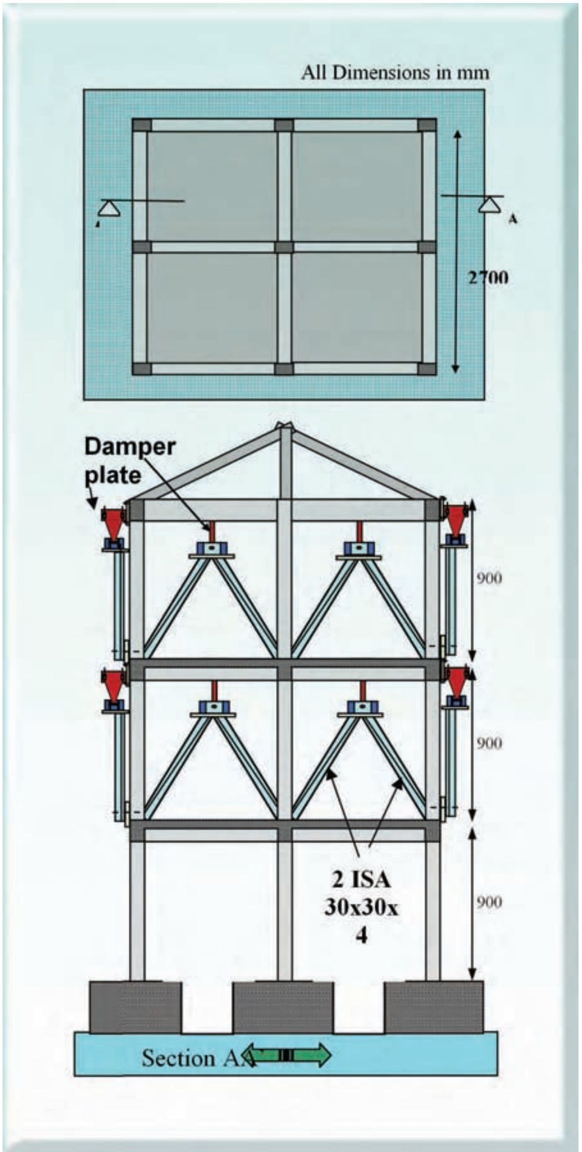

Fig. 11: Test set-up of RCC bldg. model with EPDs

framed structure, shake table tests at CPRI (Bangalore) are planned under the 10th Plan project on RCC building model with EPDs as shown in Fig. 11.

AHWR Down Comer Supported on EPD

Three possible layouts of AHWR Down Comer as shown in Fig. 12 have been considered for codal qualification, in order to ensure its operability and functionality during normal and occasional loads. Along with the codal qualification, a good layout should have less number of bends and weld joints in order to reduce the in-service inspection. Less number of bends will reduce the pressure drop in natural circulation. Among the three layouts, Layout –2 has lesser thermal stresses in comparison to Layout-1 but the number of elbows and weld joints remains similar to Layout-1.

A simple layout-3 has been considered for analysis, which has almost half the number of bends and weld joints as compared to earlier two layouts, but thermal

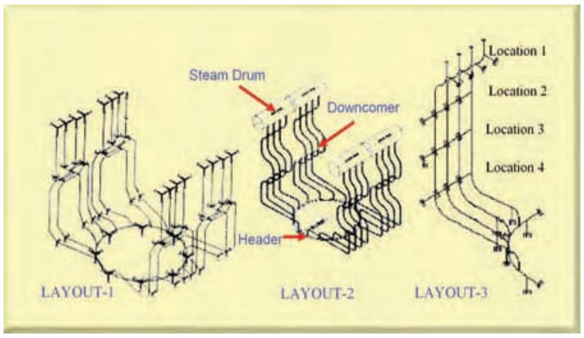

Fig. 12: Three proposed layouts for AHWR Downcomer

stresses exceed the code allowable limit when conventional supports are employed to control the seismic stresses in Layout-3. In order to qualify for the Layout-3 Elasto-Plastic Damper (EPD), supports have been employed. EPD supports absorb large amount of earthquake energy without much affecting the thermal stresses in the piping. 400 Kg dampers are to be used at location-1 and at locations 2, 3 & 4 dampers of capacity 1350 kg are to be used at each support. The comparison of thermal and seismic stresses, required lengths and welds of three layouts are given in Table 1 from which it can be inferred, that Layout 3 will be the most economical in meeting both thermal and seismic requirements.

Table 1: Comparison of maximum stress, number of welds and total length of pipe

Description	Thermal stresses (N/mm^2)	Seismic stresses (N/mm^2)	Total length of piping (m)	No. of welds
Layout-1	206.13	47.23	608.72	112
Layout-2	152.07	150.15	660.74	120
Layout-3	153.42	99.93	520	72

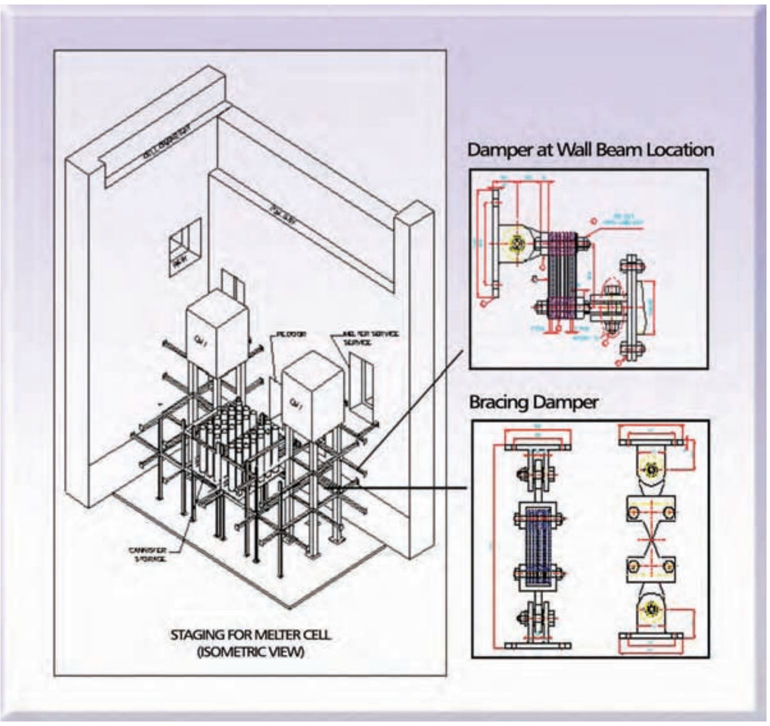

Fig. 13: Melter cell structure supported on EPDs

Design of Melter cell structure of WIP Kalpakkam, using EPDs

The Melter cell supporting structure of the Waste Immobilization Plant Kalpakkam, as shown in Fig. 13, is designed using Elasto-plastic dampers. Elasto-plastic dampers helped to reduce the loads on Embedded Parts (EPs) and facilitated the use of existing EPs. It also helped to meet the requirement of thermal loads.

Lead Extrusion Dampers (LEDs)

LEDs work on the principle of extrusion of lead. LED absorbs vibration energy by plastic deformation of lead and thereby mechanical energy is converted to heat. On being extruded, lead re-crystallizes immediately and recovers its original mechanical properties before the next extrusion.

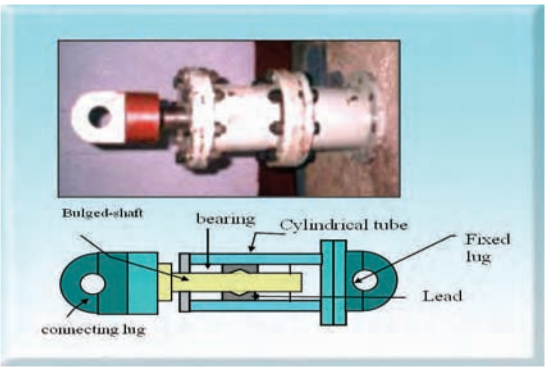

Fig. 14: Lead Extrusion Damper

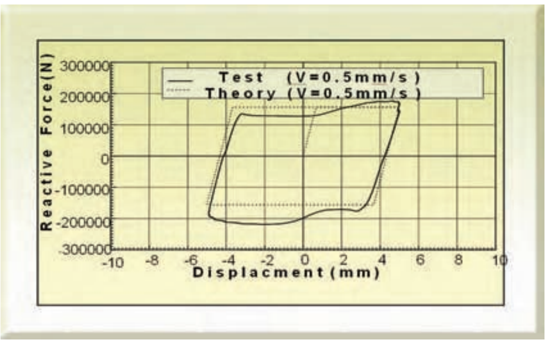

Fig. 15: Hysteretic force displacement characteristics of LED (theoretical and experimental)

Lead Extrusion Damper of 15 tonnes capacity was designed and fabricated (Fig.14). The area of force displacement relationship of the damper as shown in Fig. 15 gives the energy dissipated in the extrusion of lead. Static and dynamic tests are carried out on the LED (Fig.16) at SERC (Chennai) under the 10th Plan project. The desired hysteretic characteristics were demonstrated by this test (Fig. 15). One possible application of the LED is in the seismic response reduction of coolant channel when it is coupled to

Fig. 16: Test carried out on Lead Extrusion Damper

the fuelling machine (Fig. 17). The load transmitted to the coolant channel is significantly reduced, when the LEDs are attached to the F/Ms (Fig. 18). Shake table tests are planned on vessels restrained by Lead Extrusion Dampers at SERC (Chennai) under the10th plan project.

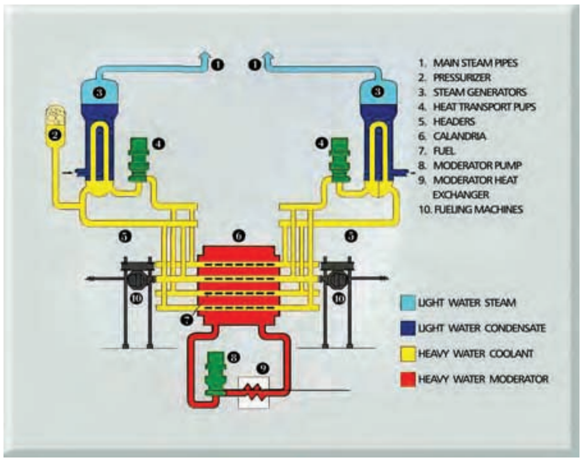

Fig. 17: F/Ms attached to either end of coolant channel during re-fuelling

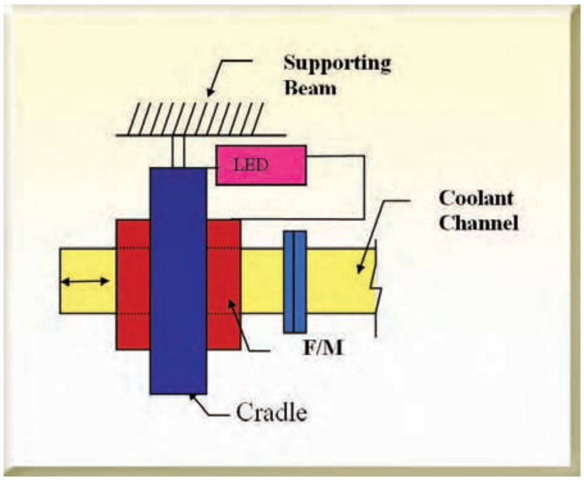

Fig. 18: F/M restrained using LED

Tuned Liquid Dampers (TLDs)

TLDs are rigid walled containers filled with liquid (mostly water) up to a certain height, to match the sloshing frequency with structure frequency and are placed at rooftop of the structure. The device absorbs vibration energy through liquid sloshing principle. A series of tests have been conducted in RSD, BARC (Fig. 19) on TLDs on a structural model excited by

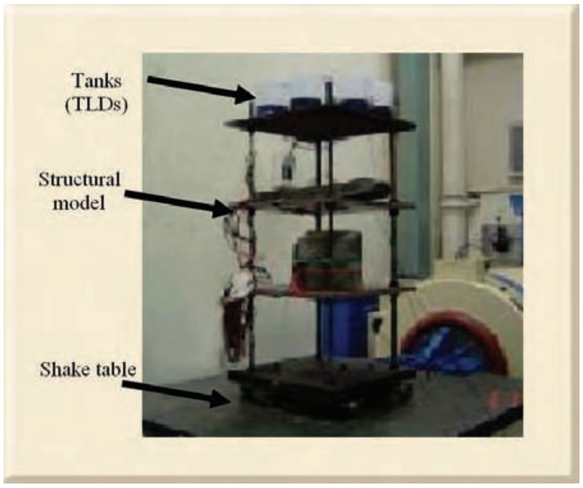

Fig. 19: Experimentation on TLDs

shake table. As the acceleration level increases, the roof displacement or the displacement at the base of the tank also increases. Aspect ratio (Fig. 20) is defined as ratio of roof displacement to diameter of the tank. For aspect ratio less than 0.03, the sloshing is essentially linear whereas above that, wave breaking might occur. The experimental and analytical results show a significant reduction in the response of the structure with TLDs.

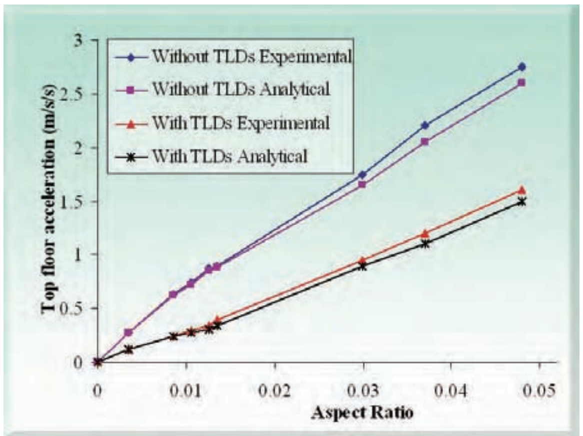

Fig. 20: Reduction in response with TLDs

Applications of Tuned Liquid Damper

Retroffitting of RLG building with Tuned Liquid Dampers

The G_E block of RLG building did not meet the seismic requirements against the earthquake, under a PGA level of 0.2g. As various important facilities are already in operation within the building, it was not practically feasible to retrofit the structure using conventional methods, because of space limitations. The retrofitting was therefore suggested using Tuned Liquid Dampers (TLDs) to control the response of the structure against earthquake. The analysis of the RLG building (Fig. 21) was performed using TLDs and it showed, that the responses reduce to a level within acceptable limits, even if the tuning is lost by 15 % on either side of perfect tuning (Fig. 22). The optimization of the design is being carried out.

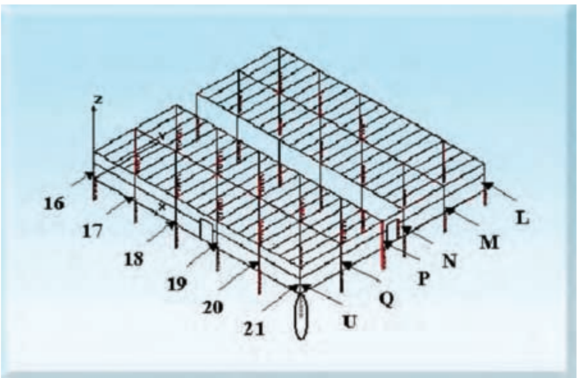

Fig. 21: FEM model of RLG building

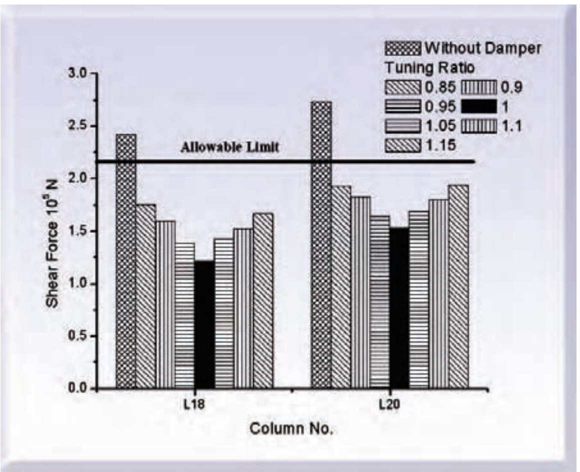

Fig. 22: Response of structure without and with TLDs

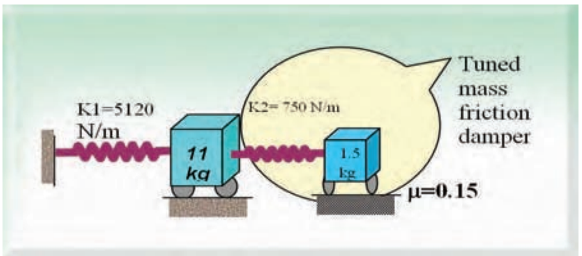

Fig. 23: Two degree of freedom

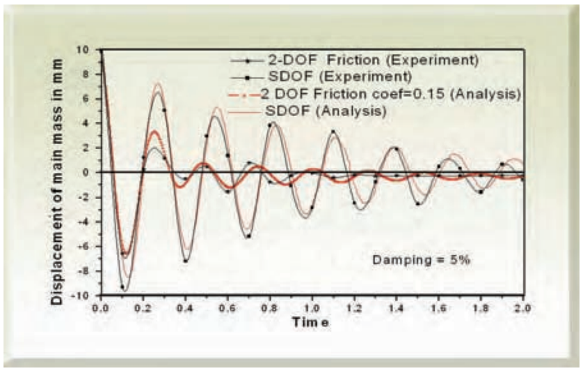

Fig. 24: Response on main mass subjected to free vibration giving initial displacement of 10 mm

Tuned Mass Friction Damper (TMFD)

TMFD is designed to utilize the effects of tuning and friction more effectively. Damping of the piping and equipment with TMFD, is higher than that with friction alone, due to the additional effect of tuning. Experiments were conducted by RSD, BARC on a tuned mass damper consisting of spring mass system (shown in Fig. 23) having the same frequency as that of the initial (SDOF) system which is attached to the main system. The friction coefficient for the damper is 0.15. The system was allowed to vibrate freely after giving an initial displacement of 10 mm. It is observed from Fig. 24 that due to effects of tuning and friction, the response of main mass is reduced considerably.

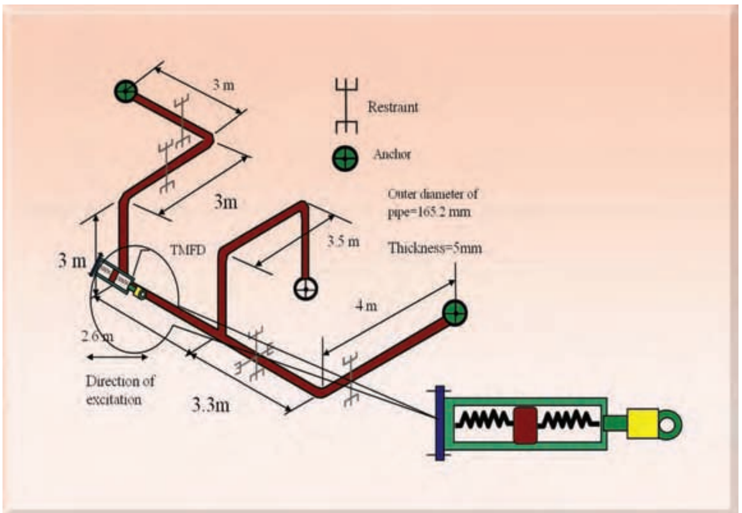

Fig. 25: Industrial piping supported on TMFD

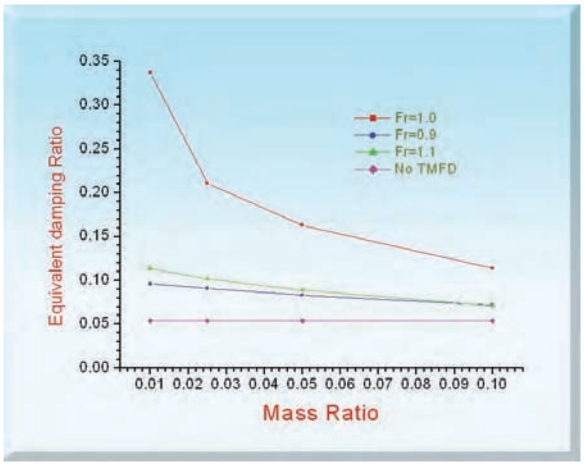

Fig. 26: Eq. damping vs mass ratio

Analysis of industrial piping system with Tuned Mass Friction Damper.

Industrial piping system shown in Fig. 25 is analyzed with TMFD with different mass ratios and damping values are evaluated. Fig. 26 shows the equivalent damping for different mass ratios, with 10 % variation in tuning frequency.

Shape Memory Alloy Damper

Shape-memory alloy damper shown in Fig. 27 is made up of wires (e.g. Nickel Titanium wires) that dissipate

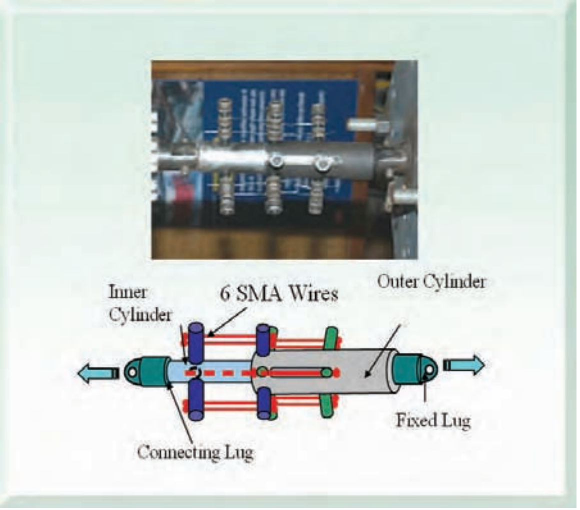

Fig. 27: SMA Damper

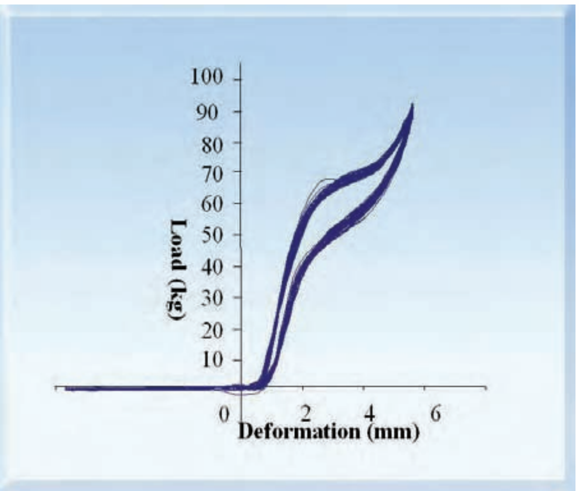

Fig. 28: Cyclic tensile tests of 1.2 mm dia. wire for 1200 cycles

energy when axially stressed. NiTi wires are very attractive for passive vibration control as they have pseudoelastic property (the property by which the alloy recovers its initial shape when external load is removed) and can sustain large amount of inelastic deformation.

Cyclic tensile tests were carried out in SERC (Chennai) under a BRNS project, on wires of 1.2 mm dia. for 1200 cycles and the force deformation relation is shown in Fig. 28. Shake table tests are planned on cantilever piping with Shape memory alloy damper under the BRNS project.

Base Isolators

The base isolation is aimed at attenuating the horizontal acceleration, transmitted to the superstructure. The isolation system attempts to decouple the building or structure, from the horizontal components of the ground motion, by interposing structural elements with low horizontal stiffness, between the structure and the foundation. This results in the shifting of fundamental frequency (≈ 0.5 Hz) of the structure, out of the range of dominant earthquake energy and in increasing the energy absorbing capacity.

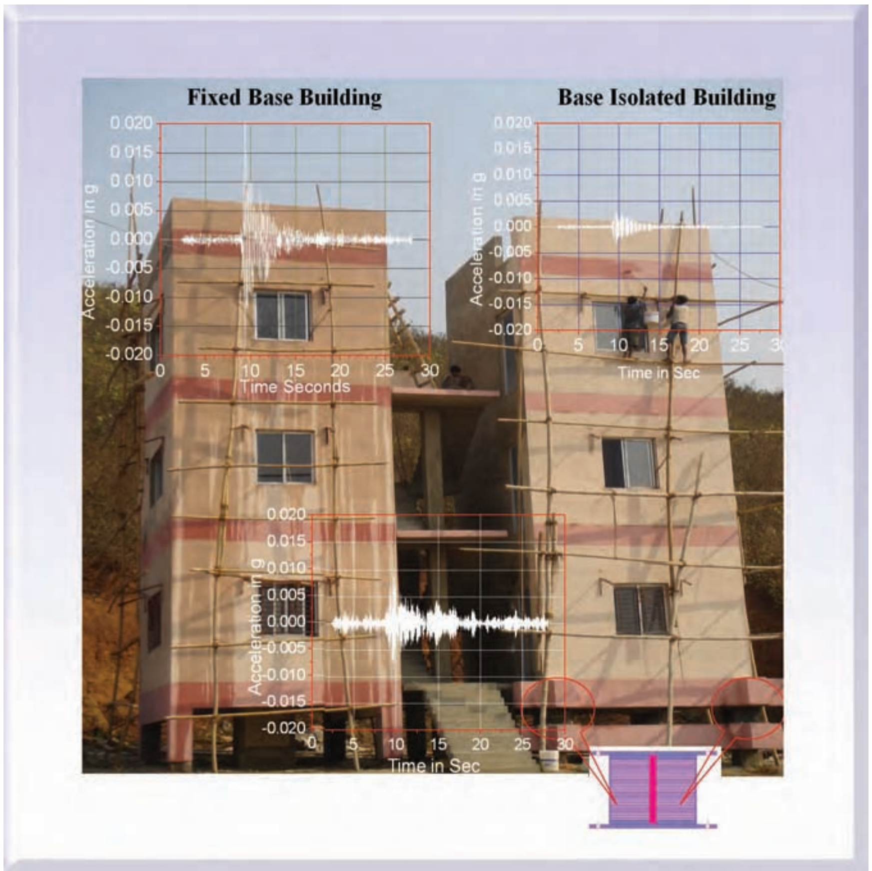

Fig. 29: Building with fixed base foundation and base isolation

Verification test of a prototype base isolated three storeyed - R.C.C. framed building subjected to actual earthquake

A prototype of three storeyed R.C.C. framed building and a base isolated three storeyed- R.C.C. framed building has been built in IIT (Guwahati) under a BRNS project. These structures recently experienced actual earthquake. The measured ground acceleration time history and the time histories recorded at the top of prototype building with fixed base and a prototype base isolated building are shown in Fig. 29. From the signal base, isolation effects can be clearly seen.

Investigations of Behavior of Nuclear Piping Systems under severe earthquake loading

Nuclear power plant piping components and systems are designed for SSE and stresses are categorized under faulted load condition as per ASME code. ASME code rule for piping design with SSE loading was based on the principle of plastic collapse. Recently it was observed that during such events, fatigue ratcheting is the most likely failure mode of piping. In view of this, ASME Boiler & Pressure Vessel code, Section-III (1995) has increased the allowable primary stress limit to 4.5 S_m for Level-D service condition. It also provides an alternate strain based approach which states, that the average through wall ratcheting strain should not exceed 5% in 10 cycle event for Level-D service condition. The ASME, Sec. III (2001) brought back the primary stress limit for Level-D loading from 4.5 S_m to 3 S_m. However, B_2 indices are modified as B_2' indices and strain based approach is not changed in this revision. The 2004 edition of the code has deleted NB-3228.6 (Reversed Dynamic Loading in Piping). Stress based approach is not changed in this revision. The basis of these changes is still under debate by many regulatory agencies in US and Europe. In view of this, RSD has initiated extensive research to understand revised ASME design rule. A large number of experiments have been planned to validate the ASME code rule.

Few ratcheting experiments conducted by us have shown that strain accumulation depends on both stress rate and stress ratio. In the biaxial test on straight pipe (Fig. 30), ovalization of pipe cross section was observed, when the pipe was subjected to constant internal pressure and cyclic bending load. Local bulging was observed at higher loading as shown in Fig. 31. The pipe did not show any shakedown behavior for the given cycles of loading and exhibited continuous

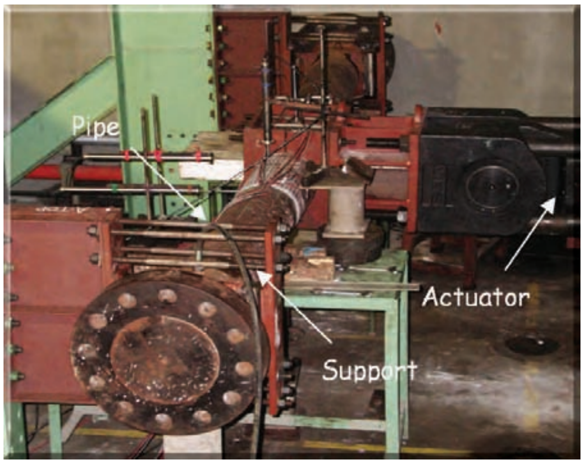

Fig. 30: Experimental set-up for straight pipe

Fig. 31: Bulging of pipe

ratcheting as shown in Fig. 32. Similar observations were made during shake table test on pressurized elbow, subjected to cyclic base excitation. (Test setup is shown in Fig. 33 and hoop strain time history in Fig. 34). During shake table tests on three dimensional piping systems (test setup is shown in Fig. 35), fatigue-ratcheting failure was observed in one test, (strain accumulation is shown in Fig. 36). In the next test, a weld failure was observed as shown in Fig. 37 after a large number of cycles. Further tests have been planned to determine the strain limit to prevent ratcheting mode of failure in the piping system under SSE.

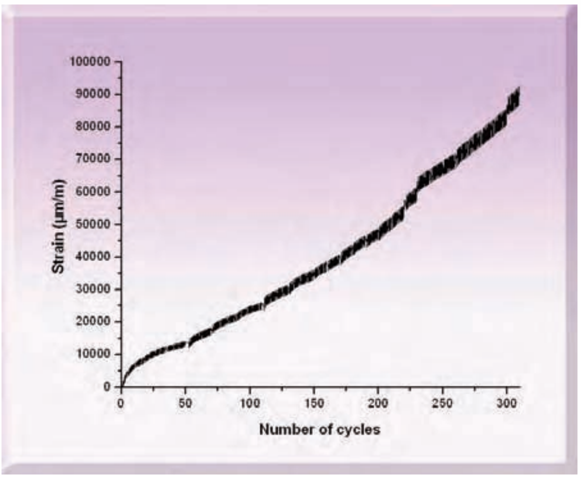

Fig. 32: Hoop strain vs number of cycles

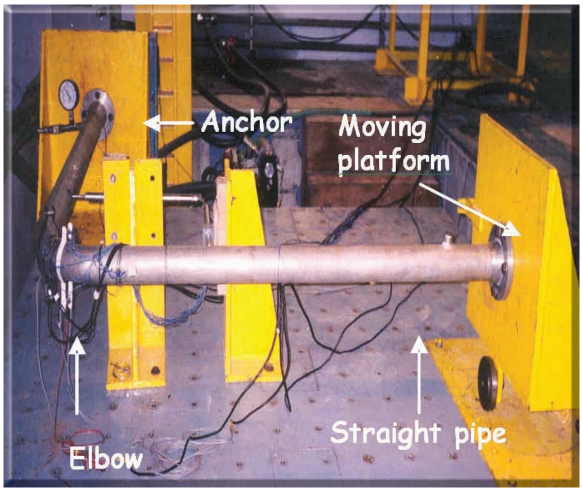

Fig. 33: Experimental set-up for elbow

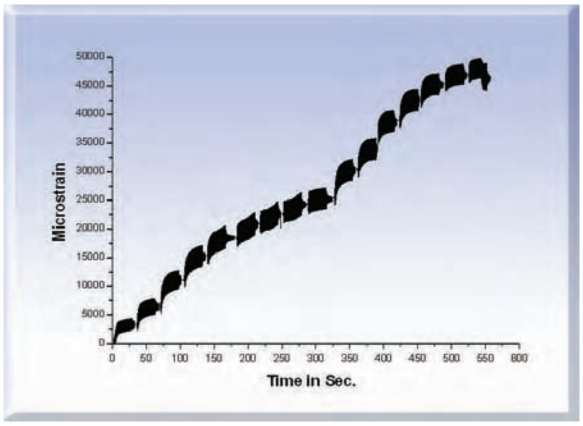

Fig. 34: Hoop strain vs time at crown

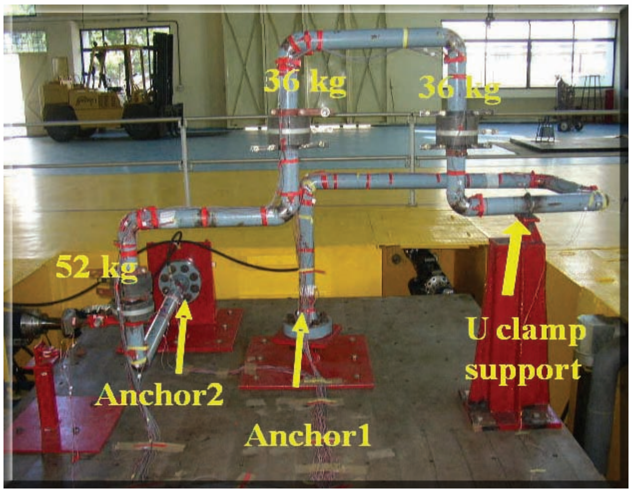

Fig. 35: Experimental set-up for 3 D piping system

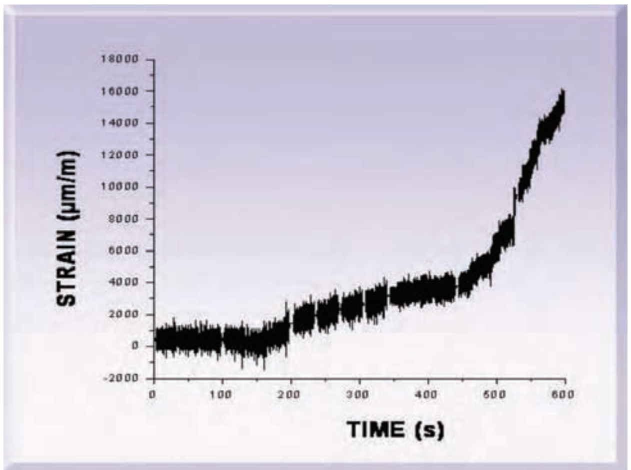

Fig. 36: Hoop strain time history at an elbow

Fig. 37: Failure of piping system

Investigations on Reinforced Concrete Structures

Behavior of concrete structures under seismic excitation still poses great challenges to civil engineers throughout the world. The vulnerability of the RC beam-column connections in a framed structure under seismic loads is also well known. Keeping these in view, a three-phase program has been designed to understand seismic behavior of RC structures under SSE loading.

The first phase of the program includes experimentation of RC beam-column connections under monotonic and quasi-cyclic loads, having varied cross section dimensions in a range of 100 mm to 1000 mm. Reinforcement detailing, shear span ratio, compressive strength of concrete and type of loading are among the parameters which are varied. In total, thirty joints have been tested till date and further twelve joints under this program have been cast. These experiments are performed under BRNS project Fig. 38 shows the testing under progress and the damaged state of (a) Small Sized Joint and (b) Large Sized Joint. Fig. 39 shows results of experimental program on beam-column joints in the form of (a) Typical hysteretic loops and (b) Variation of ductility with size of beam-column joints.

Retrofitting of beam-column joints of existing RCC structure may be required, if the capacity is less than the demand. A retrofitting technology based on strengthening of beam-column joints using Carbon Fiber Reinforced Polymers (CFRP) was developed along with IIT, Bombay under a BRNS Project. The damaged joint (Fig. 38 (a)) was retrofitted using CFRP and tested again (Fig. 40 (a)).

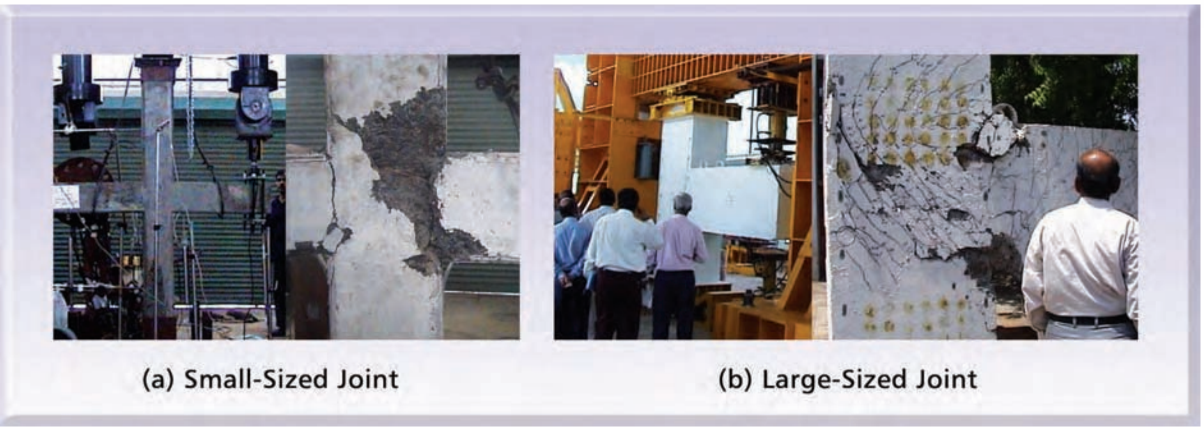

Fig. 38: Testing under progress and damaged state for beam-column joints

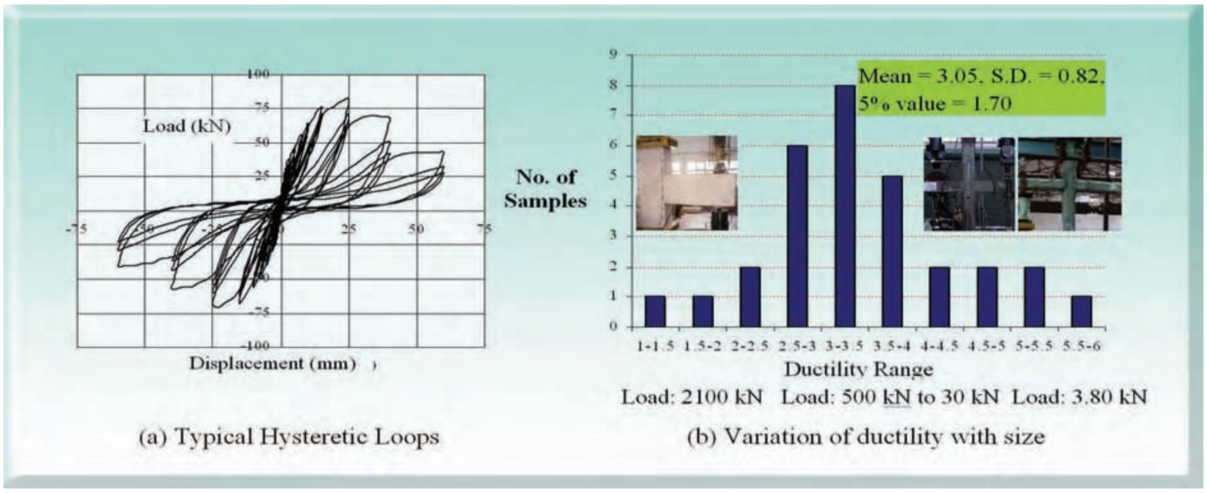

Fig. 39: Results of experimental programme of beam-column joints

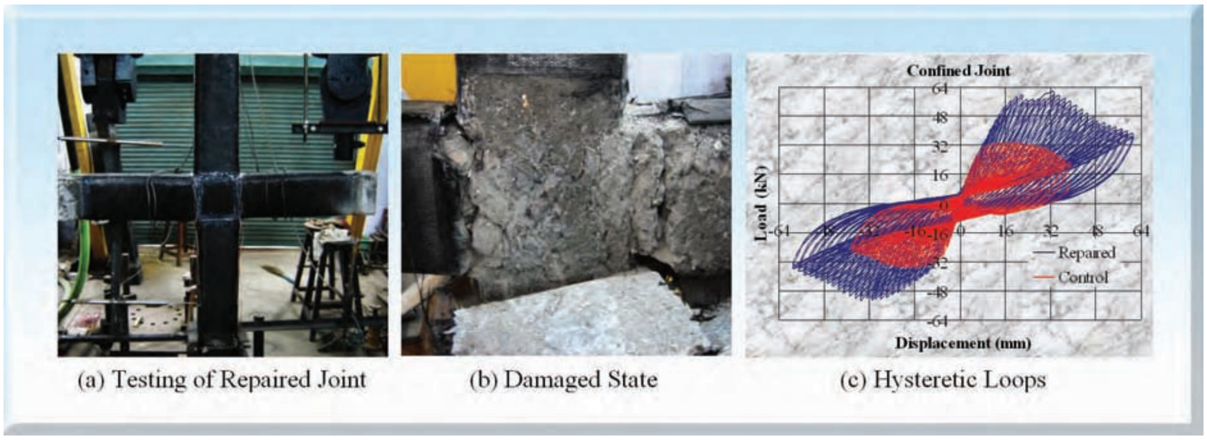

Fig. 40: Experimental programme on testing of CFRP repaired joints

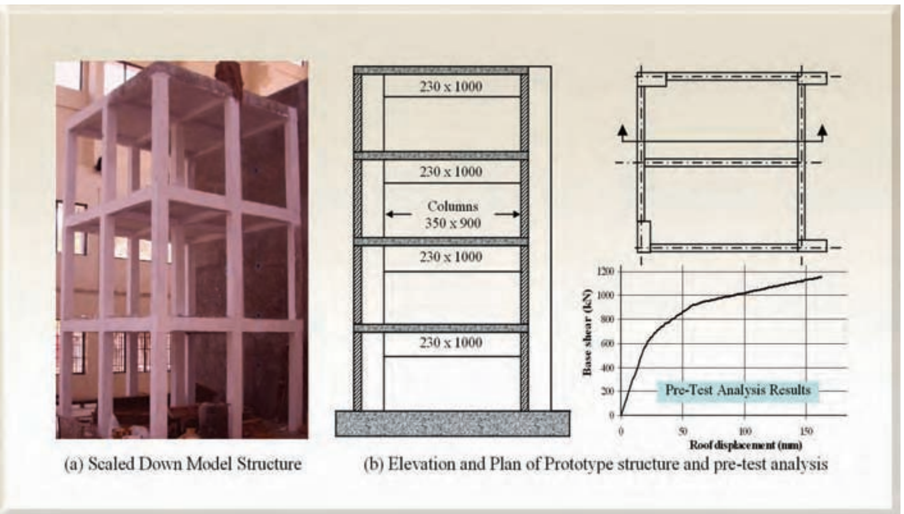

Fig. 41 : Structures for testing against pushover loading

The damaged state of the joint before repair is shown in Fig. 40 (b). The results (Fig. 40 (c)) show a significant increase both in strength and deformation capacity of the repaired joint over the control joint.

The second phase of the program includes experimentation of RC structures under monotonic pushover type loading. Pushover technique for RCC structures subjected to earthquake loading is a very useful technique to know its performance states such as initial cracking, yielding of bars, ultimate state and failure state. However, higher mode effects and damping effects are considered conservatively and hence require experimental verification.

Under this program, one scaled down model structure (Fig. 41 (a)) has already been constructed and another full-scale prototype of existing RC structure (Fig. 41 (b)) is under construction. Pre-test analysis of the prototype structure is performed (Fig. 41 (b)). The experimentation on these structures will be carried out, under gradually increasing monotonic pushover loading up to failure.

The third phase of the program includes the experimentation of RC structures under dynamic loads using shake table. Under this program three scaled down models of RC structures will be tested on tri-axial shake table. Fig. 42 shows the structure ready for testing. The structure will be tested without and with brick infill panel.

Fig. 42: Model structure ready for testing on tri-axial shake table

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WORKSHOP ON RADIOACTIVE WASTE MANAGEMENT : A REPORT

A Workshop on Radioactive Waste Management was conducted on September 28, 2007 at the Waste Immobilization Plant, Trombay. The participants included Mr. S.K. Agrawal, Director (Projects), NPCIL and other senior officers of the NPCIL Project Directorate.

The objective of the workshop was to inform the participants about radioactive waste management policy and practices followed in the country. Aspects of process development, design and operation of waste management facilities for treatment including volume reduction techniques adopted for various types of radioactive wastes and spent radiation sources were discussed. *Minimization of radioactive waste* was emphasized as a *mantra* in view of the expansion of the Indian Atomic Energy Programme and the consequent likely increase in waste generation. Aspects of near surface disposal facilities, condition monitoring of existing disposal modules and post closure surveillance were also covered. Participants were given a demonstration of the operation and maintenance of various waste management systems during their visits to the Effluent Treatment Plant, the Decontamination Centre, the Radioactive Solid Waste Management Site and the Waste Immobilization Plant.

The workshop concluded with an in-depth discussion on communication aspects with the public about the safety of radioactive waste management practices followed in the country.

Mr. Kanwar Raj, Head, Waste Management Division, BARC, explaining details of WIP, Trombay to the participants of the Workshop on Radioactive Waste Management

12TH ISMAS SYMPOSIUM-CUM-WORKSHOP ON MASS SPECTROMETRY : HIGHLIGHTS

The 12th ISMAS Symposium-cum-Workshop on Mass Spectrometry (12th ISMAS-WS 2007) was organized by the Indian Society for Mass Spectrometry (ISMAS, Mumbai) in association with the National Institute of Oceanography and was co-sponsored by the Scientific Departments (BRNS and CSIR) of the Government of India. The Symposium-cum-Workshop was held at Goa during March 26-30, 2007.

The 12th ISMAS-WS 2007 was inaugurated by Dr. T. Mukherjee, Director, Chemistry Group, at BARC Mumbai, on March 26, 2007. Dr. S.K. Aggarwal, President, ISMAS delivered the welcome address and highlighted the scope of the Symposium. Prof. P.S. Zacharias, Vice Chancellor, Goa University delivered the presidential address and Prof. V.N. Jindal, Dean of Goa Medical Collage addressed the gathering. During the inauguration function, a special ISMAS Bulletin as well as a CD containing the e-book of abstracts of the invited talks and contributed papers was released by Dr. T. Mukherjee. The inauguration was followed by a formal opening of the exhibition arranged by different vendors and manufacturers of instruments.

Around 150 participants including 10 overseas speakers attended the Symposium. The scientific programme of the Symposium-cum-Workshop was spread over 18 technical sessions. There were 16 invited talks by distinguished mass spectroscopists, 18 technical posters; 13 research scholars presentations, 11 innovative research presentations and 8 lectures by instrument manufacturers on recent developments in instrumentation. There were six panel discussions on topics of current interest viz. Accelerator Mass Spectrometry, Bio-Medical Research, MS in Earth Sciences, Indigenous Instrumentation for Mass Spectrometry, MS in Nuclear Science and Technology, Trace Elemental Analysis Techniques etc. The panel discussion on Trace Elemental Analysis Techniques also included other promising trace analysis techniques like Total Reflection X-ray Fluorescence (TXRF) and Laser Induced Breakdown Spectroscopy (LIBS). These panel discussions were appreciated by all the delegates and were highly useful to the participants. Invited speakers from overseas included Dr. Mathias Schafer, (Cologne, Germany), Dr. John P. Shockcor (Cambridge, UK), Dr. I.B. Brenner (Israel), Dr.Morris Richard (Warwick, UK), and Dr. Ronald Hergenroeder (Dortmund, Germany). The speakers from India included

Dr. T. Mukherjee, Director, Chemistry Group, delivering the inaugural address

Prof. Saranjit Singh (NIPER, Mohali), Prof. A.K. Chakraborti (NIPER, Mohali), Dr. Mahesh Kulkarni (NCL, Pune), Dr. S.K. Raza, (DRDE, Gwalior), Prof. Utpal Tatu (IISc., Bangalore), Dr. K.P. Madhusudanan, (CDRI, Lucknow), Dr. B.R. Chakraborty (NPL, Delhi). The scientific topics covered in these invited talks included Advances in Mass Spectrometry Instrumentation, Application of Mass Spectrometry in the fields of Nuclear Technology, Earth Sciences, Drug Discovery, Ionic Liquids, Proteomics etc. A novel feature of the 12th ISMAS-WS 2007 was a presentation on "Scientometric Mapping of Mass Spectrometry Research in Nuclear Sciences & Technology : A Global Perspective" by Mr. B.S. Kademani from Scientific Information Resource Division (SIRD) of BARC.

The Symposium concluded with a Valedictory function on March 30, 2007. Dr. J.P. Mittal, renowned scientist and former Director, Chemistry Group, BARC was the chief guest during the Valedictory function. During this function, prizes were awarded to the authors of the best poster and the best oral presentations.

Valedictory function : Sitting on the dais from left : Ms. D. Alamelu, Treasurer, ISMAS & Convener, 12th ISMAS WS 2007, Dr. S.K. Aggarwal, President, ISMAS, Chairman, 12th ISMAS WS-2007 & Head, FCD, Dr. J.P. Mittal, Ex-Director, Chemistry Group and Mr. P.G. Jaison, Secretary, ISMAS & Co-Convener, 12th ISMAS WS-2007

HEALTH PHYSICS TRAINING COURSE - XIII BATCH : VALEDICTORY FUNCTION

The Health, Safety and Environment Group concluded one more batch of its regular one-year training course for 28 science graduates recruited by NPCIL, specifically for the operational radiation protection functions of nuclear power plants. The valedictory function of this course was held at the Health Physics Division auditorium at the Radiation Protection Training & Information Centre on October 29, 2007. The invitees included senior officers of BARC, NPCIL and AERB.

Mr. M.L. Joshi welcomed the chief guest, dignitaries, invitees and the faculty. He presented a brief outline of the training course which was initiated in 1989, with the specific objective of developing trained manpower, in the specialized discipline of radiological safety required for the nuclear fuel cycle facilities, including nuclear power plants. He observed that Health Physics being a specialized discipline - a combination of different branches of science and engineering was not offered as a regular course, by any of the universities in India.

Mr. Joshi remarked that over the years, the Health Physics training programme has undergone significant upgradation with respect to the syllabus, structure of the training programme, training methodology, assessment procedures etc. Based on the feedback received from the faculty and the trainees and under the guidance of the apex committee, the syllabus, training material and the structure of the training programme are periodically upgraded to international standards. The apex committee also reviews the progress of each batch of trainees periodically and guides the training group for improving the overall performance. He expressed happiness over the fact that Health Physics training programme is acknowledged as a standard by other Divisions of BARC and they have been approaching the Health Physics Division for guidance when it became mandatory in BARC, to recruit all fresh entrants in scientific and technical grades, through formal training schemes only.

In the valedictory address, the Chief Guest, Mr. G. Nageswara Rao, Director (Operations), NPCIL stressed on the importance of formal training to understand the concepts of nuclear and radiological safety and also to have a clear awareness of the relevant systems. He appreciated the efforts of the Health Physics Division, to impart professional training to the graduates in this specialized discipline and to make them competent to shoulder the responsibility of ensuring radiological safety in nuclear facilities. However, he warned the youngsters, that they have an unenviable responsibility of helping the department in achieving its production targets without compromising on the safety procedures. In this context, he remarked, that a Health Physics professional should be well conversant with the plant systems for effectively contributing to the safe execution of O&M jobs. In the present scenario, he reminded that the Health Physicists have the added responsibility of interacting with a considerable number of contractor personnel engaged in various jobs in radioactive areas/ on radioactive systems and guiding them in the safe execution of jobs and meeting all the regulatory requirements.

He concluded his remarks with an advice to the youngsters to emulate the high standards of safety and achievement, set by the pioneers in Health Physics profession and to take up this profession as a torch bearer of high standards in radiological safety. The Chief Guest awarded certificates to all the trainees for successfully completing the training course.

Dr. Om Pal Singh, Secretary, AERB, in his address observed that the Health Physics professionals stationed at the sites are the ambassadors of the regulatory board. He also highlighted the necessity of carrying out the jobs through approved procedures and observing the prescribed standards. He reminded the Health Physicists of their role in reducing the plant man rem. He also congratulated the trainees for successfully completing the rigorous course and presented the cash awards and certificates to the first two rank holders, Mr. Subhasis Chatterjee and Mr. Dmonte Jason Joachim respectively.

The function concluded with a vote of thanks proposed by Mr. K. Narayanan Kutty, Officer-In-Charge, Training Group. He attributed the success of the training programme to well co-ordinated team work and the whole-hearted support and guidance of a large number of agencies. A special mention was made of the support extended by the authorities of a number of BARC and NPCIL units for facilitating 'On the Job Training' at these centres, as an integral part of the training programme.

The Chief Guest, Mr. G. Nageswara Rao, Director (Operations), NPCIL addressing the gathering. Mr. M.L. Joshi, Head, Health Physics Division and Dr. Om Pal Singh, Secretary, AERB are on the dais.

भा.प.अ. केंद्र के वैज्ञानिकों को सम्मान

BARC SCIENTISTS HONOURED


D.R. Raut


S.A. Ansari


Dr. P.K. Mohapatra


Dr. V.K. Manchanda

डी.आर. राउत, एस.ए. अंसारी, पी.के. महापात्रा एवं वी.के. मनचंदा, द्वारा लिखित "सेपरेशन ऑफ सीएस (I) फ्राम सिम्युलेटेड हाई लेवल वेस्ट सोल्यूशन यूजिंग कलिक्स [4]-बिस 2,3-नेफथो-क्राउन-6" तथा एस. ए. अंसारी, पी.के. महापात्रा एवं वी.के. मनचंदा, रेडियोरसायनिकी प्रभाग भाभा परमाणु अनुसंधान केंद्र द्वारा लिखित "इवेल्यूएशन ऑफ फेज़ मोडिफायर फॉर द एक्सट्रेक्शन ऑफ एनडी (III) बई एन,एन,एन.'एन.'टट्राओक्टिल-डि-ग्लाइकोलामाइड लेखों को एम.एस. विश्वविद्यालय, वडोदरा में आयोजित न्युक्लियर-2007 समारोह में फरवरी 14-17, 2007 के दौरान श्रेष्ठ प्रस्तुति पुरस्कार प्रदान किया गया। ये लेख श्री डी.आर. राउत, एवं श्री एस.ए. अंसारी, द्वारा प्रस्तुत किए गए।

Papers entitled "Separation of Cs (I) from Simulated High Level Waste Solution Using Calix [4]-bis 2,3-Naphtho-Crown-6" by D.R. Raut, S.A. Ansari, P.K. Mohapatra and V.K. Manchanda and "Evaluation of phase modifier for the extraction of Nd(III) by N,N,N',N'-tetraoctyl-di-glycolamide (TODGA)" by S.A. Ansari, P.K. Mohapatra and V.K. Manchanda, Radiochemistry Division, BARC, were given best presentation awards at NUCAR-2007 held at M.S. University, Vadodara during February 14-17, 2007. The papers were presented by Mr. D.R. Raut and Mr. S.A. Ansari, respectively.

श्री डी. आर. राउत, भाभा परमाणु अनुसंधान केंद्र के रेडियोरसायनिकी प्रभाग में जनवरी 2006 से जूनियर स्नातक की हैसियत से मुंबई विश्वविद्यालय एवं परमाणु ऊर्जा विभाग के सहयोग योजना के अधीन कार्यरत हैं। कालिक्स-क्राउन लाइगेंन्डस् के उपयोग से रेडियो सीज़ियम का पृथ्कीकरण इनकी विशेषज्ञता का क्षेत्र है।

Mr. D.R. Raut is working as Junior Research Fellow in Radiochemistry Division, BARC since January 2006 under the collaboration scheme between University of Mumbai and Department of Atomic Energy. His area of specialization is separation of radiocesium using calix-crown ligands.

श्री एस. ए. अंसारी भाभा परमाणु अनुसंधान केंद्र के रेडियोरसायनिकी प्रभाग में जनवरी 2006 से सीनियर स्नातक की हैसियत से मुंबई विश्वविद्यालय एवं परमाणु ऊर्जा विभाग के सहयोग योजना के अधीन कार्यरत हैं। नॉवल एक्सट्रेक्टंटस् के उपयोग से एक्टिनाइडस् एवं फिशन उत्पादनों का पृथ्कीकरण इनकी विशेषज्ञता का क्षेत्र है। प्रसिद्ध अंतर्राष्ट्रीय पत्रिकाओं में 10 प्रकाशन इनके श्रेय में हैं।

Mr. S.A. Ansari is working as a Senior Research Fellow in Radiochemistry Division, BARC since January 2003 under the collaboration scheme between University of Mumbai and Department of Atomic Energy. His area of specialization is separation of actinides and fission products using novel extractants. He has ten publications in reputed international journals.

डॉ. पी. के. महापात्रा ने भाभा परमाणु अनुसंधान केंद्र के रेडियोरसायनिकी प्रभाग में वर्ष 1987 में सदस्यता ली। विलायक उद्धरण, आयन उद्धरण, वर्ण विज्ञान एवं द्रव्य झिल्ली के प्रयोग से एक्टिनाइडस् एवं फिशन उत्पादनों का विभाजन इनकी अनुसंधान रुचि में शामिल हैं। डॉ. महापात्रा एचबीएनआइ के एक मान्यता प्राप्त गाइड हैं तथा प्रसिद्ध अंतर्राष्ट्रीय पत्रिकाओं में इनके 80 से अधिक प्रकाशन हैं।

Dr. P. K. Mohapatra joined the Radiochemistry Division, BARC in 1987. His research interests include separation of actinides and fission products using solvent extraction, ion-exchange, extraction chromatography and liquid membranes. A recognized guide of HBNI, Dr. Mohapatra has to his credit over 80 publications in reputed international journals.

डॉ.वी.के.मनचंदा इस समय भाभा परमाणु अनुसंधान केंद्र के रेडियोरसायनिकी प्रभाग के अध्यक्ष हैं। पीयू के सीक्यूसी पर आधारित ईंधन, एक्टिनाडस एवं फिषण उत्पादनों का विभाजन, दीर्घचक्री संकर एवं जलीय वातावरण में रेडियो न्युक्लाइडस् की दीर्घ आयु इनकी अनुसंधान रुचि में शामिल हैं। मुंबई विश्वविद्यालय एवं एचबीएनआइ के एक मान्यता प्राप्त गाइड डॉ.मनचंदा के 160 लेख प्रसिद्ध अंतर्राष्ट्रीय पत्रिकाओं में प्रकाशित हैं। आईएनएसीएएस एवं आइएएनएसएटी जैसी वृतिक संस्थान के अध्यक्ष के रूप में भी कार्य कर रहे हैं। रेडियो किमिका ऍक्टा एवं सॉल्वंट एक्सट्रेक्शन तथा आयन एक्सचेंज जैसे अंतर्राष्ट्रीय पत्रिकाओं के संपादकीय मंडल में भी हैं।

Dr. V.K. Manchanda is currently the Head, Radiochemistry Division, BARC. His research interests include CQC of Pu based fuels, Separation of actinides using novel extractants, Macrocyclic complexes and Speciation of long lived radionuclides in aquatic environment. A recognized guide of University of Mumbai and HBNI, he has more than 160 publications in reputed international journals to his credit. He is the President of professional organizations such as IANCAS and INASAT. He is on the Editorial Board of International Journals such as *Radiochimica Acta* and *Solvent Extraction & Ion Exchange*.


Dr Sandip Basu

डॉ संदीप बासु, आरएमसी, भाभा परमाणु अनुसंधान केंद्र को फरवरी 15, 2007 को अमेरिकन कॉलेज ऑफ न्युक्लियर फिज़िशंज़, सैन अनटोनियो, टेक्साज़, यूएसए की 33सवीं वार्षिक सभा में "ओबजरवेशन ऑन दि डिफरंशल एफडीजी अपटेक इन दि लोअर एक्सट्रीमिटी आरटरीज़ इन डायबटिक फुट विद इसकेमिक कोम्पलिकेशंस वरसेज़ देट इन न्यूरोपेथिक ओसटिओरथ्रोपेथी: एफडीजी-पीईटीएन्ड हिस्टोपेथोलोजिक्ल कोरिलेटस"नामक लेख की प्रस्तुति हेतु एसीएनपी ट्रेवलग्रांट पुरस्कार से सम्मानित किया गया। उपर्युक्त लेख को सभा में प्रस्तुत लेखों में सर्वश्रेष्ठ ठहराया गया।

Dr Sandip Basu, RMC, BARC, was awarded the 'ACNP Travel Grant Award' for his abstract entitled "Observation on the differential FDG uptake in the lower extremity arteries in diabetic foot with ischemic complications versus that in neuropathic osteoarthropathy: FDG-PET and histopathological correlates", presented at the 33rd Annual meeting of American College of Nuclear Physicians, San Antonio, Texas, USA on February 15, 2007. The above abstract was adjudged as the best abstract presented at the conference.

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