Non – structural seismic vulnerability assessment of Mahant Indiresh hospital, Dehradun (Uttarakhand)

DMMC

Hospital safety: Let's work together

Disaster Mitigation and Management centre

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A Report

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Foreword

Despite the harsh fact that non – structural losses during an earthquake often far surpass the structural losses, non – structural safety is often not accorded due importance. Loss of non – structural elements often hampers operational continuity of critical facilities on the aftermath of any disaster. This particularly holds good for hospitals that are expected to deliver additional services.

Contrary to the common perception non – structural mitigation is not cost intensive and greatly reduced the cost of repair and restoration in the post – disaster phase. It thus pays rich dividends and is thus an investment worth making.

This report is the result of the non – structural seismic vulnerability assessment undertaken in one of the prestigious hospitals of Dehradun, Mahant Indiresh hospital. Rather than bringing forth various shortcomings this report is intended to draw attention of the hospital administration towards various weak links that might hamper its operational continuity on the aftermath of a major disaster. We are sure that hospital administration would take the report in a positive spirit and undertake various mitigation measures in a phased manner as suggested in the report.

The non - structural vulnerability assessment for any structure must however be accompanied by the structural vulnerability assessment as the behaviour of non - structural elements is dependent to a large extent upon the structural behaviour of the same at time of disaster. Structural vulnerability assessment could however not be undertaken because of non - availability of the structural drawings. It is therefore recommended that the structural vulnerability assessment of the Mahant Indiresh hospital be carried out at the earliest and the recommendations of this report be modified / amended in the light of the same.

This report is the outcome of the efforts put in by the DMMC team that comprised of Dr. Girish Chandra Joshi, Ms Aneeta Salaria and Shri Rakesh Joshi. All are congratulated for their sincere efforts at different stages of report preparation.

Needless to say that this work would not have been possible without the support, cooperation and willingness of the Mahant Indiresh hospital administration. The doctors and other staff of the hospital were always ready and willing to help during the fieldwork that was undertaken between 2nd April, 2012 and 4th May 2012. Special thanks is owed to Dr. Ved Prakash (Medical Superintendent) for the support provided and Dr. P.R.Semwal (Assistant Medical Superintendent) who at every stage coordinated with different sections and helped the team in conducting the survey within hospital premises.

16th July, 2012
DMMC, Uttarakhand Secretariat
Dehradun

(**Piyoosh Rautela**)
Executive Director
DMMC

1. Seismic hazard in Dehradun

Himalayan organic belt is divided into a number of tectonic blocks that are bound by regional tectonic discontinuities. Southernmost of these is Outer Himalaya that is bound to the north and south by Main Boundary Thrust (MBT) and Himalayan Frontal Thrust (HFT) respectively. Outer Himalayan tectonic unit has a number of E-W running synclinal valleys called duns. Dehradun, the capital of Uttarakhand is located in one such valley that is bound to the east and west by Ganga and Yamuna tear faults respectively (Fig. 1). Proximity to active tectonic boundaries makes Dehradun vulnerable to seismic hazard. As per Seismic Zoning Map of India Dehradun falls in Zone IV that can experience earthquake intensity of VIII on MSK Scale.

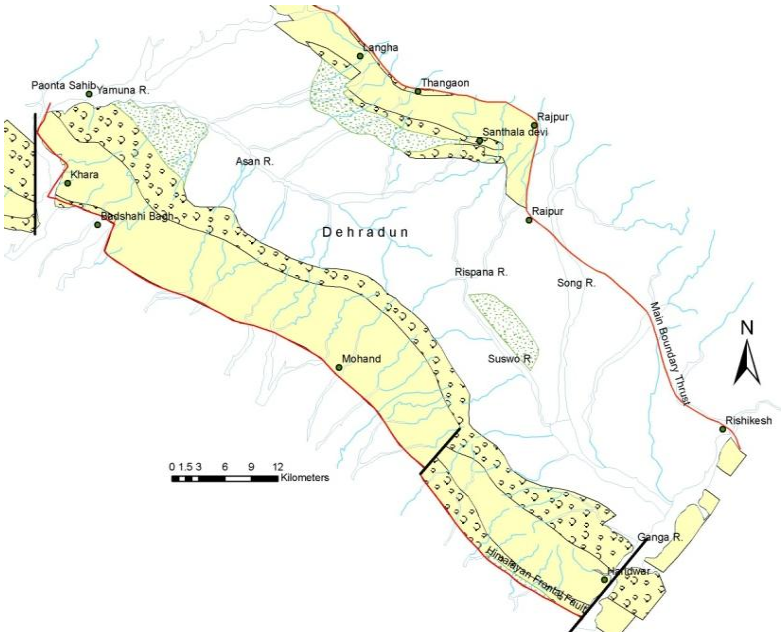

Fig. 1. Geo-tectonic setup of the area around Dehradun.

Dehradun is located at a distance of 255 km from India's capital, New Delhi and has been chosen as one of the Counter Magnets of the National Capital Region (NCR) and is being developed as an alternative centre of growth to help ease the migration and population explosion in the Delhi metropolitan area.

Dehradun also has a number of educational, research, training and corporate institutions that include Forest Research Institute (FRI), Indian Military Academy (IMA), Indian Institute of Petroleum (IIP), Survey of India (SOI), Wildlife Institute of India (WII), Oil and Natural Gas Corporation Ltd. (ONGC Ltd.), National Institute of

Visually Handicapped (NIVH), Indian Institute of Remote Sensing (IIRS) and Wadia Institute of Himalayan Geology (WIHG).

In the previous 11 years, since the creation of the state, Dehradun has grown tremendously, both in terms of infrastructure and population. In this period the population of Dehradun city has increased from 4,47,808 (Census of India, 2001) to 5,78,420 (Census of India, 2011) registering a decadal growth rate of 29.16 percent. In the same period the Municipal area of the city has increased by almost 20 percent (from 52.00 to 62.3 sq km).

With rapid growth of infrastructure and population seismic vulnerability of Dehradun has also gone up, particularly so due to non-compliance of building bye laws and other safety related provisions. There is thus an urgent need to review the seismic vulnerability of the existing infrastructure as also to ensure compliance of the techno-legal regime.

Since hospitals are one of the critical facilities that need to remain functional after any major disaster, specific efforts needs to be made to reduce the vulnerability of the hospitals with due emphasis on non-structural vulnerability.

2. Hospital safety

Hospitals are occupied round the clock, all through the year, by large number of people and their services are all the more required on the aftermath of any disaster. It is therefore necessary to give additional importance to their safety related aspects so as to ensure that these sustain minimum loss at time of disaster and remain functional even after the impact. In view social, political and economic implications of the disruption of health facilities there is an emergent need to protect critical health facilities from disaster impact.

All the new hospitals be built with a level of protection that better guarantees their functionality and delivery of health services in crisis situations has therefore been set as one of the goals under the Hyogo Framework for Action.

Safe hospital is need of the hour and safe hospital is one which would remain functional with the same capacity during and after a major disaster. For this planned efforts are required at three different levels that include structural safety, non-

structural safety and medical preparedness related aspects. Structural safety is basically a part of the building design and ensures that the same is able to withstand weight of the building (dead load) and its content and people (live load) together with the impact of wind and ground shaking (dynamic load). The non-structural elements include all those components that become part of building except the basic structure. These include furniture, electric and mechanical appliances, equipments, and the stored items. Therefore a safe hospital must be structurally, non- structurally and functionally sound so as to be in a position to deliver continuous services during and after a disaster.

Heavy investment is often incurred on non-structural components, particularly in a hospital and this many a times far exceeds the cost of the structure. Moreover non-structural aspects of any hospital are vitally important for its smooth functioning. These aspects are however often neglected. So there is immediate need to focus on this very aspect of hospital safety besides the structural component of hospital buildings.

In view of the above non-structural seismic vulnerability of Mahant Indiresh hospital located in Dehradun, the capital of Uttarakhand state was assessed. The study aims to assess the present state of various non-structural elements and suggest measures for reducing the vulnerability. The report is thus intended to provide a sound basis to the hospital management for taking appropriate actions for vulnerability reduction.

3. Methodology

The assessment involved inspection of the whole hospital according to a format that included all major components of non-structural vulnerability assessment, i.e. architecture, medical equipment, furnishing, administrative system, electricity, communication, water supply, storage and clinical gases. Every section of the hospital was surveyed and risk rating was provided. Based on this, zones of high, medium and low risk were delineated within the hospital building. The assessment thus covered three aspects; architecture, equipment and services / lifelines.

4. Development of the survey format

A number of studies carried out in India and abroad on hospital safety and non-structural assessment of hospitals were first studied with particular focus upon the preliminary data collection strategy employed in these. Based upon these a survey format was developed. It was attempted to incorporate salient features of the previous studies into this format.

Based upon the non-structural elements the survey format was split into different categories. The risk of a particular non-structural element was assigned low, moderate and high risk rating / priority depending upon the threat it would pose to life safety, economic value and operational continuity of the hospital. Based upon this suitable mitigation option was intended to be put forth.

The survey format was intentionally designed to be comprehensive so as to include almost all the non-structural elements likely to be encountered in any hospital. The categories given below were covered under the non-structural vulnerability assessment and the same were detailed in the survey format.

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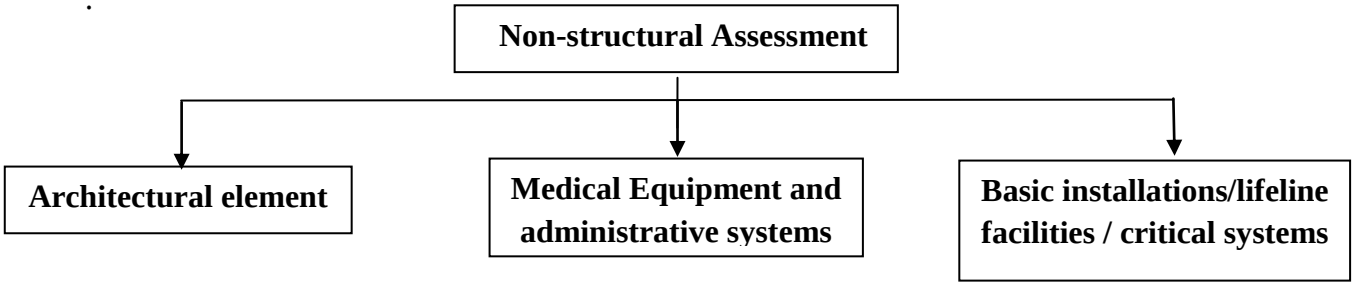

Architectural elements: This was intended to cover various components that include non load bearing exterior walls, partition walls, inner partition systems, windows ceilings and lighting systems.

Medical equipment and administrative systems: These include medical and laboratory equipments and also all the associated office furniture. Generally, equipment and furniture are built and installed taking into consideration their normal, everyday use. It is common therefore to observed lack proper support or anchorage in the hospitals components as well. This increases the risk of objects tipping over or sliding during an earthquake

The basic installations: This was to include electricity, communication and water supply systems in addition to the facilities for storage of water and clinical gases.

5. Mahant Indiresh Hospital

Mahant Indiresh Hospital is one of the important health facilities of Dehradun city, the capital of Uttarakhand. It is a 700 bedded hospital that is frequented by patients from all over the state as also adjoining areas of Uttar Pradesh. General details of the hospital are as listed below.

Table 1: General details of Mahant Indiresh Hospital, Dehradun.

1.	Name of the hospital	Mahant Indiresh Multi speciality hospital
2.	Location	Patel Nagar, Dehradun
4.	Year of establishment	1999
5.	Category of hospital	Private
6.	No. of storeys	4
7.	Bed capacity	700
8.	Medical staff	1,300
9.	No. of patients visiting daily	800 (Ranges between 600 and 900)
10.	No. of patients stationed in the hospital	300
11.	Distance from main road	100 metres
12.	Entry Points	Yes 3 proper wide entry points
13.	Exit points	Exit points have been provided for use during an emergency
14.	HTC	24 patients in one hour
15.	Ambulances	3

The hospital premise comprises of two main buildings, old hospital block and recently constructed new hospital block.

The non-structural seismic vulnerability survey was undertaken for all sections of old and new blocks of the hospital in accordance with the format developed earlier. The results have been presented with respect to the different categories of non-structural elements. The observations were subsequently tabulated and analysed and the conclusions were drawn on the basis of the same.

5.1 Architectural elements: The survey reveals that whole of the hospital contains highly vulnerable non-structural architectural elements. Of these fans and glass partitions present in each and every section of the hospital worth special mention.

All the sections of the hospital were observed to have masonry partition walls as also glass partitions (Figs. 2 and 3). Both new and old building blocks have glass partitions and only in a few sections fibre based glass partition has been used. Composite section of aluminium and glass has been generally used in each section. It is worth noting that the use of glass could have been easily avoided at many places in the hospital premises. Splintering of glass in case of strong ground shaking would pose serious threat to the patient area adjacent to windows. The splintered glass pieces on the corridors would also obstruct movement. Use of glass in chemist shop and nursing stations (Figs. 2, 3 and 4) can cause injury during intense shaking apart from disrupting their functionality. All the nursing stations of the hospital have glass partitions. It is important to note that the glass used in the hospital should be laminated immediately and in future the same should be replaced with annealed and tempered safety glass.

Fig. 2. Use of glass panels in the chemist shop.

Fig. 3. Use of glass panels at a nursing station.

Absence of proper anchorage of ceiling fans which are in majority placed over the patient beds, poses a threat to the life safety (Fig. 5). Ceiling fans would swing during ground shaking and their snapping off could cause casualties. The swing of the fans can be limited by provision of chains / wire that would attach the fan body to the ceiling.

Fig. 4. Use of glass adding to the vulnerability.

Fig. 5. Ceiling fans with inadequate anchorage above the patient beds.

In the CT MRI section of the new building false ceilings has been used. During a fire or an earthquake, suspended ceilings might be very unstable (Fig. 7). Strong ground shaking can cause the false ceiling panels to fall, and disrupt the functionality of the area. The light fixtures supported by the ceiling system could also fall and cause injury (Fig. 7). The presence of such non-structural elements is enough to categorise the section as being vulnerable.

Fig. 6. False ceiling in computer / IT section.

Fig. 7. Falling down of false ceiling and light fixtures could pose a major threat.

Various aspects of the vulnerability of the architectural elements are summarised in Table 2 together with the recommendations for vulnerability reduction.

Table 2. Vulnerability of the architectural elements and the recommendations.

Sl. No.	Aspect	Recommended strategy
1.	**Glass used and the windows**	**Engineer to check and secure with or without modification** The metal window frames generally tend to twist when subjected to large deformations. This results in splintering of the windowpanes that might pose a serious threat in case of an earthquake. The glass at important sections must be secured with the help of plastic lamination. This must be done in pathology section, nursing stations, chemist shops on priority basis.
2.	**Partitions**	Aluminium glass composite partitions have been used in almost all the sections. During strong ground shaking the partitions might separate from the supporting channels and overturn or the glass might get dislodged. Both the situations would result in a major threat. It is recommended that the partitions be checked for their stability by an engineer and the glass used in the same be secured with the help of plastic lamination.
3.	**False ceilings and light fixtures**	**Anchorage and support** The false ceilings have been used in CT MRI section, computer room, NIC and PICU. When subject to earthquake forces the ceilings is likely to fall and injure people working underneath them besides disrupting the functionality of these units. Support by additional wires would prevent the ceiling from falling. It is therefore recommended that the false ceilings be checked and properly anchored by bracing wires. Engineering advice can be taken to design the spacing and orientation of wire braces for suspended ceilings. Fluorescent tubes used in light fixtures can also fall out and break during an earthquake. Therefore the light fixtures attached to the ceiling must be provided independent support. Swinging of light fixtures during an earthquake can be limited by providing wires that attach the fixture to the body of the ceiling.
4.	**Ceiling fans**	**Anchorage and Support** All the fans need extra support to decrease the risk to life safety.

5.2 Medical equipments, furnishing and administrative systems: In most hospitals equipments, furnishing and administrative systems comprise the major proportion of non-structural elements. Detailed survey of the non-structural elements of the hospital gave us an overview of the equipments placed in different sections.

Majority of the equipments used in the hospital were observed to be trolley mounted. These are required to be properly anchored or hooked. Most beds in the wards were also observed to be wheel mounted. These are also required to be anchored.

Additionally heavy oxygen cylinders were observed to be located at many places in the proximity of the patient beds without anchorage of any kind.

5.2.1 Emergency ward: The red zone of the emergency section in the old building of the hospital was observed to have wheel mounted beds, ECG monitoring devices placed on trolleys and trolleys containing supplies (Fig. 8). In case of an earthquake these all would pose threat to life safety and operational continuity besides the economic loss the same might cause.

Fig. 8. View of the trolley containing supplies.

Fig. 9. Wheel mounted operation table and anaesthesia machine.

The reception staff sitting area of the emergency ward has normal glass windows which can threaten the safety of the staff. The blood / glucose / saline stands were observed to be placed alongside the bed. These should either be attached to be beds or anchored properly. The cupboards were observed to be ill placed and might block the exit. Wheel mounted anaesthesia machine and operation table were observed in the yellow section that is the operation theatre (Fig. 9). During strong ground motion these equipments might topple or slip past jeopardizing life safety. Provision of non slip mat needs to be provided for ruling out possibility of the equipments sliding off. The heavy equipment like monitor needs to be anchored. Oxygen and suction pipelines also need proper anchorage particularly at the joints. Wheel mounted lights were observed in the operation theatre. Strong shaking can cause these to topple or

slip past. These are thus required to be anchored with chains which can easily be removed at time of operation.

Figs. 10 and 11. Wheel mounted lights in the operation theatre.

***5.2.3 Physiotherapy section*:** Physiotherapy section is not very critical as it is visited by limited number of patients. At the same time this section has only a few equipments. The medical equipment placed alongside the beds can however get inverted in case of strong ground shaking and hamper the operational continuity besides causing economic losses (Fig. 12). These are therefore required to be properly anchored. The placement of cupboards needs to be changed as these might hamper smooth movement at some places.

5.2.4 Dental section: The patient chair in the dental section, though not trolley mounted is required to be properly anchored to the floor so as to rule out possibility of its rolling down in case of intense ground shaking (Fig. 13). The bench mounted equipments including the portable X - ray machine must be anchored with straps or chains.

Fig. 12. Unanchored medical equipments placed close to the bed in the physiotherapy section.

Fig. 13. The dental chair though not trolley based is required to be properly fixed with the floor.

The medicines in record area of the dental section are observed to be placed without any strapping. This can lead to breakage and spillage during an earthquake and therefore the same needs to be secured.

***5.2.5 Cardiac section*:** In the cardiac section the placement of cupboards need to be adjusted as toppling of the same in case of strong ground shaking can pose threat to the life safety of the person sitting close to it (Fig. 14). The trolley mounted ECG equipment is required to be anchored as the same might topple down during strong ground shaking. Loss of this important equipment would affect operational continuity of the section.

***5.2.6 Neuro ward*:** All the beds in the Neuro ward were observed to be trolley based. Rolling of these during strong ground motion can threaten life safety as also damage other equipments. Like other trolley mounted equipments these are therefore required to be properly anchored. The nursing station has many non-structural elements that require proper mitigation measures.

Fig. 14. Cupboard threatening life safety in cardiac section.

Fig. 15. Trolley mounted ECG equipment in the cardiac section.

The supplies are observed to be placed on trolleys and the trolley mounted refrigerators contain emergency drugs (Fig. 16). These are required to be secured as their loss might disrupt the operational continuity of the ward. The oxygen cylinder and autoclaves machine also require proper anchorage (Fig. 17). Toppling and leakage from these cylinders can cause a major disaster.

Fig. 16. View of the supplies placed on trolleys in the nursing section of the neuro ward.

Fig. 17. View of unanchored oxygen cylinders.

***5.2.7 Blood bank section*:** The blood bank section situated in the old block premises contains very heavy equipments and refrigerators. The heavy refrigerators placed in the section needs proper anchorage along with the supplies placed on trolleys (Fig. 18 and 19).

The main body of the refrigerators should be secured to the proximal wall. The oxygen cylinders are also observed to be placed alongside the trolley / racks without proper anchorage. Trolley mounted equipments and supplies placed on trolleys are required to be properly secured (Fig. 20). The cupboards placed close to the doors and refrigerators containing medicines are required to be relocated and secured (Fig. 21).

Figs. 18 and 19. View of unanchored refrigerator that is required to be anchored properly in blood bank section.

***5.2.8 Dialysis section*:** The dialysis section is earmarked as one of the most problematic and vulnerable areas of the Mahant Indiresh Hospital. Large numbers of equipments are observed to be placed in the limited space available. This makes the facility highly congested and in case of intense ground shaking condition , over toppling of these can hamper smooth functioning of the section.

Fig. 20. View of the supplies on the trolley.

Fig. 21. The positioning of cupboards might block the exit.

Storage of emergency drugs in cupboards and trolleys together with unanchored refrigerators and cupboards is observed to be a common problem in the hospital and the dialysis section is no exception to it (Figs. 22 and 23). The loss of these drugs in case of strong ground shaking might threaten life safety as also affect operational continuity of the hospital.

Fig. 22. View of the cupboard and the trolley containing supplies.

Fig. 23. View of the supplies in the trolley.

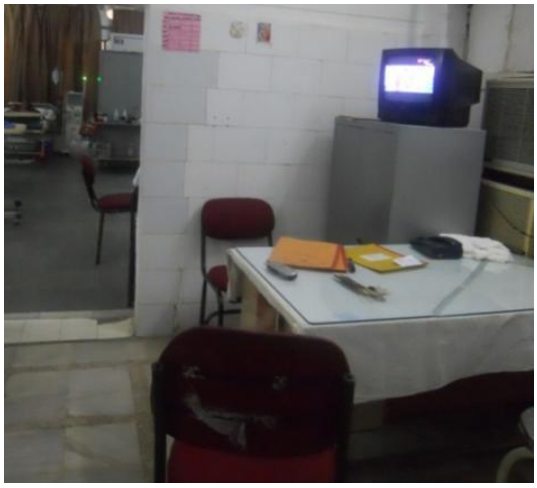

Fig. 24. View of the unanchored television and cupboard.

Fig. 25. View of the wall mounted monitors and others mounted on commercially available brackets but not properly secured to these.

The location of fans and wall mounted ECG / multi monitors in the section is such that falling of these elements might threaten the life safety of the patients (Figs. 24 and 25). The placement of the non-structural elements thus makes the section highly vulnerable.

***5.2.9 TB chest section*:** Supplies together with the emergency drugs are observed to be placed on trolleys without proper anchorage in the nursing station of the TB chest section (Fig. 26). Anchoring of the beds is required in the wards while the oxygen cylinders have to be secured and placed at alternative location.

Fig. 26. View of the Nursing station of the TB ward.

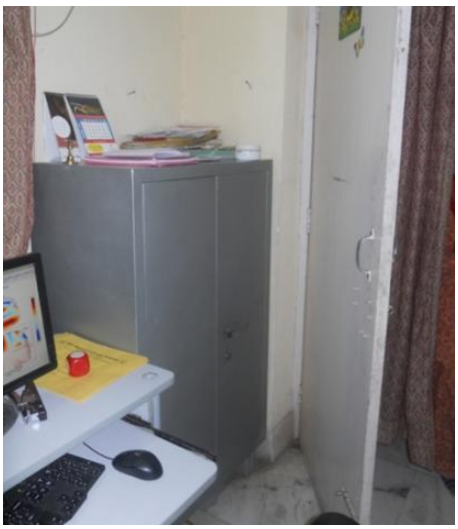

Fig. 27. View of the cupboard in EEG OPD that can lead to blockage.

5.2.10 EEG section: In the EEG OPD section the positioning of cupboards was observed to be such that their toppling during strong ground shaking could block the passage and hinder smooth movement (Fig. 27). These are therefore required to be relocated and anchored. Majority of the psychiatric wards located on ground floor were observed to be not occupied by patients regularly. The walls of the building have however developed cracks at many places and this has resulted in dampening of the walls. This problem needs to be fixed immediately as ignoring it might result in major structural problem.

Fig. 28. The ENT section also have trolley based beds need to be anchored together with the ceiling fans.

Fig. 29. The referigerators in the ENT section needs to be anchored.

5.2.11 ENT section: As in other sections of the hospital the ENT section wards also have problems related to anchoring of the beds together with trolley based equipments (Fig. 28). The placement of the refrigerator is such that it will block the exit route and also lead to loss of emergency drugs (Fig. 29). The need is to relocate and reposition along with anchorage.


Figs. 30 and 31. View of the ICU section having a number of wall and trolley mounted equipments and storage facilities.

***5.2.12 MICU, R - ICU, Surgical ICU and anaesthesia sections*:** The MICU section warrants immediate attention in view of the high patient inflow and numerous non-structural elements. A variety of equipments were observed to be placed alongside patient beds. These include ECG monitors, suction machines and other heavy equipments. All the beds in the ICU unit were observed to be trolley mounted, that is in keeping with the requirement of the unit, but provision of securing these has to be made to avoid any mishap (Figs. 30 and 31). Similar condition is observed in RICU and Surgical ICU (Figs. 32 and 33). These three sections are the critical ones and therefore adequate mitigation measures are required to be taken on priority basis. High priority also needs to be accorded to the anaesthesia section having operation theatre complex consisting of 8 operation theatres.


Figs. 32 and 33. View of the surgical ICU and R - ICU sections having wall and trolley mounted equipments.

***5.2.13 Nephro and eye section and private ward*:** In comparison to the ICU the nephro section has low vulnerability. This is largely attributed to lesser number of equipments and not so heavy rush of the patients. The placement of refrigerator in the nursing station of the nephro ward is however a cause of concern as it can lead to blockage of the exit route. Anchoring is also required for the trolley containing the supplies and the cupboards. L - brackets or steel angle can be used for securing the cupboards with the wall (Figs. 34 and 35).


Figs. 34 and 35. View of the nephro section having supply trolley as also unanchored cupboards.

Not many non-structural elements were observed in the eye section and the patient inflow was also observed to be relatively low. This section therefore has low vulnerability. The beds and racks however require anchoring. Similar is the case in the surgery section. The refrigerators in almost all the sections of the hospital are not secured and their toppling during intense ground shaking can disrupt smooth movement. The emergency drugs stored in trolleys and cupboards can also get damaged and affect the operational continuity of the hospital. In the private ward section of the old building the mitigation measures are required in the nursing station (Fig. 36). Racks in the nursing station are not properly secured. The corridors of the private wards have closed windows. These must be replaced by sliding panels that could be conveniently used in emergency situations.

Fig. 36. View of the reception section of the private ward showing unsecure trolleys and cupboards.

***5.2.14 Chemist shops*:** The hospital has three chemist shops. Of these two are located in the old building complex while the third one is in the new building. In all the shops medicines and drugs are observed to be stored in open racks without front guards arrangement of any sort (Fig. 37). In case of intense ground shaking the medicines and drugs would slip past the racks. The bottles are likely to spill and break and cause secondary hazard while the others shall get intermingled. This is likely to hamper emergency healthcare delivery at the time when the same would be needed the most.

The racks need to be anchored to the wall using L - brackets and steel angles. At the same time shelves restraints or front guards together with strapping or anchorage is required to be installed. The cupboard placed in the office area of the shop need to be repositioned so as to avoid injury to the staff.

***5.2.15 Staff room*:** The old building section has a staff room at ground floor. Cupboards as also computers constitute the main non-structural elements in the staff room. These are required to be properly anchored. The cupboards also require repositioning as these could jeopardize life safety (Fig. 38). The option of removal, relocation and anchorage has to be judiciously used in reorganising the staff room as also in all other offices, reception desks, and OPD areas of the hospital.

Fig. 37. View of the chemist shop of the hospital.

Fig. 38. View of the staff room with unanchored non-structural elements. Toppling of cupboards can hurt the staff members.

All the above sections are part of the old building block. It is observed that many critical sections are located in the old building block and these have high risk rating. With proper mitigating strategy the risk can be reduced to a certain extent

5.2.16 New building

5.2.16.1 Pathology, biochemistry and microbiology sections: These sections are located in the basement of new building and this enhances their vulnerability. These sections also have a number of bench mounted equipments (Fig. 39). It might not be possible to relocate these in all the cases and therefore it is suggested that these be secured to the benches using L – brackets. The file cabinets can also be secured to the

walls using L – brackets (Fig. 39) while the cupboards can be repositioned and anchored to rule out possibility of blockage of passage ways (Fig. 40).

Fig. 39. View of the bench mounted equipments together with file cabinets.

Fig. 40. Toppling of the of cupboard can cause blockage of exit routes.

The incubator in all the sections is heavy machinery which is observed to be placed without proper support system or anchorage (Fig. 41). Automatic analysers are heavy equipment observed to be placed without proper anchorage. Damage to these equipments during intense ground motion is sure to adversely affect the operational capability of the hospital. The placement and anchoring of the cupboards and freezers also needs to be revisited (Figs. 42, 43 and 44).

Fig. 41. View of the incubators need to be fixed with the help of L brackets.

Fig. 42. View of the unanchored freezers in the medical laboratory.

The heavy equipments in the laboratory include fridges, and stock freezers. These are required to be anchored to avoid losses and injury. The anchoring with the help of brackets and angles need to be provided at the base with the floor as also at the top with the wall.

Fig. 43. View of the incubators need to be fixed with the help of L - brackets.

Fig. 44. View of the placement of cupboard in the microbiology section that can lead to the blockage of exit routes.

Majority wall mounted equipments were observed in the pathology section and lack of appropriate attention towards their safety makes the pathology sections medium to highly vulnerable.

***5.2.16.2 Orthopaedic and radiology sections*:** The orthopaedic ward located in the new building has minimal equipments and machinery and therefore it is not highly vulnerable. The wheel mounted beds and fans over the patient beds are required to be properly secured together with racks and oxygen cylinders (Fig. 45).

Fig. 45. The ceiling fans need to be anchored along with emphasis on trolley based beds.

The radiology section consists of X - ray rooms, ultrasound rooms and the CT-MRI room. A number of heavy equipments are observed in this section (Figs. 46, 47 and 48). These are required to be properly secured as damage to these would adversely affect operational continuity of the hospital.

Fig. 46. View of the radiology section having unsecured equipment that can easily topple during intense ground motion.

Fig. 47. View of the X - ray machine which needs proper check for the present anchorage made to the floor

Strong shaking can cause the X-ray machines, CT scanners and others to slide or topple. Since the whole section is not frequented by large number of patients and therefore the risk of life safety is less as compared to other critical sections of the hospital. These equipments are however required to be secured together with the UPS placed alongside CT-MRI equipment.

Fig. 48. View of the unanchored equipment in the CTMRI Section

Fig. 49. View of the unanchored file cabinets.

The file cabinets are also required to be properly anchored as it can jeopardize life safety of the staff sitting beneath these. These can easily be anchored to the wall using L - brackets, steel angle concrete, screws and a drill machine.

***5.2.16.3 Obstetrician and Gynaecology section*:** This section contains relatively less equipments and it is therefore less vulnerable. Operation table (OT) is the main concern in this section. OT lights in the labour room are observed to be wheel mounted and are therefore required to be anchored together with the trolley containing supplies (Fig.50).

Fig. 50. View of the wheel mounted lights and supply trolley in the labour room.

Fig. 51. View of NICU with wheel mounted incubators placed close to the windows.

5.2.16.4 NICU (Neonatal Intensive Care Unit): This unit is dedicated to the care of ill or premature newborn infants. Babies were observed to be placed in wheel mounted incubators which makes the unit critical with regard to its non - structural vulnerability. At the same time the placement of incubators by the side of the windows needs to be avoided (Fig. 51). Incubators are therefore required to be anchored and placed differently.

Fig. 52. View of the PICU showing unsecured trolleys and other wheel mounted equipments.

Fig. 53. View of paediatric section.

5.2.16.5 PICU and paediatric ward section: The PICU is adjacent to the NICU. Wheel mounted equipments were observed in this unit. These include supply trolley and monitors (Fig. 52). These are required to be anchored properly so as to avoid their slippage during intense shaking. In comparison to this the paediatric ward has minimal medical equipments and the only concern is the anchorage of the ceiling fans and wheel mounted beds (Fig. 53).

Figs. 54 and 55. View of medicine and surgery wards where ceiling fans and oxygen cylinders are required to be anchored.

5.2.16.6 General surgery, medicine and private ward section: These three sections located in the new building complex have very few machinery or medical equipments. Their vulnerability is therefore relatively low. The main concerns in these sections are related to the supply trolleys in the nursing station and oxygen cylinders

in the wards. These are required to be properly anchored. The medicine and surgery wards were observed to house many patients and therefore simple mitigation measures must be implemented to reduce the risk (Figs. 54 and 55). The private ward also falls under low vulnerability.

Vulnerability of the different sections together with the recommendations for reducing the vulnerability are summarised in Table 3.

Table 3: Vulnerability of different sections, medical equipments and nursing stations together with the recommendations.

Sl. No.	Sections	Recommended strategy
1.	**Operation theatres**	**Anchorage and support.** Most equipments in OT are wheel mounted that are considered to be highly vulnerable. The equipments used in the OTs are however required to be mobile. This eliminates the possibility of their being fixed permanently. Anchoring has therefore to be undertaken with particular care so as to ensure that the same does not come in the way of operational requirements. Such an anchoring has to ensure that the equipments are fixed during the operation at the required place and these can be secured at appropriate places afterwards. Tying all the equipments to a steel frame can reduce the vulnerability of the section. Providing anchor bolt both in the ceiling as well as in the floor can help in placement of equipment rack close to the OT. At the same time provision of appropriate anchor bolts should provided in the walls of operation theatre so that the equipments could be secured when not in use.

2.	**Wards (wheel mounted beds, drip stands and oxygen cylinders)**	**Development of locking system for beds.** In the wards most beds were observed to be wheel mounted which is in keeping with the operational requirements. The same should however be provided with locking provision and the same should necessarily be resorted to while the beds are not being moved. The drip stands should either be secured with the nearby wall or the patient bed so as to ensure that the same does not fall apart during strong ground motion. The oxygen cylinders are placed close to the patient beds should either be secured with the bed itself or be placed in separate racks that are secured to the nearby walls. Oxygen cylinders are required to be given extra attention as these have the potential of causing secondary hazard.
3.	**Medical equipments** (ECG monitor, suction unit, ventilator, incubator, BP monitors)	**Hooking, strapping, anchorage for securing.** Development of proper hooking system using chain and hooks can reduce the vulnerability of the sections having wheel mounted equipments in majority. ECG monitors are observed to be wheel mounted. The provision of chains on the walls to hook these machines can effectively help in reducing the vulnerability. In many sections the portable X Ray machines are observed to be wheel mounted. Hooking of such machines to the walls with the help of chains is the best available cost effective mitigation measure. Oxygen cylinders can also be anchored to the nearby walls with the help of chains. The wheel mounted equipments in NIC, PICU must also be properly anchored to the walls. The option of strapping and anchoring is also required for the wall mounted equipments which were observed in almost all the important sections that include ICU, MICU, RICU.

4.	**Nursing stations** (supplies on trolleys, refrigerators (blood bank), and cupboards)	**Hooking, strapping, anchoring and relocation.** In all nursing stations of the hospitals the emergency supplies are observed to be placed on the trolley. All supplies must be properly strapped and there has to be provision of anchoring the trolleys to the wall. Every Nursing station in the hospital is observed to have a refrigerator for storing emergency drugs. The refrigerators need to be properly anchored to the walls by L - brackets. Same has to be done with the cupboards. In the blood bank section very heavy refrigerators are observed to be placed without anchorage. These must be properly anchored with both wall and floor with help of L - brackets and angles. Blood is a very vital requirement at the time of emergency and therefore special care needs to be taken for ensuring safety of these. At many places the placement of refrigerators containing emergency drugs is observed to be near the door. It might thus block the exit route. All such placements need to be checked and the refrigerators relocated at appropriate place within the nursing stations which will not block the exit route.
5.	**Staff room, chemist shop, medical record room and OPDs** (Cupboards and computers)	**Removal, relocation and securing.** The strapping must be done for all medicines placed in the chemist shop as well as in the store room of the hospital and at the same time front guards should be provided to avoid slipping off of the liquid supplies. The racks housing the medicines and drugs are required to be anchored with the wall as their toppling would bring the medical operations to a grinding halt. These should therefore be anchored to the walls. Similarly in OPDs the placements of cupboards need to be changed and adjusted and these are required to be anchored to the walls.

5.3 Basic installations / lifeline facilities / critical systems: This covers the electrical supply system, generators, geysers, air conditioning facility, control panel and transformers besides the water supply and storage facility and clinical gas storage and supply facility and fire protection system. Leaks from clinical gas supply lines could be a fire hazard. The electrical and mechanical equipment are a necessary to keep the hospital functioning. All these are at the same time vulnerable to earthquake damage.

The problems relating to these aspects were observed to be similar in almost all the sections. Lack of proper conduits was universally observed. The conduits were observed to be broken at many places. Damage to the conduits could shut down power or even cause fire hazard. Main circuit breaker (MCB) boxes were observed to be open at many places in different sections. Lack of proper wiring in the emergency ward can lead to short circuit (Figs. 56 and 57). The dressing of the conduits was observed to be improper, particularly near the distribution boxes (DBs) at many places.

Figs. 56 and 57. View of the emergency ward showing lack of proper conduiting, damaged cover and open wiring.

In neuro ward, the proper covering of the DB cables was observed to be missing. In the blood bank section, the dressing of the cables, particularly near the DBs together with cabling were observed to be improper, the cables were observed to be exposed at several places. Lack of proper wiring was similarly observed in the dialysis section as well. In the TB section the cover plate of the DB was observed to be requiring replacement (Fig. 58). The ENT section was observed to be no exception as regards the dressing of the wires.

Fig. 58. View of the DB with the cover plate either absent or damaged.

Fig. 59. View of the geysers in the hospital.

The problems relating to this important aspect were observed to be similar in the entire hospital premises. The major identified problems pertain to, i) open wiring, ii) improper fixing of conduits, and iii) missing covers. These can be easily fixed with the help of any electricians but ignoring this aspect could result in short circuit that could lead to a major disaster. The geyser fittings in the entire hospital are required to be checked (Fig. 59) and besides setting right electrical faults their anchorage with the walls is required to be checked and fixed, where necessary.

Fig 60 . View of the main electric control panel of the hospital.

Strong shaking during an earthquake could cause these to topple from wall mounts. This could lead to wastage of water besides causing a major electrical hazard. The intercom was observed to be functional in the entire hospital. The wiring of the same was however not found to be satisfactory. This also requires to be fixed.

The main electric supply unit and the control panels of the hospital are located in the front side of the hospital (Fig. 60). Main distribution boards of the electric control panel located in the front section of the hospital building premises need proper anchorage. The dressing and clipping of the inlet and outlet cables was observed to be missing in some boxes. This needs to be fixed immediately to avoid any type of short circuit in the main control panel area.

Fig. 61. View of the generator that has been kept in open without anchoring the same to the ground and without proper shade.

Fig. 62. View of the generator requiring anchorage at the base.

The generators were observed to be housed without proper shed and framing (Fig. 61). These are required to be provided to ensure smooth electric supply even in case of a major emergency. This would at the same time protect these from direct sunlight and rain. Proper dressing of the cables in the panel room was observed to be missing. These have to be fixed properly at places. The generator has also to be anchored properly to the ground to avoid the danger of its falling down (Fig. 62).

Figs. 63 and 64: View of the air conditioning provision in the hospital. To the left is that of the operation theatre complex.

Proper anchorage of the air conditioning units and shafts with dash fasteners is required as the major earthquake shaking would definitely hamper their functioning (Figs. 63 and 64). This at the same time has the potential of causing a major electrical hazard and therefore it needs to be addressed immediately.

5.3.1 Oxygen and suction lines: The oxygen and suction lines runs through many wards and sections of the hospital, both in old as well as the new building block. Continuous supply is ensured through main tanks located in the hospital CSSD section. The supply lines run through all the major sections of the hospital including the emergency ward, MICU, RICU and the others.

Figs. 65 and 66. View of unanchored T - junctions of oxygen and suction lines in the hospital.

During an intense earthquake shaking these pipelines could burst out and hamper the supply. This would adversely affect the functioning of the critical facilities. Besides this it has the potential of causing a major fire hazard. In order to avoid such situation the supply lines are required to be provided with special anchorage at the joints. Anchorage at the junctions was however observed to be missing in the hospital (Figs. 65 and 66). Provision of proper anchorage at every T - junction of the supply lines would greatly reduce the vulnerability to a considerable extent.

5.3.2 Fire extinguishers: In terms of fire fighting, the hospital has installed fire extinguishers at every corridor. These are however not properly mounted (Figs. 67 and 68). In case of strong shaking the improperly mounted extinguishers could well fall down and roll off to some other place. The fire extinguishers in all the sections of the hospital are therefore required to be properly anchored. It is good to note that in the new block of the hospital building proper fire alarm system has been installed and the same would be operational soon.

Figs. 67 and 68. The fire extinguishers must be anchored with the help of chains and to the wall at the base.

However the water supply lines feeding the fire extinguishers should also be properly braced so as to avoid any breakage during earthquake shaking. There exists risk of

pipes being damaged, especially at joints. Since the new building of the hospital is equipped with fire alarm system and all fittings have been done this point needs to be checked because at many places the water pipes catering to fire fighting requirements were observed to be not properly braced (Fig. 69).

Fig. 69. View of fire water supply line at the junctions in the new building block of hospital meant for catering to the fire fighting requirements.

***5.3.3 Tanks and clinical gases*:** The clinical gas storage area is one of the most vulnerable areas in any hospital premises. This section deals with compressed gas cylinders, bulk clinical gas storage, as well as roof top water tanks. Heavy machinery was observed to be placed in the Central Sterile Supply Department (CSSD). The autoclaves machines and sterilizers placed in this section are required to be anchored to the ground. The legs of autoclave machines are required to be concreted with the ground as it is not a movable item (Fig. 70).

Besides causing a major threat to the life safety disruption of this facility is sure to hamper operational and functional continuity of the hospital in case of a disaster. Supply lines providing water to the autoclave machines are likely to be disrupted during strong ground motion and therefore special attention is required to be given towards this important aspect.

Fig. 70. View of autoclave room.

The clinical gas plant and oxygen concentrator room needs to be given special attention. The oxygen cylinders were observed to be placed in this section and it is from here that the supply of oxygen in the entire hospital is ensured (Fig. 71). In the present state the cylinders are likely to fall and topple during strong ground motion. This might cause leakage of gas and prove out to be a major secondary hazard. The cylinders must therefore be anchored to the wall. The wall should also be strong enough to resist the forces the cylinders would exert on the wall. Special cylinder rack could be provided in the storage centre.

Fig. 71. View of the oxygen cylinders without proper anchorage in the CSSD section.

Fig. 72. View of the clinical gas tanks.

The clinical gas tanks were observed to be fixed to the ground. Engineering check is however required to be reassured of the strength of the anchor bolts that are fixed to the ground so as to ensure that these could hold the heavy tanks during ground shaking (Fig. 72). In case of any suspicion concreting at base might be resorted to.

Figs. 73 and 74. View of the water tanks placed on the roof of the various sections of the hospital.

The overhead water tanks placed on the roofs were observed to be without any anchorage. All the tanks are required to be provided with proper anchoring and framing (Figs. 73 and 74).

Vulnerability of basic installations, lifeline facilities and critical systems and the recommendations for vulnerability reduction are given in Table 4.

Table 4: Vulnerability of basic installations / lifeline facilities / critical systems and the recommendations for vulnerability reduction.

Sl. No.	Aspect	Recommended strategy
1.	Generators	**Restricted mobility / anchorage.** The generators and transformers must be fixed properly to the ground and provided with adequate support to prevent it from toppling. Anchorage with bolts and fasteners at the base of the generators would prevent these from toppling in case of intense shaking. Seismic resistant devices called snubbers can be added to the base of generators. While installing a new generator or replacing an old one, it should be specified that the same be mounted on seismically restrained vibration isolators.
2.	Batteries	**Anchoring.** The batteries were observed to be placed in racks in many sections. There is possibility of their toppling down. These must be placed in a strong rack and the same should be properly anchored to the floor or the wall. Proper bracing of batteries within the racks and their anchoring to the walls is also required.
3.	Geysers	**Anchorage and support.** Geysers were observed to be mounted on the walls in every section of the hospital. These are however not located near patient beds and are mostly present at the nursing stations. Their toppling could lead to disruption of electricity, leakage of hot water and other electrical hazards. The simple anchoring of geysers to walls as observed in the hospital would not be able to resist the earthquake forces. These are therefore required to be provided with proper anchoring accompanied by strapping. The geysers should be provided with straps around top and bottom and these should be bolted to wall. Geysers at the same time must have flexible water inlet and outlet pipes and proper conduits have to be provided.
4.	Window and split air conditioning units	**Anchorage support and relocation.** Strong shaking likely to cause the air conditioners to fall apart. Proper anchoring is therefore required to be provided. The AC must be providing two straps across it and these should be properly fixed at the ends. Split AC units are specially placed at the edge of the ceiling. These therefore pose a falling hazard. These should therefore be relocated. Window AC units must be anchored to the walls with bolts that are sized to resist the horizontal forces caused by earthquake shaking.

5.	**Electrical cabinet**	**Anchorage and support.** There are tall and narrow electrical cabinets located at different sections of the building that include radiology, CT MRI and labour room. Toppling of these during an earthquake could cause electric hazard. These should therefore be anchored at base. For this bolts and steel angles could be used. For the heavier cabinets restraint has also to be provided at the top.
6.	**Oxygen and suction pipelines**	**Anchorage.** The pipelines are required to be provided proper support, particularly at the junction points to avoid the risk of their bursting during strong ground motion.
7.	**Fire extinguishers**	**Anchorage.** The fire extinguisher must be properly anchored to the wall with the help of chains in a way that it permit movement but not allow the extinguisher to fall apart.
8.	**Autoclaves / Gas tanks**	**Anchorage (concreting at base).** The heavy autoclaves placed in CSSD section need to be properly anchored to the floor with help of concreting at the base. Since these are immovable items, concreting would be the appropriate strategy for ensuring their safety. Similarly the gas tanks need to be properly fixed to the floor.

The entire of the hospital is thus observed to be vulnerable as regards its non-structural elements. The old building block is more vulnerable as compared to the new one as it has many critical sections. These include the operation theatre complex, the ICU, M ICU, surgical ICU and dialysis unit. These are either required to be shifted to new building premises or appropriate non-structural mitigation measures be taken up on priority basis.

The mitigation measures for the various non-structural elements must be followed to reduce the risk for better hospital safety.

6. Risk assessment

Risk assessment helps in identifying the vulnerable areas in the hospital on the basis of the loss to life, function or property in the event of damage. The risk assessment involves not only rating the risk but also the suggestive options to reduce the risk. Thus the assessment helps in prioritising the mitigation process in the hospital.

In order to identify the type of risk associated with the various components in case of an earthquake, all the individual equipments in every section of the hospital were surveyed in detail. The surveyed components were then given risk ratings with regard to two different earthquakes; that for a medium sized earthquake of intensity VI to VII in Modified Mercalli Intensity (MMI) scale and for a severe earthquake of intensity VIII to IX in MMI scale. The type of risk was accordingly ascertained. There are basically three types of risk associated with non - structural damage. All of these have been discussed in detail in the sections below.

i) **Life safety:** This risk is related to the injury caused to human beings by falling non - structural elements. An element which has the potential of causing death, serious or moderate injury would attract the risk of life safety.

ii) **Loss of function / operational continuity:** The damage to medical equipments in a hospital would hamper its effective functional continuity after a disaster. Many a times there is a risk that non - structural damage would make it difficult to carry out the necessary functions within the hospital premises.

iii) **Loss of property / economic continuity:** Most hospitals house costly medical equipments in their premises. Damage to non-structural element of the hospital building can therefore lead to substantial economic loss. While assessing the individual component of the hospital this aspect has been taken care of. The sections having costly and heavy machinery have been accordingly given high risk rating since their loss would cause the hospital significant economic loss (to be incurred in repair or replacement) besides disrupting its functional continuity. It must however be noted that the property loss related factor would accompany every individual component. This risk has therefore been taken as present with every component. The intensity of the same might well vary and this has been considered while giving priority to various components.

Thus life safety and functional loss related risk have been assigned to all the individual components depending upon their location and the present status. An

element which can cause injury or death is placed in high and very high risk grade and would be the first priority. The functional loss of a certain equipment would affect the functionality of the hospital and therefore it has been given risk grading ranging between high to very high and accordingly the priorities have been fixed.

The risk assessment involves, i) assessment of equipment and contents (medical facilities and administration): This includes all individual medical equipments placed in every section of the hospital. The clinical and medical equipments and machinery, emergency supplies on the trolleys, the refrigerators used for storing emergency drugs together with the administrative storage facilities like cupboards, racks, file cabinets and others have been taken into consideration while undertaking the vulnerability assessment and risk analysis. These were assessed to identify their seismic vulnerability. In terms of risk the individual components have been rated for two earthquakes; moderate intensity (Intensity VI - VII on MMI scale) and severe intensity earthquake (Intensity VII – IX on MMI scale). The type of risk, risk rating and accordingly the mitigation options have then been detailed out in the inventory. Apart from this risk assessment involves ii) assessment of the equipment and contents (electricity, communication and water supply systems): Various electrical appliances like air conditioners, geysers, electric connections together with fire extinguishers were observed to have similar problems in different sections of the hospital, these have been analysed in a separate table together with the mitigation measures that would apply to a particular category of component placed in all the sections of the hospital. If anchorage has been suggested for fire extinguishers it would apply to every fire extinguisher in the building because most fire extinguishers were observed to have similar problem.

The detailed description of each component has been provided in the Table 3. The table assessing all components has been made on the basis of criteria established for placing equipment in low, medium, high or very high risk category. The methodology for the risk rating is described in Table 5.

Table 5: Summary of the criteria adopted for risk assessment.

Sl. No.	Aspects considered in an individual equipment	Risk type		Moderate (VI – VII on MMI scale)	Severe (VIII – IX on MMI scale)	Remarks
				Risk rating		
		LS	LF			
1.	**Anchorage**					
	No anchorage			VH	VH	
				H	VH	
	Poor anchorage			VH	VH	
				H	VH	
	Properly anchored			L	L	
2.	**Importance of equipment**					
	Hospital cannot function without the device / equipment			VH	VH	Generators, transformers, pipelines, roof top water tanks, pumps, machines like ECG monitor, anaesthesia, X - Ray, CTMRI, operation table, lights, ventilators, blood bank refrigerators all are necessary for maintaining hospital functionality.
	Necessary for maintaining operational continuity			H	VH	SWD, Dental chair, computers.
	The loss of equipment would not affect the operational continuity for significant time			L	L	This mainly includes the cupboards and medical records placed in a section where

						there is no danger to life safety and these contain records and files without which hospital can work for some time.
3.	**Location of equipments**					
	Near the exit (door)			VH	VH	The equipment placed at a position which might block the exit routes.
				VH	VH	
	In corridor / close to the staff section			VH	VH	The cupboards placed in staff room adjacent to chairs.
					LS = Life safety LF = Loss of functionality VH = Very high H = High L = Low	

The priorities have subsequently been fixed and the hospital needs to start implementing the mitigation measures accordingly. While setting the priorities it has been ensured to take into account, i) importance of the section, ii) patient inflow in the section, and iii) importance of some critical sections to remain operational and functional at time of emergency. The components have accordingly been prioritised into three categories; i) I: this includes the components that immediately require the mitigation measures. This includes the critical components that are required to remain functional during an emergency, ii) these components are placed in second priority. These mitigation measures are to be carried out in second phase after the work for the first phase has been completed, and iii) these components are to be taken up for

mitigation in the last phase so as to make the hospital risk free from non -structural damage.

6.1 Fixing of priority: As the mitigation measures cannot be undertaken together. Priority of undertaking these works has been suggested. Different sections have thus been placed under the different priority grades. These are summarised in Table 6.

Table 6: Listing of the sections falling under different priority classes for mitigation purposes.

Priority	Sections
I	ICU, blood bank section, dialysis, MICU, RICU, surgical ICU, operation theatre complex, pathology lab, biochemistry lab, microbiology lab, CSSD section, generator, control panel, cardiac section, chemist shop, emergency ward, N-ICU, P-ICU, labour room, inspection of wiring and conduiting for whole hospital.
II	Radiology department, CT-MRI complex, dental section, EEG, ENT, physiotherapy, dental, neuro and paedetric wards, pumps, air conditioners, geysers, TB and chest section
III	Nephro section, plastic surgery, eye section, surgery 5, private A ward, orthopaedic, obstetrician, gynaecology, private ward, medicine ward, general surgery

The priority assigned within each individual section can be ascertained from the table of assessment of individual component while implementing mitigation measures. The non – structural vulnerability assessment form is given in Tables 7 and 8.

Table 7: Non – structural vulnerability assessment form used for assessing the vulnerability of the hospital equipments and contents (Medical facilities and Administration).

Sl.No.		Non structural element	Earthquake	Risk rating	Type of risk	Mitigation option	Implementation Priority	Remarks
1.	Emergency ward	ECG monitor (OT)	Moderate	VH	LF	Anchorage	I	The OT section remains functional at time of emergency.
			Severe	VH				
		Anaesthesia (OT)	Moderate	H	LF	Anchorage and strapping	I	
			Severe	VH				
		Ventilators	Moderate	H	LF	Anchorage	I	
			Severe	VH				
		OT Light	Moderate	H	LF	Hooking	I	Operation lights on trolleys can cause life danger
			Severe	VH				
		Blood/glucose stands	Moderate	H	LF	Hooking	II	
			Severe	VH				
		Autoclave	Moderate	H	LF	Anchorage	II	
			Severe	VH				
		Suction machines	Moderate	H	LF	Anchorage	II	
			Severe	VH				
		Supplies on trolleys	Moderate	H	LF	Hooking	II	
			Severe	VH				
		Cupboards	Moderate	L		Anchorage	-	It need to be anchored to not incur loss of records
			Severe	L				

2.	Physiotherapy	SWD (short wave) equipment	Moderate	H	LF	Anchorage	III	
			Severe	VH				
		Wheeled or trolley mounted equipment	Moderate	H	LF	Hooking	III	
			Severe	VH				
		Cervical traction equipment	Moderate	H	LF	Anchorage	III	
			Severe	VH				
		Hydroculator (hot pack, cold pack)	Moderate	H	LF	Anchorage	II	Heavy and therefore need to be anchored properly
			Severe	VH				
		Cupboard	Moderate	L	-	Anchorage	-	The placement is ok the only thing needed is proper anchorage
			Severe	L				
		Racks	Moderate	L	-	Anchorage	-	Need to be anchored
			Severe	L				
3.	Dental section	Portable X ray machine	Moderate	M	LF	Strapping	III	
			Severe	H				
		Dental chair	Moderate	H	LF	Anchorage	II	The chair is although not on rollers still it needs to be checked for proper anchoring
			Severe	H				
		Cupboards/Racks	Moderate	L	-	Anchorage	-	
			Severe	L				
4.	Cardiac section	ECG monitor	Moderate	VH	LF	Hooking, strapping	I	
			Severe	VH				
		Ultrasound / Echo TMT	Moderate	VH	LF	Hooking	I	
			Severe	VH				
		Cupboards	Moderate	VH	LS	anchorage	I	The cupboard needs to be properly anchored to reduce life safety risk
			Severe	VH				
		Racks	Moderate	L	-		-	

			Severe	L				
		Computers	Moderate	H		Fixing on table	III	The damage to computer will lead to loss of office record but hospital can still be functional
			Severe	H				
5.	Neuro Paediatric section ward	Multi Para pulse Oximeter (wall mounted)	Moderate	VH	LF	Strapping	I	
			Severe	VH				
		Portable Xray machine	Moderate	VH	LF	Hooking	I	
			Severe	VH				
		Wheeled trolley mounted equipment	Moderate	H	LF	Hooking	III	
			Severe	VH				
		Refrigerator	Moderate	VH	LS, LF	Relocation and anchorage	I	Its placement will block the exit route
			Severe	VH				
		Oxygen cylinder	Moderate	VH	LS	Hooking	I	
			Severe	VH				
		Suction machines	Moderate	H	LF	Anchorage	II	
			Severe	VH				
		Cupboards	Moderate	L			-	The placement is not leading to blockage or risk to life safety but need to be anchored to preserve records
			Severe	L				
		Supplies on trolley	Moderate	H	LF	Hooking	II	
			Severe	VH				
		Rack	Moderate	L			-	
			Severe	L				

6.	Blood bank section	Wheeled /trolley mounted equipment	Moderate	H	LF	Hooking	II	
			Severe	VH				
		Blood bank refrigerators/freezers	Moderate	VH	LS,LF	Anchorage	I	
			Severe	VH				
		Bench mounted equipment	Moderate	H	LF	Strapping	II	
			Severe	VH				
		Refrigerators	Moderate	H	LF	Anchorage	I	
			Severe	VH				
		Supplies on trolleys	Moderate	H	LF	Hooking	II	
			Severe	VH				
		Oxygen cylinder	Moderate	VH	LS	Hooking	I	
			Severe	VH				
		Cupboards	Moderate	VH	LS	Relocation	I	Placement of cupboards will lead to exit route blockage
			Severe	VH				
7.	Dialysis	ECG/Multi monitor (wall mounted equipment)	Moderate	VH	LS, LF	Strapping	I	Although these are properly anchored to the wall still they need to be checked on priority basis and if strapping is required it is to be done on priority basis
			Severe	VH				
		Wheeled or trolley mounted equipment	Moderate	VH	LF	Hooking	I	
			Severe	VH				
		Supplies on trolley	Moderate	H	LF	Hooking ,strapping	II	
			Severe	VH				
		Computer/TV	Moderate	M		Anchorage	III	
			Severe	H				
		Cupboards	Moderate	VH	LS	Relocation	I	Placed near patient beds
			Severe	VH				

		Suction machines	Moderate	H	LF	Anchorage	II	
			Severe	VH				
8.	TB and Chest section (wards)	Supplies on trolley	Moderate	H	LF	Hooking	II	
			severe	VH				
		Blood/glucose stand	Moderate	H	LF	Hooking	II	
			severe	VH				
		Oxygen cylinder	Moderate	VH	LS	Hooking	I	
			severe	VH				
9.	EEG section	Wheeled trolley mounted equipment	Moderate	M	LF	Hooking	II	There is not much of machinery in this section
			severe	H				
		Cupboards (OPD)	Moderate	VH	LS	Relocation	I	
			severe	VH				
		Computer (OPD)	Moderate	H	LF	Strapping and fixing on table	II	
			severe	H				
10.	ENT wards	Wall mounted equipment	Moderate	H	LS.LF	Strapping	I	
			severe	VH				
		Supplies on trolley	Moderate	H	LF	Hooking	II	
			severe	VH				
		Refrigerators	Moderate	VH	LS,LF	Relocation	I	Placed at a position which will close the door and hence block the route
			severe	VH				
		Oxygen cylinders	Moderate	VH	LS	Hooking	I	
			severe	VH				
		Suction machines	Moderate	H	LF	Anchorage	II	
			severe	VH				
		Cupboard	Moderate	L		Anchorage	-	Loss of record
			severe	L				

11.	M-ICU	Wheeled trolley mounted equipment	Moderate	VH	LF	Hooking	I	
			severe	VH				
		Walled mounted equipment	Moderate	VH	LS,LF	Strapping	I	Although these are properly anchored to the wall still they need to be checked on priority basis and if strapping is required it is to be done on priority basis
			severe	VH				
		Supplies on trolley	Moderate	H	LF	Hooking	II	
			severe	VH				
		Computer	Moderate	H		Fixing on table	III	Although it will lead to loss of record but hospital can still function
			severe	H				
		Refrigerator	Moderate	VH	LS	Relocation	I	
			severe	VH				
		Oxygen cylinder	Moderate	VH	LS	Hooking	I	
			severe	VH				
12.	R-ICU	Wheeled trolley mounted equipment	Moderate	VH	LF	Hooking	I	
			severe	VH				
		Walled mounted equipment	Moderate	VH	LS,LF	Strapping	I	Although these are properly anchored to the wall still they need to be checked on priority basis and if strapping is required it is to be done on priority basis
			severe	VH				
		Supplies on trolley	Moderate	VH	LF	Hooking	II	
			severe	VH				

		Cupboards	Moderate	VH	LS	Anchorage	I	Staff use to sit in the room
			severe	VH				
13.	Surgical ICU	Wheeled trolley mounted equipment	Moderate	VH	LF	Hooking	I	
			severe	VH				
		Walled mounted equipment	Moderate	VH	LS,LF	Strapping	I	
			severe	VH				
		Supplies on trolley	Moderate	H	LF	Hooking	II	
			severe	VH				
14.	Nephro section	Supplies on trolley	Moderate	H	LF	Hooking	II	
			severe	VH				
		Oxygen cylinder	Moderate	VH	LS	Hooking	I	
			severe	VH				
		Cupboard	Moderate	VH	LS	Anchorage	I	
			severe	VH				
		Suction machines	Moderate	H	LF	Anchorage	II	
			severe	VH				
		Refrigerator	Moderate	VH	LS	Relocation	I	At present position at NS it will block the route
			severe	VH				
		Autoclave	Moderate	H	LF	Anchorage	II	
			severe	VH				
15.	Plastic surgery	Supplies on trolley	Moderate	H	LF	Hooking	II	
			severe	VH				
		Cupboard	Moderate	H	LS	Anchorage	I	
			severe	H				
		Rack	Moderate	H	LF,LS	Anchorage	I	
			severe	H				
		Oxygen cylinder	Moderate	VH	LS	Hooking	I	
			severe	VH				

16.	Eye section and surgery 5	Supplies on trolleys	Moderate	H	LF		II	
			severe	VH				
		Cupboard	Moderate	L			-	
			severe	L				
		Refrigerator	Moderate	M	LF	Anchoring	II	
			severe	H				
		Rack	Moderate	L		Anchorage	-	
			severe	L				
		Cupboard	Moderate	L		Anchorage	-	
			severe	L				
17.	Private A ward	Supplies on trolley	Moderate	H	LF		II	
			severe	VH				
		Cupboard	Moderate	L		Anchorage	-	Need to be anchored to prevent record loss
			severe	L				
		Rack	Moderate	L		Anchorage	-	
			severe	L				
		Oxygen cylinder	Moderate	VH	LS	Hooking	I	
			severe	VH				
		Refrigerator	Moderate	H	LF	Anchorage	II	
			severe	VH				
NEW BUILDING								
18.	Pathology section	Incubator	Moderate	VH	LF	Strapping and anchorage at base	I	
			severe	VH				
		Bench mounted equipments	Moderate	VH	LF	Strapping and anchorage at base	I	
			severe	VH				
		Computer	Moderate	H		Fixing to table	II	
			severe	H				
		Cupboard	Moderate	VH	LS	Relocation and	I	

			severe	VH		anchorage		
		Racks	Moderate	L		Anchorage	-	
			severe	L				
19.	Bio chemistry section	Bench mounted equipments	Moderate	H	LF	Strapping and anchorage at base	I	
			severe	VH				
		Heavy machines (fully automatic analyser)	Moderate	H	LF	Anchorage	I	
			severe	VH				
		Stock freezers	Moderate	VH	LF	Anchorage	I	
			severe	VH				
		Refrigerators	Moderate	VH	LF	Anchorage	I	
			severe	VH				
		computers	Moderate	H		Fixing to table	II	
			severe	H				
20.	Microbiology section	Bench mounted equipments	Moderate	H	LF	Anchorage	I	
			severe	VH				
		Incubators	Moderate	H	LF	Anchorage	I	
			severe	VH				
		Refrigerator	Moderate	H	LF	Anchorage	I	
			severe	H				
		Cupboard	Moderate	VH	LS	Relocation	I	
			severe	VH				
		computers	Moderate	H	LF	Strapping	II	
			severe	VH				
21.	Orthopaedic ward	Supplies on trolley	Moderate	H	LF	Hooking	II	
			severe	VH				
		Portable Xray machine	Moderate	H	LF	Hooking	II	
			severe	VH				
		Refrigerator	Moderate	H	LF	Anchorage	II	
			severe	VH				

22.	Radiology department CT-MRI complex	Supplies on trolleys	Moderate	H	LF	Hooking	II	
			severe	VH				
		Suction machines	Moderate	H	LF	Anchorage	II	
			severe	VH				
		CT scan machine	Moderate	H	LF	anchorage	I	
			severe	VH				
		Oxygen cylinder	Moderate	VH	LS	Hooking	I	
			severe	VH				
		Racks	Moderate	L			-	
			severe	L				
		computers	Moderate	H			III	
			severe	H				
		Xray machines	Moderate	H	LF	Anchorage	I	
			severe	VH				
		Ultrasound machines	Moderate	H	LF	Anchorage	I	
			severe	VH				
23.	Obstetrician, gynaecology, Labour room	Supplies on trolleys	Moderate	H	LF	Hooking	II	
			severe	VH				
		refrigerators	Moderate	H	LF	Anchorage	II	
			severe	VH				
		Suction machine	Moderate	H	LF	Anchorage	II	
			severe	VH				
		OT lights	Moderate	VH	LS	Hooking	I	
			severe	VH				
24.	N-ICU, P-ICU	Baby incubators	Moderate	VH	LS	Hooking	I	
			severe	VH				
		Portable X-Ray machine	Moderate	H	LF	Hooking	II	
			severe	VH				
		Oxygen cylinders	Moderate	VH	LS	Hooking	I	
			severe	VH				
		Refrigerator	Moderate	H	LF	Anchorage	II	

			severe	VH				
		Supplies on trolley	Moderate	H	LF	Hooking	II	
			severe	VH				
		Wheeled trolley mounted equipment	Moderate	H	LF	Hooking ,strapping	II	
			severe	VH				
		Suction machines	Moderate	VH	LF	Anchorage	II	
			severe	VH				
25.	Paediatric	Supplies on trolley	Moderate	H	LF	Hooking	III	
			severe	VH				
		Refrigerator	Moderate	H	LF	Anchorage	III	
			severe	VH				
26.	General surgery and private wards	Supplies on trolley	Moderate	H	LF	Anchorage	III	
			severe	VH				
		Oxygen cylinder	Moderate	VH	LS	Hooking	I	
			severe	VH				
27.	Medicine wards	Supplies on trolley	Moderate	H	LF	Hooking	II	
			severe	VH				
		Refrigerator	Moderate	H	LF	Anchorage	II	
			severe	VH				
		Oxygen cylinders	Moderate	VH	LS	Hooking	I	
			severe	VH				
							LS = Life safety LF = Loss of functionality VH = Very high H = High L = Low	

Table 8: Non – structural vulnerability assessment form used for assessing the vulnerability of the hospital equipments and contents (Electricity, communication and water supply system).

Sl. No.	Location	Non - structural element	Earthquake	Risk rating	Type of risk	Mitigation option	Implementation Priority	Remarks
1.	Near generator/control panel section and at back of new building	Transformer	Moderate	H	LF	Check the existing anchorage and proper support to be provided both at top and base	I	
			Severe	VH				
2.	At front of the old building, between old building and new building back of new building block	Generator	Moderate	H	LF	Proper anchorage at base along with proper shade for one of the generators	I	
			Severe	H				
3.	In old building premises at front	Control panel	Moderate	VH	LF	Proper anchorage of the Main distribution boards. Dressing and clipping of the inlet and outlet cables is required	I	
			Severe	VH				
4.	At different locations	Battery charger	Moderate	VH	LF	support	I	
			Severe	VH				
5.	At different locations	Electric panel	Moderate	VH	LF	Anchorage at base	I	
			Severe	VH				
6.	Roof	Roof tanks	Moderate	VH	LS.LF		I	

			Severe	VH				
7.	In CSSD section and in basement of new building complex	Pumps	Moderate	H		anchorage	II	
			Severe	H				
8.	Different locations	Oxygen and suction pipelines	Moderate	VH	LF	Need proper support and anchorage at every junction	II	
			Severe	VH				
9.	Different locations	Air conditioners	Moderate	H	LF	Need proper anchorage at interiors and at many places exteriors	III	
			Severe	H				
10.	Different locations	Geysers	Moderate	VH	LF	Need proper anchoring along with strapping	III	
			Severe	VH				
11.	CSSD	Oxygen cylinder storage	Moderate	VH	LS,LF	Need to be properly hooked with chain and support system	I	
			Severe	VH				
12.	Different locations	Fire extinguishers	Moderate	VH	LS,LF	Anchorage at base and strapping	I	
			Severe	VH				
							LS = Life safety LF = Loss of functionality VH = Very high H = High L = Low	

7. Conclusion

Non - structural vulnerability assessment of Mahant Indiresh hospital as documented in this report is intended to support the hospital authorities in planning a strategy for reducing the non - structural seismic risk.

The sections / areas of the hospital falling under high risk category have been delineated on the basis of the field survey and the assessment carried out in the hospital. The surveyed non-structural components have also been given ratings with respect to the risk posed to these in two earthquakes of differing intensities; moderate earthquake of intensity VI to VII in the MMI scale and severe earthquake of VIII to IX intensity in the MMI scale. The type of risk has accordingly identified. Based on these priorities have been delineated for undertaking non - structural mitigation measures in a phased manner. The report emphasises that the non-structural mitigation works be taken up by the hospital administration in three phases.

The assessment clearly reveals that the hospital would not be able to maintain its functional and operational continuity even during a moderate intensity earthquake. Most areas of the hospital fall under high risk and it is likely that the hospital would suffer major losses both in terms of life as well as equipments.

As per the observations made most critical facilities of the hospital are located in the old building. The hospital administration may either decide to shift these facilities to the new building or carry out the mitigation measures in the old building. It is however advised that some of the critical facilities be shifted to the new building. In addition to this electrical wiring and conduiting in the entire hospital needs to be inspected and fixed on priority basis.

This report gives clear idea about the critical areas of the hospital where mitigation work needs to be carried out on priority basis. The hospital administration is therefore advised to discuss the findings of the report and accordingly amend the priorities as per their requirement or other feasibility parameters.

It is a common perspective that mitigation measures in health facilities would require huge investment. Particular care has therefore been taken to suggest simple and basic mitigation measures.

In order to have proper utilisation of the findings of this report, the hospital authorities have to take a decision to implement the suggested measures. This would certainly require investment of both time and money. This investment is however sure to pay rich dividends in the form of reduced cost of repair and restoration n the aftermath of any disaster. More over this would ensure operational continuity of hospital after such an incidence.

However in order to achieve complete hospital safety and a well defined strategy has to be formulated to address all the three major aspects that include structural, non - structural and preparedness. The hospital's architects and engineers must review the building design in the light of seismic safety provisions as given in the Indian National Building Code. This report in combination with the structural vulnerability assessment and a well defined hospital preparedness plan would help in achieving the aim of hospital safety. Besides other things this plan should define the duties of doctors and staff in case of emergency. Periodical assessment of hospital vulnerability is also necessary to update the mitigation plan as and when required. It is advised that the non - structural mitigation measures as suggested in this report must be included in the maintenance, inspection, and upgrading plan.

The findings of this report combined with proper structural assessment as well as regular updating of hospital emergency preparedness plan would help in achieving the aim of hospital safety.