BANGALORE METRO RAIL CORPORATION LTD.
THE REPUBLIC OF INDIA

SPECIAL ASSISTANCE FOR PROJECT IMPLEMENTATION (SAPI)

APPLYING THE ON SITE VISUALIZATION AND DUST MONITORING AT BANGALORE METRO CONSTRUCTION SITES

FINAL REPORT

MARCH 2012

JAPAN INTERNATIONAL COOPERATION AGENCY

ORIENTAL CONSULTANTS, CO., LTD.

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Executive summary

The Special Assistance for Project Implementation (SAPI) applying On Site Visualization and Dust Monitoring at Bangalore Metro construction sites was executed between July 2011 and January 2012. In this survey, the two themes associated with safety and environment at work places were chosen to be addressed.

Pamphlet for this project

Cricket Stadium Station

Central College Station

(1) Safety improvement by using On Site Visualization (OSV) Monitoring

<u>Safety issues</u>

Safety First! This is the concept and the slogan shared by all, required for all, but difficult to achieve throughout the world. Construction sites are full of dangers. Workers are exposed to various kinds of “unexpected accidents” that threaten their lives, delay construction and make owners to pay more. "Staying safe" at work is a fundamental right for all. To improve safety practices at general construction sites, a new type of sensors has been developed for simultaneous monitoring and visualization of safety and risk conditions at construction sites. These sensors are designed and built based on the new monitoring concept called “On Site Visualization” and capable of 1) sensing data and 2) visually outputting the measurement results simultaneously by using LED lights for workers and all concerned. As the color of LED changes from blue to cyan, green, yellow and red, everyone can visually identify that the safety condition is changing accordingly. Necessary actions including evacuation may be incorporated in the safety manual. Employment of the OSV monitoring method, developed by Professor S. Akutagawa of Kobe University, Japan, and OSV Consortium companies, enables real-time data processing and visualization on-site, so that the state of deformation, strain, inclination, earth pressure etc. for the structures in concern can be grasped with no delay in time and is shown visually to anyone nearby. Rationally designed use of this method could give us early warning signs, if any, and minimize risks not only during construction of underground infrastructures but also during their service time. On Site Visualization, once embodied in the framework of safety management practices, could lead to a better and quicker understanding of potential risks and improved management of safety at construction sites. Monitoring safety using OSV has been applied at more than 30 locations in Japan since 2006. With the support by Japan International Cooperation Agency and Delhi Metro Rail Corporation, the OSV monitoring was also conducted at two sites in New Delhi in 2010, successfully.

Nightly view of the Cricket Stadium site with OSV sensors installed

The OSV monitoring was conducted at two stations in Bangalore as a second major operation in India. In the primary site (Cricket Stadium station) in front of HAL (Hindustan Aeronautics Limited) building, sensors connected to LEC (Light Emitting Converter) have been installed and an open and real-time system for workers, engineers and citizens, who were given 24 hour visual access to updated information on the states of construction sites, were created in July 2011, and it continued until January 2012. A limited application of the OSV monitoring was conducted at the second site, Central College station, as well.

<u>People's reaction</u>

The application of the OSV monitoring method is a growing new practice in Japan. It was really a challenge for the project team to conduct the OSV monitoring first time in Delhi, 2011. The second major application of the OSV monitoring conducted in Bangalore was based on the experiences obtained in Delhi. To reflect the lessons learnt in New Delhi, some new attempts were made to try out a combined use of Indian made sensors with Japanese made light emitting devices, use of additional light emitting units to improve daytime visibility, and so on. As weeks passed, it was obvious that the trial of using Indian made sensors together with the OSV devices made in Japan turned out to be successful, and the workers at OSV monitored sites became accustomed to the lights emitted by the sensors, fully aware of what the colors meant, knowing how to respond to the change of colors, especially when it turns red. The questionnaires conducted towards the end of the project proved that the concept of the OSV for improving safety was accepted by all concerned.

People's reaction (OSV monitoring)

Open to the public

One of the most difficult parts in promoting an OSV project is that an owner of the project does not allow disclosure of the information about safety to the public. This has been the mentality seen for most public offices around the world and they usually try to hold the information within themselves. It is usually only after an analysis is made about the risk related information that part of the information is disclosed to the public. This notice could come hours, days, or in some cases, months later. The employment of the OSV sets up a situation that the up-to-date and real-time information about the monitored site is shown and disclosed to the public at all times. This happened both at the Cricket Stadium station site and the Central College station. This was only possible due to the full support from officers of BMRC, HAL and BSNL and their courage and confidence to finish the construction project safely to the end.

New experiences

There were many non-predictable things that happened in this project. It was the second time that the OSV monitoring method was employed in India. Especially, most instrumentation works including the equipments and the engineers were prepared in India to transfer the management to BMRC and the technique and equipments to Contractor. Workers and all concerned saw pressure, strain and inclination as the color of lights. The adjacent HAL building and BSNL building were monitored and the lights from the roof top were disclosed to the public. Additionally, some of instruments were shifted to monitor the behavior of structure at the other construction site with a risk, as required by BMRC and Contractor. The actual monitoring was carried out by the joint team between JICA and Contractor to protect the safety at the construction site. In filling out questionnaire forms, many young workers were asked what they thought about a working environment where safety is visualized by LED lights and if they thought such safety measures would be recommended for future construction. Light emitting sensors were exposed to large temperature fluctuation daily, confusing engineers with definition of threshold values of color schemes. Loss of soil was also found at a location where monitoring instruments were not installed. Many of these non-predictable things happened during the project, but the proper analyses of those situations were made and appropriate actions were taken to continue the study throughout the period. Light is visible to everyone. Light travels fast to everyone. And light links people of different positions, responsibilities and backgrounds for the same cause of achieving safety.

What we did not expect

As the sites were monitored by the new methods, confidence grew gradually so that everybody believed that all causes of accidents could have been found. The reality, however, it turned out to be trickier than we thought. The OSV sensors, counted between 10 and 15, did serve as problem-finders, indeed, where they were installed. But the number of sensors was not sufficient for covering the entire construction yard. A loss of soil of certain volume behind the retaining wall on the south side of the Cricket Stadium station was found before it caused any damage or collapse for the wall structure. Although it did not lead to a major accident, it was really a potential threat to the safety management practice. The simple fact that the particular portion of the problem was not monitored by OSV sensors strongly suggested and demanded that sensors for safety management be produced at much lower cost so that larger area could have been monitored for the same budget.

Potential problem found behind the wall where OSV sensors were not installed.

Cost performance

The questionnaires showed that the concept of the OSV was accepted well in Bangalore and they are interested in conducting the similar project in future with appropriate budget prepared. Successful and fruitful operation of future OSV monitoring projects then relies on not just the quality of the OSV sensors but on the quantities, namely their cost.

The cost required for this exercise cannot be the future reference value since it had to include the initial development and shipping costs, for example. As the demand for the OSV sensors increases, the cost will naturally go down accordingly. International strategies for managing all activities required for a sustainable development and proliferation of the safety improvement using OSV, including design, manufacturing, sales, distribution, training and education, remains as important topics to be worked out in near future. In this project, all the OSV sensors had function of outputting measured information as LED light. This electricity-based approach is one of the attractive ways for disclosing critical information at construction sites indeed. However, there could be many more alternatives to issue warning message using much simpler OSV sensors. They would probably use extremely little or no electricity; have extremely simple structure, yet still can work as OSV sensors to protect workers. Organized efforts should be paid to develop those new sensors to be used along with electricity based sensors in future.

The OSV approach for safety management should be part of daily routines at construction sites. For this to happen, the simplicity and affordable cost of the devices and related system has to be maintained. Whereas high performance aspects, such as wireless data transmission or automatic data logging, are favored by managing side, the simplicity and reliability are the key concepts that need to be kept for those who actually operate the system on site within limited budget. The OSV sensors of new generation, namely those with much simpler mechanism and structure, should be developed so that much greater number of sensors can be used per site without causing too much trouble for installation. It will only be then that the OSV monitoring method becomes a truly accepted safety management routine at construction sites around the world.

(2) Environmental improvement by using Dust Monitoring

Environmental issues

Given a safe place to work, more attention is now being paid to long-term health care issues for construction workers. Among various aspects with respect to health problems at work, "*breathing clear air*" has been regarded as one of the most important features. There is a regulation in India to keep dust density below a specific value, however, the compliance with this law requires use of expensive devices, is costly and time-consuming. To improve this practice, a quick and handy dust monitoring method was developed at Shinji laboratory, Yamaguchi University, Japan. In this method, a mobile phone camera is used, instead of a digital camera, which is used to take a flash picture and calculate dust concentration immediately by itself. The new method is more economical, easy to perform, and also has a high correlation with digital dust indicators.

In India, there is a regulation that dust concentration during construction must be less than 2.5 mg/m^3. However, dust monitoring or countermeasures have not been properly implemented so far. The purpose of this dust survey, therefore, was to carry out the new dust monitoring method developed by Professor M. Shinji of Yamaguchi University, Japan, to plan and execute the environmental management system using the dust concentration data measured to inform field workers of the risk of dust and as a result to refine environmental management practices of BMRC.

Dust monitoring by mobile phone cameras has two features. One is the improvement of worker's awareness about health threats caused by industrial dust, and the other is that workers can implement the countermeasures to control the dust immediately after measurement. When this dust survey is implemented, workers can measure the dust concentration regularly by using a mobile phone camera, show the result to those concerned and implement necessary countermeasures. In addition, by presenting a colored panel in accordance with the results, all workers can identify the state of dust concentration in the field and wear no or appropriate masks.

Dust monitoring at central college station

People's reaction

The application of the Dust monitoring method is a growing new practice for spraying concrete work of tunnel construction in Japan. It was a challenge for the project team to conduct the Dust monitoring the first time in India. As the final purpose of Dust Monitoring, all engineers and workers wear the suitable musk at the construction site. The dust monitoring is one of method for warning the environmental condition at the construction site. The sigh board with color panel is applied to show the dust density at the construction. As weeks passed, the workers at Dust monitored sites aware of what the colors meant, knowing what wear the suitable mask to the change of colors. The questionnaires conducted towards the end of the project proved that the concept of the Dust monitoring for improving environmental site condition was accepted by all concerned.

People's reaction (Dust monitoring)

Open to the public

The dust concentration on the road outside of the site was not as high as in the site, however, it could be said that the concentration on the road was high. And sometimes, it was higher than that in the site. People walking the road faced such high dust concentration situation, but no one recognised the risk of dust. The dust was from Auto-Rikisya, Cars, Auto mobiles and wind. Especially, in the dry season, there was much dust on the road. With this Dust Monitoring System by mobile phone, everybody can confirm the current dust concentration. This is very useful for the public. Now, there is only monitoring and the result is not exposed to the public. There is no countermeasure at the public road. Some people wear a bandana to protect the dust. Most people do not take any actions against dust. If the monitoring results of dust concentration should be exposed to the public, most persons have to take their own countermeasures according to the dust concentration as same as JICA Project site. As one of countermeasure, the wearing dust mask will be applied on public road.

New experiences

There were many “first things” that happened in this Dust Monitoring project. It was the first application of the Dust Monitoring System outside Japan. In terms of the size of the project, probably this became the largest operation in the world so far. Workers and all concerned saw the dust concentration at the site and could take actions based on the results for the first time. Dust Monitoring by mobile camera at open cut excavation sites was the first time. Dust Box application which was used to get a dark situation for such as blight situation like Central College Station Site (Usually, this monitoring system was used only for dark situation such as mountain tunnel) was the first time. Many of these “first things” happened during the project. Especially, the signboard with color panel is applied for showing the monitoring result at the construction site. For instance, the red panel means high concentration dust at the current condition. By this color panel, everyone could know the actual dust concentration easily. And signboard links workers for the same awareness regarding the dust.

What we did not expect

At the beginning of this project, the monitoring place was only in the construction site because there was expected to be too much dust come from some construction work such as drilling work, sprayed concrete or anchor setting. However, even out of the construction site, especially on the road, there was much dust that came from vehicle movement and its exhaust gas. Sometimes, the dust concentration on the road was higher than that of the construction site when there was no work. This dust monitoring method can apply to the public roads.

Dust pollution in urban area

Cost performance

The questionnaires showed that the concept of the Dust Monitoring System was accepted well in India and they are interested in conducting similar projects in the future with appropriate budget prepared. Successful and fruitful operation of future dust monitoring projects then relies on not just the quality of the mobile phone but on the quantities, namely their cost.

This Dust Monitoring System by mobile phone requires

(1) Mobile phone with android OS and flash camera
(2) Dust Box and black board
(3) Dust Monitoring System, namely “Funjin”

(1) and (2) should be prepared for each site. As (1) mobile phone, HTC Desire is recommended and it was used in this project. HTC Desire is Rs. 31,477 in Japan and Rs. 25,708 in India (February 2012). (2) Dust Box and black board is around Rs. 7000.

The royalties for (3) Funjin is now being reviewed. It might depend on the site scale and the number of monitoring places. These royalties include the fee for programming and calibration. And if the site needs guidance for Dust Monitoring, the guidance cost is separate.

The Dust Monitoring should be part of daily routines at construction sites.

The Dust Monitoring approach for environmental dust management should be part of the daily routine at construction sites. The Dust Monitoring System of a new generation which has higher accuracy and is a much simpler, stable monitoring method without so much calibration should be developed so that many more sites can apply the system. Then, the Dust Monitoring system will work as a true environmental management tool at construction sites around the world.

(3) Lessons learnt and road ahead

The experiences and lessons learnt in this SAPI project are precious and rich with regards to practical requirements for organizing, planning and executing an OSV monitoring and a DUST monitoring in all types of construction projects. It is now confirmed that almost all concerned in the construction project see these new methods in their favor. The improvement points about the sensors such as better compatibility of light emitting devices with Indian made sensors, better visibility of light emitting devices during daytime, or methodology have already been identified and they will be followed up by appropriate processes accordingly. Needs for further studies were also identified when the unexpected things happened both for the OSV and the DUST monitoring.

For applied OSV monitoring in future, more cost performance shall be required. For applied Dust monitoring in future, the easy calibration work on smart phone programming and more weight saving dust box shall be required.

In the meantime, metro construction projects of major proportions are lined up in Delhi, Kolkata, Mumbai, Chennai, Kochi and other major cities in Asia. For those who participated in the January 24th seminar, the basic information about what the OSV and DUST monitoring could do for their projects is already implanted. For those who were unable to be at the seminar, this report should be a guideline.

Final seminar held on January 24th, 2012

As is obvious, the OSV and DUST monitoring are not confined technologies only for metro construction. These are general schemes that can be applied to any type of projects. It is our hope that the experiences and lessons we learnt through this focal project conducted in Bangalore with the full support from BMRC and all other organizations and institutions, will be shared effectively and studied fully by our colleagues in other parts of India and elsewhere. The more wide-spread these methods will become, the higher the safety and health management practice level will be, and eventually the safer and healthier each work place will be.

Final seminar held on January 24th, 2012 (site Visit)

The new safety and health management strategy tested here in Bangalore left a considerable impact on those concerned with the project at all levels; namely, workers, construction managers, contractors and even citizens residing or passing through near construction sites. The new monitoring techniques were proven to be effective to raise safety and health awareness and improve the quality of management practices compiled as the safety and health control manual of a new generation. The unique outcome of this survey regarding safety and health at construction sites shall be shared and extended by the colleagues in India and elsewhere in the future.

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List of Abbreviations

BMRC	Bangalore Metro Rail Corporation
GC	General Consulting Group
JICA	Japan International Cooperation Agency
LEC	Light Emitting Converter
OSV	On Site Visualization
SHE	Safety, Health and Environment

Chapter 1 Introduction

1.1 Background

The construction of Delhi Metro Project Phase II and Bangalore Metro Project is now ongoing supported by a Japanese yen loan. The countermeasures for construction safety have been carried out by Delhi Metro Railway Corporation (DMRC), the Consulting Group and the Contractor since the construction of Phase I. PPE（Personal Protective Equipment: the safety helmet, safety jacket and safety shoes) is worn during the construction work on the DMRC construction site, although the workers do not customarily wear safety equipment in India. It is widely known that the Delhi Metro Phase I project became a milestone through which safety practices at construction sites improved dramatically in India. Workers started to wear PPE, construction sites were kept tidy and clean and safety awareness improved. The same effort was or is now being taken at Delhi Metro Phase II and Bangalore Metro projects.

However, construction accidents still remain at a considerable level. The safety control is the primary factor at the construction site. The excavation work for the underground stations is carried out in congested urban areas, as is the building work for the viaduct bridge upper railway and public road. The effects on the residents and workers would be great if the excavation area caved in or the bridge fell. The development of safety control is the most important item required at the construction site.

With this background, the special project, "Special Assistance for Project Implementation (SAPI) applying the monitoring method by On Site Visualization at Delhi Metro construction sites: SAPI for Delhi Metro Phase II Project utilizing Japanese ODA" was conducted in New Delhi in the DMRC Phase II project between March and August 2010. The main purpose of this was to check and confirm that a new monitoring method that had been developed and tested in Japan for improving safety management practices at construction sites would also work in India. The very first OSV project outside Japan proved to be simple, understandable, and acceptable for workers, managers and civilians in New Delhi, while improving their safety awareness. The experiences learned made clear what could be done by visualizing engineering data real-time using light, and what the problems would be.

There has been a strong request from Bangalore Metro Rail Corporation to promote safety improvement practices based on the newly acquainted experiences in the Delhi Metro Phase II project in which the new monitoring based on OSV was successfully implemented.

And also dust is a big problem for the health and environment at construction sites in India. In India, there is a regulation regarding dust during construction work. However, because the dust measurements are expensive, there are no countermeasures for this at construction sites now. In Japanese construction sites, the method which uses a digital camera for dust measuring has started. And recently, because the performance of mobile phone cameras has been developed, field research using a mobile phone camera has been done. Cooperation regarding the dust environment improvement and dust measuring using digital cameras (or mobile cameras) is required by the implementing agency.

1.2 Objective of the Survey

(1) OSV monitoring

In this survey, the new monitoring scheme called "On Site Visualization" is going to be implemented to improve safety management practices as it was done in the Delhi Metro Phase II project. By using this new approach for safety monitoring, it is expected that safety at construction sites and safety awareness among workers and residents in the neighbourhood will improve, and finally, safety management work by BMRC will be lifted to a higher stage.

Implementation of OSV monitoring brings new things to construction sites. Workers and anyone around light emitting devices can know safety conditions real-time and on the spot. The new flow of information introduced by the OSV monitoring is compared with the traditional one in which there are many intermediate steps that need to be carefully managed. The simplicity and speed achieved by the OSV monitoring are important new features which should be coordinated with appropriate action plans such as evacuation in an emergency.

The figure comparing the traditional monitoring and monitoring by OSV is shown in Figure 1.1.

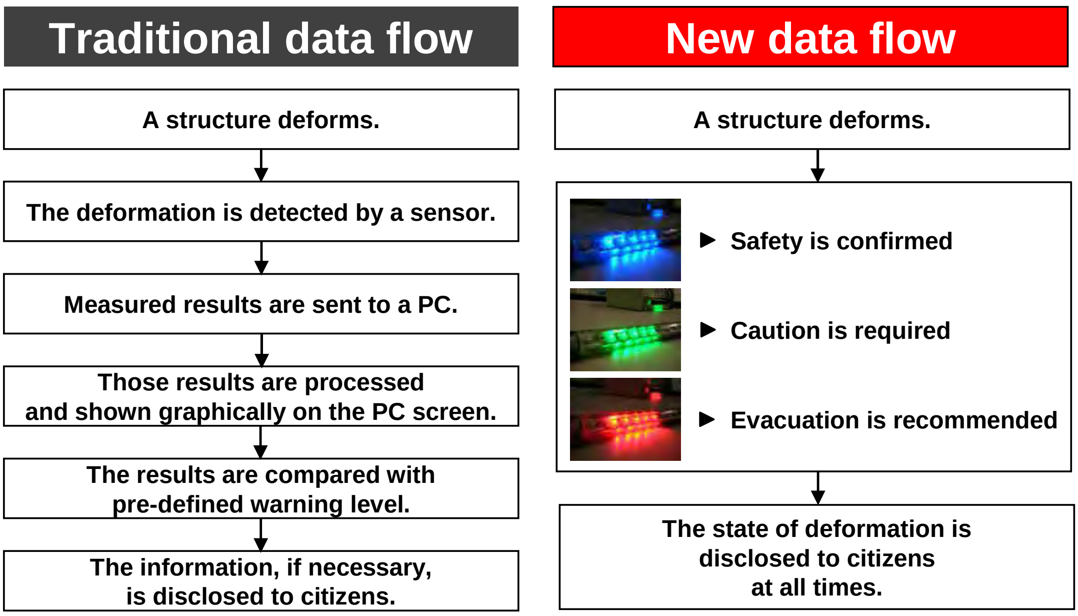


Figure 1.1 Comparison between the traditional monitoring and monitoring by OSV

The excavation work and installation of struts and other works are carried out in the construction area. Additionally, the construction area of the Metro Project is located near existing buildings and public roads. If monitoring data over the trigger value is shown by displacement of the ground, the LED on a strut emits light immediately. A light of green, yellow or red is shown. For example, the plan of monitoring by OSV at the excavation area is shown in Figure 1.2.

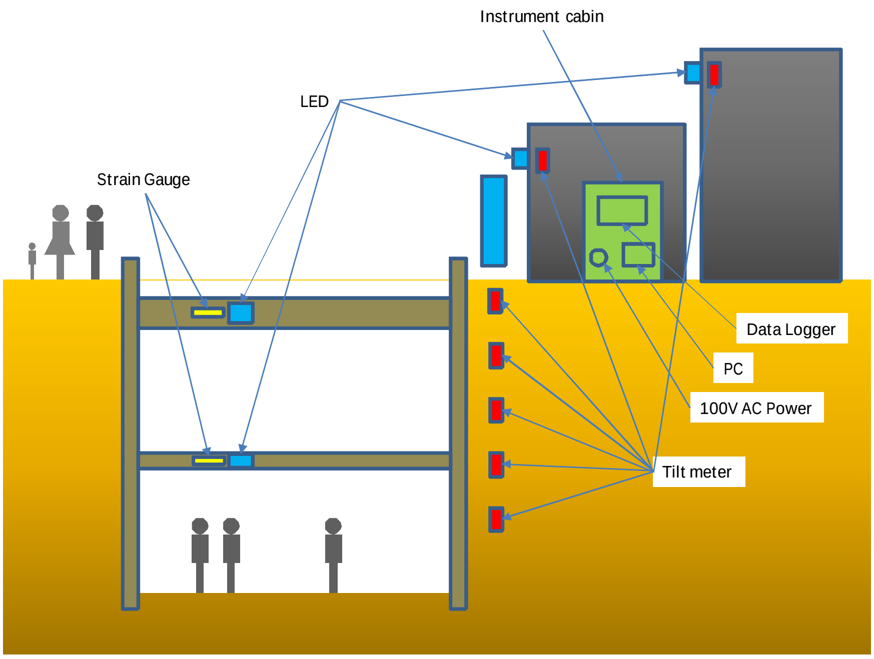


Figure 1.2 Example plan of monitoring by OSV at the excavation area downtown

Therefore, for the safety control which uses OSV monitoring in construction, a safety control plan will be prepare to be conducted by the construction site manager of the enforcement organization, construction site leader of the contractor and construction site workers, and it will be with their common knowledge (Confirmation of the OSV monitoring, communication and taking refuge when the color of the OSV changed). In addition, these actions will be explained to the residents of neighboring buildings. In case abnormal slanting or settlement of neighboring buildings is observed, the color of OSV will change, communicated to the subject parties and the "take refuge" signal will be confirmed.

By these actions, the safety degree of a construction site and neighboring buildings will be confirmed by the workers' and residents' own eyes. Improvement of safety awareness that was not seen before is expected. To confirm the effectiveness of this measure, a questionnaire survey for the construction site manager, construction site leader, construction site workers and neighboring residents will be carried out. Thus, improvement of the safety awareness will be confirmed.

A seminar regarding the questionnaire, including the result of this survey, to help the improvement of the safety control of the local enforcement organization will be implemented. The result of the safety control which uses OSV monitoring and the report about the improvement of the safety awareness of the workers and neighboring residents will be confirmed. In addition, for similar work that the enforcement organization will perform in the future, a proposal for the technical improvement of the safety control will be prepared. It is also designed such that information and experiences to be gained through this project will be shared to improve safety management practices and awareness by inviting those associated with promotion of rail transit infrastructure in India (Delhi, Mumbai, Chennai, Kolkata, Hyderabad) and elsewhere (Dakka, Hannoi, Jakarta).

Action and expecting effects of this survey are shown in Table 1.1.

Table 1.1 Activities and expected results by OSV monitoring

	Activities	Expected results
1)	Surveying state of the art of OSV monitoring in Japan	• Confirmation on the updated states on development of light emitting sensors
2)	Current status of OSV monitoring in Japan and problems identified	• Checking similar projects in Japan • Confirmation of the OSV monitoring and problems to be solved
3)	Selection of sites for OSV monitoring and compiling safety management plans	• Putting OSV safety management in action • 6) Outline of safety manual
4)	Execution of OSV monitoring and safety management	• Recording of OSV monitoring • Recording of OSV safety management practices
5)	Investigating responses from workers and neighbours about changes in safety consciousness	• Extraction of the issue of OSV • Extraction of the issue and effects of safety control • Confirmation of improvement of safety awareness
6)	Preparing safety management manuals	• Definition of what should be measured, how they must be checked visually and how people must respond to what is been visualized
7)	Holding seminars on the outcomes of the project	• Disclosure of the lessons learnt • Sharing what has been done and digested in Bangalore by those concerned with other projects in India or others.

(2) Dust monitoring

The purpose of this dust survey is to carry out the new measurement of dust concentration by mobile phone cameras, to plan and execute the dust management system using the dust measurement by mobile phone cameras, to inform field workers of the risk of dust and as a result to support technology upgrade of the implementing agency's dust monitoring.

Figure 1.3 Dust monitoring result

Dust measurement by using mobile phone cameras has two features. One is the improvement of worker's crisis awareness about dust, and the other is that workers can implement the countermeasures to control the dust immediately after dust measuring. In India, there is a regulation that dust concentration during construction must be less than 2.5 mg/m^3. However dust monitoring or countermeasures have not been taken at all. When this dust survey is implemented, workers can measure the dust concentration regularly by using mobile cameras, show the result to the construction site personnel and can implement the countermeasures. The measurement result is displayed on the mobile camera soon after taking a picture with a flash as shown in Figure 1.3. And by showing a color panel in accordance with the results, workers can know the dust concentration in the field.

Therefore, through the dust control activities using dust measurement with mobile cameras, a dust control plan can be created with rules (the dust measurement verification tasks using mobile cameras, countermeasures corresponding to dust concentrations) for administrators of the agency, field commanders and workers of the contractor and these keep everyone informed and also promote wearing of a dust mask with better understanding of the impact of dust on the human body. Figure 1.4 shows Pneumoconiosis.

Figure 1.4 Left: Healthy lung Right: Pneumoconiosis

Through these approaches, it is expected that workers will confirm the dust concentration of the construction site by themselves, and their critical awareness of dust will be improved. As an indication to evaluate the results, questionnaires for administrators of the agency, field commanders and workers of the contractor are going to be distributed to check how much they understand the importance of dust control and improve their awareness.

Regarding these survey results including these questionnaires, local seminars are to be held in order to help improve the dust management of local implementing agencies. The results and improvements divulged and confirmed. And recommendations about technology improvement for dust management for the same sort of construction by the implementing agency in the future will be realized.

Table 1.2 shows the activities and expected results of this survey.

Table 1.2 Activities and expected results by dust monitoring

	Action	Expecting Effect
1)	Developing dust monitoring by mobile phone cameras in Japan	• Investigating the situation and usability regarding dust monitoring by mobile phone cameras
2)	Current situation and concerns in Japan	• Investigating similar monitoring in Japan • Investigating previous monitoring data regarding installing dust monitoring by mobile phone cameras
3)	Selection the monitoring sites, monitoring and environmental management plans	• Environmental plans using dust monitoring by mobile phone cameras • Environmental management manuals based on the above environmental plan
4)	Site monitoring by mobile phone cameras and planning & execution for environmental management	• Recording of Dust monitoring by mobile phone cameras • Recording of environmental management practices by dust monitoring
5)	Investigating responses from workers and neighbours about changes in environmental consciousness	• Listing improvements to be made for devices used in dust monitoring by mobile phone cameras • Listing the achievements and improvements of environmental management by dust monitoring • Investigating the environmental awareness
6)	Creating environmental management manuals	• Discussion of panel color method, consideration, trigger value and site action plan for environmental management using dust monitoring by mobile phone cameras
7)	Executing seminars	• Sharing the information regarding dust monitoring by mobile phone cameras • Developing systems for other projects in India

1.3 Survey Area

In the Bangalore Metro Project Phase-I, the east-west line underground station have been under construction since October 2010, and the north-south line is being prepared now. Some excavation sites which do not interfere with the ongoing construction will be selected as the monitoring site. Figure 1.5 is the route map of Bangalore Metro.

Figure 1.5 Route map of Bangalore metro

1.4 Basic Composition of this Survey

The basic composition of this survey is shown in the tentative schedule. This survey includes both OSV monitoring and DUST monitoring. Each survey is composed of 3 Phases.

First, OSV monitoring, basic organization is shown in Figure 1.7

Phase 1: Rearranging of the development situation in Japan regarding Monitoring by OSV, and Analysis of the present conditions regarding use of the system of Monitoring by OSV in Japan will be performed. Concretely, Construction site OSV monitoring, Outline and present conditions regarding safety control, grasp of problems and the prospects, Monitoring management which will be performed by this survey and direction of safety control are all confirmed.

Phase 2: OSV Monitoring and safety control will be implemented based on the measurements and safety control plan. In addition, to confirm the effectiveness of this measure, a questionnaire survey for the construction site manager of the enforcement organization, construction site leader, construction site workers and neighboring residents will be carried out.

Phase 3: Safety control manuals will be prepared based on the result of this survey and the monitoring by OSV in overseas construction. In addition, seminars will be implemented for the enforcement organization in Bangalore, construction related persons, representatives of residents, and the measurement company. With the inspection of the result and discussion of confirmation and possibility of the future development, the examples based on Japanese construction site safety control and methods will be introduced. Technology transfer to the local people will be executed. The persons in charge of the enforcement organizations of the Metro Projects in India, which are supported by a Japanese Yen Loan, such as Kolkata and Chennai also will join in these seminars. Sharing of the information and increasing of safety awareness are planned.

Next, regarding DUST monitoring, basic organization is shown in Figure 1.8.

Phase 1: Rearranging of the development situation in Japan regarding dust monitoring by mobile phone cameras and analysis of the present condition regarding use of the system of dust monitoring by mobile phone cameras in Japan will be performed. Concretely, Construction site dust monitoring, Outline and present conditions regarding safety control, grasp of problems and the prospects, monitoring management which will be performed by this survey and direction of safety control are to be confirmed.

Phase 2: Dust monitoring and environmental management in construction sites will be implemented based on the measurements and an environmental management plan. In addition, to confirm the effectiveness of this measure, a questionnaire survey for the construction site manager of the enforcement organization, construction site leader, construction site workers and neighboring residents will be carried out.

Phase 3: Environmental management manuals will be prepared based on the result of this survey and the practice of dust monitoring by mobile phone cameras in overseas construction projects. In addition, seminars will be implemented, which will be joined by the enforcement organization in Bangalore, construction related persons, representatives of residents, and the measurement company. With the inspection of the result and discussion of confirmation and possibility of future development, examples of Japanese construction site environmental management and methods will be introduced. Technology transfer to the locals will be executed.

The persons in charge of the enforcement organization of metro projects in India which are supported by a Japanese Yen Loan, such as Delhi, Kolkata and Chennai also will join in this seminar. And sharing of the information and an increase in safety awareness are planned for the urban transportation projects in India (Hyderabad, Mumbai), Hanoi, Jakarta and Dhaka.

Figure 1.6 is project schedule.

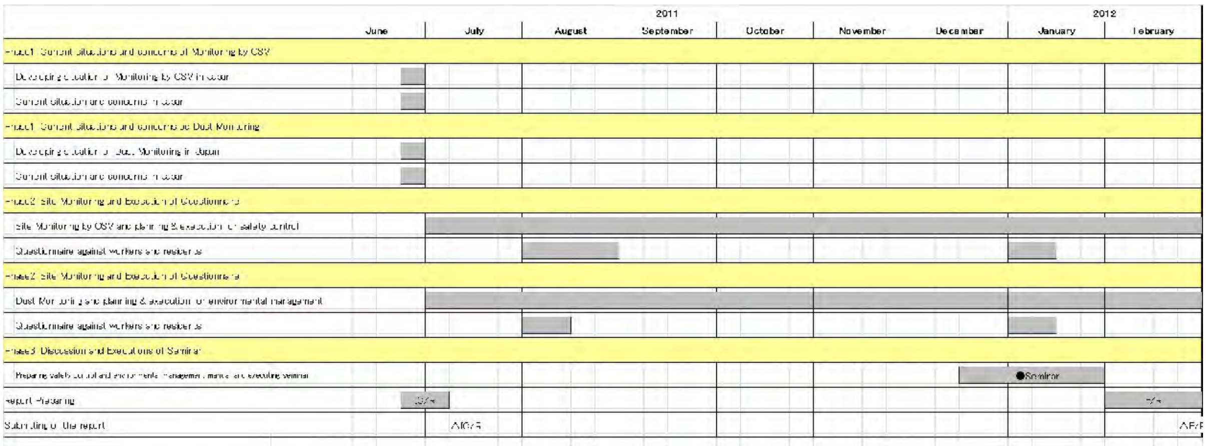


Figure 1.6 Project schedule

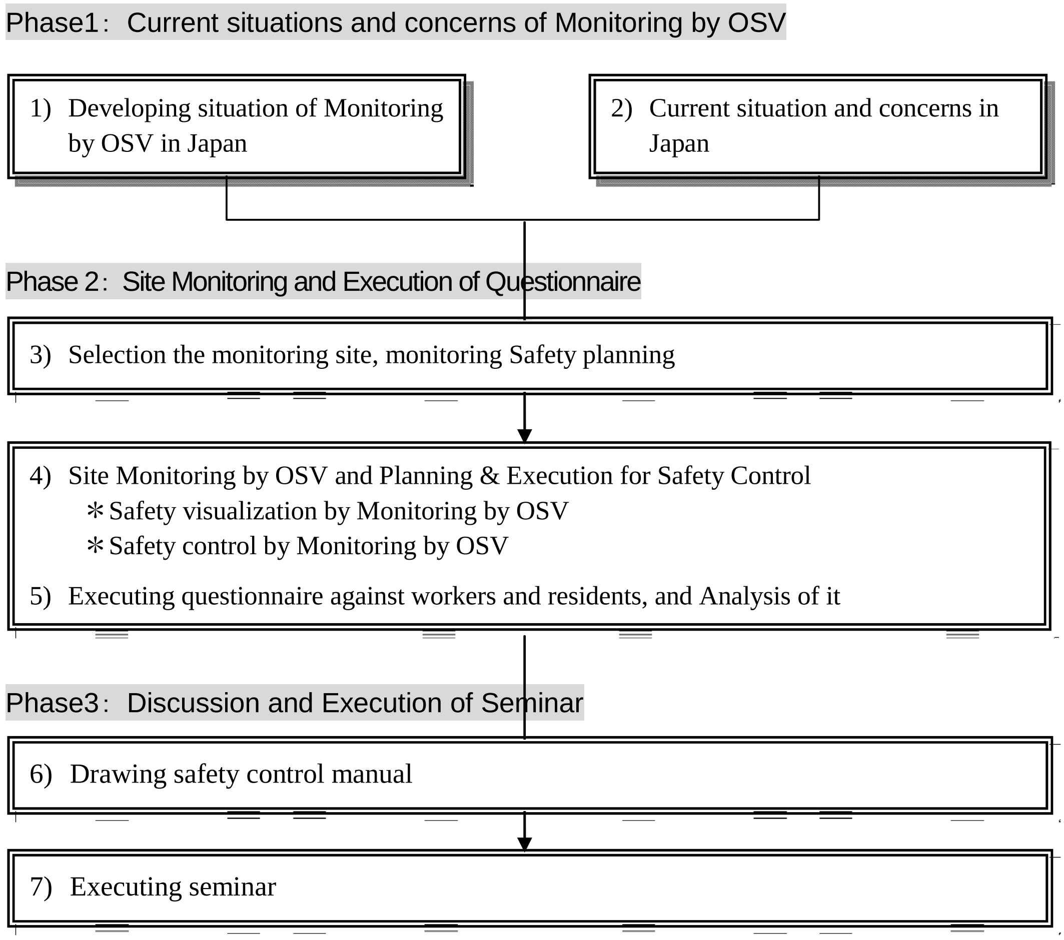


Figure 1.7　Basic organization (OSV monitoring)

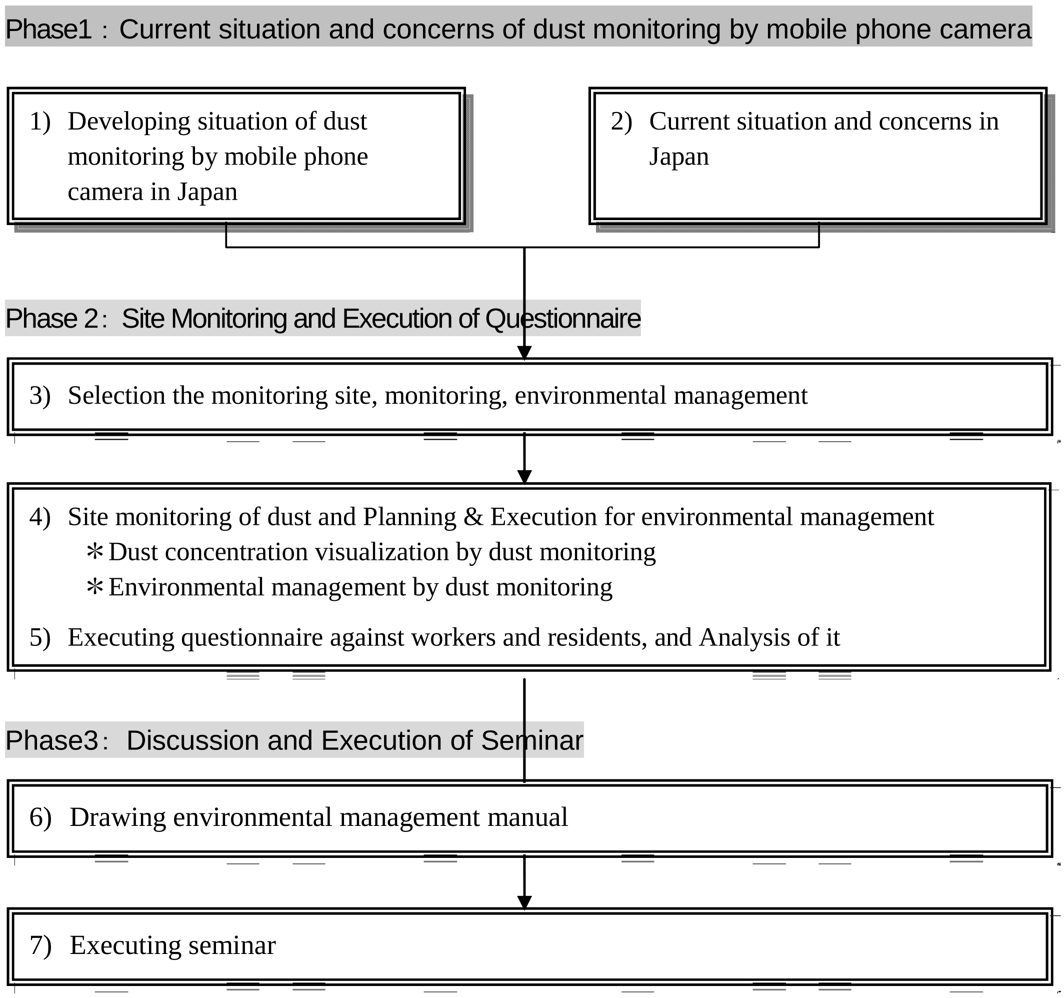


Figure 1.8 Basic organization (Dust monitoring)

Chapter 2 Investigation of current status with OSV and DUST monitoring in Japan

2.1 Current status of light emitting devices used in OSV within Japan

It is a commonly accepted practice in monitoring schemes for infrastructures that information gathered by monitoring devices is stored on a PC and printed later for reporting. As far as visual presentation of the measured data is concerned, it is usually performed on either paper or a PC screen. The time required for this data processing has decreased dramatically recently; however, the term “real-time” may not be used in a strict sense, since at least several seconds are required to process raw data into visible forms either on PC screen or printed materials. More importantly, one is informed with the current state of deformation and etc. not where the event is happening, but where one can look at the PC screen which could be far away from the site. In addition, technical problems associated with data gathering and transmission, or human errors in machine operation could jeopardize correct management of measured information, thus putting workers and citizens nearby in endangered positions as the necessary information to them is not transmitted properly. It is also the case that the majority of sites, such as dangerous steep slopes or high walls seen in construction sites, are not monitored at all due to budget problems. Therefore, most of us are exposed to potential dangers with those un-monitored sites as nothing is measured, and therefore, nothing about them is known.

Use of “Light” as a warning sign has been available for many years. However, the way the warning light has been used is somehow limited to such a case that one or very limited number of light devices are used to launch a warning light when pre-determined conditions are met. For the case of rock fall detection, as an example, a wide zone is monitored by a single long rope set at certain height from ground such that a piece of rock falling at an arbitrary position could be trapped by the rope or give temporary deformation to the rope, thus switching on the warning light. This approach could tell us that something has happened. But it does not tell us exactly where the rock has fallen, how much deformation had occurred before the rock fall, or if there is any similar dangerous location on the slope and so on. Therefore, it can be said that both the quality and the quantity of information that can be gathered and transmitted to us in this traditional method, are very limited in many ways.

A totally new approach designed for infrastructure monitoring has been proposed by Professor S. Akutagawa of Kobe University, Japan, since 2006. Akutagawa, a registered member in this project, characterizes this new approach with the use of “light emitting sensors”. For example, a new deformation sensor used in this approach is capable of 1) measuring displacement and 2) showing it by the designated color of LED in real-time. The same concept can be applied for monitoring of strain, inclination, earth pressure, water pressure, temperature, etc. Since these new devices are equipped with light emitting function or used together with the specially designed data converter with light emitting capability, the monitored data are translated in real-time into the color of light visually identifiable by workers and citizens around. In comparison with the traditional method in which the monitored data are basically processed by data loggers or PCs, the new method using light emitting sensors could lead to an establishment of a totally new approach for the safety monitoring of infrastructure. The new approach is termed “***On Site Visualization***”. Akutagawa and his associate member companies (general contractors, consultant companies, and manufacturers) established the research consortium in January 2010, which aims for development and deployment of effective light emitting sensors and relevant strategies to promote the concept of the OSV in wide engineering disciplines. It is therefore important to follow the past activities and recent developments made by this group in order to optimize the effectiveness of this project for the BMRC.

(1) Current status for light emitting devices used for OSV

Based on the fundamental development research in 2006 at Kobe University, Akutagawa jointly worked with a partner company in the OSV consortium, to manufacture the first model of Light Emitting Deformation Sensors, LEDS for short, in 2007. Since that time, the member companies started development of various light emitting sensors. Figure 2.1 shows 6 different types of sensors, each of which is briefly documented hereafter.

Figure 2.1 Light emitting sensors developed by the OSV group

<u>Light Emitting Deformation Sensor (LEDS)</u>

The LEDS, probably the first such device in the world as a deformation sensor with an added function of outputting the measurement result by the color of LED, was first developed in 2007 and has been modified several times while they have been used in the field tests in tunneling, open excavation in urban areas, old cut slopes, etc. The most recent model is designed such that 5 different colors are shown with 2mm displacement intervals, making the total stroke to be 10mm. With an additional attachment device, the stroke can be adjusted.

Light Emitting Deformation Sensor for Rockbolts

A modified LEDS specially designed for rockbolts has been developed. Up to three relative displacements over the length of a rockbolt can be measured and their values shown by LED attached in a box. Fundamental laboratory tests were conducted, however, field application has not been performed yet.

Light Emitting Deformation Sensor for Ground anchors

A modified LEDS specially designed for ground anchors has been developed. Relative displacement over the length of a ground anchor can be measured and their values shown by LED attached in a head cover. Fundamental laboratory tests were conducted, however, field application has not been performed yet.

Light Emitting Inclination Sensor

An accelerometer was used as a key sensor to measure inclination which is shown by rotation lamps of different colors. The censoring unit is the accelerometer generally used for automobiles. Two of those units with a temperature control unit were boxed in a single container that is connected to the light emitting part made of three rotation lamps. Field application example in Japan has not been conducted yet.

Light Emitting Converter with arbitrary sensor

The most recent development made by the OSV consortium is a new type of data converter which can log data from an arbitrary measurement device and shows the results with the LED attached to it. By using this data converter, called Light Emitting Converter (LEC, for short), with a designated sensor (which could be for measuring strain, displacement, earth pressure, water pressure, temperature, acid contents, etc.), almost anything can be measured and its result shown by the color of LED in real time. It is also possible to let an LEC be connected to more than one sensor whereby an additional algorithm written in the LEC can process all data coming in from those sensors and identify a maximum datum for showing the color of light.

Laser pointers

Laser pointers that are available to anyone are also used as auxiliary light emitting devices. A laser pointer itself is not a sensor, but it can be used as a visual tool to show inclination or deformation of a point of installation. Simple experiments and a field test have been conducted in Japan.

Tables 2.1, 2.2, 2.3 show a summary of: 1) application of LEDS at Kobe University as basic experiments, 2) application of LEDS in the field, and 3) application of LEC in the field, respectively. Figure. 2. shows the locations of these activities in Japan.

Table 2.1 Experiments conducted at Kobe University using early models of LEDS, LEIS, and Laser pointers

	**Simulation of landslide** Student-hand-made LEDSs were used to simulate landslide. Four wood panels were prepared to represent moving blocks of the slope while three LEDSs were installed with the initial color of white. As one of the panels was moved, the induced displacements were picked up by the LEDS, and their color changed from white to blue. This was the very first On Site Visualization experiment by the LEDS made by students.
	**Simulation of rock fall** A rock net was supported by LEDS so that trapped rocks would pull the net, and therefore pull the LEDSs to change their color. Like in this example, LEDSs can be used as part of support structures of various forms used in engineering applications.
	**Visualization of water flow** An LEDS was fixed to a structure at one end, and the other end was put in a stream of water flow. As the flow speed increases, the tension in the LEDS increases enabling real-time representation of flow speed as the color of LEDS. A similar practice would make it possible to visualize wind by the LEDS.
	**Watching scaffolding at a construction site** Scaffolding is generally used at most construction sites. Materials used vary nation by nation. In this example, steel pipes are used as main structural elements of the scaffold which was covered by wind breaking sheets. Four LEDSs were used to monitor any unexpected movement of the scaffold structure to visualize safety condition of the construction site.
	**Watching structural damages during earthquake** In the event of an earthquake, LEDSs installed on any structure can perform as real-time deformation viewer during the quake, and automatic structural damage viewer when the quake shock finishes. As judging the danger level of the buildings in an earthquake hit urban area is very demanding, in terms of man power and time, the LEDSs can be used as automatic damage viewers.
	**Monitoring soil wall failure by Light Emitting Inclination Sensor** Light Emitting Inclination Sensors, initially hand-made by students, were used to visualize soil wall failure. Heavy rain or earthquakes cause damages in various forms to residential areas. In this experiment, several LEIS were installed before the soil wall was intentionally damaged. After the damage, only the LEIS in the damaged zone were lit up showing the zone of severe damage. This type of application shows the use of light emitting sensors during natural disasters can help identify the area of damage quickly and make rescue operations more effective.
	**Visualizing bridge inclination by Laser beams** Laser pointers were used as alternative Light Emitting Sensors. As a laser pointer can be fixed to the selected point of a structure, the subsequent movement or inclination of that particular point can be visualized as a shift of the laser beam spot on a screen properly set up at a distance. Installation and visualization of a laser pointer is relatively simple and this method is recommended to be used at night as you get the maximum visibility of the laser beam spot.

Table 2.2 Examples of field application of LEDS

	**Safety monitoring at an open cut excavation site** Safety monitoring was performed at a late stage of a tunnel construction site. The tunnel was constructed by a cut and cover method and the LEDSs were mounted between the retaining wall and steel columns to monitor what they call “unexpected small displacement”. While a worker loosened one of the strut beams, the closely positioned LEDSs changed their colors showing to everyone around that the movement occurred just by a small amount within a range of assured safety.
	**Monitoring an old shotcreted slope** An old shotcreted high slope was chosen as a test case to install LEDSs for the first time in the field. Four LEDSs were installed, each measuring displacement between two points approximately 5m apart. As the site was by a national roadway with substantial traffic, lighting up of LEDS was only allowed during a limited time in the evening. However, the visibility of the LEDSs installed in the range of 100m or more was excellent. This was a good example to demonstrate how the use of LEDS could help maintenance works since the safety over a wide area can be checked at a single glance.
	**Monitoring tunnel convergence (Hokkaido)** LEDSs having a 1m long light emitting part were used to monitor extra convergence displacement of a tunnel in which soft and squeezing ground conditions were observed occasionally. LEDSs were installed on its side wall to ensure the further displacement after extra reinforcement of shotcrete was confined to its minimum level.
	**Monitoring of a high slope at a tunnel portal** Stability of a high slope just outside of a tunnel portal was monitored by two LEDSs. To ensure additional visibility of the LEDS, an optional LED unit cabled from the original sensor was hung on the side wall of the tunnel entrance.
	**Safety monitoring during repair work** Part of a concrete lining was damaged due probably to environmental factors such as underground water or aging concrete. To ensure safety during repair work of the damaged section, LEDSs were installed to visualize deformation during the work involving some drilling into the damaged rock mass.
	**Tunnel loading experiment** A scaled down experiment was conducted to load tunnel lining concrete to its final state. While oil jacks gave loading to the lining, three LEDSs were mounted to monitor deformation during the test.

Monitoring reinforced soil wall during road tunnel construction

An LEDS was installed between the reinforced soil wall and a steel column to ensure that the construction works nearby did not affect the reinforced ground. As this site was right in the middle of Tokyo in a heavily populated area with heavy traffic, the maximum care had to be paid to achieve safety throughout the construction just beneath the road.

Monitoring landside near a lake

An identified zone of landslide near a dam lake was monitored by an LEDS and a laser pointer. This was necessary to ensure safety during casting concrete for reinforcement piles to be constructed to stop landslide displacement.

Watching temporary structures during bridge construction

Several LEDSs were mounted on a temporary structure used during bridge construction. A cable suspended bridge was used as the temporary structure for which the safety monitoring was performed by using the LEDSs. The LEDSs were used to measure axial force of the main cables during construction.

Safety monitoring of a wood structure

Repairing and maintenance works had to be performed for one of the old facilities near a power generation plant. A wood frame that had to support a cable to be suspended over a distance of 400m was monitored by 4 LEDSs. A specially designed optional LED board was prepared so that a machine operator was able to have a good view at 4 LED units.

LEDS for rockbolts

The modified LEDS for rockbolts was developed and tested in a lab. In this example, three relative displacements were measured from one rockbolt and their colors were shown in the LED unit box outside the rock mass. Further cost reduction and simplification of the device is awaited for field application.

LEDS for ground anchors

The modified LEDS for ground anchors was developed and tested in a lab. Generally, estimation of axial force of a ground anchor requires use of an oil jack and several men, and it is a costly practice. Once the newly developed LEDS for a ground anchor is installed, its axial force in usual condition, or after heavy rain, earthquake, etc. can be simply visualized by the color of LED attached on its cap.

Table 2.3 Application of LEC

	**Visualizing pressure of fresh concrete for tunnel lining** A portion of a NATM tunnel had to be heavily reinforced in the concrete lining. To ensure and visualize how fresh concrete is poured into the steel form through re-bars reaching to far corners, LECs were used jointly with pressure sensors so that a confirmation could be visually identified when the fresh concrete reached the pre-installed pressure sensors at the far corners in the form.
	**Checking safety during tunneling under special conditions** A NATM tunnel had to be constructed with an overburden of only 30cm due to the constraints of the project. After the top thin layer was completed as a reinforced concrete structure sitting on reinforced ground, the tunnel was driven while allowing daily traffic above. Three displacement sensors were used with LECs to make sure that the traffic load during tunnel construction was within the expected range and the tunnel structure remained safe.
	**Checking axial forces in ground anchors** Some movement was observed on a slope near a highway construction site. To stop its movement, additional anchors were installed while the monitoring axial forces in the existing anchors.
	**Checking temperature and moisture** Temperature and moisture were visualized during a concrete curing process. To optimize moisture and temperature during the concrete aging process, LECs were used together with moisture and temperature sensors. Workers were able to use visualized information to control their work.
	**Checking acid content in underground water** Water quality can also be monitored by OSV. Injection for soil reinforcement uses materials with various chemical ingredients. A pH sensor can be connected to LEC to monitor and show the acid content of underground water.

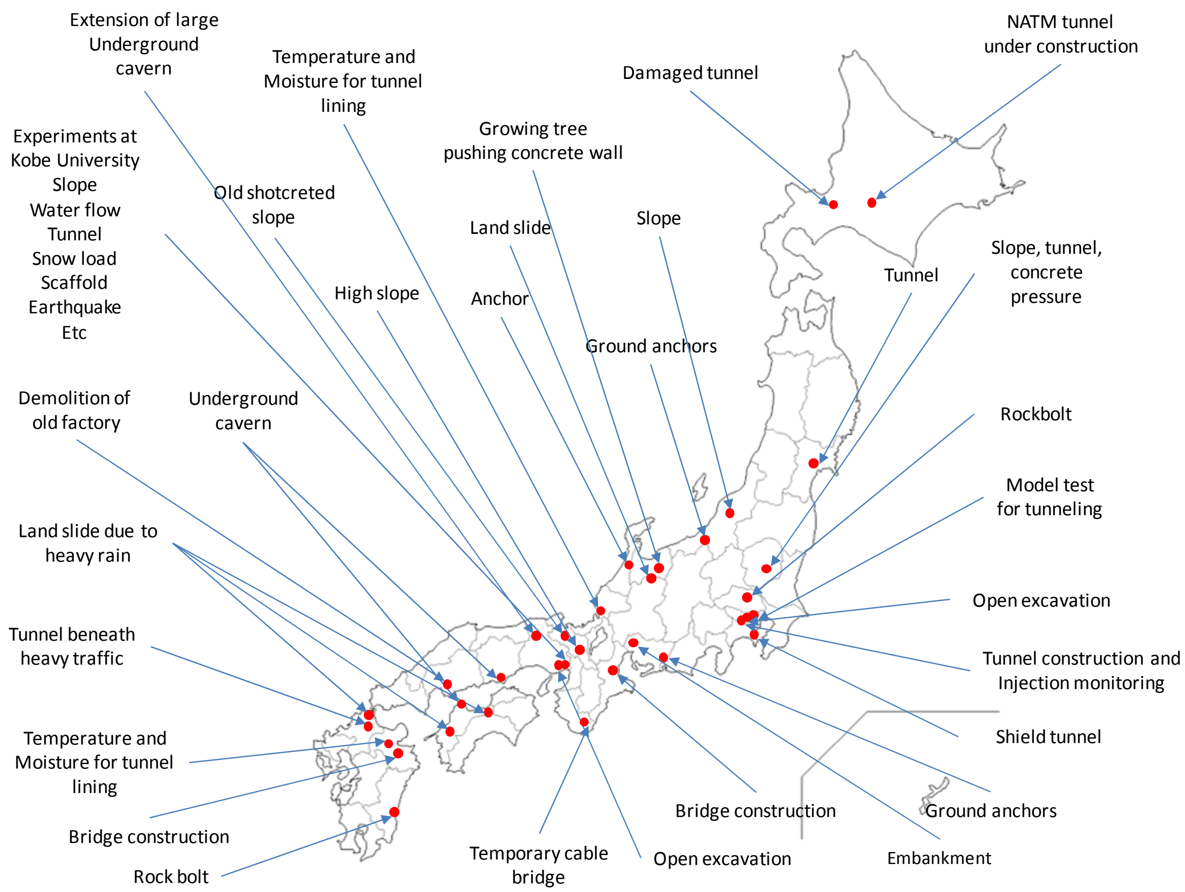


Figure 2.2 Locations of the laboratory experiments and field applications using light emitting sensors

Although the number of light emitting devices used in each of these cases is limited, its effectiveness of showing the measurement results in real-time has been confirmed in almost all the cases. By employing these sensors, it is expected that rational design of the monitoring scheme for DMRC sites would be possible. As far as the cost is concerned, most of the light emitting sensors available in Japan are still in their early stage of development and prices are rather high at this moment. However, they would be lowered as monitoring by using OSV becomes more popular in Japan and elsewhere. Inquiries will be conducted as to the past experiences and updated status of the device development from those companies involved in the OSV application in Japan.

Use of these new types of sensors requires an optimized solution with regards to 1) locations where the sensors are to be installed, 2) the number of sensors to be used, and 3) relationship between the color of LED and displacement, for example. Training is necessary for workers and citizens as to how they should react to each color in terms of safety control. Therefore, in addition to installing these light emitting devices, it becomes very important that the education program about safety under the umbrella of the OSV approach and an action manual be presented in the course of a successful execution of the project.

2.2 Current status of cameras with flash devices for DUST Monitoring

2.2.1 Current status of digital camera devices for DUST Monitoring

The dust that occurs in a construction site makes the site environment worse and can become the cause of worker's health problems. So, the ministry of health determined that it is necessary to measure dust concentration twice a month, and the dust measurement and management are important duties at the site. Now, in Japan, digital dust meters are generally used for dust measurement. This instrument uses light that is scattered by the dust and is highly accurate. However, it is very expensive and takes a long time to measure the concentration. Therefore, cheaper and easier dust measurement has been desired.

In this situation, cheaper and easier dust measurement compared with the existing one was proposed by a group associated with [Shinji] Yamaguchi University who are on this survey staff. This new method uses flash pictures with a digital camera. It produces results that have a high correlation with a digital dust indicator. Figure 2.3 shows the mechanism of dust monitoring. And in recent years, because of the performance improvement of mobile phone cameras, a method using mobile phone cameras has been introduced. The method using digital cameras is not so practical because it needs a computer to calculate the dust concentration from the image. Mobile phone cameras can do the process independently. So, it became possible to calculate the dust concentration soon after taking a picture. Figure 2.4 shows a dust mask.

Figure 2.3 Dust monitoring mechanism

Figure 2.4 Dust mask

2.2.2 Current status of mobile phone devices for DUST Monitoring

Shinji did the basic research in 2007, and made the world's first prototype of "the dust measurement by a mobile phone camera" in 2010.

Since the autumn of 2010, Shinji has conducted field trials and confirmed the correlation with the previous system.

There currently is a problem due to environmental differences. All of the construction sites the trials were carried out at were in a mountain tunnel where it was dark. In the current instance the construction site uses an open-cut method and the site is brighter than the mountain tunnel. Because this measurement uses the flash function of the camera, it is unsuitable to use in such a bright place. However, it is expected that this problem can be solved by shading the instrument from the sunlight.

Moreover, the designer and the administrator of the structure should determine the dust measuring place, how will they change the color of the panel associated with the dust concentration and what to do as countermeasures for the various users (for example: workers, residents, audience, general by passers). Workers should learn about the risk of dust and the meaning of the panel's color in order to take countermeasures based on the color of the panel. If workers find the dangerous situation, they have to report it to the administrator immediately. To achieve the full effect of the dust measurements, it needs not only high accuracy of dust measurement using mobile phone cameras, but also the development of a manual for users. Analysis of the arrangement and issues of the actual use of the systems should be done through interviews of the personnel at the construction sites where the dust measuring has been done.

Chapter 3 Study for OSV Monitoring

3.1 Site selection

The sites for the monitoring by OSV should be selected in such a way that the effectiveness of the monitoring by OSV will be evaluated properly, considering such factors as construction schedule, three dimensional spatial conditions with proper visibility of lights emitted from the sensors, and feasibility for conducting questionnaires with construction workers and citizens. In order to meet these requirements, the sites having the following characteristics are recommended as candidate sites.

- ✓ In general, independent standard monitoring (subsidence monitoring by level, and position surveys using light waves) should be performed, therefore the results could be compared with those obtained by the monitoring by OSV.
- ✓ For the case of open excavations with retaining walls, the depth of excavation should greater than 10m, therefore, there could be a possibility for the wall to displace posing danger to workers and potential damage to buildings nearby.

Considering the conditions listed above and the actual construction phase, the following two sites (see Figure 3.1) were selected as the application sites of the monitoring by OSV.

1) Open excavation with retaining wall construction site and neighboring buildings at Cricket Stadium Station (main monitoring site)
2) Open excavation with retaining wall construction site at Central college Station (sub monitoring site)

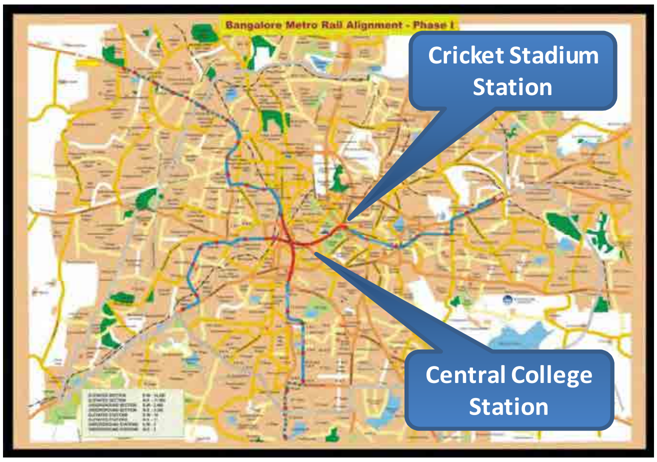


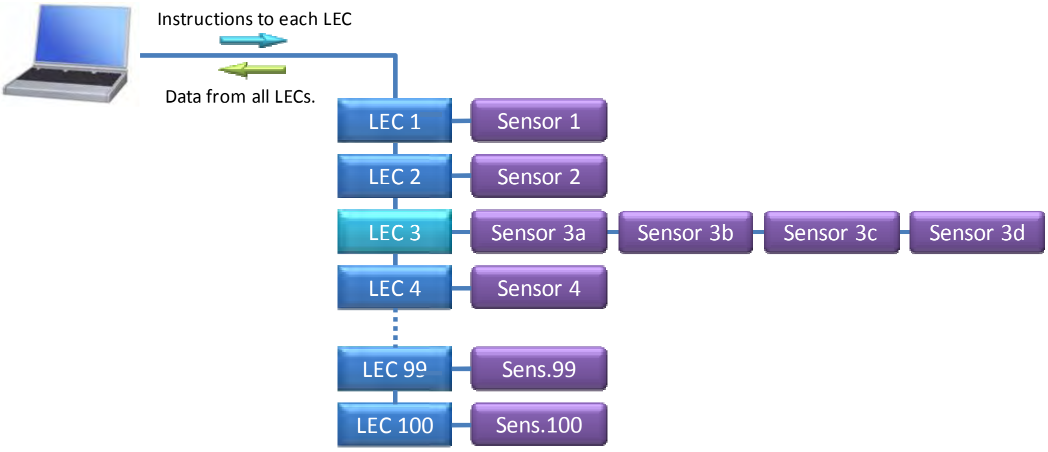
Figure 3.1 Route map for Bangalore Metro Phase 1

3.2 Specifications of the light emitting sensors used in this project

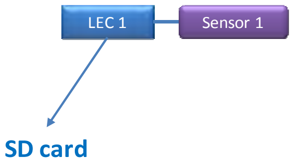
Light Emitting Converters (LEC) with arbitrary sensors

A Light Emitting Converter (LEC for short) is a compact data converter that is capable of 1) converting analog signals from an arbitrary sensor connected to it into digital signals, and 2) showing it by the color of LED based on a pre-defined color scheme. A sensor to be connected to an LEC can be chosen from a family of available sensors for measurement of deformation, strain, inclination, pressure, temperature, moisture, etc. The color scheme can be defined for each LEC-sensor pair by the control software installed on a PC. For a special case, more than one sensor can be connected to an LEC which has a specific program to handle multiple sensors. For the case of inclinometers, an LEC could be connected to, for example, four inclination sensors, read data from those sensors, and identify a maximum datum to show the color of light. Up to 100 pairs of LEC and an arbitrary sensor can be connected to one personal computer. Each pair is given its own ID number and the data can be recorded on the hard disk with specified time intervals. For a special case, a stand-alone layout of using just one pair of LEC and sensor is also possible. In this case, data are recorded on an SD card and could be retrieved on demand.

(a) Light Emitting Converter



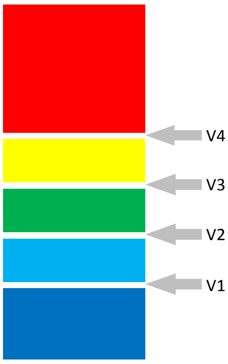
(b) Standard layout for connecting LECs and sensors



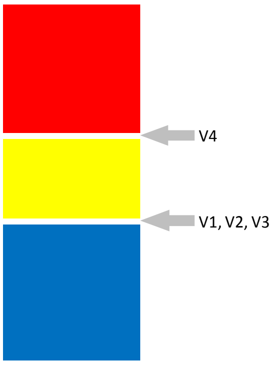
(c) Stand-alone layout with SD card

Figure 3.2 Light Emitting Converter (LEC) and its combined use with arbitrary sensors

Five colors can be chosen from the available seven colors. Figure 3.3 shows a standard color selection using 5 colors whereby blue represents “safe” and red “dangerous”. In order to use five colors, four threshold values, V1 to V4 must be specified in the control software. By setting those values as shown in Figure 3.3(b), a 5 color scheme can be displayed as a 3 color scheme.



(a) Standard 5 color scheme



(b) A variation

Figure 3.3 Specification of various color schemes

In this project, the LEC is used for axial force, inclination and anchor force sensors. Their specifications are given in Table 3.1.

Table 3.1 Sensors to be used with LEC

Type	Photo	Specification
Axial force sensor		Measuring range : ±1500×10^{-6} Temperature range : -10 to 80 degrees Size : φ22 ×L104mm Weight : 0.2kgf Maker : TOA Elmes (Japan)
Tilt Meter		Measuring range : ±1 degree (60 arc minutes) Liner range : ±0.5 degrees (30 arc minutes) Resolution : 1 arc second Repeatability : ±3 arc seconds Temperature range : -20 to 55 degrees Maker : Encardio-Rite (India)
Inclination sensor		Measuring range : ±15 degrees, ±30 degrees Accuracy : 0.1 % of fs Temperature range : -20 to 80 degrees Maker : Encardio-Rite (India)
Center hole load cell		Capacity : 1000kN Over range capacity : 150% Temperature range : -10 to 55 degrees Size : φ225×H40mm (except connecting part) Weight : 8.0kgf Maker : Encardio-Rite (India)

3.3 Principles for color schemes

Considering the time of installation of light emitting devices with respect to construction stage, there could be several different schemes for setting colors. Figure 3.4 shows color scheme 1, which is for monitoring TOTAL quantity of data, provided that light emitting devices are installed before construction starts. The first three colors; namely, blue, cyan and green are associated with the first, second and third 25% of MAX (the expected maximum design value of the data). The fourth color, yellow, is associated with the data band of 75% up to 110% of MAX. The fifth color, red, is assigned for data beyond 110% of MAX.

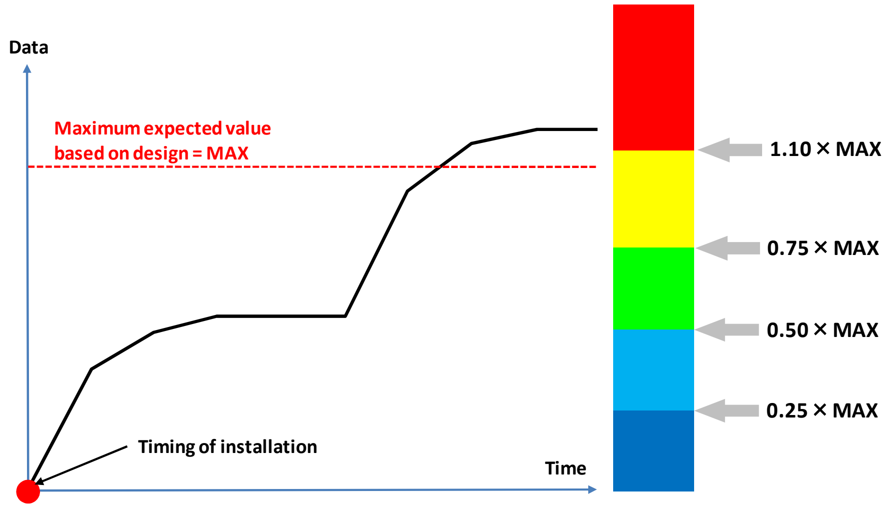


Figure 3.4 Color scheme 1 for monitoring TOTAL quantity

Figure 3.5 shows color scheme 2 to be used when light emitting devices are installed in the middle of construction. Since the measurement misses the un-monitored portion of data D0, the indices specified in the control software have to be set with care.

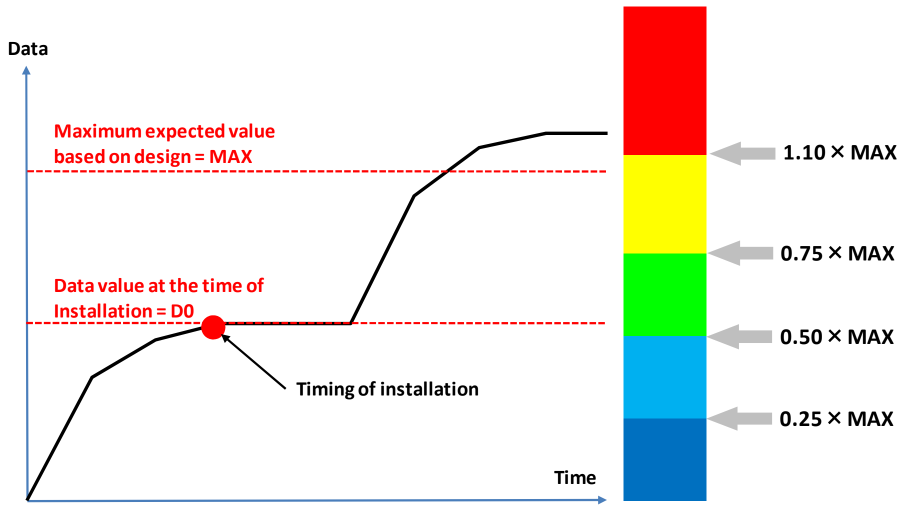


Figure 3.5 Color scheme 2 for monitoring TOTAL quantity with delayed device installation

Figure 3.6 shows color scheme 3 which is for monitoring INCREMENTAL quantities provided that the devices are installed in the middle of construction. Assuming that D0 (missed quantity) and MAX are both known, five colors could be assigned to cover the data range of MAX-I=(MAX-D0) and beyond.

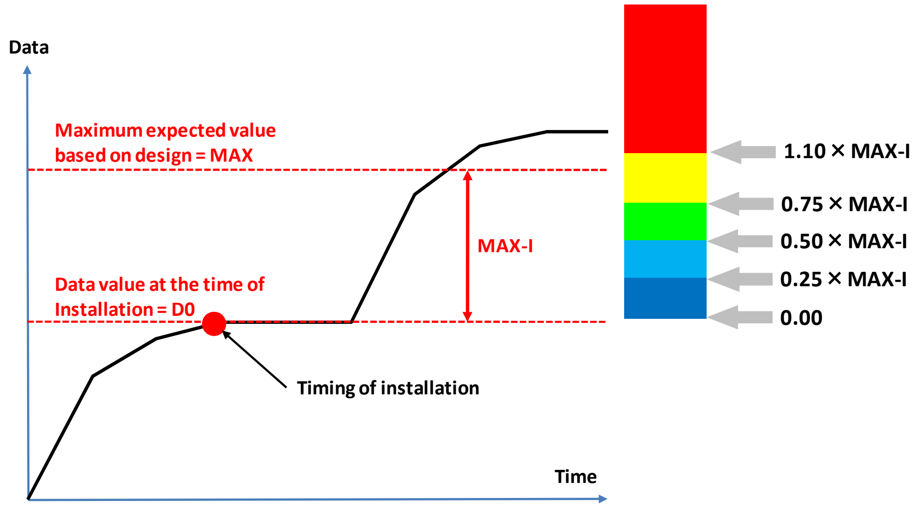


Figure 3.6 Color scheme 3 for monitoring INCREMENTAL quantity

Figure 3.7 shows color scheme 4 which is for monitoring a STABLE STATE. There could be a situation in which all stages of construction are finished and there should be no more change in monitored quantity. However, if there is a need to confirm that there is NO change occurring, devices could be installed at a delayed stage. Preferred colors and their ranges can be defined by the choice of the user.

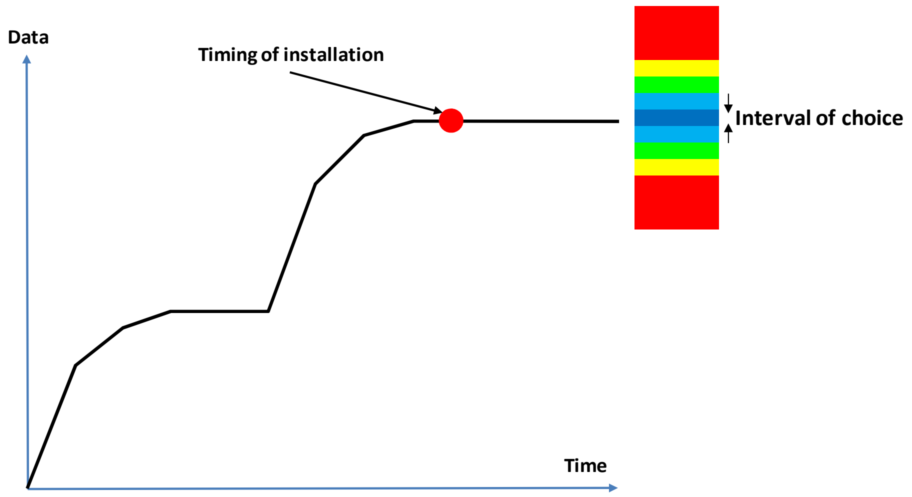


Figure 3.7 Color scheme 4 for monitoring STABLE-STATE

3.4 OSV monitoring at Cricket Stadium station

3.4.1 Site characteristics and color scheme

Figure 3.8 shows an areal view of the Cricket Stadium station. Maximum excavation depth for this site is 14m and there is a four story building (HAL building) on the north side.

Figure 3.8 Areal view of Cricket Stadium station

Figure 3.9 illustrates the key points for OSV monitoring. Key factors at this site are;

1) axial forces in strut beams,
2) inclination of Scan pile,
3) inclination of ground behind retaining wall,
4) inclination of HAL and BSNL buildings and
5) axial force in ground anchors.

Figure 3.10 shows the detailed locations for the instruments used for OSV monitoring. Table 3.2 summarizes the sensors used and associated color schemes.

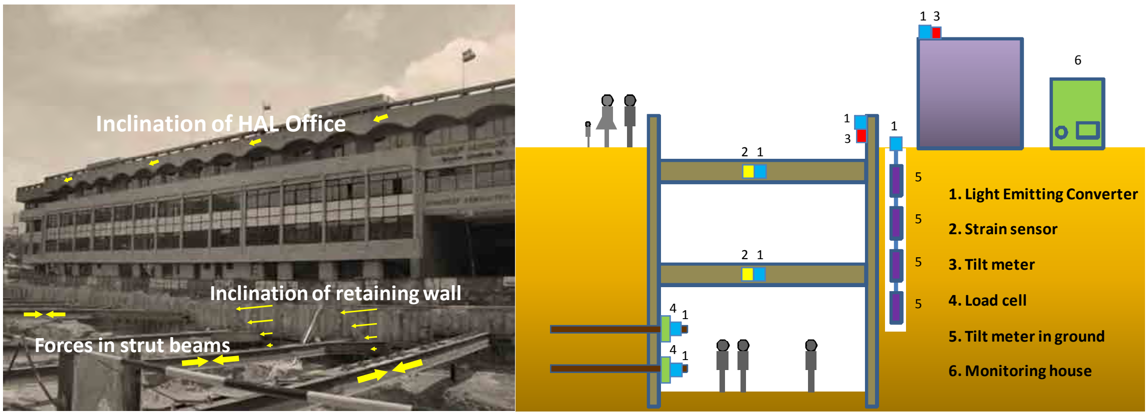


Figure 3.9 Key points for OSV monitoring

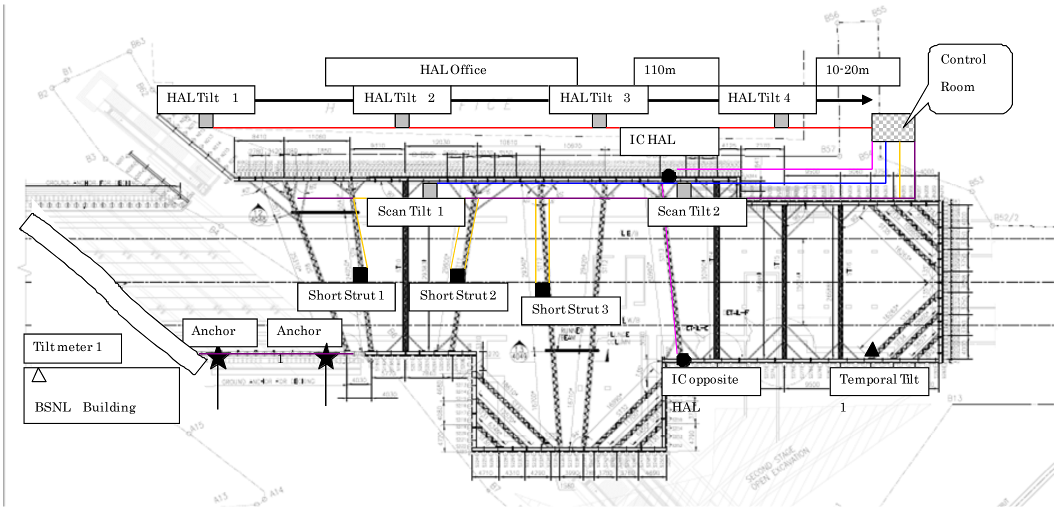
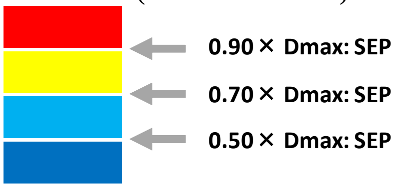
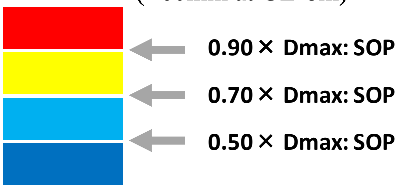
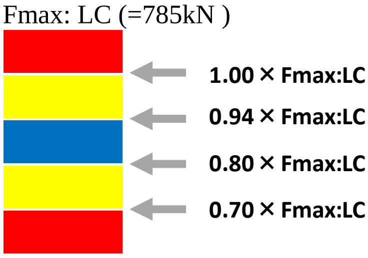


Figure 3.10 Plan view of installation of OSV devices

Table 3.2 List of light emitting sensors and provisional color scheme

Target	Sensors	Color scheme
Short strut 1 Short strut 2 Short strut 3	LEC +Axial force sensor	Maximum allowable axial force for beam strut Fmax: BS (=1632kN for short strut 1) (=1840kN for short strut 2) (=2052kN for short strut 3) 0.45 × Fmax:BS 0.35 × Fmax:BS 0.25 × Fmax:BS
Scan Tilt 1 Scan Tilt 2	LEC +Tilt meter	Maximum allowable inclination for secant pile Imax: SP (=10/1000 or 0.573 degrees) 0.90 × Imax:SP 0.70 × Imax:SP 0.50 × Imax:SP
HAL Tile 1 HAL Tile 2 HAL Tile 3 HAL Tile 4	LEC +Tilt meter	Maximum allowable inclination for building establishment Imax: HAL (=18/1000 or 1.031degrees) 0.90 × Imax: HAL 0.70 × Imax: HAL 0.50 × Imax: HAL
BSNL Tilt 1 BSNL Tilt 2	LEC + Tilt meter	Maximum allowable inclination for building establishment Imax: BSNL (=10/1000 or 0.573degrees) 0.90 × Imax:BSNL 0.70 × Imax:BSNL 0.50 × Imax:BSNL

IC HAL	LEC(special program) +Multiple inclination sensors	Maximum allowable horizontal deflection for secant pile Dmax: SEP (=16mm at GL-1m) (=18mm at GL-3m) (=20mm at GL-5m) (=20mm at GL-7m) 
IC Opposite HAL	LEC(special program) +Multiple inclination sensors	Maximum allowable horizontal deflection for soldier pile Dmax: SOP (=28mm at GL-2m) (=40mm at GL-4m) (=50mm at GL-6m) (=60mm at GL-8m) 
Anchor 1 Anchor 2 Anchor 3	LEC +Center hole load cell	Maximum allowable axial force for anchor Fmax: LC (=785kN) 

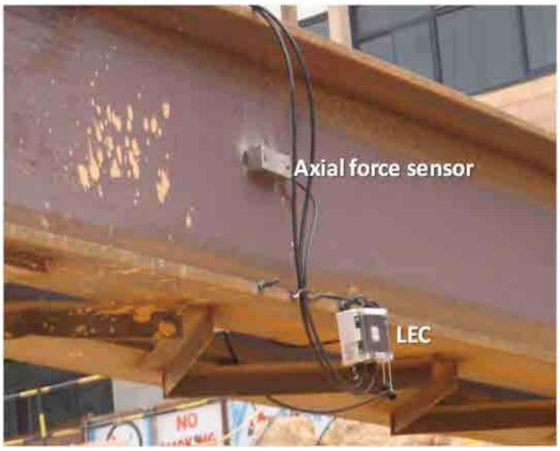
Background information used to determine the provisional color schemes are as follows.

Axial forces in strut beams

Figure 3.11 shows the site and devices that were installed for axial force monitoring. The maximum axial forces or inclination values presumed are indicated in the table. At the beginning of the project, temperature effect was not considered.

(a) Three strut beams for which axial forces are monitored

(b) Axial force sensor welded to a beam



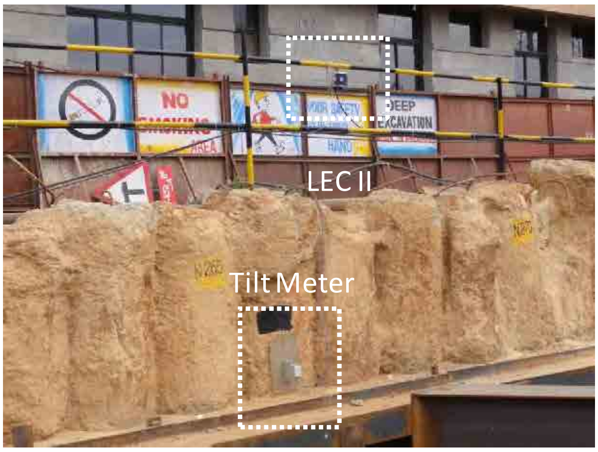
(c) Axial force sensor connected to LEC

Figure 3.11 Installation of axial force sensor

<u>Inclination of Scan pile</u>

Figure 3.12 shows an LEC installed to monitor inclination of a top part of Scan pile.

(a) Scan pile and a tilt meter



(b) Tilt Meter connected to LEC

Figure 3.12 LEC installed for a Scan pile

Inclination of HAL and BSNL buildings

Figure 3.13 shows inclination sensors installed on the roof top of the HAL building. Inclination sensors were anchored to concrete, and then connected to LEC so that workers and the public could observe them. Additional LED ropes were also used to enhance the visual effect.

(a) Locations (blue circles) of tilt meters

(b) Tilt meter supplied by Encardio-Rite (India)

(c) LEC installation for workers

(d) Nightly view of HAL building and the excavation site

Figure 3.13 Installation of tilt meters on HAL building

Figure 3.14 shows the location and inclination sensor installed on the roof top of BSNL building. This brick building is older than 100 years and has very small tolerance in terms of inclination. The LEC used here is a stand-alone type and data retrieval was done manually using an SD card mounted on the LEC.

(a) BSNL building on the south-west corner of the excavation site

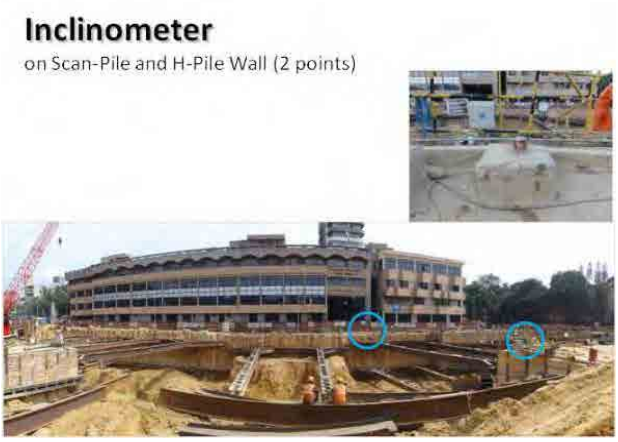
(b) BSNL building and a stand-alone LEC set up on its roof top

(c) Night view of BSNL building

Figure 3.14 Installation of tilt meters on BSNL building

Inclination of ground behind retaining wall,

Figure 3.15 shows the locations and LEC installed for monitoring inclination behind a retaining wall. Four inclination sensors were installed in one casing pipe. Data from those sensors were taken into the LEC through a switch box, therefore the LEC was able to read data from more than one sensors. The maximum value from those sensors was compared with the threshold value to determine the color of the LED.



(a) Two locations (in blue circles) where multiple inclination sensors were installed

(b) Top of a casing pipe for inclination sensors

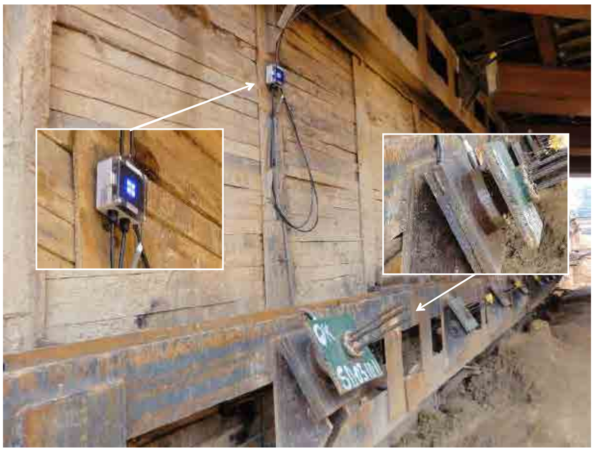
(c) LEC with specially designed program

Figure 3.15 LEC installed to monitor inclination behind a retaining wall

Axial force of ground anchors,

Figure 3.16 shows the location and LEC installed for monitoring anchor forces. Center hole load cells were used and the LEC was placed a short distance from the load cell in a better position for workers to watch them.

(a) Location for anchor force monitoring

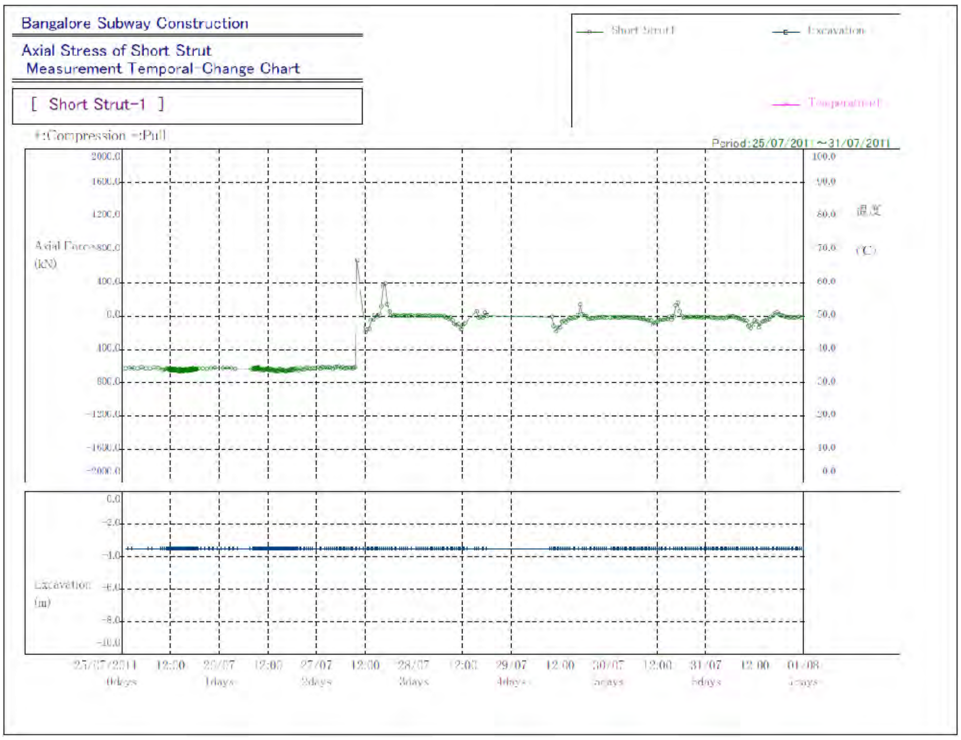


(b) The anchor with a centre hole load cell

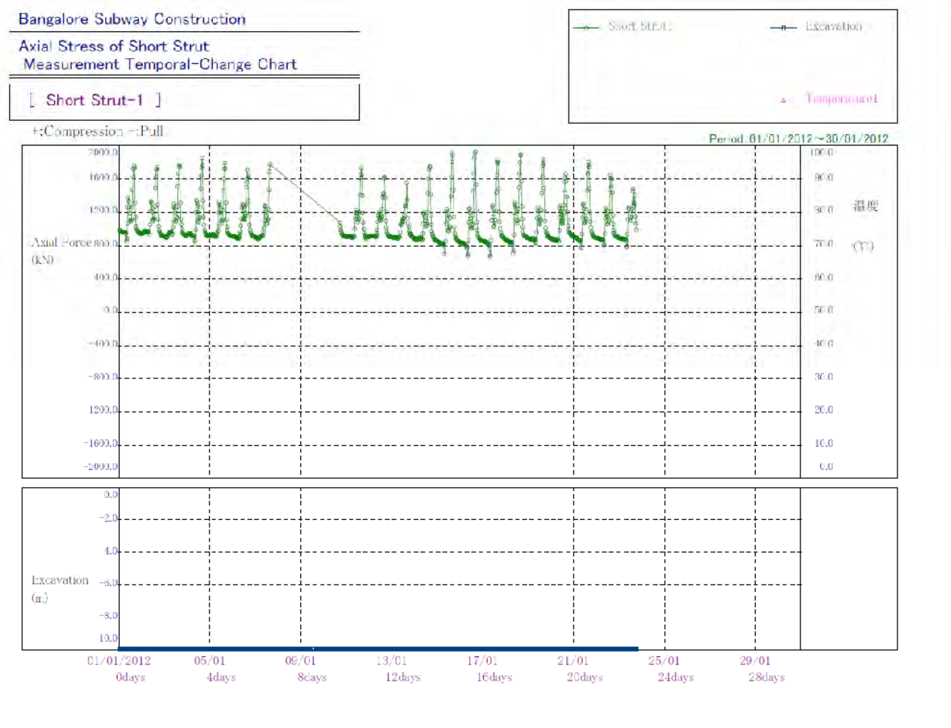
Figure 3.16 LEC installed for monitoring axial force of anchors

3.4.2 Measurement result

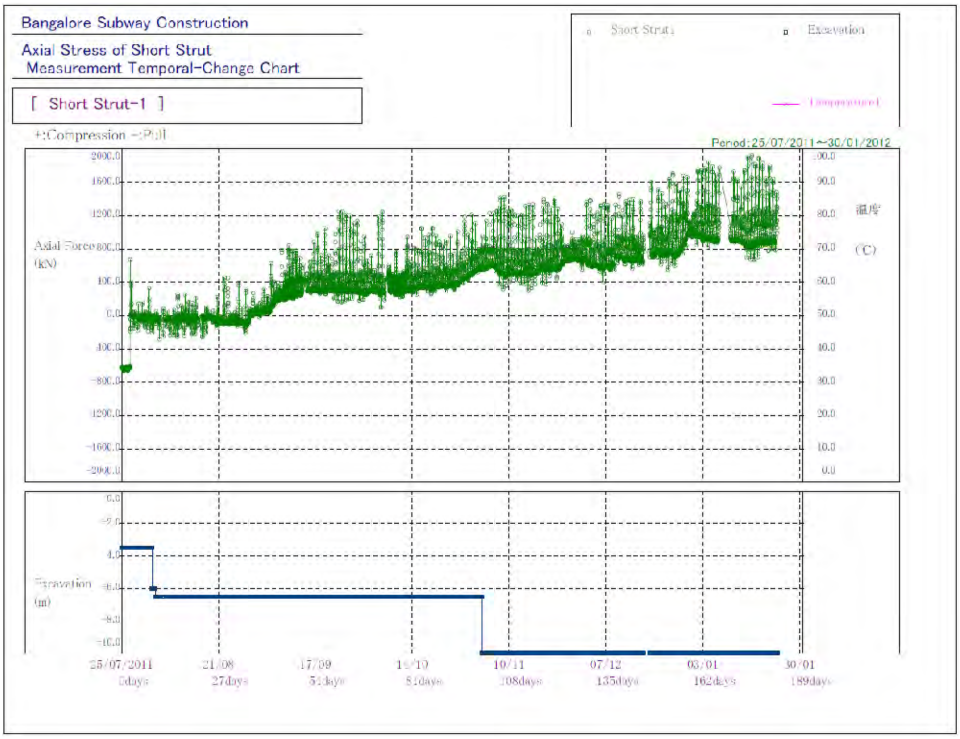
<u>**Axial forces in strut beams**</u>



(a) Strut 1, first week



(b) Strut 1, final week



(c) Strut 1, 6 months

Figure 3.17 Measurement results for Strut 1

General trend

Figure 3.17 shows the measured axial forces for Strut 1 for the period of the first one week, final one month and the entire project period of six months. The initial part of the record in Figure 3.17 (a) can be neglected and the actual record started at 12:00 of July 27th, 2011. As can be seen throughout the project period, a general trend in the axial force reflects the progress of excavation, where an approximate increase of 1000kN is recorded. This is calculated based on the value of axial force at the lowest temperature of any given day. Daily fluctuation of the axial force in a day varies, but its magnitude is considerably large. In the final month of the period, the axial force varied between 600kN in the morning to 1900kN in the mid day, approximately.

Temperature effect

This daily fluctuation due to temperature caused confusion associated with the definition of the threshold values and colors of light. The axial force sensor used in the Bangalore project was made in such a way that the temperature effect was automatically cancelled because a pair of interactive gauges was installed (one is free to deform and the other strains exactly as the main beam), as shown in Figure 3.18. That is that if the sensor is attached to a steel member that expands due to temperature increase and the member is free to deform, the sensor output becomes zero while strain increases. But in a real situation, the Strut 1 is fixed at both ends, therefore it is NOT free to deform as temperature increases, therefore building up the force in compression at mid day.

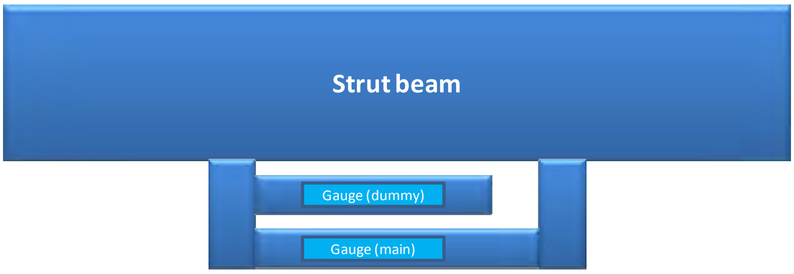


Figure 3.18 Fundamental structure of an axial force sensor with automatic temperature compensation

Average temperature difference on the surface of a strut beam in a day in the monitoring period is believed to be around 15 to 30 degrees. By assuming this, the expected increase in compressive axial force in a strut beam can be calculated as shown in Figure 3.19.

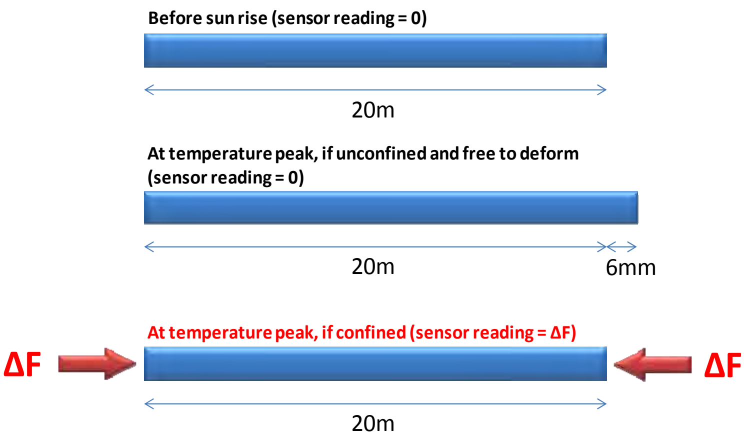


Figure 3.19 Mechanism of an increase in compressive force due to temperature fluctuation

For a beam with a length of 20m, an increase in temperature of 15 degrees would lead to elongation of the beam by as much as 6mm. If this is not allowed due to fixed boundary conditions, the compressive force in the beam goes up by as much as 982kN, using the parameters shown in Table 3.3.

Table 3.3 Parameters required to calculate temperature effect on axial force

Parameters	Value
Linear expansion coefficient due to temperature	$11.05*10^{-6}$/degree
Temperature change during a day	15 degrees
Strut length	30m
Young’s modulus	2100000kgf/cm^2
Stress increment provided that the strut elongation is not allowed	315kgf/cm^2
Total cross section area of the strut	318cm^2
Increase in strut force due to temperature	982kN

Threshold values versus temperature effects

When the initial set of values was determined for threshold values, temperature effect was not considered. However, the actual fluctuation of axial force due to temperature was quite large such that it was in many cases larger than the increase due purely to the effect of excavation. As this is illustrated in Figure 3.20, the initial assumption of axial force history was represented by the blue line for which the color scheme on the right hand side was assigned. The actual change in the axial force was represented by green lines so that color of the LED would have to change several times every day.

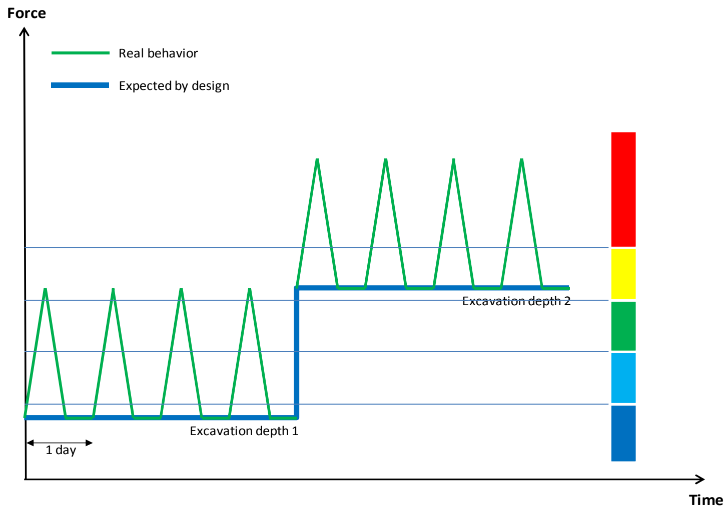


Figure 3.20 Assumption versus reality with respect to temperature effect on axial force

Figure 3.21 LEC showing *Red* due to temperature effect

To overcome the frequent color change of LEC due to temperature, the threshold value between yellow and red was modified by raising it manually during a particular period everyday as shown in Figure 3.22. Referring to the previous results of each strut, timing and the temporal threshold values were determined for short strut 1 and 2 as shown in Table 3.4.

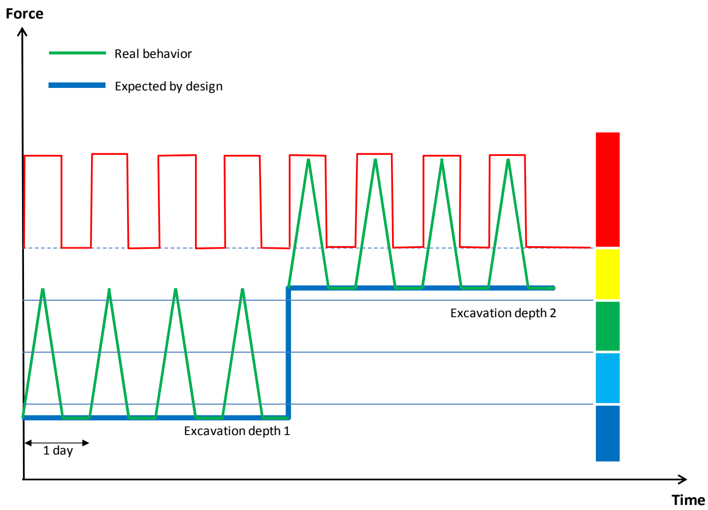


Figure 3.22 Temporal threshold value between yellow and red

Table 3.4 Temporal threshold value between yellow and red

	Term	Temporal value
Short strut 1	14:00 to 17:00	1,000kN
Short strut 2	8:00 to 12:00	1,200kN

Afterwards, actual axial forces considered in design of short strut 1 and 2 were recalculated by the design team including the effect of temperature as shown in Figure. 3.23. According to these calculations, the LEC color scheme for the axial force sensors was also reviewed as below.

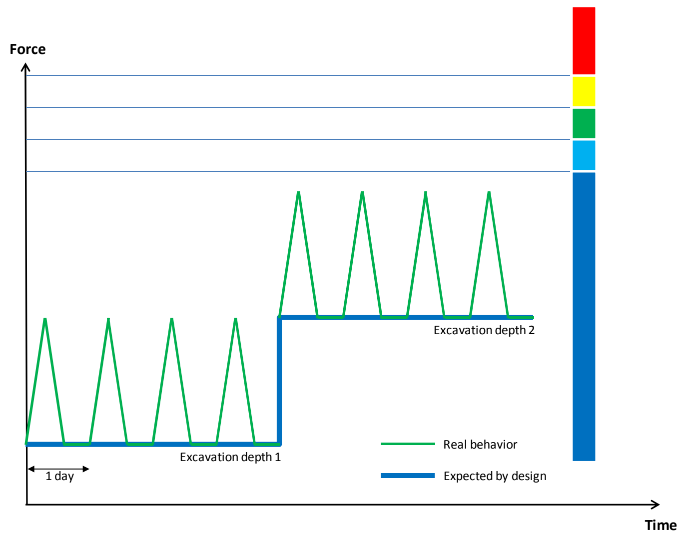
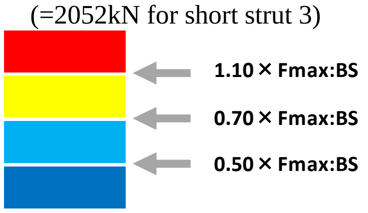


Figure 3.23 Modified threshold values

Table 3.5 Revised color scheme for LEC and axial force sensor

Target	Sensors	Color scheme
Short strut 1 Short strut 2 Short strut 3	LEC +Axial force sensor	Maximum allowable axial force for beam strut Fmax: BS (=1811kN for short strut 1) (=2018kN for short strut 2) (=2052kN for short strut 3) 

Having identified the reason for frequent color change over a day, the arrangement for threshold values was modified by raising their values so that the temperature effect is not reflected in the daily color change. This modification was found to be effective for the remaining period of the project.

Axial forces for other strut beams

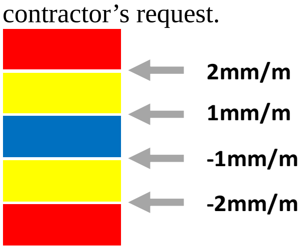
Axial forces for other strut beams behaved in a similar fashion to those for Strut 1. The detailed records are given in the Appendix.

Moving sensors to more troubled locations

In the course of the monitoring, some unexpected problems were encountered in areas where the OSV monitoring was not initially planned. An unstable portion of the retaining wall on the south side of Cricket Stadium station was found where loss of soil was found behind the wall. It was decided that one of the tilt sensors on the roof top of BSNL building should be moved to this trouble location to watch while remedial measures were taken as shown in Figure 3.24.

Figure 3.24 Loss of soil behind the wall on the south side of Cricket Stadium station

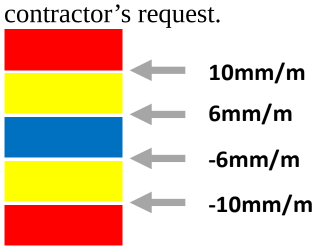
Table 3.6 Color scheme for the LEC and Tilt meter moved to the soldier pile at the Cricket Stadium site

Target	Sensors	Color scheme
Soldier pile	LEC +Tilt Meter	Maximum allowable inclination was determined by the contractor’s request. 

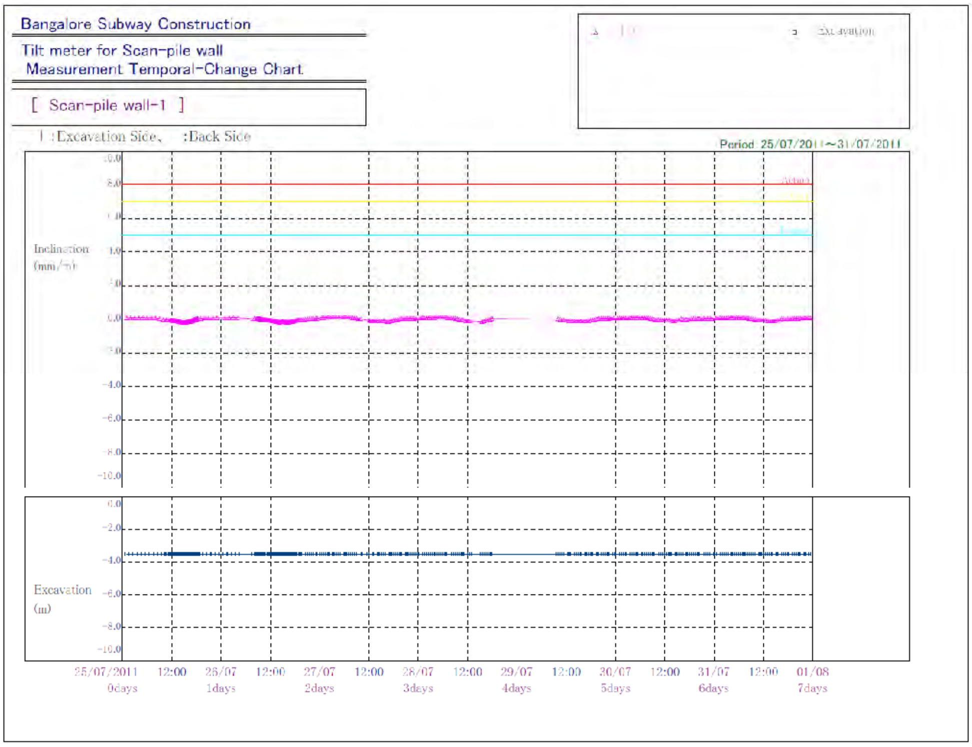
This tilt sensor with LEC was again moved to another troubled location in the Central College station, where a very large block of rock was found in an unstable position behind the retaining wall. Some loss of soil was also found as shown in Figure 3.25.

Figure 3.25 Trouble location in Central College station

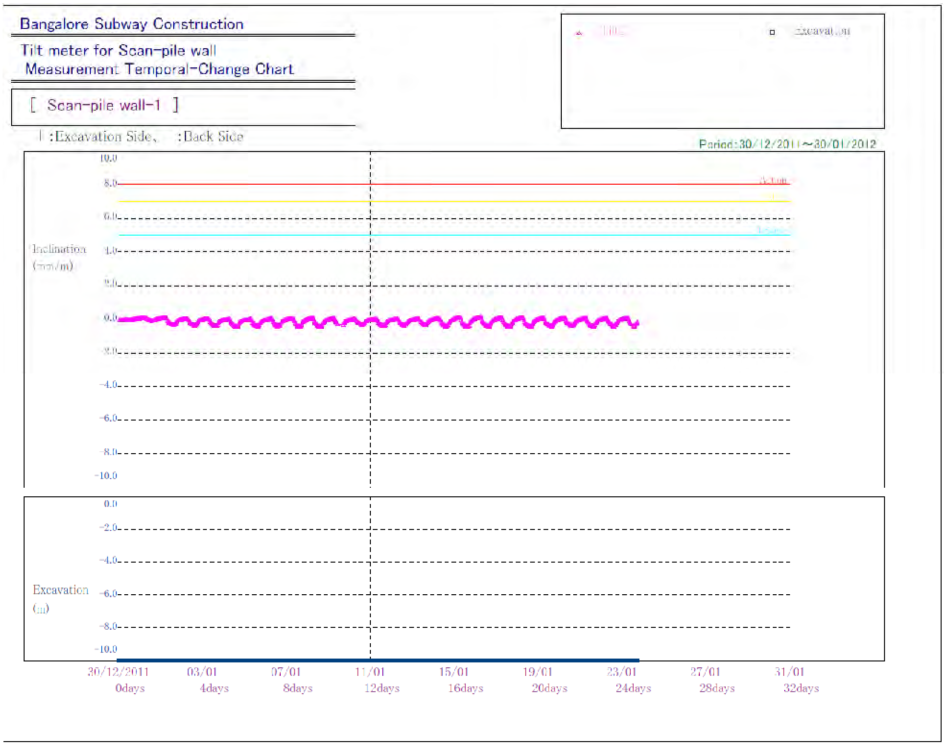
Table 3.7 Color scheme for LEC and Tilt meter moved to soldier pile at the Central College site

Target	Sensors	Color scheme
Soldier pile	LEC +Tilt Meter	Maximum allowable inclination was determined by the contractor's request. 

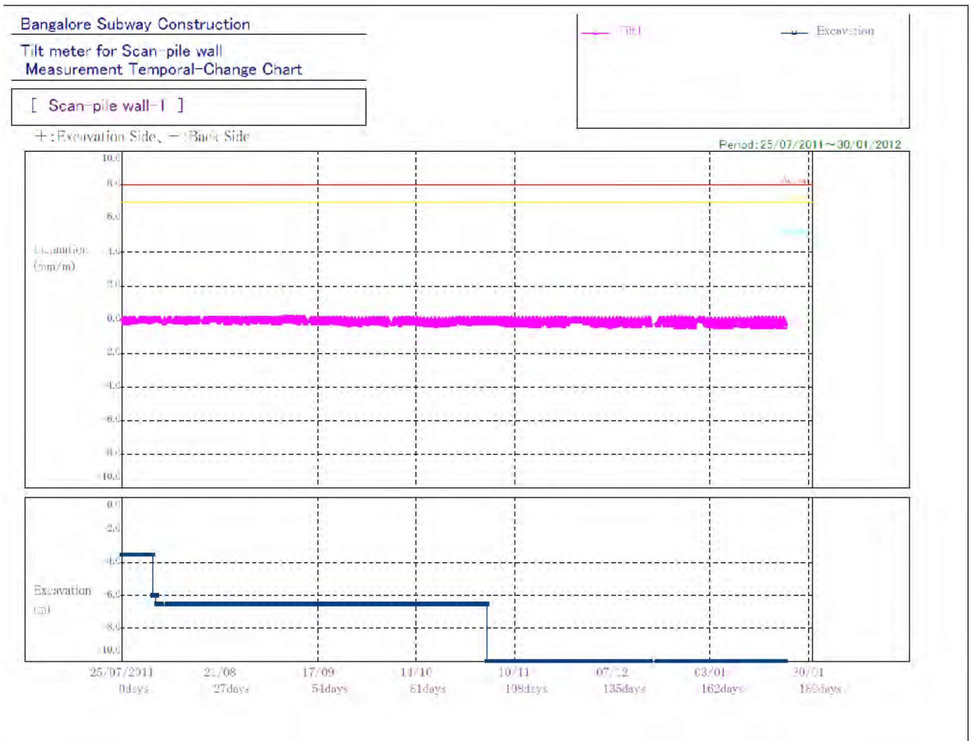
Inclination of Scan pile



(a) First one week



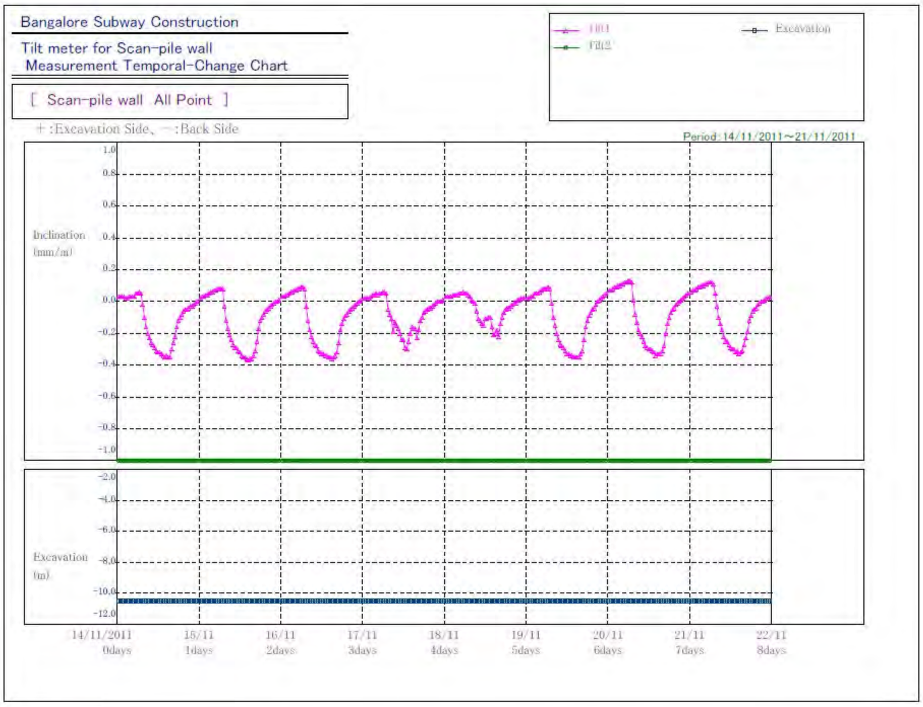
(b) Last month



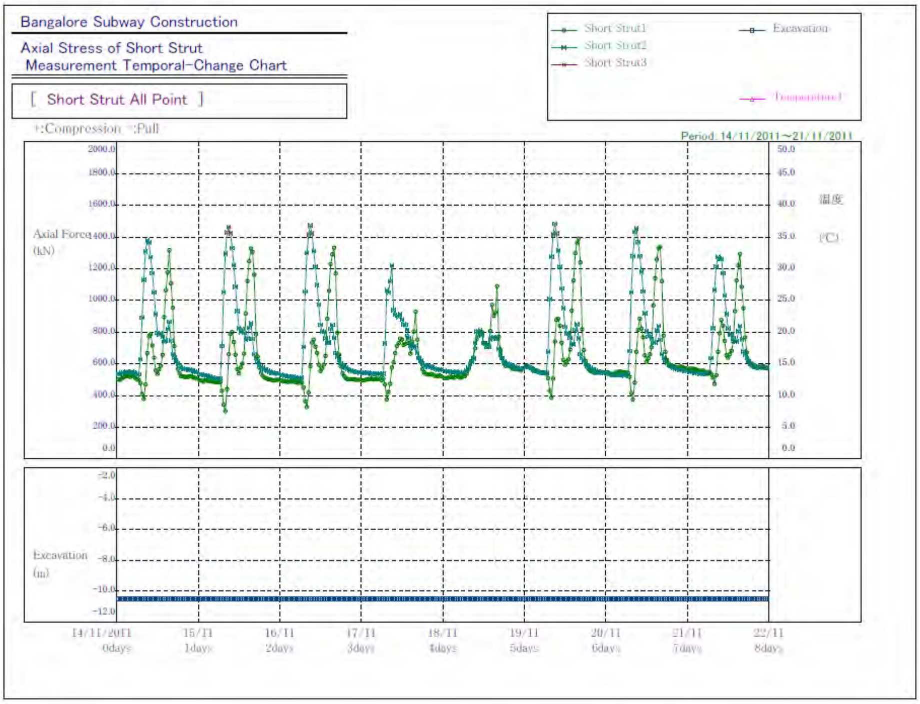
(c) Six months

Figure 3.26　Measured results for the inclination of Scan pile 1

Figure 3.26 shows the measurement results for the inclination sensor installed at the top of Scan pile 1. As it is obvious, the inclination for this Scan pile is very small throughout the period of the project. This indicates that the stiffness of the retaining wall is satisfactory to hold the forces generated by the strut beams.



(a) Scan pile



(b) Strut

Figure 3.27 Relationship between the behaviors of Strut 1 and Scan pile inclination 1

However, it is also observed as shown in Figure 3.27 that the strut beams trying to expand due to temperature effect everyday seem to be pushing the retaining wall. The figures show clearly that the Scan pile is pushed outward while the axial force builds up at mid day due to a temperature increase. It should be noted though that the magnitude of this outward inclination is small enough so that its influence on stability of the wall and HAL building is negligible.

Inclination of ground behind retaining wall

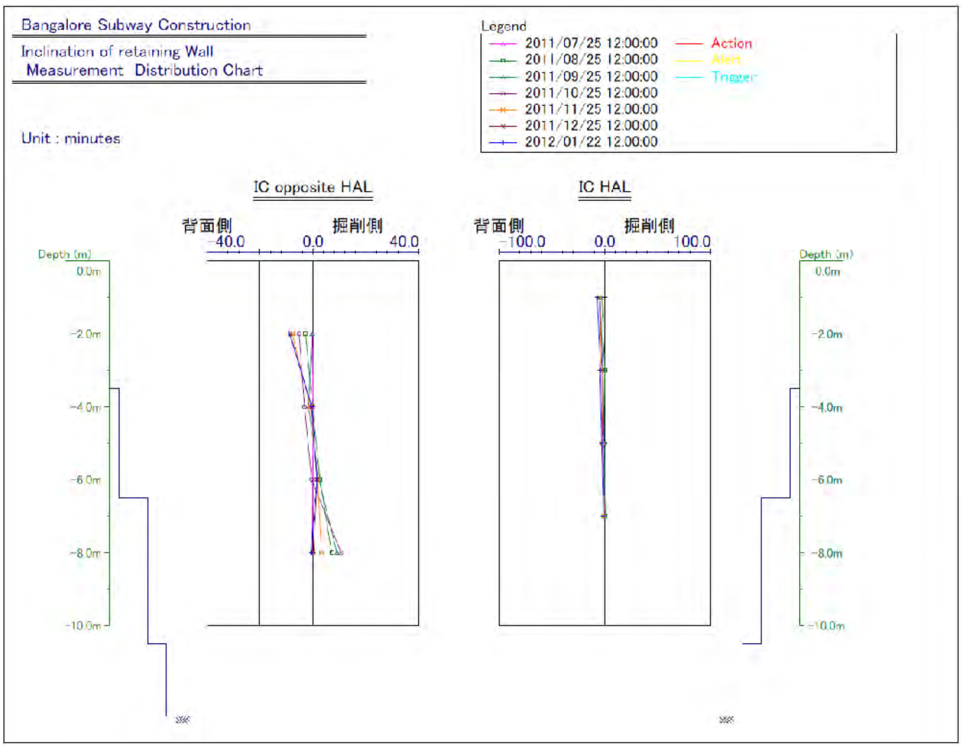


Figure 3.28 Inclination of ground behind retaining walls

Figure 3.28 shows the measurement results of ground inclination behind the retaining walls. As for the HAL side (north side of the excavation), it is observed that the retaining wall is pushed outward due to cyclic loading from strut beams due to temperature changes, though its magnitude is very small. This trend is also found on the opposite side (south side) where the magnitude of inclination is fairly large compared to that on the north side. Since the stiffness of the walls on both sides is supposed to be the same, the difference in the magnitude of inclination may be attributed to the fact that there is the four story HAL building on the north side, whereas there is nothing on the south side. This trend is illustrated in Figure 3.29.

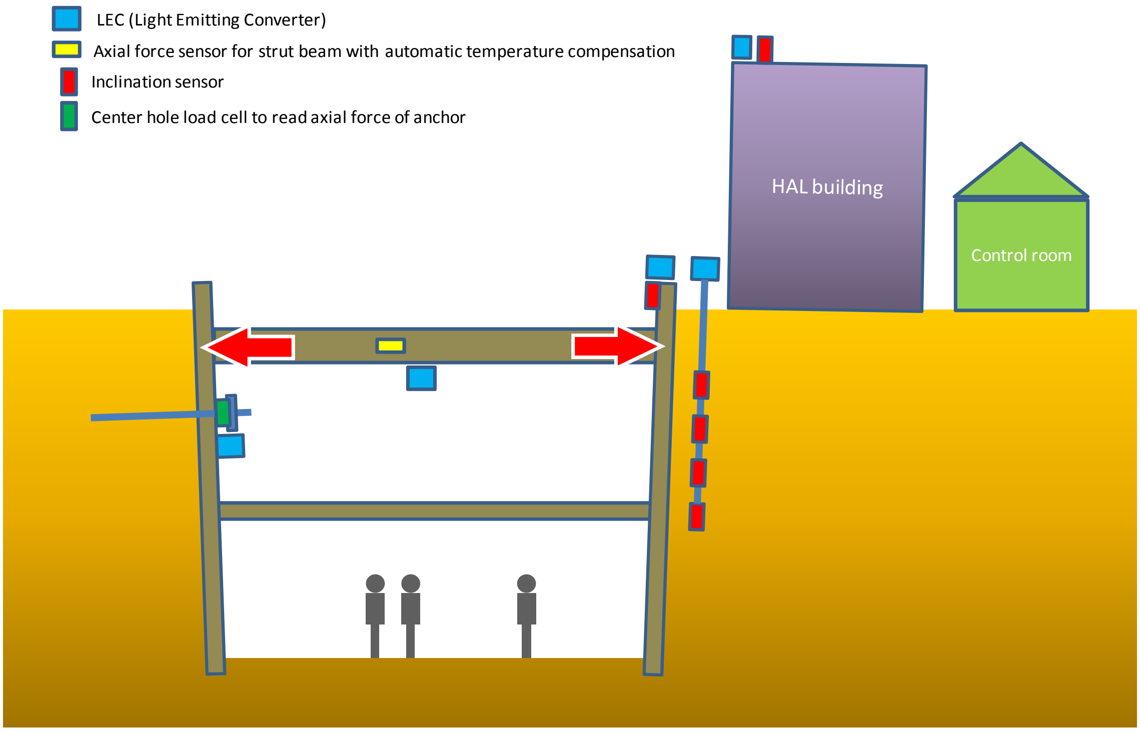
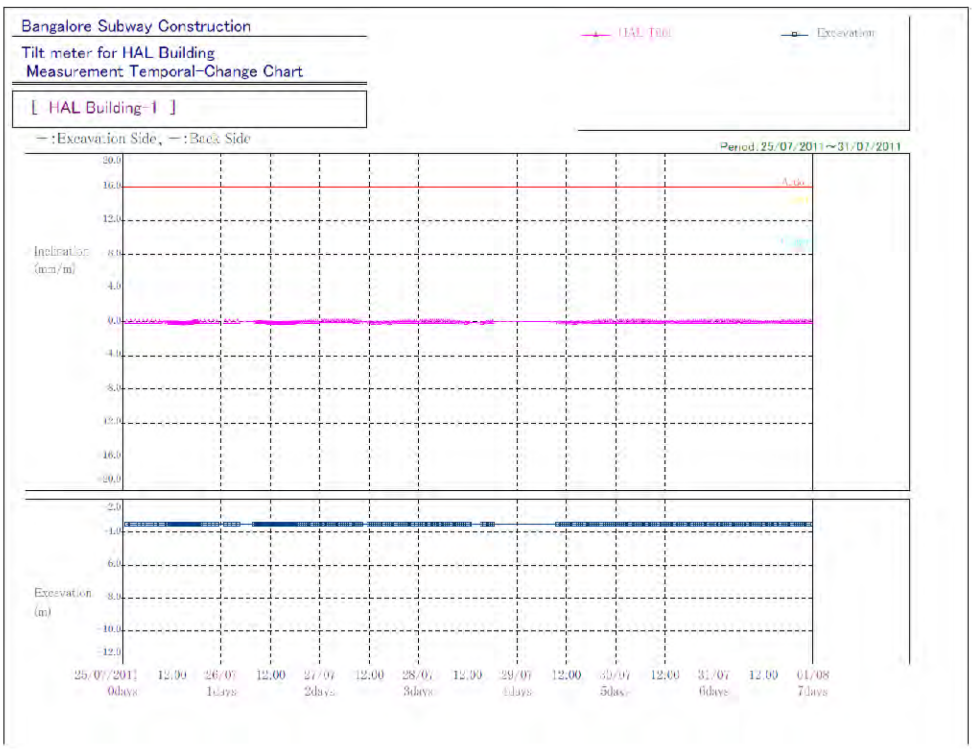
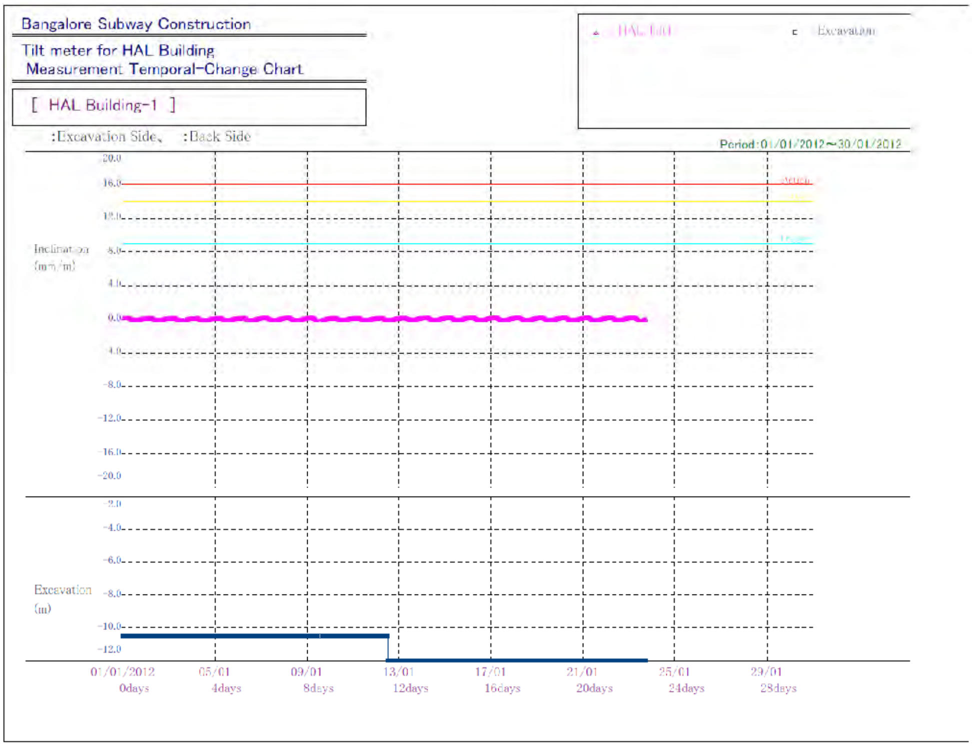


Figure 3.29 General trend of inclination of the retain walls. Note that the actual behavior is exaggerated in this illustration.

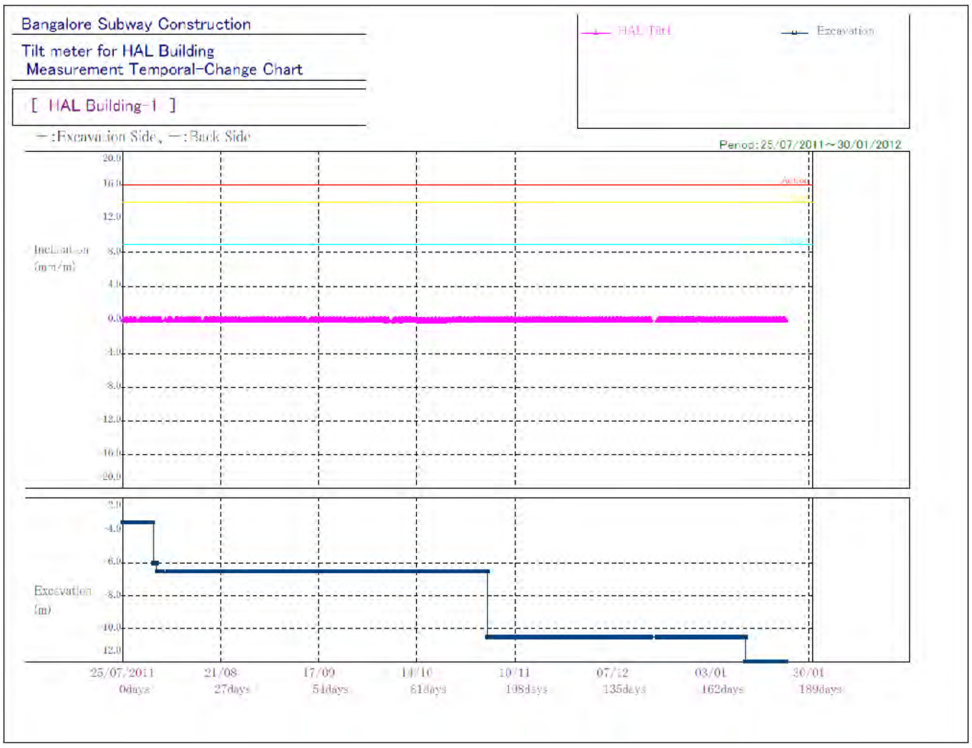
Inclination of HAL and BSNL buildings



(a) First week



(b) Final month

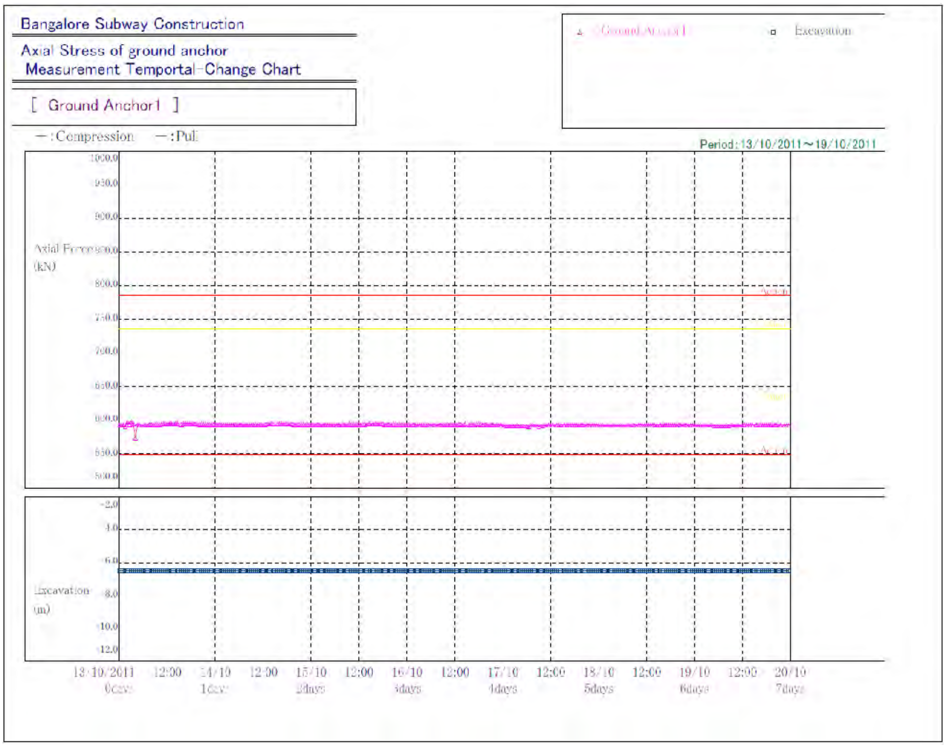


(c) Six months

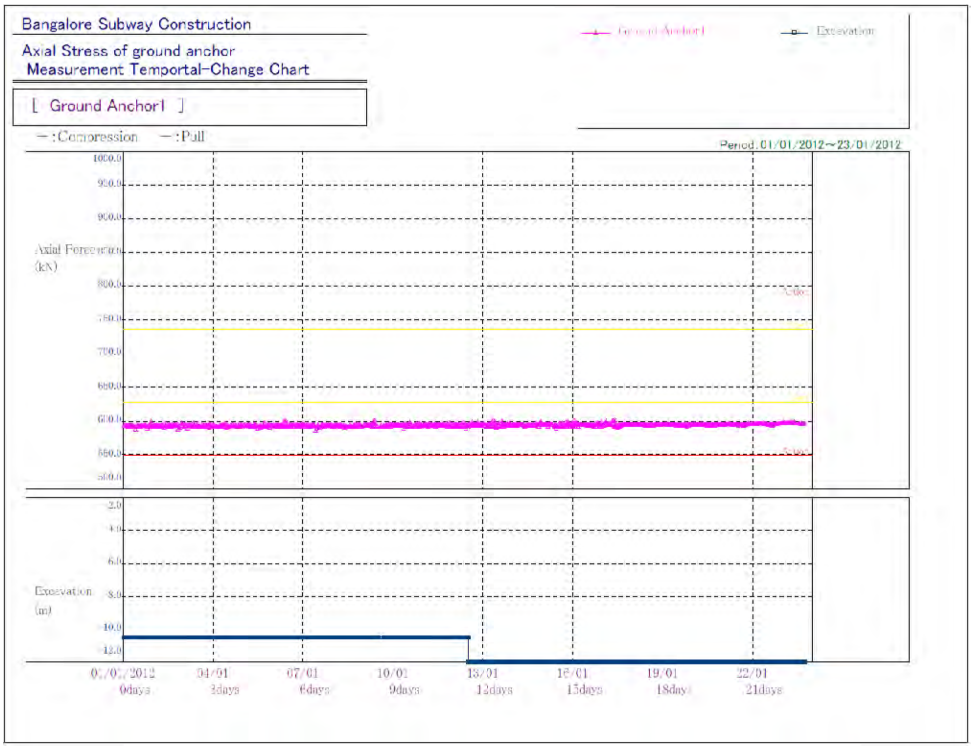
Figure 3.30 Measurement results for HAL roof top inclination 1

Figure 3.30 shows the measurement results for HAL roof top inclination 1. It is observed that the magnitude of inclination is very small throughout the project period. However, the trend observed for the retaining wall is also found where the outward inclination of very small magnitude is present.

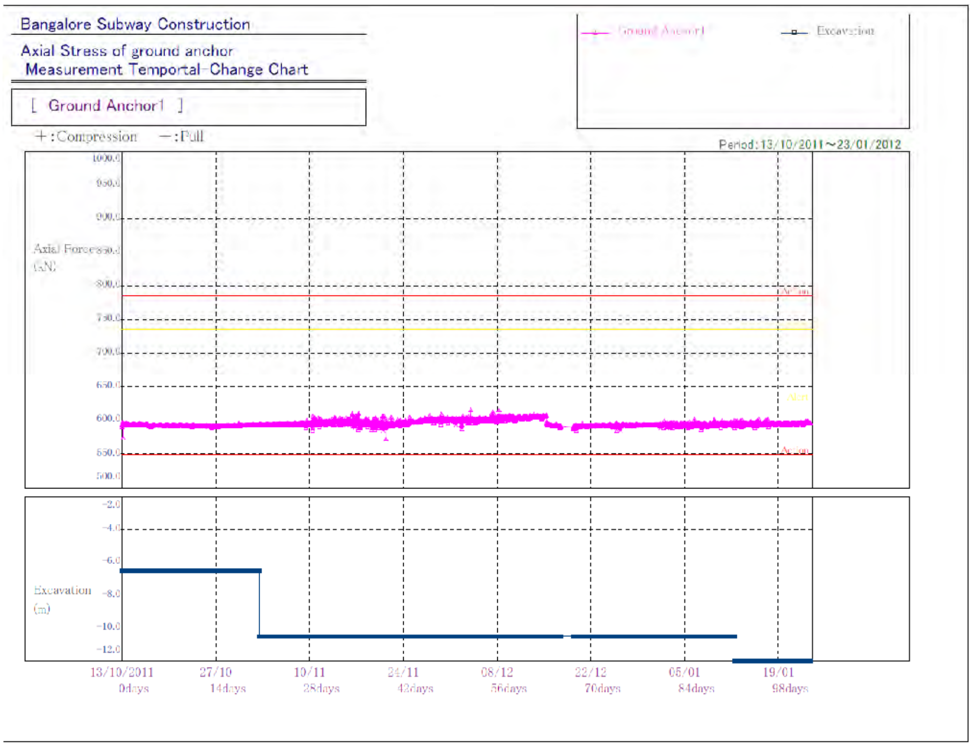
Axial force in ground anchor



(a) First week



(b) Last month



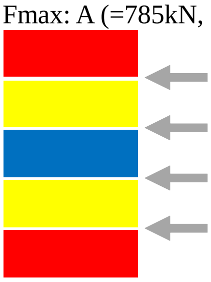
(c) Three months

Figure 3.31 Measurement results for axial force in Anchor 1

Figure 3.31 shows the measurement results for the axial force in Anchor 1. Since all anchors had to be installed after the excavation reached respective depths, the measurement was conducted only for three months. A general trend observed here is that the axial force is very stable throughout the monitoring period. Some fluctuations seen in Figure 3.31 (c) are believed to be caused by the technical problem associated with earthing a power cable.

On one load cell installed where the trouble was found behind the retaining wall at the Central College site, the axial load started to drop by more than 40% of the initial value for an unknown reason. Because of this phenomenon, the sensor unit was moved to another anchor. Data after re-starting the sensor dropped beyond the RED threshold values, forcing those threshold values to be modified as shown in Table 3.8.

Table 3.8 Revised color scheme for LEC and centre hole load cell

Target	Sensors	Color scheme
Anchor 3	LEC +Center hole load cell	Maximum allowable axial force for anchor Fmax: A (=785kN,)  1.00 × Fmax:LC 0.94 × Fmax:LC 0.64 × Fmax:LC 0.57 × Fmax:LC

3.4.3 Lessons and comments regarding OSV Monitoring

General summary

In this project conducted in Bangalore, the OSV monitoring was conducted at two stations where key factors to watch were

1) axial forces in strut beams,
2) inclination of Scan pile,
3) inclination of ground behind retaining wall,
4) inclination of HAL and BSNL buildings and
5) axial force in ground anchors.

The overall results from the sensors were in good agreement with what was predicted initially, except for some temperature effects on the axial forces in the strut beams. No major accident or trouble occurred during the monitoring period.

New features

* Compatibility with Indian made sensors
  In this project, LEC made in Japan was used together with several sensors made in India. The compatibility between the two groups of OSV devices was found to be faultless, reliable and promising.

* Processing data from more than one sensor
  An LEC with a specially modified internal program was tested so that more than one sensor was connected to one LEC. The switch box and the algorithm written in the LEC functioned as they were supposed to without error.

* Stand-alone layout
  The stand-alone arrangement of using LEC was found to be very convenient. The workability of this method was found to be satisfactory since a pair of LEC and sensors does not have to be connected to a PC in a control room, and data could be retrieved from an SD card anytime.

* Visibility
  Secondary connection of an LED to an LEC was found to be effective to enhance visibility of the light emitted from the LEC. LED ropes were used for this purpose on the roof top of the HAL building and strut beams for improving visibility of the light for the workers.

Temperature effect

Magnitude of change in axial force of a strut beam due to temperature change was found to be larger than or almost equal to that caused by excavation. This finding would force inclusion of temperature effect for the determination of threshold values defining the color scheme for the strut beam. Some modification in software for the LEC may also be necessary for more flexible definition of threshold values.

Chapter 4 Study for Dust Monitoring

4.1 Site Selection

Regarding the environmental management of using dust measurement in construction sites, the following conditions should be fulfilled to confirm the efficacy and advantage of the equipment, and the improvement of the environmental awareness of the field manager, supervisors and workers.

- The site where the dust may remain airborne a long time and has continuous construction activities, which will permit observation of the effect of the measurements.
- Large amount of rock excavation and the construction practices which could threaten worker's health.

As a result of considering the site which fulfils the above conditions and where the dust measuring can be carried out without construction lags, the following site is given.

Sri M. Vishvashwaraya Station construction site.

4.2 Principles for smart phone with dust monitoring program

A Dust Monitoring System using a photo with a flash. The following Figure was taken in a mountain tunnel by digital camera. Figure 4.1 was taken with flash, and Figure 4.2 was without flash.

Figure 4.1 With flash

Figure 4.2 Without flash

In Figure 4.1, there are many white dots in the flash photo. These are floating dust particles near the camera lens. The mechanism of the white dots is shown in Figure 4.3.

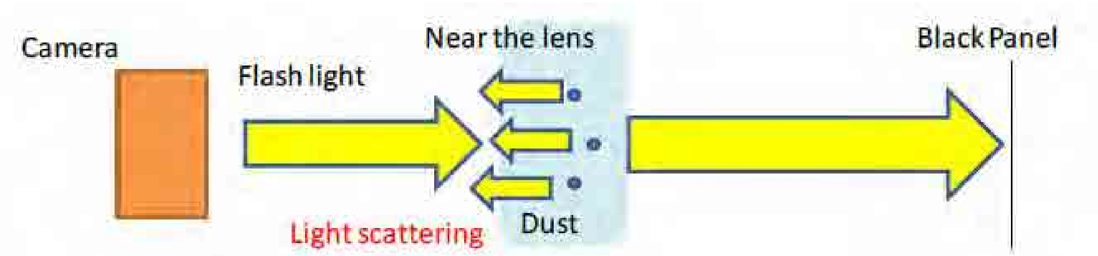


Figure 4.3 Mechanism of white dots

The floating dust particles near the lens cause light from the flash to scatter. It appears in the photo as a white dot. The Dust Monitoring System by mobile phone uses these white dots to calculate dust concentration. As shown in Figure 4.4, the number of white dots increases according to dust concentration. And also the brightness of the photo is increasing. By calculating this brightness, dust concentration can be determined.

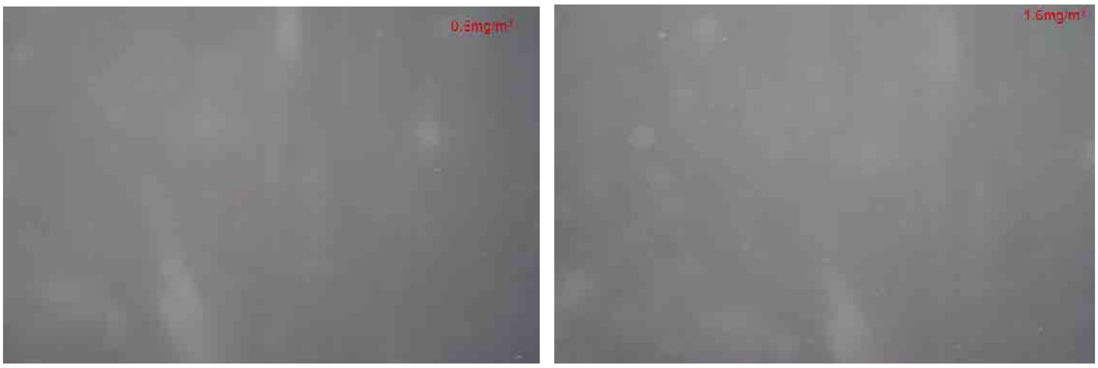


Figure 4.4　Dust Photograph

Figure 4.5 shows the flowchart of the Dust Monitoring System. First, input the flashed photo. Second make it greyscale. Third, calculate characteristic values (average and variance of the brightness) of the photo. Fourth, discriminate dust concentration from the characteristic value by Artificial Neural Network. Fifth, output the dust concentration.

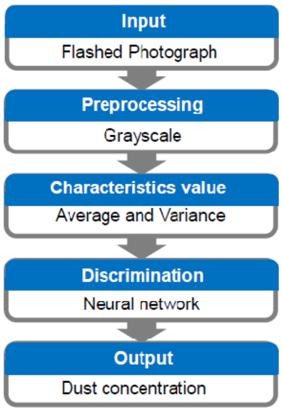


Figure 4.5　Flowchart of Dust Monitoring System

An Artificial Neural Network is a discrimination which can reproduce the unidentified phenomenon. Numerical formula cannot reproduce such phenomenon. An Artificial Neural Network has a learning function and can be a suitable system for dust monitoring. Figure 4.6 shows the flow of an Artificial Neural Network.

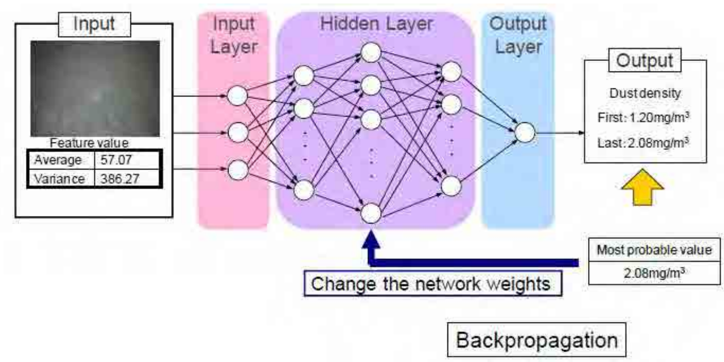


Figure 4.6 Flow of Artificial Neural Network

And to create an appropriate program, the Dust Monitoring System by mobile phone needs to be calibrated. Figure 4.7 shows the calibration flow.

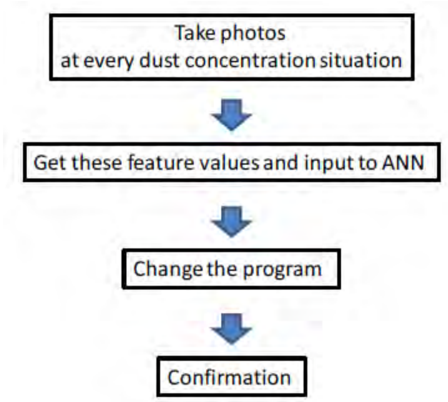


Figure 4.7 Calibration flow

The Dust Monitoring System can identify 0 to 10 mg/m^3. Over 10 mg/m^3, like 18 mg/m^3, it appears as 10 mg/m^3 on the mobile phone. However, that's accurate enough to evaluate the risk produced by the dust.

4.3 Excavation with DUST Monitoring

4.3.1 Monitoring Location and Color Scheme

(1) Monitoring Location

Figure 4.8 shows the monitoring location in the Central College Station. Location 1 is a soil excavation point. Locations 2 and 3 are rock excavation points. The office is a point near the office. Monitoring location was decided by the number of workers who work at the point. The above 4 points are expected to hold many workers.

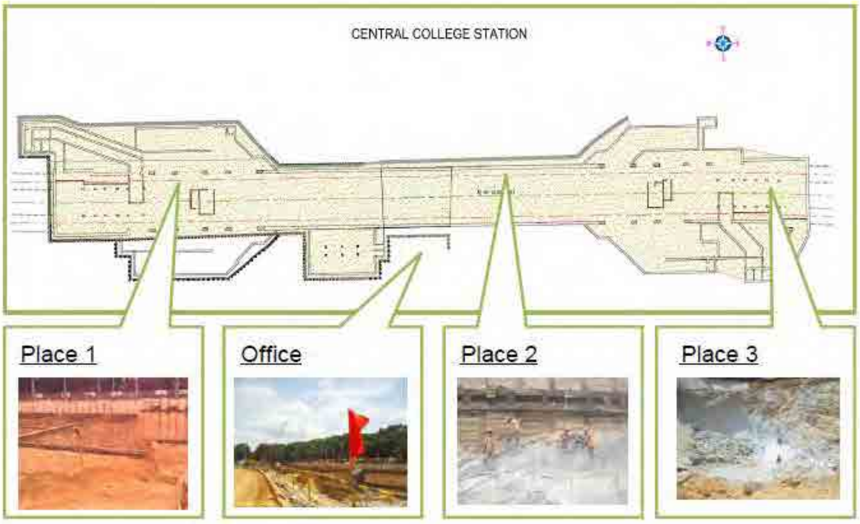


Figure 4.8 Monitoring locations

Figure 4.9 shows the monitoring location in Vidhana Soudha Station. In this site, there was only monitoring, and no action. And as a special monitoring, there was monitoring on a road near the site.

Figure 4.9 Monitoring locations at Vidhana Soudha Station

(2) Color Scheme

The monitoring result is shown on a signboard to workers as shown in Figure 4.10. The signboard is put in front of the site entrance.

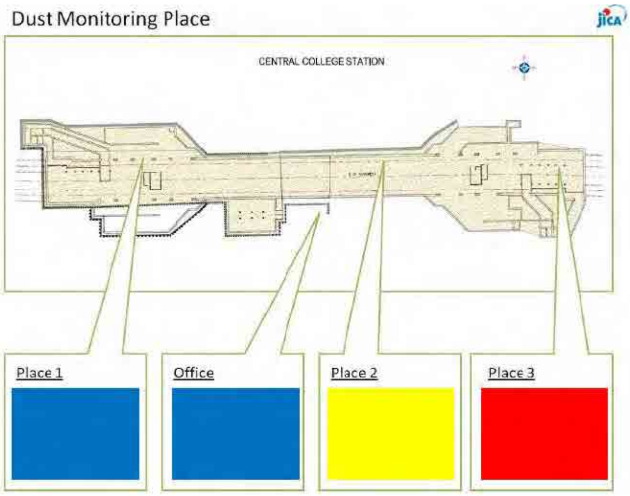


Figure 4.10 Example of signboard and color panels

These color panels indicate the dust concentrations and actual action plan as shown in Figure 4.10. A blue color panel means the dust concentration is 0 ~ 3.0 mg/m^3. A yellow color panel means the dust concentration is 3.0 ~ 6.0 mg/m^3. A red color panel means the dust concentration is over 6.0mg/m^3.

4.3.2 Monitor using a smart phone

To identify the dust features, air sampling was taken where it was expected to have a lot of dust, a drilling place. As a result of air sampling, the dust was found to be granite and it contained particles of a size harmful for the human body. And by this survey, it could be said that applying the Dust Monitoring System by mobile phone there was no problem.

Figure 4.11 Air sampling

Figure 4.12 is the actual dust in Central College Station observed by Scanning Electron Microscope. Dust concentration in this sampling was 4.91mg/m^3. The white lines are glass fibres of the filter and the others are suspended dust particles from the rock excavation.

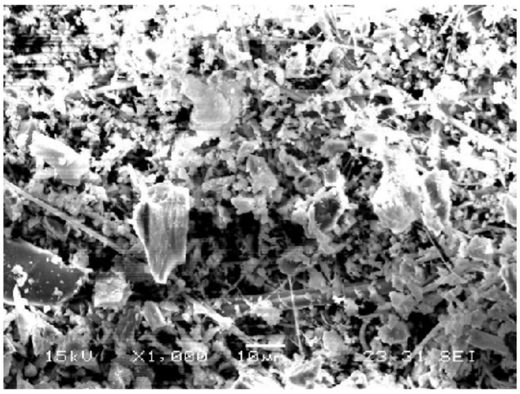


Figure 4.12 Actual Dust (1000 times)

Figure 4.13 shows the particle size distribution of Central College Station. The average particle size is 2.2μm and it contains particles of the high risk zone.

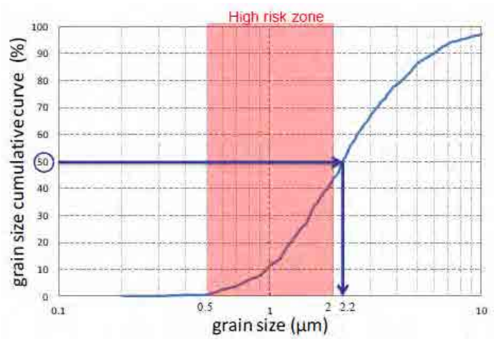


Figure 4.13 Particle size distribution

However, there was a problem in attempting to apply the system at the site. The Dust Monitoring System by mobile phone was developed to use only in mountain tunnels and needed a dark environment to get the flash light scattering from the dust. Central College Station Construction Site was an open cut excavation site. So it was difficult to get the flash light scattering with the same scheme as in a mountain tunnel. To solve this problem, using a box made of aluminium (shown in Figure 4.14) was selected. This box had a black board inside and a mobile phone setting function on the side. Using this Dust Box, the dust was captured clearly and there was no need to worry about the weather.

Figure 4.14 Dust Box

Dust monitoring procedure with Dust Box is,

1) Bring Dust Box to the monitoring point
2) Attach the mobile phone to the box
3) Open the box and keep it open 1 minute to take a sample of the dust
4) Close the box and do the dust monitoring

And on the mobile phone,

1) Start the program “Funjin”
2) Touch “Camera” and take a picture
3) Confirm the dust concentration and touch “Save”

Figure 4.15 Dust Monitoring by mobile phone

4.3.3 Measurement Result

(1) The accuracy of Dust Monitoring System by mobile phone

An example of a correlation graph between the Dust Monitoring System by mobile phone and a digital dust indicator is shown in Figure 4.16. The correlation coefficient is 0.958. It is said that this program has enough accuracy.

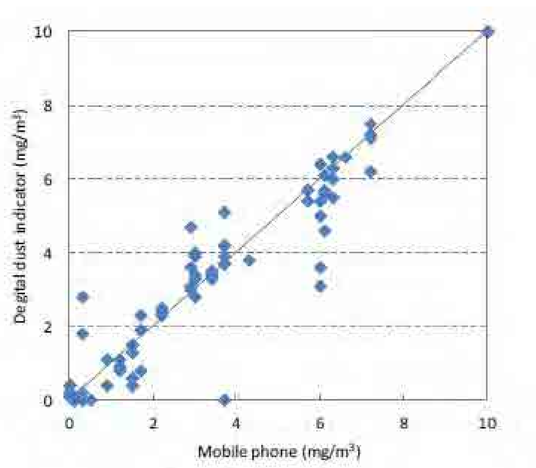
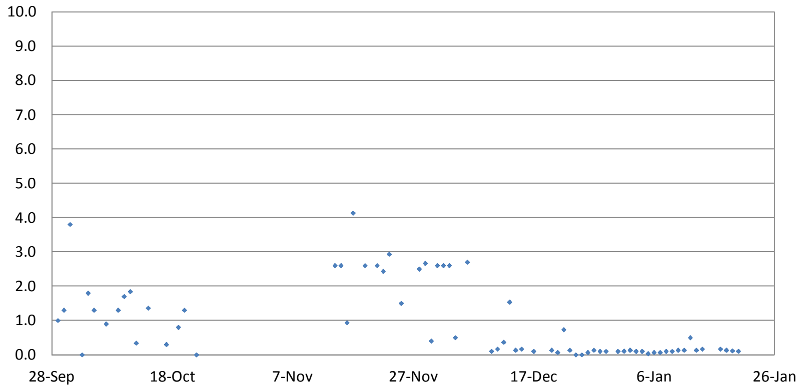


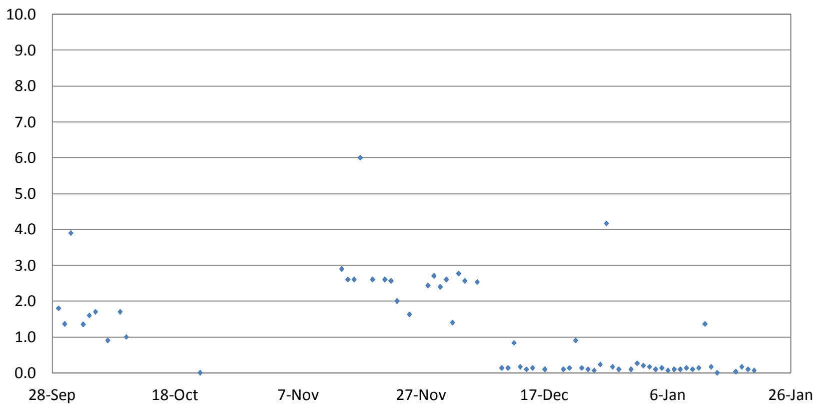
Figure 4.16 Correlation graph

(2) Monitoring result by Dust Monitoring System by mobile camera

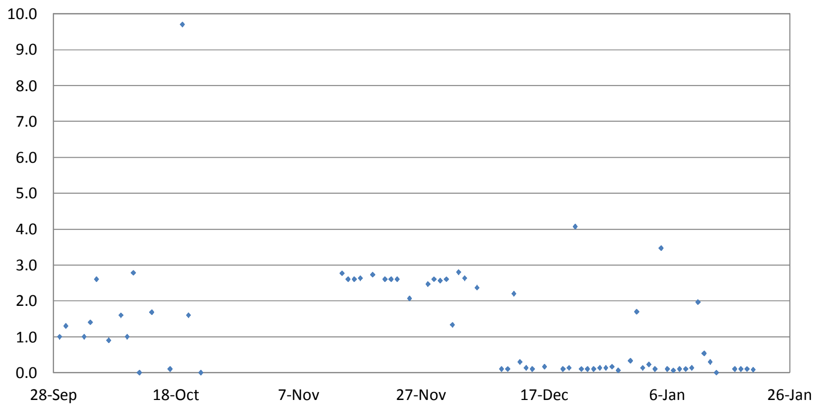
Figure 4.17 shows the dust monitoring result over the entire project at Central College Station of each monitoring location.



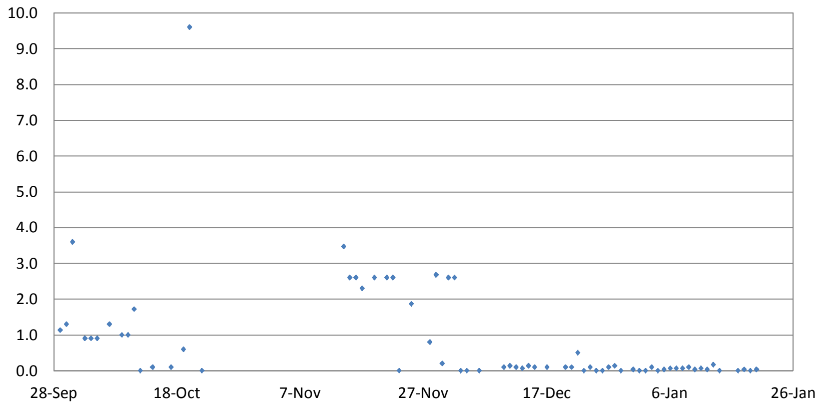
(a) Location 1



(b) Location 2



(c) Location 3



(d) Office

Figure 4.17 Monitoring result by mobile camera

Between 26th October and 13th November, there was a calibration problem, so there was no monitoring. As shown in the graph, usually there was no dust at any point. However, the drilling work at Locations 1,2, and 3 and the vehicle movement at the Office makes some dust. Especially, before December, there was dry weather and it raised the dust from sand. That is why the dust concentration before December was higher than after December.

Figure 4.18 shows the actual monitoring data on 22 September. At Location 2, 11:00 and 17:00, and at Location 3, 9:00, 11:00 there was drilling work, and dust occurred. At the office, 9:00 and 17:00, and at Location 1, 11:00, there was vehicle movement and it raised dust.

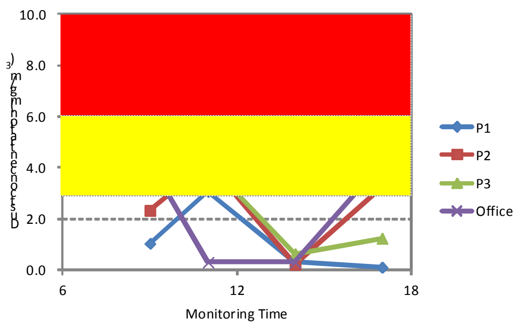


Figure 4.18 Monitoring Data (22nd Sep.)

Figure 4.19 is on 30 September. The dust concentration was stable.

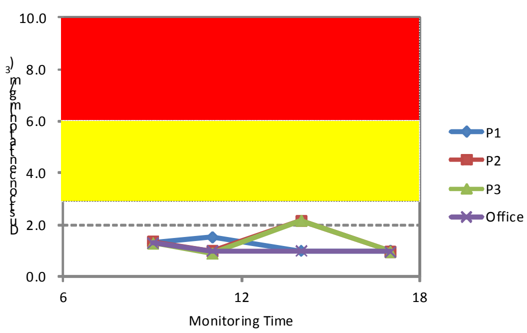


Figure 4.19 Monitoring Data (30th Sep.)

Figure 4.20 is on 23 November. At Location 2, 17:00, the dust concentration was very high because there was drilling work very near the monitoring place.

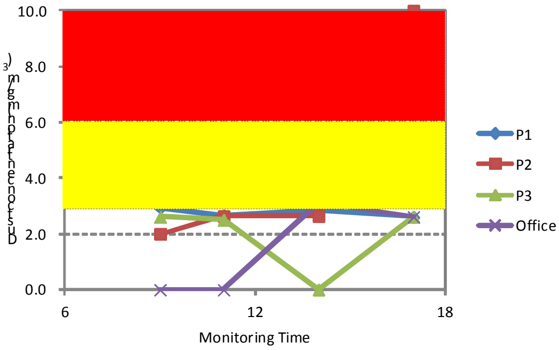


Figure 4.20 Monitoring Data (23rd Nov.)

Figure 4.21 is on 5 January. At Location 3, there was full-time drilling work.

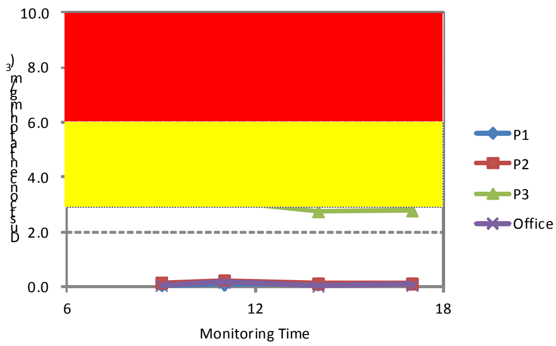


Figure 4.21 Monitoring Data (5th Jan.)

These monitoring results were recorded in the check sheet as shown in Figure 4.22 and shown on the signboard at the site entrance as shown in Figure 4.23.

Figure 4.22 Dust monitoring check sheet

Figure 4.23 Signboard and Color panel

And also, the monitoring result was shown on the web site as shown in Figure 4.24.

Date	1/12/2011		Name	Praveen H.G		Mobile	8	Box	Paul
Time	Place	1st	2nd	3rd	4th	5th	Ave.	Drilling	Remark
9:00	Office	2.6	2.6	2.6	2.6	2.6	2.6	No	No work
	P1	2.6	2.6	2.6	2.6	2.6	2.6	No	No work
	P2	2.6	2.6	2.6	2.6	2.6	2.6	No	No work
	P3	2.6	2.6	2.6	2.6	2.6	2.6	No	No work
11:00	Office	0.0	0.0	0.0	0.0	0.0	0.0	No	No work
	P1	2.6	2.6	2.6	2.6	2.6	2.6	No	Muck bucket
	P2	2.6	2.6	2.6	2.6	2.6	2.6	No	Sand filling
	P3	2.6	2.6	2.6	2.6	2.6	2.6	No	No work
14:00	Office	0.0	0.0	0.0	0.0	0.0	0.0	No	No work
	P1	0.8	1.1	0.3	1.6	2.0	1.2	No	Muck bucket
	P2	6.0	6.0	6.0	6.0	6.0	6.0	Yes	
	P3	4.0	5.7	4.0	3.0	5.3	4.4	No	
17:00	Office	2.0	2.8	3.2	2.7	3.0	2.8	No	Vehicle
	P1	2.6	2.7	2.6	2.7	2.6	2.6	No	Muck bucket
	P2	2.6	6.2	3.4	6.3	3.7	4.4	Yes	
	P3	5.5	4.6	4.5	5.3	6.1	5.1	Yes	

Figure 4.24 Web Site upload file

Workers, especially where drilling is taking place, always face a high dust concentration as shown in Figure 4.25.

Figure 4.25 Drilling work

Both digital dust indicators and the Dust Monitoring System by mobile camera also recorded high dust concentrations while drilling work was going on as shown in Figure 4.26. As mentioned above, the Dust Monitoring System cannot recognise concentrations over $10mg/m^3$.

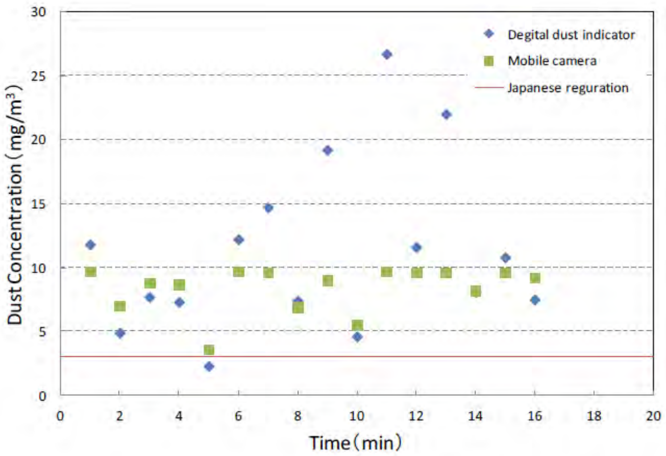


Figure 4.26 Dust concentration during drilling work

4.3.4 Lessons and Comments regarding DUST Monitoring

The Dust monitoring for open cut construction sites has given us the following lessons and associated comments that are summarized below.

(1) Hardware aspect : Dust Box

The Dust Monitoring System by mobile phone needs a dark environment to capture the dust. The Dust Box played a great roll in providing a dark environment. And as an additional, unexpected effect of the Dust Box, there was no wind while dust monitoring because the Dust Box prohibited any air movement in the box. However, there is a problem with the black board in the Dust Box that through daily use, it became dirty and that strongly affected the accuracy of monitoring. To avoid this, periodic calibration should be conducted.

(2) Software aspect : Dust Monitoring System by mobile phone

The Dust Monitoring System by mobile phone had a good correlation coefficient with the digital dust indicator such as 0.958. Whereas, as mentioned above, it was a very sensitive system and it needed periodic calibration. However, it can be said that as a simple dust measurement, the Dust Monitoring System by mobile phone is effective.

(3) Dust at the site

Normally, there is no dust in the site. Dust was caused by vehicle movement, drilling work, splayed concrete work, anchor setting, and wind during dry conditions. Especially, the drilling work made a lot of dust and many people were working near the drilling place. This dust was identified to be granite. And it contained particles that were a size that are harmful to the human body.

Chapter 5 Questionnaire Survey Regarding OSV Monitoring and Dust Monitoring

5.1 Objective and Scope of the Survey Study

5.1.1 Objective of the Survey Study

The main objective of the study is to evaluate the use of On-Site Visualization (OSV) and a Dust monitoring method at construction sites of Bangalore Metro Rail Construction (BMRC) by considering the following evaluating criteria

- Safety awareness and consciousness among various stakeholders during construction.
- Recognizing of OSV, Dust Monitoring and safety issues
- Effectiveness of OSV and Dust Monitoring techniques
- Contribution of OSV in the safety activities/management
- Improvement of safety outlook/consciousness and health consciousness through OSV dust monitoring techniques and activities

5.1.2 Scope of the Survey Study

To achieve the above objectives, the scope of the study has been defined as given below:

- Identification of parameters to evaluate safety and health consciousness
- Preparation of an opinion survey Questionnaire based on the identified parameters
- Finalization of the Questionnaire in consultation with Oriental Consultants
- Conducting the opinion survey with OSV of various stakeholders such as Site Engineers, workers, residents of HAL and the BSNL building (OSV monitoring).
- The workers of day and night shifts at the cricket stadium station and day shift workers at Central College Station and City Railway Station (without OSV) to be covered by the survey.
- Conducting the opinion survey on dust monitoring of various stakeholders such as Site Engineers, workers, road users in front of central college station and around the site on a random sample basis.
- The day shift workers at Vidhan Soudha Station (without Dust Monitoring) are to be covered by the survey.
- The size of the sample would be at least 100 samples for the worker group at Cricket Stadium Station and 30 at City Railway station and Central college station; 40 from HAL and MTNL building residents, 30 from road users in front of central college station and about 30 from site engineers/officers of General Consultants.

5.2 Methodology

The methodology adopted in order to fulfil the objectives and scope of the study is discussed in this chapter. The approach to methodology mainly consists of interaction with the JICA team and Prof. S. Akutagwa and Prof. M. Shinji on technical aspects discussion for identification of parameters to evaluate the safety and new method of OSV and Dust monitoring and to design the questionnaires for various groups namely site engineers, workers and building residents and road users. The random sample size has been decided based on the sizes of the various groups. After that, data collection and data coding was carried out. Category analysis has been carried out to evaluate the OSV and Dust Monitoring techniques. Figure 5.1, shows a detailed overview of the structure of the methodology adopted by CSIR- CRRI for this study.

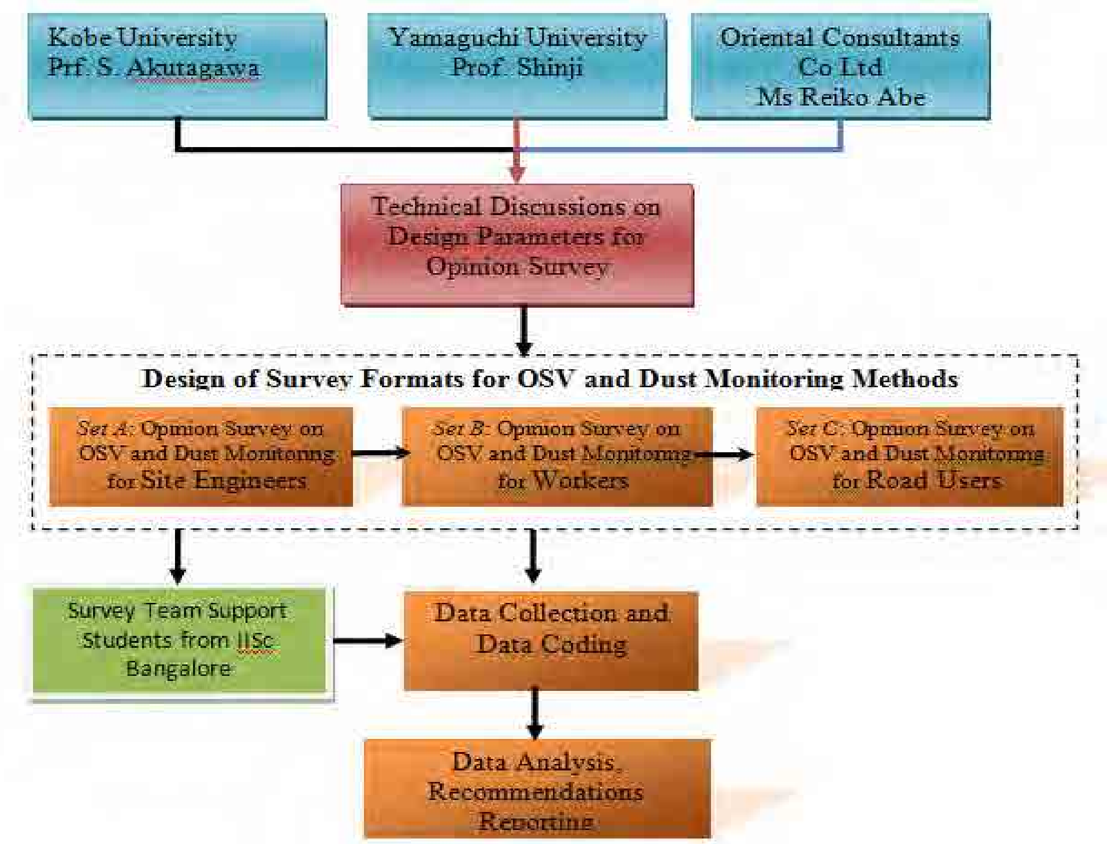


Figure 5.1 Approach Methodology for Evaluation of Users of OSV and Dust Monitoring Method

5.3 Data Collection and Coding

The data were collected in the designed formats for various groups. During the surveys discussions were also held with various officials and site engineers of BMRC and General Consultants. The data formats have been designed separately for OSV monitoring and Dust monitoring for the three groups namely Site Engineers, Workers and Residents/Road Users. The key parameters considered in the opinion survey on OSV monitoring and Dust monitoring are briefly discussed in the following Sections.

5.3.1 Opinion Survey on OSV Monitoring

Site Engineers and Officers

JICA gave a demonstration and trained the site engineers of SOMA, officials (GC) and other BMRC officials associated with Cricket Stadium metro station construction monitoring system located near UG 2 office on the OSV method. Scientists of CRRI were also shown the site and demonstration by Ms. Reiko Abe and Professor S.Akutagawa at this station. A separate format named Set A has been devised for this group and is presented in *Annexure 1*. The information collected includes personal details, working experience, and safety monitoring and control experience.

Site Workers

The opinion survey on OSV for the worker group for day shift and night shift has been carried out at Cricket stadium metro station. The detailed parameters, such as personal details, working experience, safety experience and OSV experience, have been collected. Data collection of this group, Set B has been used which is given in *Annexure 2*. Before conducting the survey, JICA have organized a preliminary OSV safety awareness programme and also, emergency evacuation training by applying OSV monitoring system change of color (from safe condition - Blue Color to unsafe condition- Red Color) in order to gauge the sensitivity of the workers while working. In this evacuation programme JICA also used an alarm technique to warn the workers while working. The questionnaire survey was conducted before and after training to learn how the level of safety consciousness was enhanced for the workers of the stake holders.

Residents Near the Construction Site

Hindustan Aeronautical Limited building and BSNL building are adjacent to the cricket stadium station (Under construction). Deformation sensors have also been installed on the top of these buildings to monitor the safety of the building during the construction. During the questionnaire survey, the survey team demonstrated OSV related safety awareness for the employees working in these buildings. After that, an opinion survey for this group has been carried out as per the designed parameters. The performa that was used for this group is provided in Annexure 3 (Set C). This Format has been especially designed for this group.

Workers at Central College Station and City Railway Station

In order to make a comparative evaluation of safety awareness with and without OSV, significant samples of workers and site engineers was taken and data collected at Central College Station and City Railway station. The same formats have been used for this purpose. The knowledge of OSV was already provided to the site engineers and Workers at these metro stations.

Surveyed sample size

Table 5.1 presents the time schedule adopted and number of samples surveyed for the opinion survey for all the groups. A total sample of 318 persons from various groups was taken and data collected from them.

Table 5.1 Schedule of Opinion Survey for OSV Monitoring

Sl.No	Name of The Opinion Survey	Date of Survey	Location of Survey	Sample Size
1	Workers - Before Training	22/8/2011	Cricket Stadium Station	46
2	Workers - After Training	5/9/2011	Cricket Stadium Station	39
3	Workers - After Training	5/1/2012	Cricket Stadium Station	32
4	Workers (Night Shift)- After Training	5/1/2011	Cricket Stadium Station	19
5	Workers - No - OSV Situation	5/1/2012	Central College Station	46
6	Workers - No - OSV Situation	6/1/2012	City Railway Station	22
7	Engineers/Officers - Before Training	22/8/2011	Cricket Stadium Station	17
8	Engineers/Officers - After Training	6/9/2011	Cricket Stadium Station	8
9	Engineers/Officers - After Training (Day Shit and Night Shift)	6/1/2012	Cricket Stadium Station	8 +7
10	Engineers/Officers - No - OSV Situation	6/1/2012	City Railway Station and Central College Station	7+7
11	Engineers/Officers – at Site Offices	6/1/2012	JV Office, UG 2 Office	6+9
12	Residents of Adjacent Buildings at Cricket Stadium Station.	6/1/2012	HAL and BSNL Office	45

5.3.2 Opinion Survey on DUST Monitoring Method

Site Engineers and Officers

JICA gave a demonstration and trained the site engineers of M/s. SOMA Enterprise Ltd, officials of General Consultants (GC) and other BMRC officials associated with central college metro station. Scientists of CRRI also had been shown the site and demonstration by Ms. Reiko Abe, Prof S.Akutagawa at Cricket stadium station and Professor M.Shinji at Central college metro station. A separate format has been devised (Set A) for this group and is presented in *Annexure 4*. The information collected includes personal details, working experience, Dust Monitoring and control experience, and dust monitoring experience by mobile phone camera method.

Site Workers

The opinion survey on the Dust monitoring survey for the worker group for the day shift was carried out at central college metro station. The detailed parameters such as personal details, working experience, dust awareness and dust monitoring experience by mobile phone camera have been collected. Data collection of this group, Set B has been used and is given in *Annexure 5(Set B)*. Before conducting the survey, JICA have organized Dust awareness programmes for site workers and engineers at this site. For a view of the confirmation and counter measures appropriate to all dust concentrations for workers during construction, the dust concentrations were reported on display boards provided in the study area. The action plan display board can be easily distinguished and is useful to site personnel to consider appropriate counter measures. By changing the panel color with the result of measuring, workers can easily know the level of dust concentration and implement the countermeasures.

Road Users

Road users in front of central college metro station were also surveyed. The survey team organized a brief demo for the road users by showing them pamphlets on Dust related safety awareness. After that, an opinion survey for this group was carried out as per the designed parameters. The performa that was used for this group is provided in *Annexure 6 (Set C)*. This Format has been specially designed for this group and also for the randomly selected public who are closely moving around the construction site near Central college metro station which includes students and faculty of central college, Lawyers of Bangalore judicial court and the general public (road users).

Workers at Vidhan Soudha Station

In order to make a comparative evaluation of safety awareness with and without OSV, sufficient samples of workers and site engineers was taken and data collected at *Vidhan Soudha* metro station. The same formats have been used for this purpose. The knowledge on Dust was already provided to the site engineers at the Vidhan Soudha metro site office. For this group, *Set C (Annexure 6)* with limited information has been used for data collection.

Table 5.2 Schedule of Opinion Survey for DUST Monitoring

Sl.No	Name of The Opinion Survey	Date of Survey	Location of Survey	Sample Size
1	Workers - Before Training	22/8/2011	Central College Station	43
3	Workers - After Training	5/1/2012	Central College Station	46
5	Workers - No – Dust Monitoring	5/1/2012	Vidhan Soudha	31
7	Engineers/Officers - Before Training	22/8/2011	Central College Station	11
8	Engineers/Officers - After Training	6/9/2011	Central College Station	14
10	Engineers/Officers - No - OSV Situation	6/1/2012	Vidhan Soudha	8
11	Engineers/Officers – at Site Offices	6/1/2012	UG 2 Office	8
12	Road Users	6/1/2012	In front of Central College	29

5.3.3 Training Participants at IISc Bangalore

A survey has also been carried out with the participants of the JICA training programme on OSV and dust monitoring on Bangalore metro project at IISC Bangalore on 22 November 2011. During this training programme various students and faculty members of IISc and other universities in Bangalore have attended. In order to learn their opinions on these innovative techniques and implementation in the Bangalore metro project, a questionnaire survey was organized after the Workshop. A separate and simple one page format has been devised and is presented in *Annexure 7 and Annexure 8* for OSV and Dust Monitoring methods. The information collected includes personal details, working experience, safety monitoring awareness and OSV experience in the case of the OSV survey and for opinions on dust Monitoring survey parameters it included personal details, dust monitoring experience, dust monitoring and control experience.

5.3.4 Data Coding and Transformation

Data Coding for OSV Monitoring

The data collected through the opinion survey for OSV monitoring from the three groups were coded and transferred appropriately in Microsoft excel software for carrying out detailed category analysis. The collected data for various groups are presented in Annexure 9 (Site Engineers/Officers/ at Cricket Stadium). Annexure 10 (Workers at Cricket Stadium), Annexure 11 (Workers at Central College and City Railway Station), Annexure 12 (HAL and BSNL building Residents), and Annexure 13 (Participants of Training at IISc Bangalore)

Data Coding for Dust Monitoring

The data collected through the opinion survey for Dust monitoring from the three groups were coded and transferred appropriately in Microsoft excel software for carrying out detailed category analysis. The collected data for various groups are presented in Annexure 14 (Site Engineers/Officers/ at Central College station), Annexure 15 (Workers at Central College station), Annexure 16 (Workers at Vidhan Soudha Station), Annexure 17 (Road Users in front of Central College Station), and Annexure 18 (Participants of Training at IISc Bangalore)

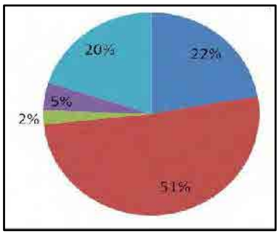
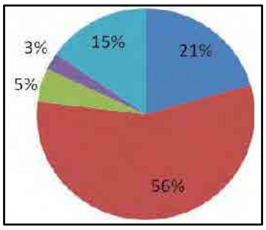
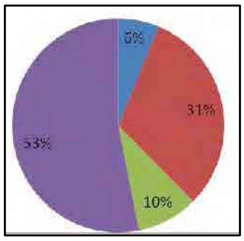
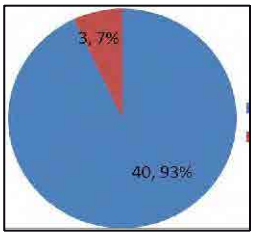
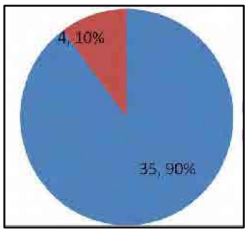
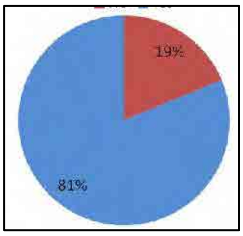
5.4 Data Analysis for OSV Monitoring

Data Analysis has been carried out on various issues such as understanding the level of safety knowledge, and the safety experience of workers, Engineers and residents. Some important parameters for various groups are considered and analyzed. The result of the analysis is discussed group wise in the following sub sections. The analysis has been carried out in two types (i) grading the opinion in a four/three grade point scale and (ii) categorization of the choice of the opinion expressed (pie chart).

5.4.1 Site Workers

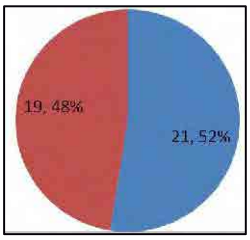
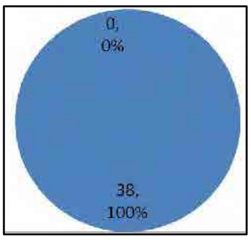
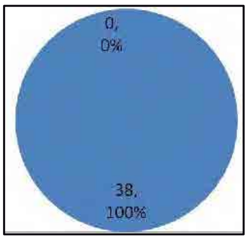
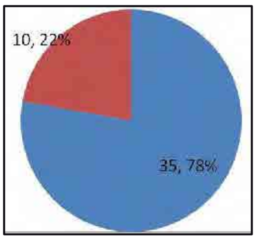
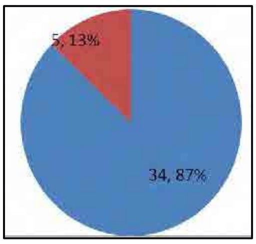
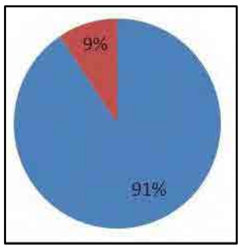
Randomly, 117 site workers at Cricket stadium metro station (with OSV experience Workers) and 68 workers at Central college station and City railway station (Without OSV Experience Workers) have been interviewed. Day and night shift workers have been considered at Cricket stadium metro station to identify the behavior of safety monitoring. The opinion survey on OSV has been organized in three phases, the initial phase was organised before training and the other two phases were conducted after the training to compare the behavior on safety consciousness. The results of safety experience and OSV experience of the workers have been presented in Table 5.3 and Table 5.4.

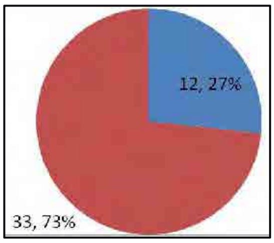
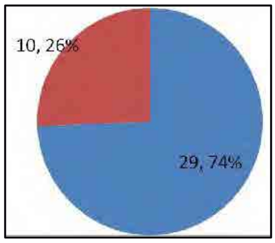
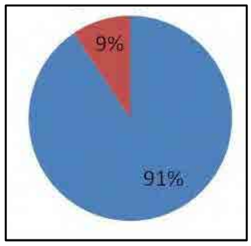
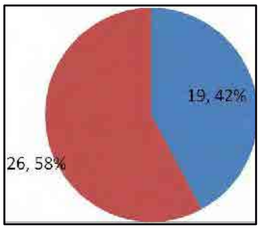
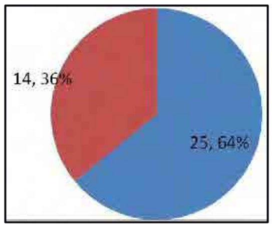
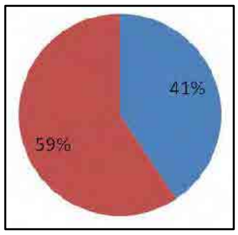
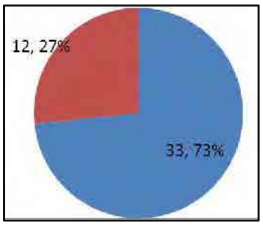
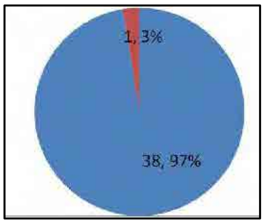
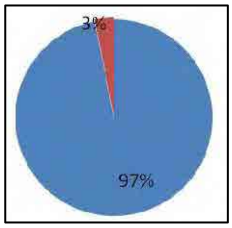
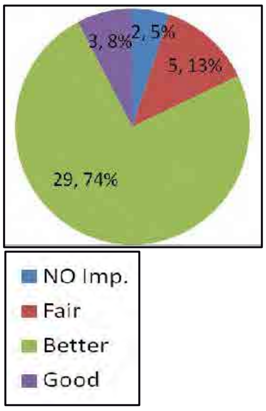
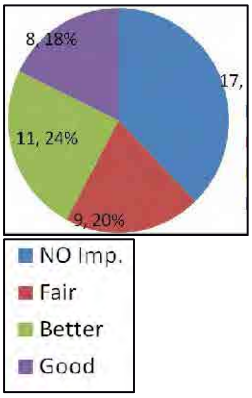
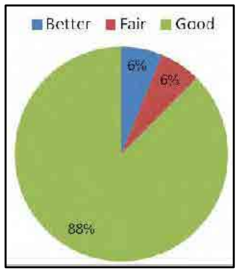
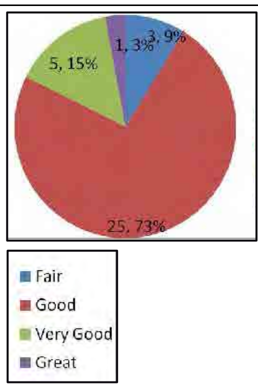
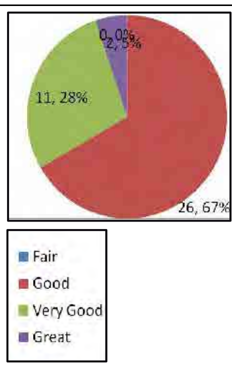
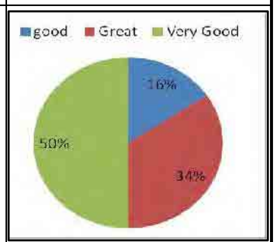
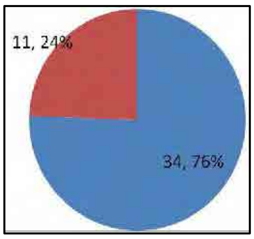
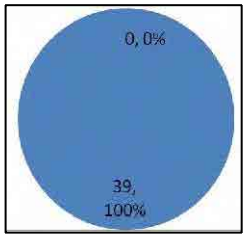
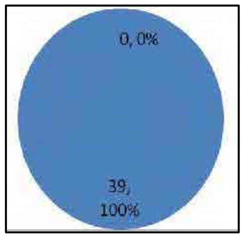
Table 5.3 Safety Experience (Historic) of Site workers

Sl. No	Parameters of Opinion Survey	Workers Before Training (Samples size 45)	Workers After 1st Training (Sample size 40)	Workers After 2nd Training (Sample Size 32)
1	How much safety conscious do you have Fair Good NA poor Very Good			
2	Do you think current safety control measures are enough (Blue: Yes; Red: No;)			

From Table 5.3, it can be identified that the level of safety consciousness is good for workers after the training program compared to before at cricket stadium station. The workers at this station were satisfied with the current level of safety measures before training, whereas after training their perception is slightly shifted, this marginal shifting factor indicates that use of advanced monitoring methods works at this construction site. Workers at this station have visually seen and understood the use of the new safety monitoring method; this will result in the improvement of thinking of the workers at this station.

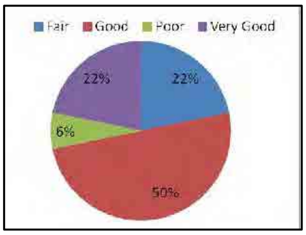
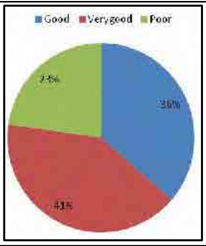
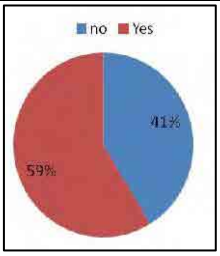
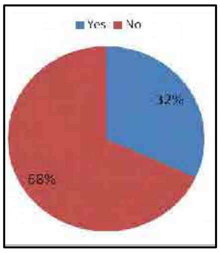
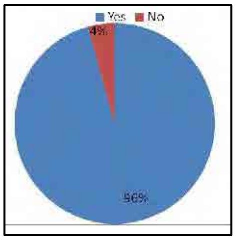
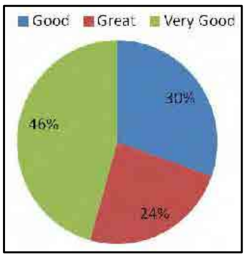
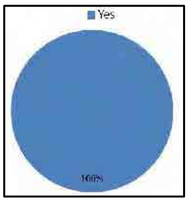
Table 5.4 Opinion of Site Workers about On-Site Visualization

Sl. No	Parameters of Opinion Survey	Workers Before Training (Sample Size 45)	Workers After 1st Training (Sample Size 40)	Workers After 2nd Training (Samples Size 32)
1	Do you understand the purpose of the OSV method? (Blue : Yes Red: No)			
2	Have you observed the sensor during work (Blue : Yes Red: No)			

3	Do you understand which actions are required based on Change of color? (Blue : Yes Red: No)			
4	Do you think the numbers of sensors are sufficient for this site?			
5	Do you agree that this OSV Monitoring method will change your attitude and safety conscious?			
6	If yes, How much has your safety consciousness improved?			
7	How would you rate use of OSV in construction safety monitoring?			
8	Will you recommend the OSV monitoring method for other /Future Metro constructions? Blue : Yes Red: No)			

From Table 5.4, it can be concluded that almost all the respondents to the opinion survey have recommend the OSV monitoring method for other /future metro constructions. The rate of use of OSV in construction safety monitoring was quantified on a 4 point measurement scale. Day shift and Night shift workers at Cricket stadium station rated that OSV is very good technology. The improvement of safety consciousness by introducing OSV has been quantified on a 4 point measurement scale. From the results, it is identified that the workers' group safety consciousness improved significantly between the before training phase and after the 2nd training phase. Most of the workers understood actions are require based on Change of colour. Initially, before training, 30 % of the workers could not understand the use of coloured lights and the required action to be taken during changing of the colour. This ratio was significantly reduced to 5% by providing evacuation training during the 2nd training.

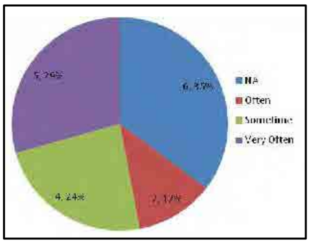
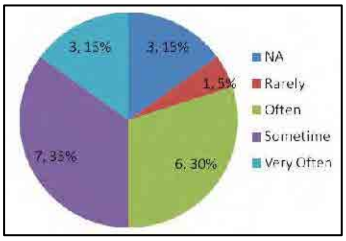
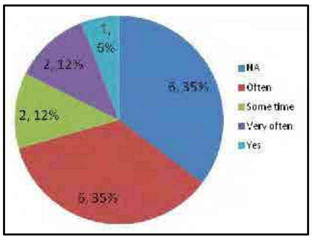
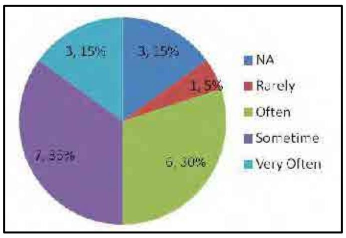
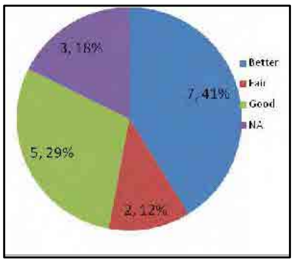
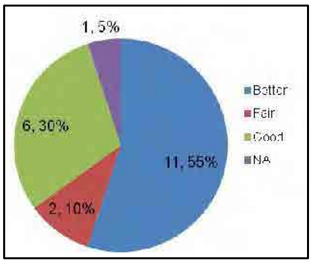
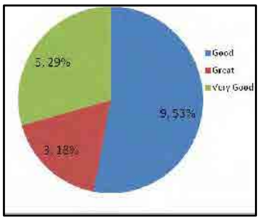
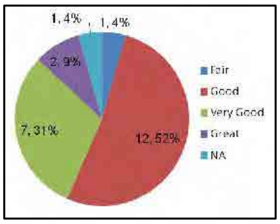
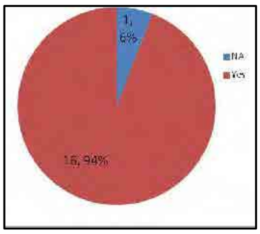
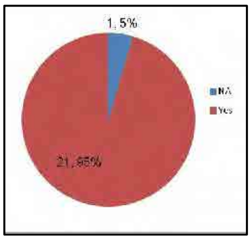
Table 5.5 Opinion of Site Workers about No OSV- Situation

Sl. No	Parameters of Opinion Survey	Central College station (Samples 46)	City Railway Station (Samples 22)
1	How much safety conscious do you have?		
2	Do you think current safety control measures are enough?		
3	Do you agree that this OSV Monitoring method will change your attitude and safety conscious? **After Explanation**		**No Reply from Most of the Samples**
4	How would you rate use of OSV in construction safety monitoring? **After Explanation**		**No Reply from Most of the Samples**
5	Will you recommend the OSV monitoring method for other /Future Metro constructions? **After Explanation**		**No Reply from Most of the Samples**

5.4.2 Site Engineers and Officers

A total of 40 officials comprised of Site Engineers of SOMA, and officers of BMRC, have been interviewed before and after evacuation training. The safety experience and opinion on OSV has been presented in Table 5.6. Results from Table 5.6, show that they often observed the sensors while they are at work. This emphasizes that Site Engineers and Officers have taken a keen interest in monitoring the safety condition through OSV. All this group agree that they improved their safety consciousness due to introducing the OSV method.

Table 5.6 Opinion of Site Engineers/Officers about On-Site Visualization

Sl. No	Parameters of Opinion Survey	Before Training (Sample Size 17)	After Training (Sample Size 23)
1	Do you understand the purpose of the OSV method?	100 %	100%
2	How often did you check the sensors in a day?		
3	Do you think that accidents could have been avoided if the site was monitored by OSV		
4	How much has your Safety consciousness improved by introducing OSV?		
5	Rate the use of OSV		
6	Would you recommend OSV for other/Future Metro constructions?		

Results from Table 5.6, reveal that 100% of this group understand the purpose of OSV. Almost 75% of site engineers agreed that the number of sensors installed at this station is sufficient and the remaining engineers and officers did not agree with the number of sensors. Most of them in this group suggested that more lights (e.g mirror images) should be provided at the location of the BSNL building. The use of the OSV safety monitoring method was evaluated with respect to reducing the severity of incidents in terms of men and material has been quantified. From the result, it can observed that about 90% emphasize that by introducing the OSV monitoring method, men and material can be saved to a higher extent from the accidents. Also willingness to allocate budget for the OSV monitoring method for other/future metro constructions have been quantified, about 80% of the Engineers/officers are agreed to allocate budget provision from moderate to sufficient. This means that this group is suggesting to have sufficient budget provision for the OSV method.

5.4.3 Residents of the HAL and BSNL Buildings

Randomly, 24 employees of Hindustan Aeronautical Limited (HAL) working in the HAL building at Cricket stadium station have been interviewed. Similarly 37 employees of BSNL office located on the other end of Cricket stadium station were interviewed. Safety knowledge and Opinions of OSV method for these groups have been analyzed and represented in Table 5.7 and Table 5.8 respectively.

From Table 5.7, it can be observed that most of the people have some kind of worry about safety while passing near Bangalore Metro Construction, also these employees have a good level of safety consciousness captured through this survey.

Table 5.7 Safety Knowledge of HAL and BSNL Building Residents

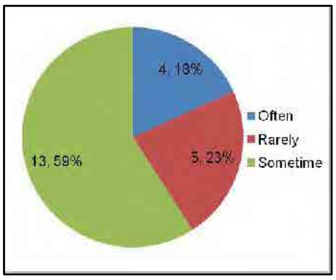
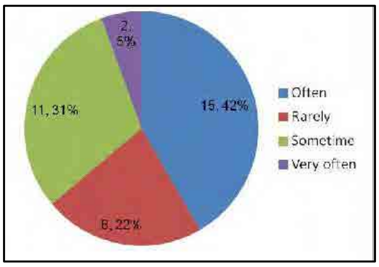
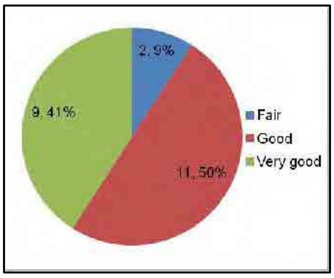
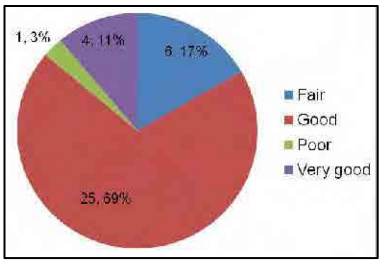
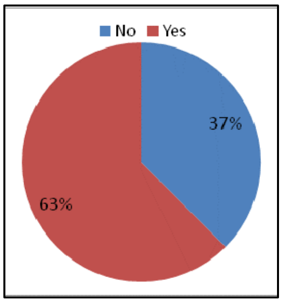
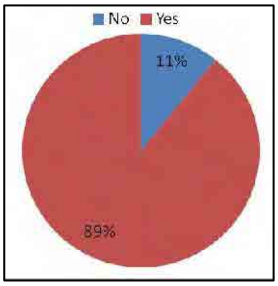
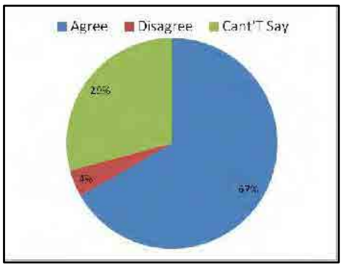
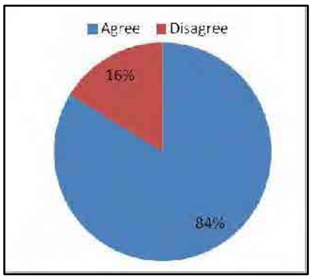
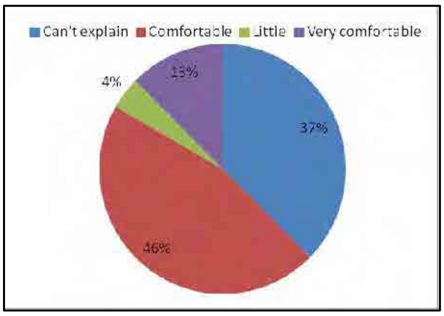
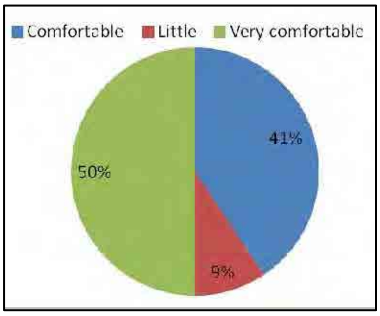
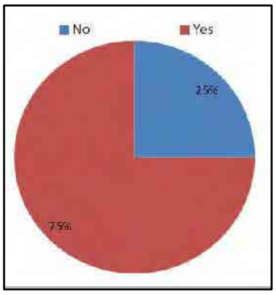
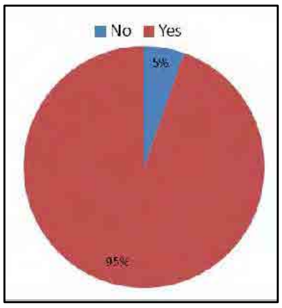
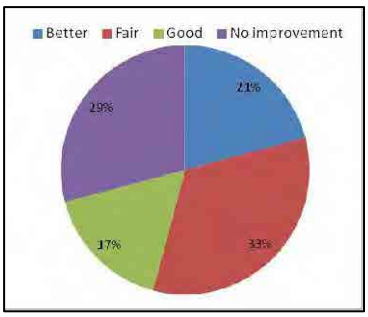
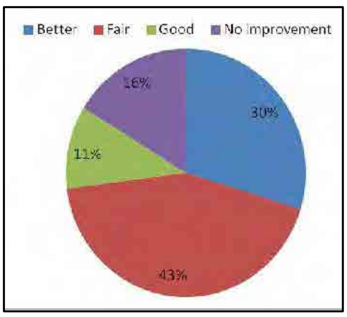
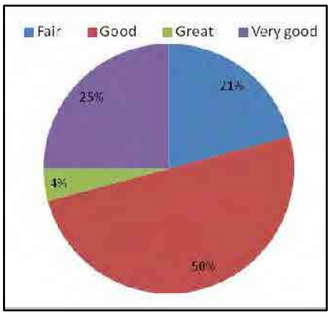
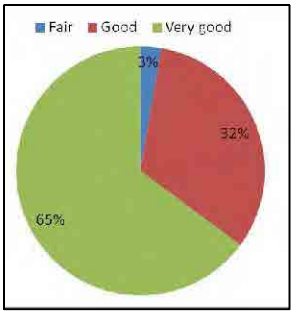
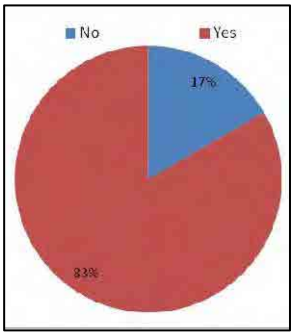
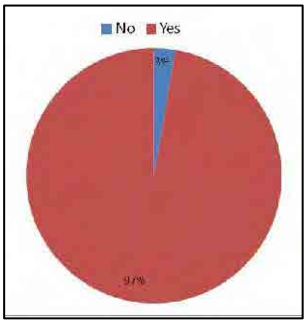
<table>
<tr><th>Sl. No</th><th>Parameters of Opinion Survey</th><th>HAL Building Residents</th><th>BSNL Building Residents</th></tr>
<tr><td>1</td><td>Have you ever worried about your safety while passing near Bangalore Metro Construction</td><td>
</td><td>
</td></tr>
<tr><td>2</td><td>How much safety consciousness do you have?</td><td>
</td><td>
</td></tr>
</table>

Table 5.8 Opinion of HAL and BSNL Building Residents about On-Site Visualisation

<table>
<tr><th>Sl. No</th><th>Parameters of Opinion Survey</th><th>HAL Building
(Sample 24)</th><th>BSNL Building
(Samples 37)</th></tr>
<tr><td>1</td><td>Have you observed the blue light on top of the building?</td><td>
</td><td>
</td></tr>
<tr><td>2</td><td>Do you get any sense of security by this?
After Explanation</td><td>
</td><td>
</td></tr>
<tr><td>3</td><td>If you agree, can you explain how you feel regarding your security as a resident/ common man</td><td>
</td><td>
</td></tr>
<tr><td>4</td><td>Do you agree this OSV monitoring method will change your attitude and safety consciousness?</td><td>
</td><td>
</td></tr>
<tr><td>5</td><td>How much has your safety consciousness improved?</td><td>
</td><td>
</td></tr>
</table>

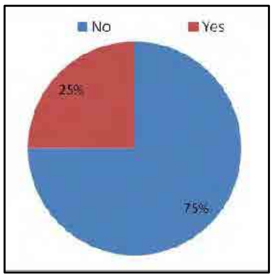
6	How would you rate use of OSV in construction safety monitoring?		
7	Will you recommend the OSV monitoring method for other /Future Metro constructions?		

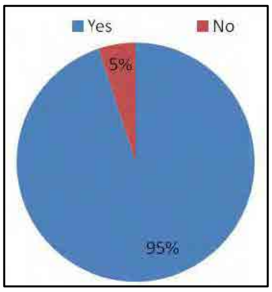
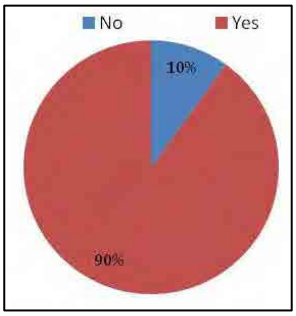
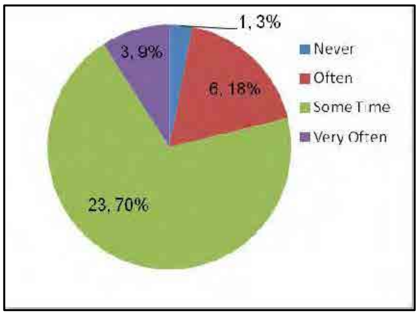
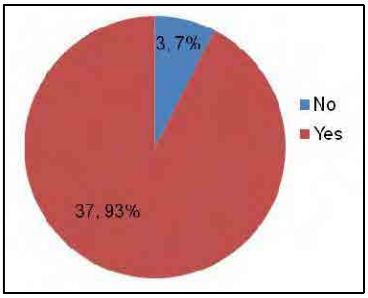
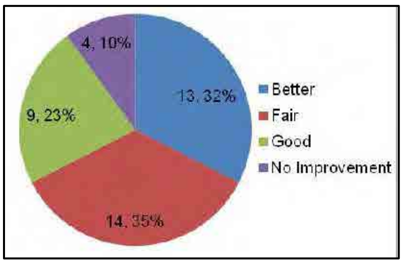
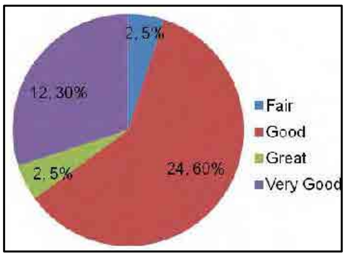
From Table 5.8, it can be noticed that, 63% of HAL building residents and 89% of BSNL building residents are very keen in watching the sensor lights installed on top of the buildings and the same percentage of those in the buildings agree that they feel that the security is higher by installing lasers on top of their office buildings which are monitored by the OSV method. The feeling of safety has been quantified and the result showed 67% of the employs of the HAL building and 91% of the BSNL employees felt safer by installing OSV monitoring on their buildings. Also most of the employees recommended this monitoring method for other/future metro projects.

5.4.4 Training Participants at IISc Bangalore

A simple questionnaire was especially designed for the participants of the training programme organized by JICA in IISc Bangalore. The data from the opinion survey of 40 participants including students, faculty members, research associates and research analysts have been collected. Opinions on OSV have been analyzed and represented in Table 5.9.

Table 5.9 Opinion of Training Participants about On-Site Visualization

Sl. No	Parameters of Opinion Survey	Participants at IISc Bangalore (Sample Size 40)
1	Do you think current safety control measures used in India are adequate?	

2	Do you understand the purpose of the OSV Method?	
3	Do you understand the concept of light emitting sensors used in OSV?	
4	Do you think that past accidents that happened on any construction site could have been avoided if the site had been monitored by OSV?	
5	Is this OSV method useful as a safety check for metro construction?	
6	How much has your safety consciousness improved?	
7	Rate your opinion of the OSV Training programme on safety monitoring and control systems?	

From Table 5.9, it can be concluded that, 95% of the participants have understood the purpose of OSV and its applications at construction sites and 90% agree that they have improved their safety consciousness by attending this training programme. A total of 92% of the participants agree that the OSV method is useful as a safety check for metro construction and 85% agree that the OSV monitoring method will change your attitude and safety consciousness. Most of the participants expressed that this method is a simple, efficient, economical and efficient real time monitoring method. Also these groups emphasis that this system is easily understood by the workers at the construction site.

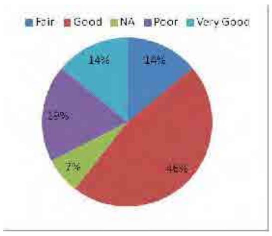
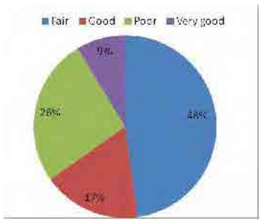
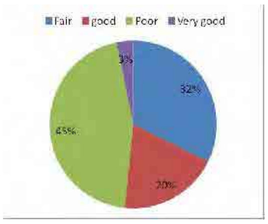
5.5 Data Analysis for Dust Monitoring

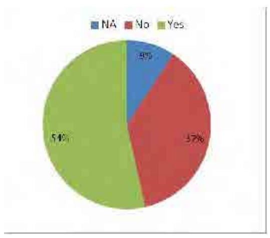
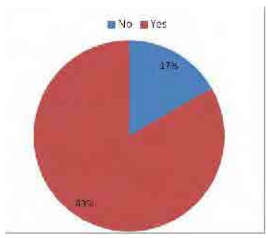
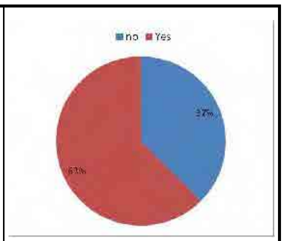
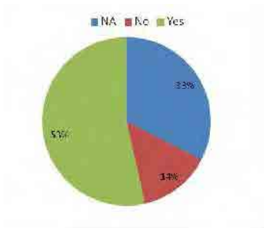
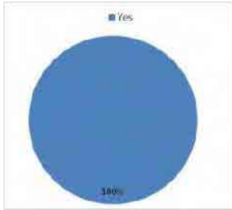
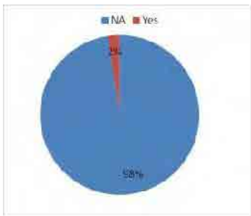
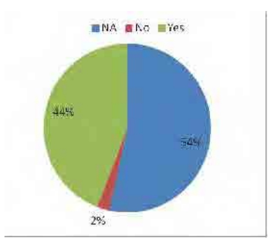
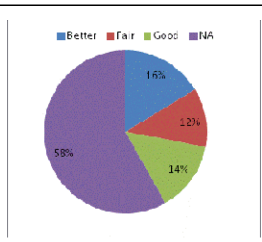
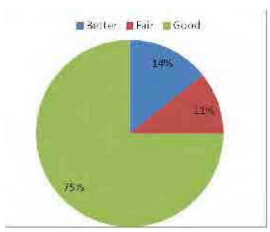
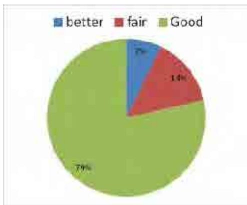
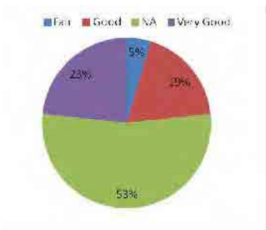
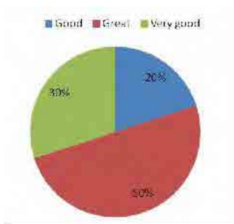
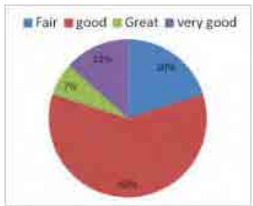
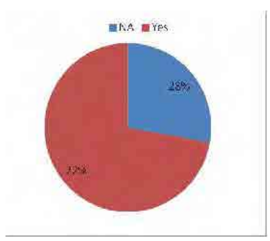
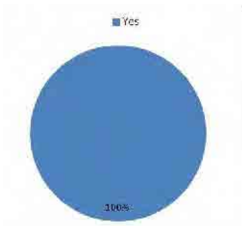
Data Analysis has been carried out for dust monitoring on various issues such as understanding the level of safety knowledge, and the safety & health experience of the workers, Engineers and Road users. Some important parameters for various groups were considered and analyzed. The result of analysis is discussed group wise in the following sub sections. The analysis was carried out in two types (i) grading the opinion in four/three grade point scale and (ii) categorization of the choice of the opinion expressed (pie chart).

5.5.1 Site Workers

Randomly, 46 site workers at Central College Station (CCL) were interviewed before and after training and about 31 site workers at Vidhan Soudha (VS) station (Without monitoring method) have been interviewed. From Table 5.10, it can be identified that the level of dust consciousness was adequate before training at CCL but consciousness has reached very good after training. The percentage of workers with dust related safety awareness at CCL station has been increased from 54% to 83% whereas, workers with awareness at VS station are at 63%. After training, the workers at CCL station become fully aware regarding the color code of dust monitoring techniques, improve their attitude towards health consciousness and fully agree that future metro constructions projects should be monitored. The workers at Vidhan Soudha station also fully agree that this monitoring method changed their attitude and health consciousness after explaining through the pamphlets on dust monitoring. All the workers at central college station understood the purpose of the monitoring method after training. In the case of Vidhan Soudha station, about 94% of the workers understood the purpose of dust monitoring method at construction sites.

Table 5.10 Opinion of Site Workers about Dust Monitoring

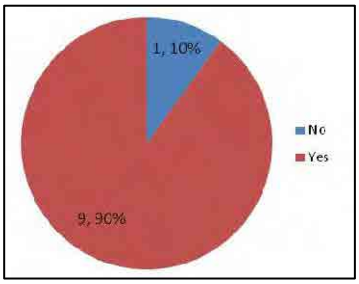
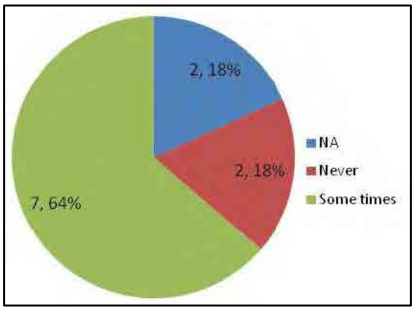
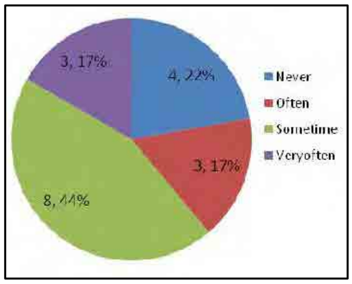
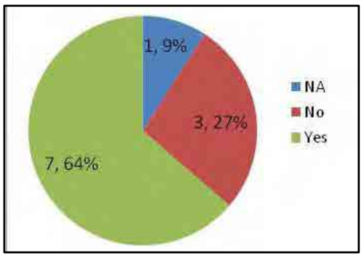
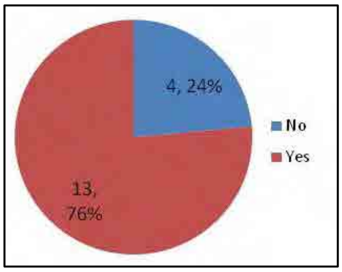
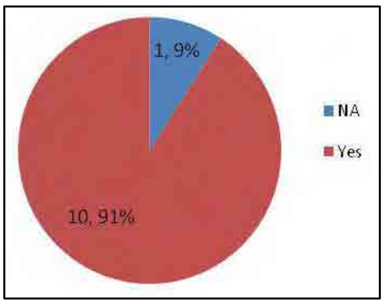
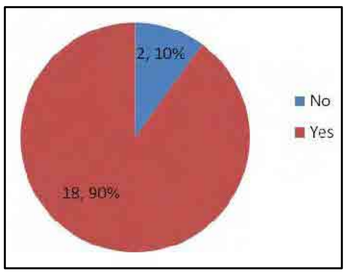
Sl. No	Parameters of Opinion Survey	Workers Before Training at CCL (Samples Size 41)	Workers After Training at CCL (Sample Size 46)	Workers No Dust Monitoring at VS (Sample Size 31)
1	How much consciousness of dust do you have during working at the site? Fair Good NA poor Very Good			

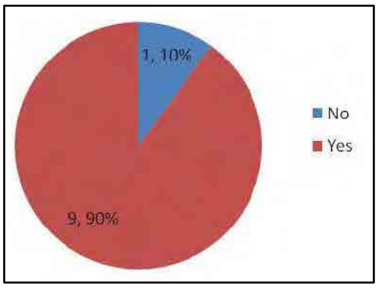
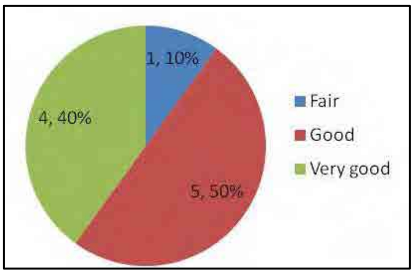
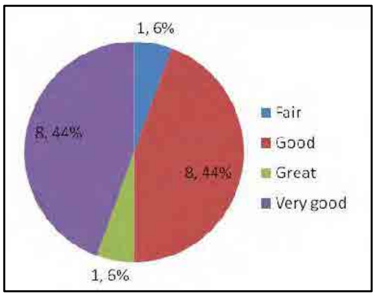
2	Do you think current dust related safety measures are adequate? (Blue: Yes; Red: No; Green : Can' Say)			
3	Do you understand the purpose of the Dust Monitoring method? (Blue : Yes Red: No)			
4	Have you understood the meaning of dust color panel color provided at the work site? (Blue : Yes Red: No)			
5	Do you agree this dust monitoring method will change your attitude and health consciousness?			
6	If you agree, how do you rate your improvement in health consciousness by introducing the Dust Monitoring Method?			
7	How would you rate use of the dust monitoring method in construction monitoring?			
8	Will you recommend the dust monitoring method for other /Future Metro constructions?			

5.5.2 Site Engineers and Officers

A total of 31 officials comprised of Site Engineers of SOMA, officers of BMRC, were interviewed before and after evacuation training. The experience in dust monitoring and opinions on present dust monitoring has been presented in Table 5.11. Results from Table 5.11, show that most of the engineers/officials have awareness of dust effects, also this group has attended dust monitoring control programmes. Almost all the engineers understood the purpose of the mobile phone camera based dust monitoring programme. About 90 % of the engineers rated this method as good in construction monitoring and 90% of engineers before training recommended this method for future metro monitoring, after trainings all the engineers recommended this method for future metro constructions.

Table 5.11 Opinion of Site Engineers/Officers about Dust Monitoring

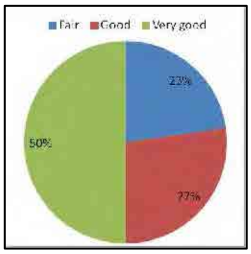
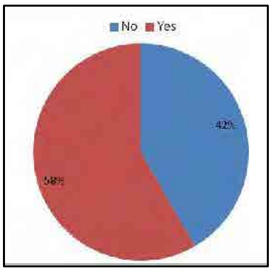
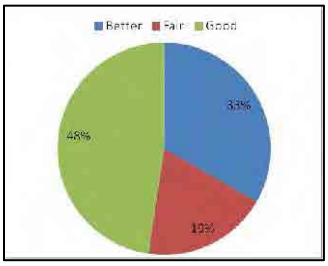
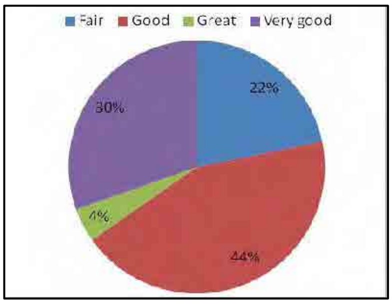
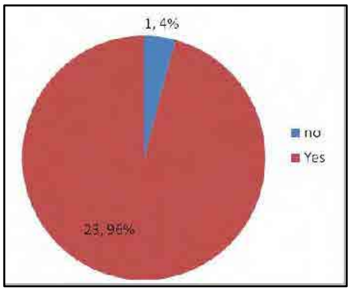
Sl. No	Parameters of Opinion Survey	Before Training (Sample Size 11)	After Training (Sample Size 20)
1	Are you aware of the effects of dust?		100%
2	How often have you attended dust Monitoring and Control programming?		
3	Do you think current dust control measures are adequate?		
4	Do you understand the purpose of the Dust Monitoring method?		

5	Will you recommend the dust monitoring method for other /Future Metro constructions?		100%
6	How would you rate use of the dust monitoring method in construction monitoring?		

5.5.3 Road Users

Randomly, 29 road users in front of Central College station were questioned regarding their knowledge of Safety and their Opinions on the OSV method and the responses from this group have been analyzed and represented in Table 5.12. From the Table, it can be observed that 50% of the road users were health conscious and also 50% of the objects were aware of the dust monitoring at the BMRC construction site. The survey team explained through pamphlets about the mobile phone dust monitoring method and 80% of the road users significantly improved their health conscious by being introduced to the dust monitoring method. A total of 75% of the samples replied that the use of the dust monitoring method is good in construction monitoring and also most of this group recommend the dust monitoring method for other /Future Metro constructions

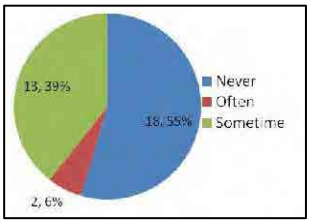
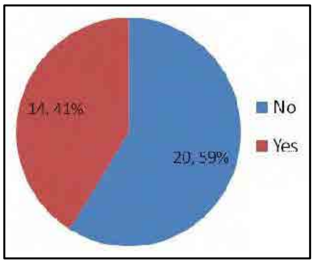
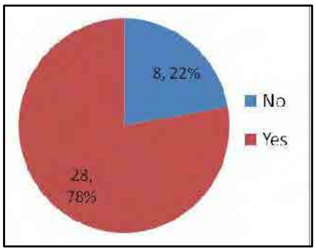
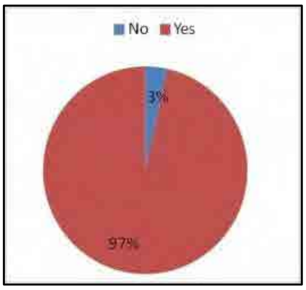
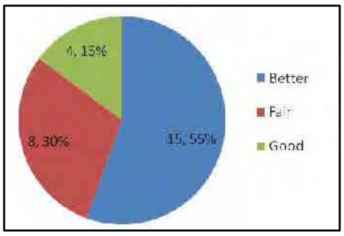
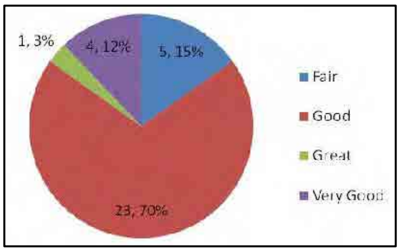
Table 5.12 Opinion of Road Users about Dust Monitoring

Sl. No	Parameters of Opinion Survey	Road Users at Central College Station (Sample 29)
1	How much health consciousness do you have?	
2	Are you aware of the dust monitoring at the BMRC construction site?	
3	How much was your health consciousness improved by being introduced to the Dust Monitoring Method?	
4	How would you rate use of the dust monitoring method in construction monitoring?	
5	Will you recommend the dust monitoring method for other /Future Metro constructions?	

5.5.4 Training Participants

A simple questionnaire was specially designed for the participants of the training programme organized by JICA in IISC Bangalore. The data from the opinion survey of 36 participants that included students, faculty members, research associates and research analysts have been collected. Their opinions on dust monitoring have been analyzed and represented in Table 5.13.

Table 5.13 Opinion of Training Participants about Dust Monitoring

Sl. No	Parameters of Opinion Survey	Training Participants
1	How often have you attended dust Monitoring and Control programming?	
2	Do you think current dust control measures at construction site are adequate?	
3	Do you understand the purpose of the Dust Monitoring Method?	100%
4	Do you understand the meaning of dust color panel	
5	Do you agree this dust monitoring method will change your attitude and health consciousness?	
6	How much has your dust related consciousness been improved by introducing the mobile camera method?	
7	How would you rate use of the dust monitoring method in construction monitoring?	
8	Will you recommend the dust monitoring method for other metro construction?	100%

From Table 5.13, it can be concluded that all the participants have understood the purpose of dust monitoring and its applications at construction sites. About 97% agree that they have improved their health consciousness by attending this training programme. A total of 70% of the participants have significantly improved dust related consciousness by introducing the mobile phone camera method. A total of 95% of the participants rated that dust monitoring method was good to use for monitoring construction sites. Most of the participants expressed that this method was good and economical for monitoring at constructions sites. Also these groups recommended this method for other metro constructions.

5.6 Observations for Improvement of OSV and Dust Monitoring Methods

The following recommendations were observed from the collected samples for further improvement of OSV and Dust Monitoring Methods

5.6.1 OSV Monitoring Method

- *Location and Number of Sensors:* The location of sensor and optimum number of sensors required are to be designed/installed based on some relation with construction area and the type of construction.
- *Flash Emitting System:* There should be a flash emitting system when the laser color changes from one color to another color (Blue to Green, Green to Yellow and Yellow to Red) to attract the attention of the workers and safety engineers.
- *Audio Interface System:* The early warning system should be interface with an audio alarm which would be beneficial because all the workers in the site would hear an audio alert. Also it would be beneficial to engineers to manage the safety of the workers.
- *Wireless and Centralized Monitoring:* The OSV monitoring should be wirelessly controlled with a centralized system to monitor the safety of various metro construction sites as this will be very useful to the large group of workers in Bangalore Metro Constructions

5.6.2 Dust Monitoring Method

The dust monitoring by mobile phone camera method is dynamic and an ideal alternative to traditional methods such as the digital dust indicator.

- *Awareness Programmes:* Further, frequent awareness programmes on the health impacts of dust are required to enhance the awareness of the workers. This will motivate the workers to use proper masks during work at metro construction sites.
- *Real Time Dust Data Collection:* Real time dust data collection and information will be very useful to site workers and engineers to take proper precautions during working
- *Dashboard Display:* Both the online measurement and presentation of the information to workers through electronic display messages during the construction is very useful to

the engineers as well as the workers to consider proper protection measures immediately

- *Meteorological Information:* Weather information, in particular seasonal and daily wind patterns, will give additional information to the site engineers and workers to take additional precautions during blasting or drilling
- *Development of guideline dust levels:* Development of proper guidelines and set of procedures for these innovative monitoring techniques in metro construction sites are essential. This will be useful as a baseline for dust levels for metro construction sites in India

5.7 Concluding Remarks and Recommendations

The following key findings of the study are discussed and recommendations have been proposed for further improvement of the OSV and Dust Monitoring methods.

5.7.1 Concluding Remarks for OSV Monitoring

In this section the analysis of the questionnaire survey results are summarized in five parts. In the Initial part, general findings were summarized. They are the most relevant findings from various categories. The other four parts include various findings from Site Workers, Site Engineers/officers, HAL and BSNL building residents and training participants, which are described as follows. The analysis also is the reference for the "Safety Control Manual through OSV Monitoring" made in this project.

(1) General findings from the questionnaire Survey

- Almost all the respondents to the opinion survey in each category have recommended the OSV monitoring method for other /Future Metro constructions.
- The rate uses of OSV in construction safety monitoring were quantified on a 4 point measurement scale. For site workers it is about 2.3, for HAL and BSNL building residents it is about 1.8 and for site Engineers/Officers/ Scientists it is about 1.4
- The improvement of safety consciousness by introducing OSV has been quantified on a 4 point measurement scale. From the results, it is revealed that for the workers group, it is about 2.8, for Engineer/Officers/Scientists it is about 2.3 and for HAL and BSNL building residents it is it is about 1.3.

(2) Findings from Site Workers

- Randomly, 117 site workers at Cricket Stadium metro station have been interviewed from both the day and night shifts. All of the workers understand the purpose of OSV. They observed the sensor very often during their work. This emphasizes that site workers are keenly interested in monitoring the safety condition through OSV.

- Most of the workers understood the actions that are required based on the change of color. Initially, before training, 30% of the workers could not understand the use of colored lights and the action to be taken. This ratio was significantly reduced to 5% by providing evacuation training.
- About 97% of the workers agree that the OSV monitoring method will improve their attitude and safety consciousness.

(3) Findings from Site Engineers/Officers

- Site Engineers of SOMA, and officers of BMRC have been interviewed (total 40 samples before and after). This entire group understands the purpose of OSV. They observed the sensors very often during their work. This emphasizes that Site Engineers and Officers have keen interest in monitoring the safety condition through OSV.
- Some of them suggested that more sensors need to be provided. Also the optimum number and their location need to be studied.
- The use of the OSV safety monitoring method was evaluated with respect to reducing the severity of incidents in terms of men and material has been quantified on a 4 point measurement scale. From the result it can be observed that it is about 1.60. This emphasizes that by introducing the OSV monitoring method, accidents causing injury to men and material can be significantly reduced.

(4) Findings from HAL and BSNL Residents

- Randomly, 24 employees from the HAL building and 37 employees from the BSNL building have been interviewed. Out of this, 63% of the HAL building and 89% of the BSNL building residents were very keen in watching the lights installed on top of the buildings and 67% of the residents of the HAL building and 91% of the BSNL building agree that they feel safer due to the installing of the OSV on top of their buildings.
- All most all of the employees recommended this monitoring method for other/future metro projects.

(5) Findings from Training Participants

- The data have been collected from an opinion survey of 40 participants, which includes students and faculty members attended training the programme at IISc Bangalore. Out of this, 95% of the participants have understood the purpose of OSV and 90% agree that thy have improved their safety consciousness by attending this training programme.
- A total of 92% of the participants agree that the OSV method is useful as a safety check for metro constructions. Most of the participants expressed that this method is simple, efficient, economical and a real time monitoring method.

5.7.2 Concluding Remarks for Dust Monitoring

In this section the analysis of the questionnaire survey results are summarized into four parts which includes various findings from Site Workers, Site Engineers/officers , road users in front

Central College metro station and training participants, which are described as follows.

(1) Findings from Site Workers

- Randomly, 87 site workers (included before and after training) at central college metro station have been interviewed. All of the workers understand the purpose of the Dust monitoring by mobile phone camera method. These workers are keenly interested in monitoring their health through this method.
- The percentage of workers with dust related safety awareness at this station has increased from 54% to 83%
- After training, workers at this construction site were fully aware of the color code of the dust monitoring techniques.

(2) Findings from Site Engineers/Officers

- Almost all the engineers understood the purpose of the mobile phone camera dust monitoring method. About 90% of the engineers indicated that this method is good in a construction monitoring programme
- Before the training programme 90% of the engineers recommended this method for future/other metro constructions

(3) Findings from Road Users

- Randomly, 29 road users in front of central college station were interviewed. A total of 50% of this group were health conscious and also 50% of the road users were aware of the dust monitoring at this construction site.
- A total of 75% of the samples commented that the use of dust monitoring is good in construction.
- All most all of the subjects recommended this monitoring method for other/future metro projects.

(4) Findings from Training Participants

- The data has been collected from an opinion survey of 36 participants that included students and faculty members that attended the training programme at IISc Bangalore. About 97% agree that they have improved their health consciousness by attending this training programme.
- A total of 70% of the participants significantly improved their dust related consciousness by introducing the mobile phone camera method. A total of 95% of the participants stated that the dust monitoring method was good for monitoring construction sites.
- Most of the participants expressed that this method is good and economical for monitoring constructions sites.

5.7.3 Recommendations

(1) OSV Monitoring Method

- The OSV method should be further improved by consideration of sensor interface with an audio visual system. Also during the change of color, for some period of time the sensor lights (LED) should be blinked to warn the people about the color changes.
- A dashboard type safety message based on the OSV at the entrance of the work site will be quite beneficial to the workers, engineers and road users for the over all safety of the construction site.
- A safety monitoring system like the OSV should be assessed and incorporated at the design stage itself depending upon the site conditions.

(2) Dust Monitoring Method

- Dust monitoring by mobile phone camera method is a dynamic and ideal alternative to traditional methods such as the digital dust indicator.
- Further, the results from this method compare well with those of the standard digital dust indicator.
- Online measurement and information presented to workers through electronic display messages during the construction is very useful to the engineers as well as the workers to implement proper protection measures immediately.
- Frequent training for Workers should be required to teach them the impact of dust and its impact on health, this will change their attitude and convince them to use proper masks during blasting and drilling.

Chapter 6 Site Safety management by OSV monitoring

6.1 Safety concept in INDIA - regarding underground construction

In India the construction industry is the second largest employer next to agriculture whereas the accidents in the construction industry are next largest to the road accidents in the country. The annual turnover of the construction industry in India is about 4000 Billion Rupees, which is more than 6% of the National GDP employing a large work force including labourers. The construction works in the infrastructure industry are increasing and it is being planned to spend 1trillon US$ for the next five year plan 2012-17 of the Govt of India. The number of fatalities occurring from construction works in the industry is quite disturbing. The mobile nature of the work force that moves from once place of work to another poses challenges in ensuring that all of them are adequately trained. In India, construction safety management indeed is a challenging task due to the dynamic nature of construction activity coupled with involvement of an unskilled, illiterate and mobile work force. Since the projects are located in remote regions of the country, the surrounding population involved in construction activities is substantial. These personnel are generally from an agricultural background, speaking and understanding local languages only. This poses additional challenges due to the limitation in communication.

Construction hazards are rated as eight times more risky than those from the manufacturing sector. With strong planning, effective implementation and continuous training with focussed safety management a good safety record could be achieved comparable to the international level. In India, there is already a focus on the following aspects while planning and implementation of safety management:

- Innovation in the training methodologies to achieve higher effectiveness of training among the contractor employees.
- Developing and implementing behaviour based safety programs to improve orientation of the work force towards safety in work.
- Implementation of innovative engineering measures to strengthen the safety requirements at design stages to achieve a safe working environment during construction.
- A well designed safety organisation for contractors, sub-contractors and interface with departments is essential. Implementation of Safety is a line management function; therefore its ownership lies with them.
- Area-wise Task Force for enforcing safety at construction Projects
- Periodic Safety Audits

The dynamicity, complexity and parallel activities in construction are unavoidable at times. These activities, though planned, are carried out by the work force which is skilled in the execution of work but lacks awareness of safety requirements, therefore, overconfidence and complacency, at times, leads to a breach in safety requirements. There is a lack of strict enforcement of the safety rules at construction sites. Hence, a regular monitoring and surveillance program along with coaching & mentoring of employees during execution becomes necessary to correct the aberrations in safety implementation. The use of modern teaching aids such as audio-visuals, and mobile training will improve the performance of training.

In India, the National Safety Council (NSC) was set up by the Ministry of Labour, Government of India (GOI) on 4th March, 1966 to generate, develop and sustain a voluntary movement on Safety, Health and Environment (SHE) at the national level. It is an apex non-profit making, tripartite body, registered under the Societies Registration Act 1860 and the Bombay Public Trust Act 1950. To fulfil its objective NSC carries out various activities. These include organising and conducting specialised training courses, conferences, seminars & workshops; conducting consultancy studies such as safety audits, hazard evaluation & risk assessment; designing and developing HSE promotional materials & publications; facilitating organisations in celebrating various campaigns e.g. Safety Day, Fire Service Week, and World Environment Day. A computerised Management Information Service has been setup for collection, retrieval and dissemination of information on HSE aspects. To its credit, NSC has successfully organised many national and international conferences e.g. XIII World Congress (1993) and XI APOSHO Conference (1995) and implemented many a prestigious project. It also serves as a gateway to the state-of-art information on HSE aspects at the international level. In the course of its services for the last 45 years, it has built up technical expertise and competence to meet the emerging challenges in the HSE aspects due to continuous advancements in technology.

The construction of underground tunnels, shafts, chambers, stations and passageways are part of infrastructure development and are essential yet dangerous activities. Working under reduced light conditions, limited or difficult access and way out, with the potential for exposure to air contaminants and the hazards of fire and explosion, construction workers in underground construction face many such dangers as listed above. The owner or the employer must maintain a check-in/check-out procedure to ensure that above ground personnel maintain an accurate accounting of the number of persons underground and to prevent unauthorized persons from gaining access to the site. In the event of an emergency, this is especially important but is a common sense requirement at all times. When an underground construction project designed for human occupancy is completed to the point that permanent environmental controls are effective and any remaining construction activity does not have the potential to create an environmental hazard or structural failure in the construction area, this procedure is not required. Any time an employee is working underground, at least one designated person must be on duty above ground to monitor his movement and the above ground person should be in contact with the person underground all the time. This person is responsible for calling for immediate assistance and keeping an accurate count of employees who remain underground in the event of an emergency. The following topics should be part of an underground construction employee training program: Air monitoring and ventilation, Illumination, Communications, Flood control, Personal protective equipment, Emergency procedures, including evacuation plans, Check-in/check-out procedures, Explosives, Fire prevention and protection, and, Mechanical equipment.

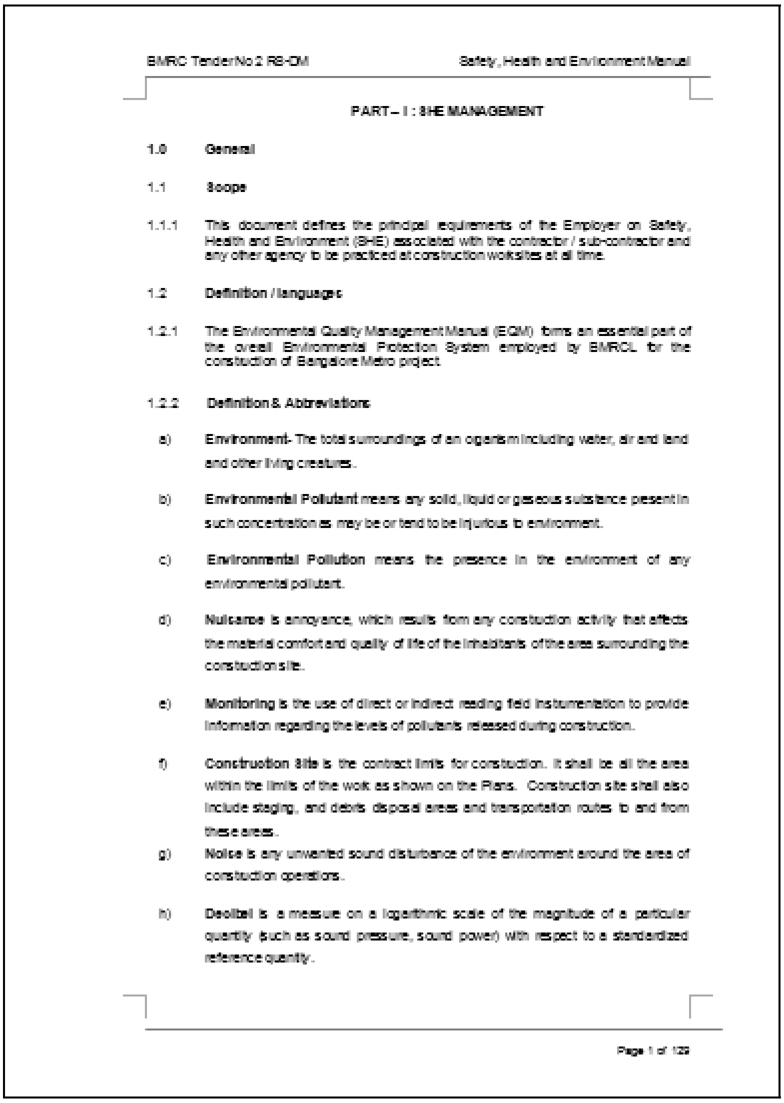
Even with all things in place, while the construction work is in progress; Safety Related Deficiencies (SRD) emerge either due to change in status at the work floor or multiple agencies working in parallel. SRD also get generated due to a decline in the safety culture. It is therefore required that SRDs are detected and corrected promptly on a routine basis. Presently a LAN based system of communicating SRD is in practice in India's nuclear plant construction sites. The system is called "SRD Management System" in the nuclear industry. As could be seen from the various accident dominos, before a serious or fatal accident occurs, we get number of opportunities to correct the unsafe conditions or unsafe practices from the minor accidents or near misses, which occur as a precursor. These need to be recorded, reported and analyzed as this provides immense experience feed back for improvement. It is more common to see more accidents on the above ground than the underground construction sites, as people are more complacent on the ground and are also over confident.

Construction sites have many types of hazards as explained earlier due to the complexity of the work environment. Even after the implementation of the safety requirements through engineering means during design, there would always be residual risk to the workers. Personal protective equipments (PPE) including Safety helmets, Safety belts, Safety shoes, hand gloves, goggles, fall arresters etc. should be made available and also compulsory near the work spot for ease of use by workers. Thus, as a good safety culture, all workers should use the required PPE. At times some workers may feel some inconvenience in using the PPE, but we should scrupulously enforce the use of PPE right from day one and each worker should be made to consider these as the last in depth defence to save his life. In order to ensure proper coordination and communication on safety aspects on a periodic basis, it is necessary to have a regular exchange of views and experience.

6.2 Site Safety Plan with OSV

6.2.1 Risk Assessment and OSV monitoring allocation

The BMRC SHE Manual stipulated that a Safety Risk Assessment must be submitted prior to the commencement of any potential high-risk operation. The Contractor has already submitted and gotten approval for a Risk Assessment Report of High Level Risk Hazards at the beginning of the project.



BMRC Tender No 2 RS-DM Safety, Health and Environment Manual

PART – I : SHE MANAGEMENT

1.0 **General**

1.1 **Scope**

1.1.1 This document defines the principal requirements of the Employer on Safety, Health and Environment (SHE) associated with the contractor / sub-contractor and any other agency to be practiced at construction worksites at all time.

1.2 **Definition / languages**

1.2.1 The Environmental Quality Management Manual (EQM) forms an essential part of the overall Environmental Protection System employed by BMRCL for the construction of Bangalore Metro project.

1.2.2 **Definition & Abbreviations**

a) **Environment-** The total surroundings of an organism including water, air and land and other living creatures.

b) **Environmental Pollutant** means any solid, liquid or gaseous substance present in such concentration as may be or tend to be injurious to environment.

c) **Environmental Pollution** means the presence in the environment of any environmental pollutant.

d) **Nuisance** is annoyance, which results from any construction activity that affects the material comfort and quality of life of the inhabitants of the area surrounding the construction site.

e) **Monitoring** is the use of direct or indirect reading field instrumentation to provide information regarding the levels of pollutants released during construction.

f) **Construction Site** is the contract limits for construction. It shall be all the area within the limits of the work as shown on the Plans. Construction site shall also include staging, and debris disposal areas and transportation routes to and from these areas.

g) **Noise** is any unwanted sound disturbance of the environment around the area of construction operations.

h) **Decibel** is a measure on a logarithmic scale of the magnitude of a particular quantity (such as sound pressure, sound power) with respect to a standardized reference quantity.

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Figure 6.1 BMRC SHE Manual

According to the report, the general risk assessment for the retaining wall excavation is as shown in Table 6.1.

Table 6.1 General Risk assessment for Retaining wall excavation

Event/Activity	Risk Code.	Name of Hazard	P	G	R	Measures taken
Excavation and support of working shaft	B-1	Piping failure (flow-in of water and soil) caused by inadequate quality of diaphragm wall	P3	G2	R2	Low permeability of soil and deeper groundwater level are observed so the possibility of this hazard is low. QA/QC plan for wall construction will be delivered to prevent the failure. Monitoring and tests will be carried out during the construction of wall to ensure the wall integrity.
	B-2	Excessive deformation of diaphragm wall caused by over-digging and delay of props installation	P3	G2	R2	Well- control of excavation level and no further delay of prop installation will reduce deformations of the diaphragm wall. Wall deflection will be observed during the construction and excavation plan will be adjusted if an excessive wall deformation is found.
Excavation and support of working shaft (Continue)	B-3	Failure casued by inadequate site investiagtion resulting in optimistic design assumption of strength of soil and groundwater level	P2	G3	R2	Very conserve assumptions for soil strength and groundwater level are used in the design. Feedback analyses will be delivered in order to confirm design assumptions from site investigation. Reasons for greater variance in groundwater level will be further explored.
	B-4	Failure caused by inadequate quality of structural dealing	P2	G3	R2	Loads on props will be measured during the construction. Immediate actions will be taken if prop load is over the alert level.
	B-5	Failure caused by changes in loading from groundwater	P3	G2	R2	Groundwater level and pore pressure will be observed during the construction and design will be checked if the observation is significantly different with design assumption.
	B-6	Faliure caused by excavation stability	P2	G3	R2	Ground movements will be observed during the construction and immediate actions will be taken to increase stability of the excavation if excessive ground movements are seen.
	B-7	Failure caused by excessive up-lift groundwater pressure	P2	G3	R2	Piezometeric levels inside the excavation will be measured during the excavation. If observations are significantly different with design assumptions, immediate action such as pumping or grouting will be taken in order to avoid the failure caused by up-lift groundwater pressure.
	B-8	Severely damage of adjacent structures induced by additional ground movements	P2	G2	R2	Influences on adjacent structures will be evaluated in advance. Tilting and settlements of adjacent structures will be measured during the construction and immediate action will be taken if these movements are over the alert level.

(Reference by International Tunnel Association, 2002)

Note: Index of risk matrix

P: Probability of Occurrence Categories;

P1: Very unlikely, P2: Unlikely, P3: Occasional,

P4: Likely, P5: Very likely

G: Severity of Loss or Damage Categories;

G1: Insignificant, G2: Considerable, G3: Serious,

G4: Severe, G5: Disastrous

Level of Risk

	Level of Risk	Mitigation Strategy
R4	Unacceptable	Should not carry out engineering design, must put risk mitigation strategies into action to decrease level of risk
R3	Unwanted	Must take measures to mitigate risk
R2	Acceptable	Carry out risk management procedures
R1	Negligible	No action necessary

Risk Matrix

Probability Of Occurrence	G1 Insignificant	G2 Considerable	G3 Serious	G4 Seve	G5 Disastrous
Very Likely P5	P5 G1	P5 G2	P5 G3	P5 G4	P5G5 Unacceptable
Likely P4	P4 G1	P4 G2	P4 G3	P4 G4	P4 G5
Occasion P3	P3 G1	P3 G2	Unwanted P3 G3	P3 G4	P3 G5
Unlikely P2	P2 G1	Acceptable P2 G2	P2 G3	P2 G4	P2 G5
Very Unlikely P1	Negligible P1 G1	P1 G2	P1 G3	P1 G4	P1 G5

Severity of Loss or Damage

Based on the above general risk assessment, the OSV team made a specific Risk Assessment with allocation for OSV monitoring devices for the entrance excavation at the Cricket Stadium station.

Table 6.2 Risk Assessment and OSV devices allocation at Cricket Stadium Station

Risk code	Name of Hazard	P	G	R	Risk management measures to be taken	OSV devices allocation
S-1	Piping failure (soil & water) caused by weakness of timber	P3	G1	R2	Ground water level is low. Timber lagging to be tightened to prevent the leakage of soil.	LEC tilt-meter on soldier pile LEC load cell on pile
S-2	Excessive deformation of soldier pipe / scan pile caused by over-digging and delay of props installation	P3	G2	R2	Excavation level shall be well-controlled. Wall deflection will be monitored to check for excessive deflection.	LEC tilt -meter on pile LEC load cell on pile
S-3	Failure caused by inadequate site investigation resulting in optimistic design assumption of strength of soil	P2	G2	R2	Conservative assumptions for soil strength are used. Strut force will be checked by on-line OSV monitoring.	Strut force with LEC
S-4	Failure caused by inadequate quality of structural provisions	P3	G2	R2	Connection of Struts, walers and piles to be checked by "Permit to Work" system	(Checked by Permit to work with OSV)
S-5	Failure caused by changes in loading from groundwater	P1	G3	R2	* Ground water level is very low * It is dry season until end of June	LEC inclinometer in ground
S-6	Failure caused by lack of excavation stability (boiling, heaving of soil)	P1	G3	R2	* Ground water level is very low * Embedment of piles are adequate to prevent failure	LEC inclinometer in ground
S-7	Failure caused by excessive up-lift due to ground water pressure	P1	G3	R2	* Ground water level is very low	(No OSV required)
S-8	Severe damage of adjacent structures (HAL building, BSNL building) induced by additional ground movements	P3	G2	R2	* Minimum distance between excavation and hostel is 8m. Various OSV devices will be installed to check for any ground movement.	LEC tilt-meter on building

According to the results of the Risk Assessment at the Cricket Stadium Station's excavation, it was concluded to carry out the site construction based on the above risk management measures with OSV monitoring

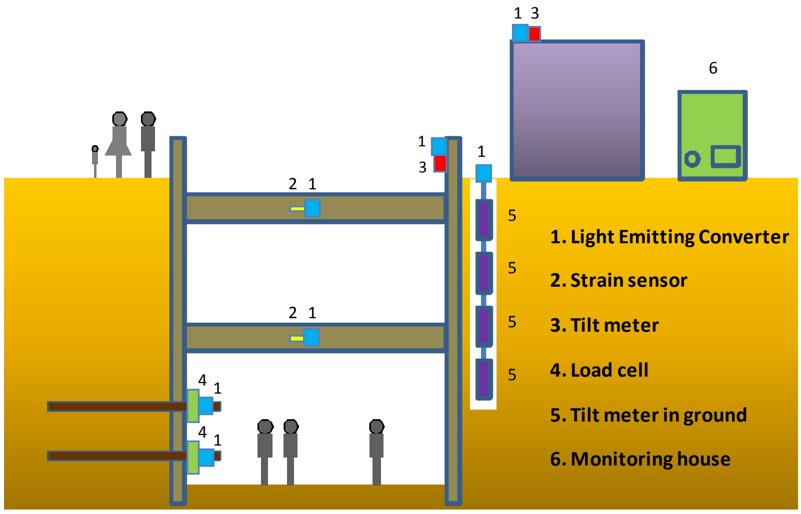

Figure 6.2 Typical arrangement of OSV devices at Cricket Stadium Station site

6.2.2 Contractor's Safety Management System

According to the contract requirement, the Contractor shall establish a Safety Plan including Safety Management system after the award of the contract. The objectives of the Safety Management system can be summarized as:

- provide a safe place of work
- identify lines of responsibility for safety
- provide safe working practices for carrying out normal operations of the worksite
- provide for the identification of hazards and establish safeguards against those hazards
- provide through investigations into safety incidents or near miss incidents and establish safeguards to prevent recurrence
- create awareness that safety is an integral part of work and that production and safety are inseparable
- provide response to Emergency situations
- strive to continuously improve safety management skills

The major safety management activities for the above objectives are summarized below;

(1) Safe work practices/procedures

All work items at the site shall be performed with proper working procedure in terms of safety. The objective of the Safe work practices/procedures is to eliminate, or reduce to a minimum, the risk of death or injury to persons, and damage to properties and assets, during the execution of the work. Major items of safe work practices/procedures are listed below;

1. Permit to Work
2. Excavation Works
3. Transportation
4. Working at height
5. Electrical work

6. Crane operators
7. Welding & Cutting
8. Fire prevention
9. Handling of chemicals
10. Noise control
11. Dust control
12. Waste management

(2) Site safety performance

Safety talks and meetings are important methods of ensuring successful supervisor and worker communication by making effective use of communication time by allowing workers' participation and providing equal exposure to vital information. The site inspection is conducted to ensure that all safety requirements are observed and any unsafe acts/conditions are immediately corrected. The major items of Site safety performance are listed below;

1. Daily tool-box talks day / night shifts
2. Safety induction talks for new comers
3. Monthly Safety Committee meetings
4. Site Safety walk – BMRC/GC, Site Management
5. Alcohol test of workmen prior to start of shift
6. Daily site inspection by Safety team
7. Monthly electrical inspection

Figure 6.3 Site safety performance

(3) Safety awareness training & programs

The objective of safety training and programs is to equip personnel with the knowledge, skill and attitude, which will enable them to perform their duties in a safe manner. Major activities of Safety awareness training and programs are listed below;

1. Training for Crane operators, Riggers and Signalmen
2. Training on Gas Cutting and Welding Operations
3. First Aid training program
4. Emergency Evacuation drills
5. Lifting Equipment and Tool Tackle Inspection and awareness
6. Waste segregation awareness program
7. SHE days celebration (National Safety Day, World Health Day, Fire Safety Day)

Figure 6.4 Safety awareness training & programs

6.2.3 Safety Management Activities with OSV

The Safety management activities with OSV at the Cricket Stadium Station site are evaluated and selected in terms of the following aspects;

- Integration of OSV monitoring effectively into the safety activity
- Improvement of safety awareness both for workers and citizens to build an advanced safe working environment
- Improvement of the safety control techniques through the execution of OSV monitoring.

Based on the above evaluation items, the following activities are selected for the execution of safety management activities with OSV at the Cricket Stadium Station site;

1. Safety OSV induction talks to BMRC/GC, Contractor and citizens
2. Daily site walks and inspections with OSV
3. Permit to work with OSV
4. Emergency evacuation drills with OSV

In the Method Statement for the Entrance Excavation at Cricket Stadium Station, the above activities were specified with detailed required procedures.

6.2.4 Execution of Safety Management Activities with OSV

(1) Safety OSV induction talk to the Contractor

a) Approach

OSV monitoring and its safety activities are new to the Contractor. The presentation and discussion of Safety OSV induction were conducted to BMRC/GC and Contractor's engineers for good understanding of OSV. The following items were explained and discussed;

- Target of OSV
- Contents of OSV devices
- Site arrangement of OSV monitoring
- Trigger values of OSV monitoring
- Action plan for color changes

A Safety OSV induction talk to all workers at the site was given by the OSV team. The explanation in the local language covered:

- The colors show the movement of the ground and structures;
- “Yellow color” means “ inform the Safety officer”;
- “ Red color” means “keep off the site and inform the Safety officer”;
- The safe place was identified under the evacuation stage at the site and was given by the Contractor’s safety officer.

Figure 6.5 Safety OSV induction talk to workers

b) Results

Usually there is no information given to site workers for site monitoring issues, the role of the report for color changes or detailed action for evacuation. Therefore these activities had a great effect for uplift of safety consciousness and improvement of safety techniques for the BMRC/GC, Contractor and workers.

(2) Safety OSV induction talk to the citizens

a) Approach

This is the first time in Delhi Metro projects that the safety monitoring information was shown to the public during the construction stage. Through the OSV induction talk, the message to the citizens for good management of site safety could be transferred. Safety OSV information was given to residents in the adjacent buildings (HAL Building and BSNL building) next to Cricket Stadium Station.

Information to residents in the adjacent hostel

- Provide pamphlets for OSV monitoring on the building entrance
- Safety OSV induction talk by OSV team
- OSV information cards were given to all residents

b) Results

Based on the above activities, the citizens could appreciate the safety procedures and conditions at the site. The nurses were very interested to know what the structural condition of their hostel was and what kind of action is required in case OSV colors are changed at the site. Through this induction talk, citizens understood they could obtain the safety confirmation of their hostel and road by OSV monitoring.

(3) Daily site walk and inspection with OSV

a) Approach

A daily site walk and inspection covered on the WEB Site were conducted with BMRC/GC, the JICA team and the Contractor during the excavation stage at the excavation of Cricket Stadium Station.

Figure 6.6 Daily OSV check on WEB Site

Figure 6.7 Daily site walk with BMRC/GC, the Contractor and JICA team

b) Results

Through these activities, the following effects were observed;

- Improvement of safety awareness was achieved
- Technical discussions and advice were given
- Safety team sprits among BMRC/GC and the Contractor were obtained

(4) Permit to work system with OSV

a) Approach

A permit to work system was introduced to define and confirm the proper standards and processes for work activities. The permit to work system with OSV was conducted for the entrance excavation with a retaining wall system with struts & walers.

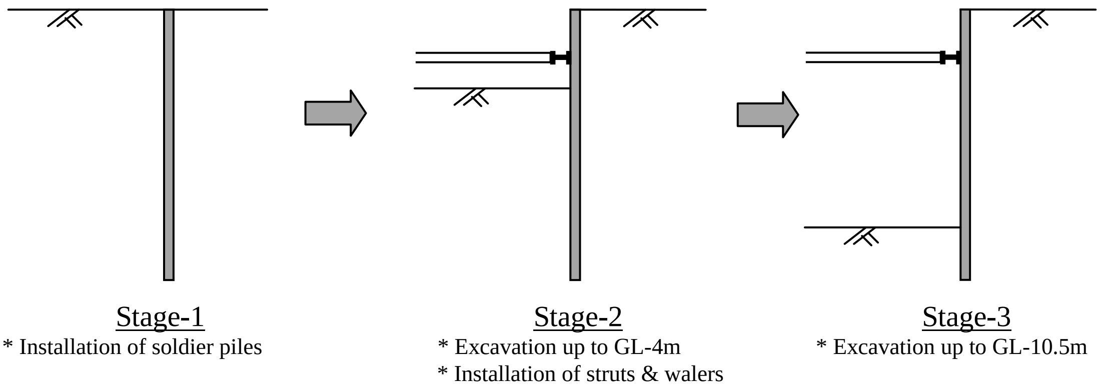

Figure 6.8 Excavation sequence for Cricket Stadium Station

After Stage-2 construction as shown in Figure 6.9, a Permit to work inspection was conducted by BMRC/GC, the JICA team and the Contractor.

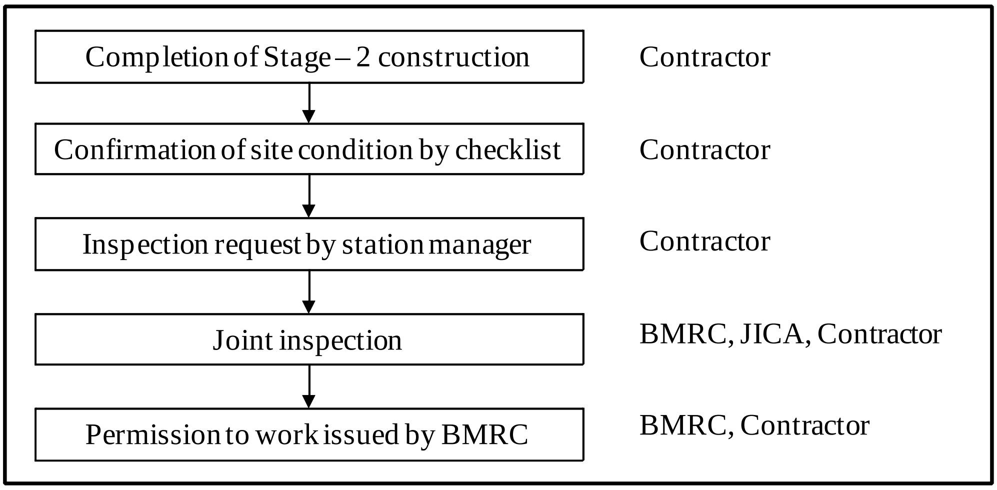

Figure 6.9 Permit to work procedure

Figure 6.10 Permit to work inspection with BMRC/GC, Contractor and OSV team

b) Results

The effects of the Permit to work inspection with OSV are as follows;

- Check of the safety condition visually and directly at inspection time
- Uplift of safety awareness through joint confirmation of OSV monitoring

(5) Emergency evacuation drill with OSV

a) Approach

The Contract documents on the Emergency Preparedness Plan specify that "The contractor must perform the emergency refuge training for all workers in the construction site at a frequency of once a month." According to that, the evacuation drill plan was discussed and made by the OSV team;

Safe place in case evacuation is given
↓
Change the OSV color from “Blue” to “Red”
↓
Engineer to instruct “evacuation” to workers
↓
Monitor the evacuation scheme
↓
Safety site talk to all workers

* In the safety OSV induction talk, information of safe place under evacuation was given to all work

* The colors of deformation sensor of retaining wall to be changed.

* The Contractor’s engineer knows the drill.

* The number of workers and time taken for evacuat

* The target and result of evacuation drill is explaine

Figure 6.11 Emergency Evacuation drill procedure

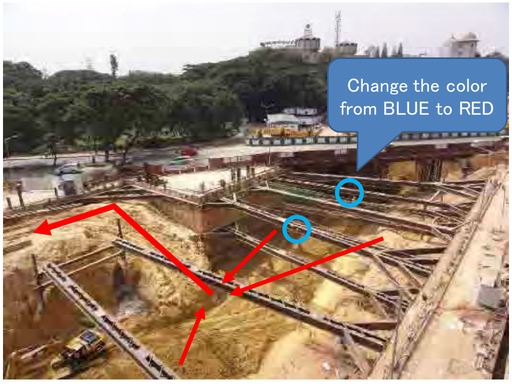

Figure 6.12 Safe place under evacuation at AIIMS entrance

Figure 6.13 The condition before evacuation and after evacuation

b) Results

All workers (about 30 people) could evacuate successfully within 1 minute to the indicated safe place.

The following observations were obtained through the evacuation drill;

- The workers understood the meaning of color change and action required well
- The safety site talk after the evacuation drill was very effective to encourage the safety awareness and increase of safety attitude

6.2.5 Information for site safety

The web site was created at http://cistup.iisc.ernet.in/~osvbng/ wherein the data from all the sensors have been uploaded with a password at the site http://cistup.iisc.ernet.in/~osvbng/osv.html.

Figure 6.14 Display on PC screen

Instrumentation Details are as follows:

1) Tilt-meters for building incline monitoring – 4nos on the building of Hindustan Aeronautics Ltd (HAL) and 1no on the building of BSNL, Cricket Stadium Station
2) Tilt-meters for pile incline monitoring – 2nos on the secant pile, Cricket Stadium Station, Cricket Stadium Station
3) Inclinometers for ground movement monitoring - 4nos in the secant pile (HAL building site) at 1, 3, 5 and 7m depth, and 4nos in the secant pile (opposite HAL building site) at 2, 4, 6 and 8m depth, Cricket Stadium Station
4) Strain gage for strut pressure monitoring – 3nos on the strut, cricket stadium station
5) Load cell for anchor pressure monitoring – 2nos in the anchor, Cricket Stadium Station
6) Tilt-meters for pile incline monitoring – 1no on the soldier pile, Central College Station
7) Load cell for anchor pressure monitoring – 1no in the anchor, Central College Station

The back up of all the OSV data starting from July 2011 and running to Jan 2012 has been uploaded at the CiSTUP website in the Indian Institute of Science, Bangalore. This was continuously accessed on a daily basis by all the stakeholders i.e. IISc, BMRC/GC, Oriental consultants, Kobe University and Yamaguchi University. Details of the project, site map and sensor locations have been uploaded at the site along with the analysed data plot of all the sensors. Further, the photographs of the site as the excavation was in progress (every day) have also been uploaded. Typical plots of data are also enclosed in Figure 6.15.

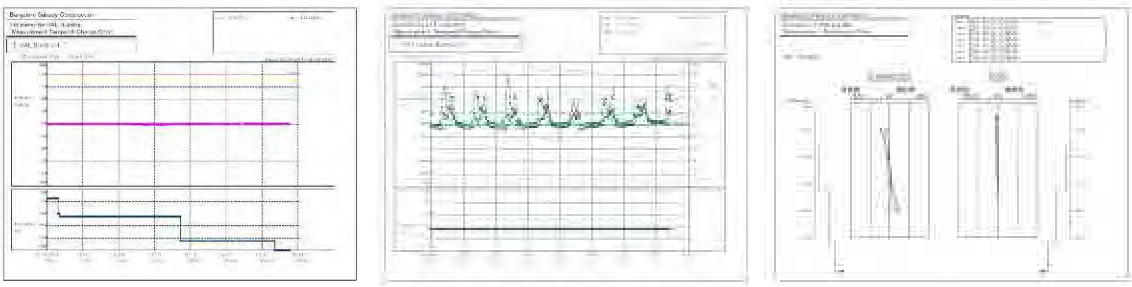

Figure 6.15 Typical plot of data on PC screen (OSV monitoring)

6.2.6 Considerations for site safety

The basic concept of OSV monitoring is ”A Visual tool for safety confirmation at the site” and about 350 people, namely the BMRC/GC, the JICA team, the GC, Contractor’s engineers & workers and the residents of the Nurse hostel participated in the Site Safety management by OSV monitoring. Through these activities, additional achievements were obtained because of “real-time” and “visible to all” effects by OSV.

- Safety confirmation with visual monitoring tools at the site (Basic role)
- Uplift of individual safety consciousness
- Solidarity among the client, engineers and workers -
- Alarm tool for preparation of safety counter measures

BMRC/GC staff, GC’s Safety Manager, the Contractor’s Station Manager and Junior engineers participated in the above safety management activities and realized the effectiveness of OSV monitoring for safety management.

In the Seminar for the above activities, BMRC/GC emphasized their improvement of safety control techniques through OSV monitoring. Other Metro representatives from Chennai and Kolkata proposed to apply the same techniques to their Metros. A Safety management system with OSV monitoring can contribute to successful completion of the project, especially for the critical construction sites such as deep excavations near the buildings and bridge construction above the existing traffic.

In addition to that, disclosure of safety OSV information to the citizens has been made for Bangalore Metro projects. The citizens could observe BMRC/GC’s safety consciousness and sincere attitude for the safe construction adjacent to public structures.

Chapter 7 Site Environmental management by DUST monitoring

7.1 Environmental concept in INDIA

The State Pollution Control Board is a body corporate constituted in all the states of India under section 4 of the Water (Prevention and Control of Pollution) Act, 1974. It was first constituted on February 7, 1975, with the objectives of prevention, and control of water pollution and maintaining or restoring of the wholesomeness of water. Later, it was also entrusted with the responsibilities of prevention, control and abatement of air pollution under the provisions of the Air (Prevention and Control of Pollution) Act, 1981. The Water (Prevention and Control of Pollution) Cess Act, 1977 has been enacted to make the State Board financially independent. Under this act the State Board has been given powers to collect cess on the basis of water consumed by the industries and others. Additionally, the State Board is also implementing the provisions of the Public (Liability) Insurance Act, 1991. Enactment of the Environment (Protection) Act, 1986 has further widened the scope of the activities of the Board. This act being umbrella legislation, different rules for addressing the problems of various sectors have been enacted under this act. Currently, the State Boards are engaged in implementation of the following rules under EPA, 1986:

- Hazardous Waste (Management, Handling and Transboundary Movement) Rules, 2008.
- Manufacture, Storage & Import of Hazardous Chemical Rules, 1989.
- Public (Liability) Insurance Act, 1991.
- Environmental Impact Assessment Notification Dated 7.5.1992.
- Environmental Impact Assessment Notification dated 14.09.06.
- Bio Medical Waste (Management & Handling) Rules, 1998.
- Plastic Manufacture & Usage Rules, 1999.
- Noise (Pollution Control & Regulation) Rules, 2000.
- Municipal Solid Waste (Management & Handling) Rules, 2000.
- Batteries (Management & Handling) Rules, 2001.

The workplace environment affects the health of workers. The Central Pollution Control Board (CPCB) is bringing out a series of publications entitled the “Comprehensive Industry Document Series” (COINS), which is designed to cover the status of each specific type of Industry in the country incorporating all environmental issues to facilitate concerned units in the Sector to improve their environmental performance and attain compliance with the National Environmental Standards.

Construction dust is classified as PM-10, i.e. particulate matter of less than 10μm diameter, and workers are at risk of inhaling these particles. The incidence of damage to construction workers depends upon the chemical composition of the dust, size of the particles, duration of exposure and individual susceptibility. Dust originating from work operations like drilling, blasting and grinding becomes airborne and inhalation of the particles may induce accelerated lung function decline. Dust control at construction sites is a very important aspect of the environmental management at construction sites. Individuals working in a dusty environment face the risk of inhaling particulate materials that may lead to adverse respiratory effects. The occupationally related lung diseases are most likely due to the deposition of dust in the lung and are influenced by the sort of dusts, the period of exposure, and the concentration and size of the airborne dust in the breathing zone. Reduction in lung function has been reported in cotton workers, coal miners, grain and flour mill workers, workers exposed to tobacco dust, barley dust, talc dust and in quarry workers, and workers engaged in building and construction in India. Not much has been reported on the effects of dust in the underground construction sites in India. All construction sites generate high levels of dust typically from concrete, silica, asbestos, cement, wood, stone, sand etc. Silica is a mineral found in the earth's crust. Airborne silica dust is generated during chasing or drilling into concrete, brick work, ripping up old concrete, and excavating sites with sandstone or clay. Occupational respiratory diseases are usually caused by extended exposure to irritating or toxic substances that may cause acute or chronic respiratory ailments. In construction sites, even though the workers are exposed to various dusts, the concentration of exposure is less compared to workers in cement factories, quarry workers, and tunnel workers. The public condition of air pollution is shown as below Figure 7.1.

Figure 7.1 Public condition of air pollution

In India, millions of people are exposed to a dusty environment (See the figures below). They are exposed to different types of occupational health hazards such as fumes, gases, and organic and inorganic dusts which are risk factors in developing occupational lung diseases. Workers engaged in building and construction work are at risk of developing impaired lung function due to exposure to high levels of dust generated at the construction site. There are different types of construction dust that are created at the workplace. The type of construction and location of the site will determine what is in the air. Unlike road dust, construction dust is more than basic road dust. The dryer regions of the country have a problem with particulate matter floating in the air whose makeup is different than in the wetter regions where the nuisance dust is greater. The cleaning up of the loose debris is the solution for most dust problems that are actually created on the construction site that are directly caused by the construction process. The health hazards of construction site dust could include cement residue, asbestos, mineral fibres with a man made origin and the most common is wood dust. The reason for the concern is the effects it has on the people working at the site and the surrounding region. In India, construction dust control from the particulate matter smaller the 10 micrometers or PM10 has to be approached from a different perspective than those that are naturally occurring in our environment. The airborne crystalline silica that originates from the concrete, masonry and rock on the site can become lodged in the membranes and lungs of the respiratory systems of the people on and near the site. Once there, they become hardened and cause permanent damage and even death. The condition of traffic jams in urban areas is shown in Figure 7.2

Figure 7.2 The condition of traffic jams in urban areas

Construction dust control for this problem can be accomplished when the proper precautions are taken along with the right equipment. The blades that are used to cut concrete and other masonry items should be equipped with a water attachment to make the dust too heavy to become airborne. When drilling into rock the same accessory should be used to weigh down the dust and prevent it from becoming airborne. Cleaning up afterwards at the blade level is just as important. The water that was used to weigh down the dust particles will evaporate over time. Collection and proper disposal is a necessary part of keeping the work site as free as possible of nuisance dust. When these materials are used, the operator should be using a dust mask to prevent inhalation of the particulate matter. With the proper precautions, control of construction dust can minimize the adverse effects on the people on and near the construction site.

7.2 Site Environmental Plan with DUST Monitoring

7.2.1 Environmental Assessment and DUST monitoring allocation

The BMRC SHE Manual stipulates that the contractor shall take all necessary precautions to minimise fugitive dust emissions from operations involving excavation, grading and cleaning of land and disposal of waste. The Contractor has already submitted and gotten approval for an air quality programme at the beginning of the project.

According to the manual, the summary of the contractor’s monitoring program for air is shown in Table 7.1

Table 7.1 Summary of contractor's monitoring program for air

Parameter	Air
Sampling	RSPM, SPM 24-ours of the day CO:12hrs from 8:00 to 20:00hrs
Frequency at Each location	Two 24-hour Samples every fifteen days at uniform intervals
Location	To be determined by the Contractor based on air sensitive receptors
Number of Locations	2 Locations
Duration of Monitoring by Contractor	During Civil Construction
Additional Requirements	Ad hoc monitoring as required

Based on the above summary of the contractor's monitoring program for air, the Dust Monitoring team made a specific Environmental assessment with allocation for a Dust Monitoring System for Central College Station construction site as shown in Table 7.2.

Table 7.2 Specific Environmental assessment with allocation for a Dust Monitoring System for Central College Station construction site

Parameter	Dust Monitoring System
Sampling	Floting Dust
Frequency at Each location	Four times, 9:00, 11:00, 14:00 and 17:00 in each location
Location	Soil excavation place, Rock excavation place and nearthe office
Number of Locations	4 Locations
Duration of Monitoring by Contractor	During Civil Construction
Additional Requirements	Ad hoc monitoring as required

7.2.2 Contractor's Environmental Management System

According to the contract requirement, the Contractor shall establish an Environmental plan including Dust Monitoring after the award of the contract. The objectives of the Dust Monitoring can be summarized as:

- measure the dust concentrations at the site
- inform the concentration to workers in the site
- take action depending on the dust concentration
- provide a dust monitoring system practice to carry out normal operations of the work site
- create awareness that dust management is in the workers' future best interest
- strive to continuously improve dust management skills

(1) Environmental work practices/procedures

All work items at the site shall be performed with proper working procedure in terms of SEH. The objective of the Safe work practices/procedures is to eliminate, or reduce to a minimum, the risk of death or injury to persons, and damage to properties and assets, during the execution of the work. Major items of safe work practices/procedures are listed below;

1. Permit to Work
2. Excavation Works
3. Transportation
4. Working at height
5. Electrical work
6. Crane operators
7. Welding & Cutting
8. Fire prevention
9. Handling of chemicals
10. Noise control
11. Dust control
12. Waste management

(2) Site environmental performance

In spite of the above mentioned Dust control, there is no mention about monitoring and the JICA team didn't find such inspections for dust monitoring or actions for dust. The Environmental dust monitoring should be conducted to protect the workers' health and in high dust concentration situations, actions for dust are to be immediately taken. The major items of Site Environmental dust performance are listed below;

1. Daily dust monitoring by SHE engineer
2. Education regarding actions to be taken based on the dust concentration
3. Environmental dust induction talks for new comers
4. The accuracy check of the Dust Monitoring System by the JICA team
5. Site inspection by SHE engineer

(3) Environmental awareness training and programs

The objective of the environmental training and programs is to equip personnel with the knowledge, skill and attitude, which will enable them to perform their duties of dust monitoring. Major activities of the Environmental dust awareness training and programs are listed below;

1. Training for site SHE engineers
2. Training on the Dust Monitoring System
3. Wearing dust mask training program
4. Dust monitoring drills
5. Lifting Equipment and Tool Tackle Inspections and awareness
6. Environmental dust awareness program

7.2.3 Environmental Management Activities with DUST Monitoring

The Environmental management activities with a Dust Monitoring System at Central College Station are evaluated and selected in terms of the following aspects;

- Integration of dust monitoring effectively into the environmental activity
- Improvement of environmental awareness both for the contractors and workers to build an advanced working environment
- Improvement of the environmental control techniques through the execution of dust monitoring.

Based on the above evaluation items, the following activities are selected for the execution of environmental management activities with a Dust Monitoring System at the Central College Station;

1. Environmental Dust Monitoring System induction talk to BMRC, Contractor and Workers
2. Daily dust monitoring and inspection with Dust Monitoring System
3. Environmental training by medical doctor regarding the risk of dust

In the Method Statement for the Excavation at Central College Station, the above activities were specified with detailed required procedures.

7.2.4 Execution of Safety Management Activities with DUST monitoring

(1) Environmental Dust Monitoring System induction talk to the Contractor

a) Approach

Dust monitoring and its environmental activities are new to the Contractor. The presentation and discussion of Environmental Dust Monitoring System induction were conducted to BMRC and the Contractor's engineers for good understanding of the Dust Monitoring System. The following items were explained and discussed;

- Target of Dust Monitoring System
- The risk of dust
- Contents of Dust Monitoring System
- Site arrangement of dust monitoring
- Trigger values of dust monitoring
- Action plan for color changes

Figure 7.3 Presentation of environmental Dust Monitoring System induction

An Environmental Dust Monitoring System induction talk to all workers at the site was given by the JICA team. The explanation was in the Hindi language:

- The risk of dust
- The colors show the dust concentration at each place;
- "Yellow color" means "wear a simple dust mask";
- " Red color" means "wear a filter dust mask";
- As a special action, drilling workers always face a high dust concentration situation, so they should wear an electric fan dust mask;

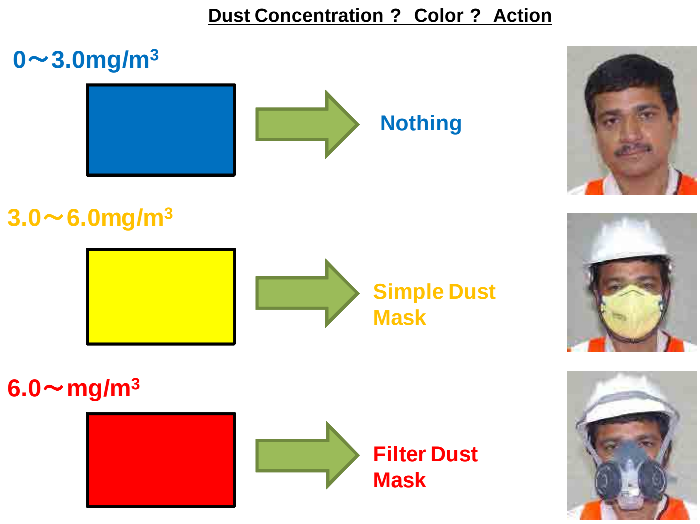

Figure 7.4 Actual action plan

Figure 7.5 Environmental Dust Monitoring System induction talk to workers

b) Results

Usually there is no information given to site workers for site monitoring issues, the role of the report for color changes or detailed action for dust. Therefore these activities had a great effect for uplift of environmental consciousness and improvement of dust monitoring techniques for BMRC, the Contractor and workers.

(2) Daily dust monitoring and inspection with the Dust Monitoring System

a) Approach

Daily dust monitoring and inspections with the Dust Monitoring System were conducted with BMRC, the JICA team and the Contractor during the excavation stage at Central College Station.

Figure 7.6 Daily dust concentration check sheet at Central College Station

Figure 7.7 Daily site walk with BMRC, the Contractor and JICA team

b) Results

Through these activities, the following effects were observed;

- Improvement of environmental awareness was achieved
- Technical discussion and advice were given
- Environmental team sprits among BMRC and the Contractor were obtained

(3) Environmental training by medical doctor regarding the risk of dust

a) Approach

The contractor and workers did not recognise the risk of dust. To enhance the awareness of dust risk, a medical doctor was invited for the environmental training by the dust monitoring team.

Figure 7.8 Environmental training with medical doctor at Central College Station

Before training   After training

Figure 7.9 The worker's condition before training and after training

b) Results

All drilling workers (about 4 people) began to wear an electric fan mask everyday.

The following observations were obtained through the evacuation drill;

- The workers understood the risk of dust and the meaning of dust monitoring
- The medical doctor's talk was very effective to encourage the environmental awareness regarding dust and increase of a safe environmental attitude

7.2.5 Information regarding the environmental site

A web site was created at http://cistup.iisc.ernet.in/~osvbng/ wherein the data from the dust monitoring programme have been uploaded with a password at the site http://cistup.iisc.ernet.in/~osvbng/osv.html. Dust monitoring has been done using two systems.

The back up of all the Dust monitoring data starting from …. and running to Jan 2012 has been uploaded at the CiSTUP website in the Indian Institute of Science, Bangalore. This was continuously accessed on a daily basis by all the stakeholders i.e. IISc, BMRCL, Oriental consultants, Kobe University and Yamaguchi University. Details of the project, site map and location of dust monitoring have been uploaded at the site along with the analysed data regarding the dust density. Further, the photographs of the site as the excavation was in progress (every day) have also been uploaded.

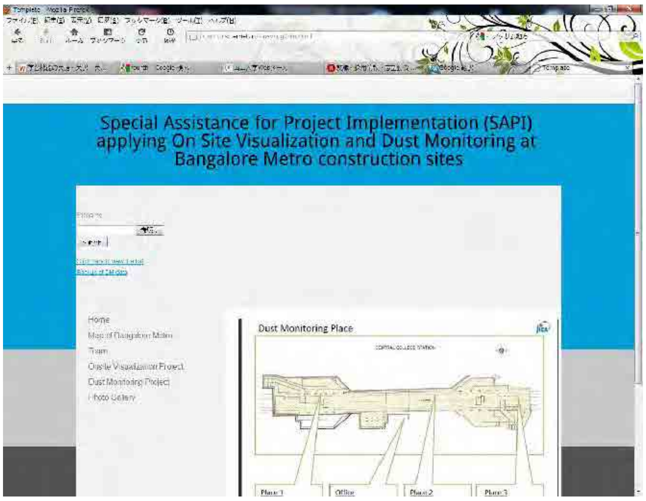

Figure 7.10 Display on PC screen (DUST monitoring)

Figure 7.11 Dust data on WEB site

7.2.6 Considerations for the environmental site

The basic concept of the Dust Monitoring System is ”cheap and easy dust monitoring at the site” and about 100 people, namely the BMRC, the JICA team, the GC and Contractor’s engineers & workers participated in the Site Environmental management by a Dust Monitoring System. Through these activities, additional achievements were obtained because of the effects of the Dust Monitoring System.

- Environmental confirmation with mobile phone at the site (Basic role)
- Uplift of individual environmental consciousness
- Solidarity among the client, engineers & workers -
- Alarm tool for preparation of environmental counter measures

BMRC staff, namely the Station Manager, Safety Manager, and Safety Engineers participated in the above environmental dust management activities and realized the effectiveness of dust monitoring for environmental dust management.

In the Workshop of the above activities, BMRC emphasized their improvement of environmental dust control techniques through dust monitoring. Other Metro representatives from Chennai, and Kolkata proposed to apply the same techniques to their Metros. An Environmental dust management system with dust monitoring can contribute to successful completion of the project, especially for the high dust concentration places such as drilling work.

In addition to that, dust monitoring on the road near the construction site has been undertaken for the first time in Bangalore Metro projects. On the road, people also face a high dust concentration situation. This dust comes from vehicle exhaust gas. And many more people are on the road compared with those in the construction site. The Dust Monitoring System can also be adopted to the road monitoring, and that location should be monitored.

Chapter 8 Training Program and Workshop

8.1 Training Program

The purpose of this training program is to offer training for safety control activities by OSV monitoring and environmental control activities by DUST monitoring activities. The training program was presented to young engineers at BMRC/GC/Contractor and master/doctor students of the university in Bangalore.

The agenda of the seminar is shown below. Additionally, the seminar program is shown below.

- The brief introduction regarding Bangalore Metro Project
- The brief introduction regarding the JICA project in India
- The brief concept of OSV & DUST monitoring
- The preliminary achievement of safety control activities by OSV monitoring under this project
- The preliminary achievement of environmental control activities by DUST monitoring under this project
- The preliminary result of the questionnaire survey
- The suggestions for the improvement of safety and environmental control in construction work

<u>Training Program for the On Site Visualization and Dust Monitoring on the Bangalore Metro Project</u>

Location : Faculty Hall, Indian Institute of Science (IIs) in Bangalore
Date : 22 Nov. 2012

10:00-10:30	Reception
10:30-10:50	Opening Speech by Prof. Sitharam, IIs
10:50-11:20	Report on OSV Monitoring for Bangalore Metro Project by Prof. Akutagawa, Kobe University
11:20-11:30	Discussion of preliminary Result of Questionnaire Survey by Dr. Ravi, Central Road Research Centre
11:30-11:50	Keynote Lecture regarding the JICA Project by Mr. Sano, JICA INDIA
11:50-12:10	Coffee Break
12:10-12:30	Special lecture regarding the Bangalore Metro project by Mr. Shivanada, BMRC
12:30-13:00	Report on Dust Monitoring for Bangalore Metro Project by Prof. Shinji, Yamaguchi University
13:00-13:20	Demonstration from Kobe University and Yamaguchi University

13:20-13:30	Presentation by Mr. Yoshino, Tokyo University
13:30-13:40	Closing Speech by Miss ABE, Project Manager of the JICA Team (Oriental Consultants)
13:40-14:40	Lunch and Question & Answer

Figure 8.1 Picture of Training Program

8.2 Workshop Program

The purpose of this workshop is to exchange information regarding safety control activities by OSV monitoring and environmental control by DUST monitoring. Additionally, this workshop is to contribute to the improvement of safety control techniques and environmental control techniques of BMRC. The workshop was presented to the Managing Director, Directors and managers of BMRC, experts of the consulting group, managers of the Contractors, Professor of the University in Bangalore, senior engineers of the institute in India, and the representative of the monitoring company. The workshop was also presented to the project manager / senior experts of Indian inland metro (Delhi Metro, Kolkata Metro, Chennai Metro, Mumbai, and Kochi Metro) and overseas metros (Jakarta, Dhaca and Bangkok Metro). The list of persons attending is attached in ANNEX 3.

The agenda of the workshop is shown below. Additionally, the seminar program is shown below.

- Brief Introduction regarding Bangalore Metro Project
- The brief concept of OSV & DUST monitoring
- Achievement of safety control activities by OSV monitoring under this project
- Achievement of environmental control activities by DUST monitoring under this project
- Data analysis of the questionnaire survey
- Suggestions for the improvement of safety and environmental control in construction work

Figure 8.2 Mr. Sivasailam (Managing Director) speech at Workshop

Figure 8.3 Picture of Workshop

JICA Study Team cordially invites you to

The Final Workshop for On Site Visualization and Dust Monitoring on Bangalore Metro Project

on 24th January 2012, 9:45 to 17:00 Onwards
at Banquet Hall, The PRIDE HOTEL (+91-80 43484348), 93 Richmond Road, Bangalore

Program

09:15-09:55	Reception
09:45-10:00	Opening Speech by **Mr. S. Yamanaka**, Chief Representative, JICA INDIA
10:00-10:10	Welcome / Inaugural Speech by **Mr. N. Sivasailam**, Managing Director, Bangalore Metro Rail Corporation (BMRCL), INDIA
10:10-10:20	Speech by **Mr. S. Chandra**, Director Projects, BMRCL, INDIA
10:20-10:30	Speech by **Mr. N. P. Sharma**, Chief Engineer (Underground), BMRCL, INDIA
10:30-10:45	Presentation regarding Bangalore Metro Project by **Mr. K. R. Shivananda**, Dy. Chief Engineer, BMRCL, INDIA
10:45-11:30	Report on OSV monitoring by **Professor S. Akutagawa**, Kobe University JAPAN
11:30-11:45	Presentation regarding OSV monitoring in Delhi Metro by **Mr. J. Tyagi**, Chief General Manager, Delhi Metro Rail Corporation, INDIA
11:45-12:00	Coffee Break
12:00-12:10	Speech by **Mr. Pahuja. D. D.**, Director Projects, BMRCL, INDIA
12:10-12:20	Brief Introduction of Special Invitees from other Metro Projects
12:20-13:00	Report on Dust Monitoring by **Professor M. Shinji**, Yamaguchi University, JAPAN
13:00-13:20	Report on geological analysis for OSV by **Professor T. G. Sitharam**, Indian Institute of Science, INDIA
13:20-14:20	Lunch Break
14:20-14:40	Report on Question Survey of OSV & DUST monitoring, **Dr. Ravi S.**, Central Road Research Institute, INDIA
14:40-15:00	Q & A
15:00-15:10	Closing Speech by **Ms. R. Abe**, Project Manager of JICA Study Team (Oriental Consultants), JAPAN
15:10-17:00	Site Visit for OSV and Dust Monitoring at BMRC construction site

Figure 8.4 Workshop Program

A site visit for the attendees was conducted after the seminar for understanding of the actual condition of OSV monitoring and Dust monitoring.

Figure 8.5 Picture of Workshop (Site Visit at Cricket Stadium Station)

8.3 Workshop Discussion

A review and analysis of the issues raised in the Workshop Discussion highlighted the concerns and positive expectations shared by the participants.

Visibility of the lights emitted from the sensors is the most crucial element in executing successful OSV monitoring. A concern was presented about the visibility of OSV sensors under strong sunlight. Direction for assuring sufficient visibility was pointed out where a different method will also be considered using a new device other than LED.

It was also pointed out that reliable operation of OSV monitoring must be carefully planned considering the possibility of the multi-function of the devices and tampering by strangers or animals. The importance of setting threshold values correctly was also emphasized, because too strict a criterion forces frequent red light display to the public who might be misguided and get used to a "Red, but nothing happens." situation. The opposite is also expected that the threshold values set too low give no warning to the public before an accident happens. The difficulty in setting the right threshold values has been one of the most challenging agenda in civil engineering. It was emphasized that a good dose of experienced manpower must be collected to define the best threshold values at the time of a project. It is also necessary that when the initially set values are found to be inappropriate, that they be changed accordingly.

Extending the application of the OSV monitoring was also pointed out. In the operations conducted at the AIIMS site, the monitored quantities were displacement, strain and inclination. As translating general engineering quantities into color of light can be applied to any properties, OSV monitoring can be done with moisture in soil, underground water level, pressure between objects in contact, strain in concrete, etc. By exploring all these possibilities, it can be realized that almost any type of monitoring can performed with an OSV approach.

A concern was also raised as to how anyone should relate the color of, for example, a single OSV sensor to the overall safety of the structure. This is also not an easy question to answer in simple terms. Since the complexity of a project and how OSV monitoring is conducted have too many possible combinations, there cannot be a straight answer to this. If a sensor is positioned to pick up the most crucial information of the structure, the information released from it should be dealt with carefully. If the positioning of the sensor is not appropriate, the value from that sensor will be reduced. When the number of sensors used in one project is small, the positioning of those sensors becomes extremely important. On the other hand, if the cost of sensors drops dramatically and one can distribute them evenly over the monitored area, the judgment of safety level would be much more clear and reliable.

It was also very important that there is strong interest in conducting or testing OSV monitoring at Bangalore MRT, Kolkata MRT, Chennai MRT and Hyderabad MRT in India. Questions posed were concerned with the cost of current OSV devices, consultation and technology transfer. The feeling was shared among the participants that the continuing support from JICA is required in promoting the application of the OSV monitoring in subsequent metro construction projects in major cities in India. This need was well shared with JICA officials and the discussion turned out to be a fruitful one with a strong sense of expectation for future international collaboration to be continued.

Chapter 9 Conclusions

9.1 "Stay safe" & "Breathe clean"

Safety First! This is the concept and the slogan shared by all, required for all, but difficult to achieve throughout the world. Construction sites are full of dangers. Workers are exposed to various kinds of “unexpected accidents” that threaten their lives, delay construction and make owners to pay more. "*Staying safe*" at work is a fundamental right for all.

Given a safe place to work, more attention is now being paid to long-term health care issues for construction workers. Among various aspects with respect to health problems at work, "*breathing clear air*" has been regarded as one of the most important features. There is a regulation in India to keep dust density below a specific value, however, the compliance with this law requires use of expensive devices, is costly and time-consuming.

These two topics were identified for their importance and have become the main themes to be addressed in the Special Assistance for Project Implementation (SAPI) applying On Site Visualization and Dust Monitoring at Bangalore Metro construction sites, to be executed between July 2011 and January 2012.

9.2 Disclosure to the public

9.2.1 Disclosure to public for OSV monitoring

One of the most difficult parts in promoting an OSV project is that an owner of the project does not allow disclosure of the information about safety to the public. This has been the mentality seen for most public offices around the world and they usually try to hold the information within themselves. It is usually only after an analysis is made about the risk related information that part of the information is disclosed to the public. This notice could come hours, days, or in some cases, months later. The employment of the OSV sets up a situation such that the up-to-date and real-time information about the monitored site is shown and disclosed to the public at all times. This happened both at the Cricket Stadium station site and the Central College station. This was only possible due to the full support from officers of BMRC, HAL and BSNL and their courage and confidence to finish the construction project safely to the end.

9.2.2 Disclosure to public for DUST monitoring

The dust concentration on the road outside of the site was not as high as in the site, however, it was high. And sometimes, it was higher than that on site. People walking along the road faced such high dust concentration situation, but no one recognised the risk of dust. This dust was raised by Auto-Rikisya, Cars, Automobiles and the wind. Especially, in the dry season, there was a great deal of dust on the road. With this Dust Monitoring System by mobile phone, everybody can confirm the current dust concentration. This is very useful for the public.

9.3 Open information links people.

9.3.1 Light links people for OSV monitoring

There were many non-predictable things that happened in this project. It was the second time that the OSV monitoring method was employed in India. Especially, most instrumentation work including the equipment and the engineers were prepared in India to transfer the management to BMRC and the technique and equipment to the Contractor. Workers and all concerned saw pressure, strain and inclination as the color of lights. The adjacent HAL building and BSNL building were monitored and the lights from the roof top were disclosed to the public. Additionally, some of the instruments were shifted to monitor the behavior of structures at other construction sites that were at risk, as required by BMRC and the Contractor. The actual monitoring was carried out by the joint team made up of JICA and the Contractor to protect the safety at the construction site. In completing the questionnaires, many young workers were asked what they thought about the system. Light emitting sensors were exposed to various temperatures day after day. Many non-predictable things happened during the project and the light emitted from the sensors for showing safety conditions were the main cause of all these "first things". Light is visible to everyone. Light travels fast to everyone. And light links people of different positions, responsibilities and backgrounds for the same cause of achieving safety.

9.3.2 Signboard links workers for DUST monitoring

There were many “first things” that happened in this project. It was the first application of a Dust Monitoring System outside Japan. In terms of the size of the project, probably this became the largest operation in the world so far. Workers and all concerned saw the dust concentration at the site and took actions based on the results for the first time.　It was the first time for Dust Monitoring by mobile camera at an open cut excavation site. It was the first time for a Dust Box application. Many of these “first things” happened during the project and the signboard showing the monitoring result by color panel was the main cause of all these first things. By this color panel, everyone could know the actual dust concentration easily. And signboard gives the workers the same awareness regarding the dust.

9.4 Cost performance

9.4.1 Cost performance for OSV monitoring

The questionnaires showed that the concept of the OSV was accepted well in Bangalore and they are interested in conducting similar projects in the future with appropriate budget prepared. Successful and fruitful operation of future OSV monitoring projects then relies on not just the quality of the OSV sensors but on the quantities, which is largely controlled by their cost.

The cost required for this exercise cannot be the future reference value since it had to include the initial development and shipping costs for example. As the demand for the OSV sensors increases, the cost will naturally go down accordingly provided that they are manufactured in Japan. International strategy for manufacturing OSV sensors remains as an important topic to be worked out in the near future. In this project, all the OSV sensors had the function of outputting measured information as LED light. This electricity-based approach is one of the attractive ways for disclosing critical information at construction sites. However, there could be many more alternatives to issue warning messages using much simpler OSV sensors. They would probably use extremely little or no electricity; have extremely simple structure, yet still can work as OSV sensors to protect workers. Organized efforts should be expended to develop those new sensors to be used along with electricity based sensors in the future.

The OSV approach for safety management should be part of daily routines at construction sites. For this to happen, the simplicity and affordable cost of the devices and related systems have to be maintained. Whereas high performance aspects, such as wireless data transmission or automatic data logging, are favoured by the managing side, the simplicity and reliability are the key concepts that need to be kept for those who actually operate the system on site within limited budget. OSV sensors of a new generation, namely those with much simpler mechanisms and structures, should be developed so that a much greater number of sensors can be used per site without causing too much trouble for installation. It will only be then that the OSV monitoring method can become a truly accepted safety management routine at construction sites around the world.

9.4.2 Cost performance for DUST monitoring

The questionnaires showed that the concept of the Dust Monitoring System was accepted well in India and they are interested in conducting the similar projects in the future with appropriate budget prepared. Successful and fruitful operation of future dust monitoring projects then relies on not just the quality of the mobile phone but on the quantities, which is largely controlled by their cost.

This Dust Monitoring System by mobile phone requires

(1) Mobile phone with an android OS and flash camera
(2) Dust Box and black board
(3) Dust Monitoring System, namely "Funjin"

(1) and (2) should be prepared for each site. As (1) mobile phone, HTC Desire is recommended and it was used in this project. HTC Desire is Rs. 31,477 in Japan and Rs. 25,709 in India (February 2012). (2) Dust Box and black board is around Rs. 7000.

The royalties for (3) Funjin are now being reviewed. It might depend on the site scale and the number of monitoring locations. These royalties include the start-up fee for programming and calibration for the site. The calibration, if required, is excluded. If the site needs guidance for Dust Monitoring, the guidance fee is also an additional cost.

The Dust Monitoring approach for environmental dust management should be part of the daily routine at construction sites. A Dust Monitoring System of a new generation which has higher accuracy and is a much simpler, stable monitoring method without so much calibration required should be developed so that many more sites can apply the system. Then, the Dust Monitoring system will work as a true environmental management tool at construction sites around the world.

9.5 Lessons learnt and future direction

The experiences in this SAPI project are precious and rich with regard to practical requirements for organizing, planning and executing OSV monitoring and DUST monitoring in all types of construction projects.

The training for workers and site engineers is the most important subject for improvement of safety and a healthy environment. Several training methods were also applied and modified at the construction site of the JICA project. For instance, the second evacuation training was carried out with loud siren based on one worker's request. Additionally, a medical doctor attended the second environmental training for the JICA Project to explain the relationship between future disease and dust concentration. After the first environmental training, one worker had a very simple question, which was "what is the problem regarding dust?" The safety and environmental training for engineers was applied using a video before the site training. The visualization is more effective for understanding the training. A DVD film including training methods is produced instead of a paper manual.

Additionally, for junior engineers in BMRC/GC/Contractor and master/doctor students, the training program to understand the safety and environmental at the construction site was hold on 23 Nov. 2012 in Indian Institute of Science in Bangalore. The each suitable training shall be required against workers, site engineers, junior engineers and students for future.

It is also important to recognize the lessons learnt in Bangalore to further improve cost performance so that a much wider area can be monitored for its safety with low cost devices, and to improve the programming for dust monitoring work and easy handling. It is now confirmed that almost all concerned in the construction project see that these new methods are in their favor. The improvement points about the sensors or methodology have already been identified and they will be followed up by appropriate processes accordingly.

In the meantime, metro construction projects of major proportion are lined up in Delhi, Kolkata, Mumbai, Chennai and Kochi in the inland areas of India, and Jakarta, Bangkok and Dhaka of other major cities in Asia. For those who participated in the January 24th seminar, the basic information about what the OSV and DUST monitoring could do for their projects is already implanted. For those who were unable to be at the seminar, this report and DVD film should be a guideline. After the seminar, Chennai and Kalkata metro have contacted the JICA Project team to learn more of this project. Jakarta Metro also strongly request the final report of this project.

As is obvious, the OSV and DUST monitoring are not confined technologies only for metro construction. These are general schemes that can be applied to any type of projects. It is our hope that the experiences and lessons we learnt through this focal project conducted in

Bangalore with the full support of BMRC and all other organizations and institutions, will be shared effectively and studied fully by our colleagues in other parts of India and elsewhere. The more wide-spread these methods will become, the higher the safety and health management practice level will be, and eventually the safer and healthier each work place will be.

The new safety and health management strategy tested here in Bangalore left a considerable impact on those concerned with the project at all levels; namely, workers, construction managers, contractors and even citizens residing or passing through near construction sites. The new monitoring techniques were proven to be effective to raise safety and health awareness and improve the quality of management practices that were compiled as the safety and health control manual of a new generation. The unique outcome of this survey regarding safety and health at construction sites shall be shared and extended by the colleagues in India and elsewhere in the future.