

IEI Centenary Publication

# Dr K L Rao Memorial Lecture

A Compilation of Memorial Lectures  
presented in

**National Conventions of Civil Engineers**

**35th Indian Engineering Congress**

December 18-20, 2020



**The Institution of Engineers (India)**

8 Gokhale Road Kolkata 700020







## **Background of Dr K L Rao Memorial Lecture**

Dr Kanuru Lakshmana Rao was born on July 15, 1902. After passing his Intermediate Examination in Science from the University of Madras, he took the B E Degree in Civil Engineering with Honours from the College of Engineering, Guindy in 1925.

His first appointment was as Assistant Engineer in the Visakhapatnam District Board in 1926. He subsequently worked in the College of Engineering, Rangoon and Guindy, and later in the Cauvery – Mettur project. During this period he also qualified for the M Sc (Eng) Degree of the University of Madras by research, being the first recipient of a research degree in engineering from that University. In 1939, he proceeded to England to specialize in reinforced concrete and obtained his Ph D Degree from the University of Birmingham.

Between 1943 and 1945, he was employed as a Senior Lecturer in Loughborough Engineering College, England. On his return to India in 1946, he was appointed by the Madras Government as Design Engineer in the Ramapadasagar Project and in 1951 joined the Central Water and Power Commission at New Delhi as Director (Dams). In 1954, he became Chief Engineer (Planning and Designs), and then became a Member (Designs and Research) in the same Commission.

During these later years, Dr Rao was closely associated with major dam projects in this country, notably Lower Bhavani, Tungabhadra, Hirakud, Malampuzha, Kosi and Umtru and with flood control on the Brahmaputra River at Dibrugarh. His personal contributions to these projects are acknowledged as outstanding.

Dr Rao is the author of a well known standard work 'Calculation, Designs and Testing of Reinforced Concrete' published by Sir Isaac Pitman and Sons. His contributions to technical journals are numerous. Dr Rao joined the Institution as a member in 1947 and became its President for two sessions (1958-1960). He was also a Minister of Government of India.

**In memory of his dedicated service, The Institution of Engineers (India) instituted an Annual Memorial Lecture in his name during the National Convention of Civil Engineers.**

## **Dr K L Rao Memorial Lecture** presented during **National Conventions of Civil Engineers**

### **Infrastructure Development Strategies for the Transport Sector 1**

Shri N Vittal

*(Delivered during the Thirteenth National Convention of Civil Engineers on 'Infrastructure Development Strategies for the Transportation Sector' organized by Delhi State Centre, October 16-17, 1997)*

### **Making of Good Roads for Economic Prosperity 5**

Prof P K Sikdar

*(Delivered during the Nineteenth National Convention of Civil Engineers on 'Role of Civil Engineers in Alleviation of Poverty' organized by Jharkhand State Centre, November 22-23, 2003)*

### **Role of Civil Engineers in Earthquake Risk Reduction in India 15**

Padmashree Dr Anand S Arya

*(Delivered during the Twenty-third National Convention of Civil Engineers on 'Seismic Responses : Design and Strengthening of Buildings and Structures' organized by Jabalpur Local Centre, October 27-28, 2007)*

### **Infrastructure Development in Water Sector — Key to National Growth 31**

Shri A K Ganju

*(Delivered during the Twenty-fourth National Convention of Civil Engineers on 'Infrastructure Development – Key to National Growth' organized by Orissa State Centre, October 25-26, 2008)*

### **Some World Records in Structures Designed for India/Overseas 36**

Mr C R Alimchandani

*(Delivered during the Twenty-eighth National Convention of Civil Engineers on 'Role of Infrastructure for Sustainable Development' organized by Roorkee Local Centre, October 12-14, 2012)*

### **Sesimic Vulnerability Aessment of Existing Buildings — Developments and Challenges 46**

Prof Subrata Chakraborty

*(Delivered during the Twenty-ninth National Convention of Civil Engineers on 'Disaster Resistance, Cost Effective Building Technologies' organized by Meghalaya State Centre, November 11-12, 2013)*



# Infrastructure Development Strategies for the Transport Sector

Shri N Vittal

Chairman, PESB

1. Infrastructure is being increasingly recognised as the main missing link in India's thrust for a more rapid growth of the economy. In the years after Independence infrastructure was perceived to be an area where because of high up-front investment and long gestation period only the public sector or the govt. can invest. But, after four decades of our experiment with leftist ideology we are now realising that as the govt. does not have the resources, we should tap the private sector both within the country and abroad for meeting our investment, requirements in infrastructure. The common minimum programme mentions that an investment of the order Rs. 700000 crores will be needed in infrastructure to sustain a growth rate of 10% in the next 5 years.

This total infrastructure investment requires about Rs. 4000 to 4500 billion (US \$ 115 to 130 billion) over the next five years. This would rise to about Rs. 7500 billion (US \$ 215 billion) in the following five years (2001-02 to 2005-06). If we expect, about 40 percent of total external capital inflows go into the financing of infrastructure, we could expect about 15 per cent of total capital requirements for infrastructure to be externally financed. The rest-as much as 85 per cent — will have to be domestically financed.

2. "The share of private sector investment in infrastructure has been projected to rise from the current 1 per cent of GDP to 2.5 per cent by 2000-01 and 3.5 per cent by 2005-06. This means that in absolute terms, this investment would have to rise from about Rs. 120 billion now to Rs. 380 billion in 2000-01 and Rs. 800 billion in 2005-06". (Rakesh Mohan Committee Report).

The issues relating to the infrastructure requirements had been gone into by the Rakesh Mohan Committee Report and it will be worthwhile to take note of the main points made by that report, so far as the transport sector is concerned.

3. From 1951 to 1994 the average yearly growth of road traffic has been of the order of 8 to 10 per cent. Freight traffic has increased from 6 BTK in 1951 to 350 BTK in 1994 and passenger traffic from 23 BPK to 1,500 BPK during this period. Factors that contributed to this are flexibility, door to door service, reliability and speed. In line with the increase in traffic carried by roads, the total number of vehicles has also grown from 0.3 million in 1951 to 25.3 million in 1994. It is expected that the total number of registered vehicles will increase to 54 million by the year 2001.

4. The main roads have also not kept pace with the traffic demand in terms of their quality. Out of the total 165000 km length of National and State Highways, only 2 per cent of their length is four-lane, 34 per cent two lane and 64 per cent single-lane.

5. Inadequate road networks have led to higher transportation costs which have also severely eroded international competitiveness of the Indian economy. Commercial vehicles are able to run only 200-500 km on an average per day, as compared to 500- 600 km per day in developed countries. The problem is further compounded by congested sections, existence of railway level crossings, octroi posts and other tax barriers, all of which lead to abnormal delays in travel and higher fuel cost. The economic losses due to the bad condition of the main roads are estimated to be of the order of Rs. 200 to Rs. 300 billion per annum. Add to that security, safety and pollution problems.

6. It is imperative that the development plans for the main roads be highway-user-oriented. Priority should be given to the reconstruction of weak and distressed bridges and major mission bridges. Improvement works must be taken up depending on the intensity of vehicular traffic. This approach has already been initiated for National Highways by dividing the network into high, medium and low traffic volume zones. A similar approach should be followed for the State Highways. Corridor development should form the basis of highway strategy. Based on the traffic volume to be served and other development potential in the corridor, improvements have to be planned in the form of expressways, widening to four-lanes, construction of paved shoulders and strengthening of pavements etc. for a





period of 20 years and projects taken up accordingly in stages and in order of priority. Highway policy should address the issue of the sources of funding of such improvement projects.

7. A central body like a Road Board should be established to ensure coordinated development of the trunk route system. The roles of the Central and State governments have to be clearly defined. A highway development policy should be prepared and adopted by the Government.

8. On the road sector of transport management the Committee has made the following recommendations.

\* Supernational Highways, bypasses and spot, improvements be taken up through the private sector or in collaboration with it.

\* A Highway Infrastructure Savings Scheme be set up on the pattern of the National Savings Scheme.

\* Substantial portions, if not all, of the revenues from taxes on motor vehicles and transportation fuel be earmarked for road development.

\* A Road Board be set up to ensure coordinated development of the trunk route system. A highway development policy be prepared and adopted by the Government.

\* Four-laning of some of the existing highways be done through the public toll-road method.

\* Comprehensive guidelines and procedures be laid down for approval of private sector projects.

9. Railways are another major element of the Indian transport scene. With 63,000 km of lines we have perhaps the largest railway system in the world. Being a public service, railways have to operate loss making lines also. Raising the tariff has also become a sensitive issue. Innovative non-tariff methods will have to be thought of for meeting the investment needs of the railways. Using the lines of the telecom systems commercially and inviting private parties to lay optic fibres along the railway lines to build the back bone for National Telecom Network is an initiative that must be taken immediately.

10. Ports are another important aspect of the transport sector especially in the context of Indian economy plunging into the global economy. It will be relevant to take note of the observations and recommendations made by the Rakesh Mohan Committee report on ports.

"India has 11 major ports and the primary responsibility for development and management of these ports rests with the Central Government. These ports are governed by the Major Port Trusts Act, 1963, which enables these ports to conduct regulatory as well as commercial functions. The State Governments administer 139 intermediate and minor ports. Each major port has a Board of Trustees representing various interests".

"The total capacity as on March 31, 1995 in all major ports was about 175 million tonnes which is expected to be over 215 million tonnes by the end of the Eighth Five Year Plan in 1997."

"Most Indian ports are operating at more than 100 per cent capacity utilisation, and yet are inefficient when compared to other ports in the region. One reason for this anomaly is that due to certain economic compulsions, the general cargo berths are often used to load or unload bulk cargo such as coal. This temporarily increases capacity utilisation of the ports."

One criterion for determining the efficiency of berth use is berth occupancy. In India, the percentage of idle time at berth to working time at berth is around 36 to 37 per cent. The productivity of the ports in terms of Average Ship Turn Around (ASTA) and Average Ship Berth Output (ASBO) also does not compare favourably with that of efficient ports in the Asian region. Labour and equipment productivity levels too are low.

The major ports account for 95 per cent of total traffic handled. During the decade 1951-61, traffic growth was only around 5.2 per cent annum. Between 1961 and 1971, it increased to around 6.8 per cent annum and slowed to 4.4 per cent in 1971-1981. However, between 1981 and 1991, traffic grew faster, by around 8.9 per cent per annum.

Over time, the commodity composition of traffic handled at major ports has also undergone a substantial change. Petroleum and petroleum products accounted for only 8 per cent of the total traffic in 1950-51 but today account for over 41 per cent.

Problems Faced by Indian Ports: The key problem is low productivity. The major factors contributing to this have been identified.



- \* Operational constraints such as frequent breakdown of cargo handling equipment due to obsolescence and wrong specification.
- \* Inadequate dredging and container-handling facilities.
- \* Inefficient and non-optimal deployment of port equipment.
- \* Lack of proper coordination in the entire logistics chain.

"Our estimates indicate that creating 350 million tonnes of additional cargo handling capacity by 2005-06 will require about Rs. 250 billion. During 1996-2001, the requirement would be about Rs. 100 billion and an additional Rs. 150 billion during 2001-06. The resource requirements are significantly higher when compared with actual expenditure of just under Rs. 16 billion in the last four years (1992-96). Total plan allocation in 1990-1997 was also only Rs. 42 billion. The resources required over the next 10 years will either have to be internally generated by the ports or will have to come from other new sources.

The internal accruals of the ports are expected to be about Rs. 135 billion (Rs. 60 billion between 1996-97 and 2000-2001 and Rs. 75 billion from 2001-02 to 2005-06). Additional requirements are estimated at Rs. 40 billion from 1996-97 to 2000-2001 and Rs. 80 billion between 2001-02 and 2005-06."

- \* Port authorities be permitted to raise resources from the primary market by way of debt and equity and from financial institutions.
- \* Major Port Trust Boards be delegated powers to incur capital expenditure up to Rs.500 million to facilitate speedy creation and operation of assets.
- \* The Major Port Trust Act, 1963 be amended to permit expansion projects to be taken up on a BOT basis.
- \* Options of leasing out berths or other assets, wherever it is cost-effective, be considered.
- \* A moving away from a monolithic pay structure for workers to a piece-based wage structure.
- \* At least two ports, one each on the east and west coasts, be developed as mega ports the warehouse for the Indian sub-continent.
- \* While commercial operation of ports be entrusted to existing port authorities with adequate autonomy, a separate regulatory authority be set up to consider issues relating to pricing and conditions which would govern private sector participation.
- \* Ports with private participation be continued to be exempted from corporate taxes to augment internal resource base and increase eligibility for raising resources from the market.

11. As I see it today, we have a lot of information available about the order of investment required for the transport sector. We also appreciate the significance of the transport sector. Experts like the Rakesh Mohan Committee have made recommendations. But when it comes to action we find we are in a situation where we have mega-talk leading to micro action.

12. It is obvious that unless we are able to initiate action or think of strategies the never ending studies and analysis of the requirements of the transport sector made are not likely to see major developments.

13. I would therefore suggest the following strategies.

14. The first step must be to see whether we can improve the productivity of the existing infrastructure. When it comes to the transport infrastructure we can apply the principles of Industrial Engineering to see whether there is a scope for enhancing the productivity of the systems. For instance, if we take the road transport systems, octroi is a major bottleneck. Apart from being a source of corruption the octroi check posts also hold up the movement of road transport. If we apply information technology, at least the hold up at the octroi check posts can be reduced and to that extent, we would be making a contribution in speeding up the road transport system.

15. The second major issue relates to the under utilisation of the existing capacities. For instance, in the railways if we are able to introduce information technology extensively we should be able to achieve better turn round of the wagons and better movements of freight. Equally, important for the railways we will have to see whether the existing assets can be improved in productivity so that they generate additional resources needed for investment. A case in point is the right of way, for 63,000 km. of the railways. If the railways can persuade the private sector to





come and invest in optic fibre backbones, the telecommunication infrastructure of the country can be substantially enhanced. This will also bring in additional revenues to the railways. Even the present telecommunication systems of railways are probably under utilised. It is high time that railways are allowed to exploits this infrastructure and generate revenue for investment.

16. The second major area we have to focus our attention on is overcoming the man made procedural bottlenecks which hold up investment in infrastructure. Recently, there was a report that about Rs. 800 crores have been sanctioned for the power projects by one of the development banks but they could not disburse the money because of some legal complications. It is high time that we introduce principle of sunset laws in our legal system so that legal bottlenecks are overcome and we don't have the legacy of old legal complications. A time bound programme to modernise our legal systems and procedures will go a long way in attracting investment in the infrastructure sector.

17. Equally, important would be fine tuning policies to make investment in infrastructure investments attractive. For example, in the area of telecommunication we have made the policies in such a way that the return is hardly 2% to 2.48%. This is because we have put restrictions like no long distance calls, not allowing parties beyond a certain number of telecom circles and so on. Above all we have also put a ceiling about the tariff which can be charged by the private party. Removal of these unimaginative policies itself will go a long way in attracting investment. I would like to highlight the fact that government does not have resources to invest. If we remove at least the procedural bottlenecks then market dynamics will come into operation and investments will be attracted.

18. Another strategy I would suggest, for example in the area of roads is what Maharashtra has done. I understand that there are a number of projects which do not cost more than Rs. 25 crores but which are very critical like bridges. These can and they have enhanced the productivity of the roads. So a clear systematic identification of the bottlenecks in our transport systems which will call for relatively smaller investments and then mobilising the resources from organisations like the infrastructure lease financing services (ILFS) would be of tremendous help.

19. Yet another issue relates to mega investments. So far our mega investment proposals have only resulted in mega scams. This calls for greater transparency in the system. I would suggest as a matter of strategy the following approach.

(i) As far as possible entry barriers must be low and clearly defined so that anybody qualified can come and invest. We should make extensive use of build operate, transfer or build lease transfer mode.

[ii] If tender system can be avoided by having a respectable negotiating committee and the systems are transparent probably we will be able to take speedy decisions. One negative aspect of infrastructure projects is the high time taken in and heavy investments which are needed up-front. If we can at least reduce the time taken in decision making it will go a long way in clipping the projects.

20. Another strategy we should think of is to apply the standard principles of Industrial Engineering to see how best we can solve our problems of infrastructure. Those five principles are studied elimination, combination, resequencing, substitution, and modification. Unless we adopt these strategies merely identifying the investments required and hoping that something will turn out will be an exercise in futility.



# Making of Good Roads for Economic Prosperity

Prof P K Sikdar

Director, Central Road Research Institute, New Delhi 110 020

## 1. INTRODUCTION

Good roads are vital to support the economic growth. They are the main and most detailed level of network for access to the community services. The service and tourism industry also rely heavily on efficient and safe road system. The roads, therefore, must be managed to provide safe and efficient conditions for public transport, private cars and freight vehicles for transport of men and materials. The roads existed from the prehistoric age in one form or the other and in all ages there have been significant improvements brought to it. The stone-sett pavements of Roman Empire to operate the iron tired chariots and provision of roadside drains in city streets of Mesopotamia and Mahenjodaro are some of the finest examples of the principle of road making in the olden days. However, the vehicles using the modern roads have many other requirements in terms of speed and riding comfort, and therefore, the designs and specifications have changed gradually to some of the best ones of all times.

A good road can be defined as the one, which has sufficient strength to carry designed traffic load and has good riding quality. A road must be cost effective to both user and the road agency in terms of its maintenance. A good road can be planned and implemented only by a rigorous system of delivery without any compromise at any stage. While good roads are loved by all, they seem to be an illusion only, when we see the roads which exist in India, whether they are National Highways or any of the state roads or even village roads. Thus, fundamentally there is always a quest for good roads in this country. It will be proper to make a check list about all the questions that the road engineers (the architects of the roads) may be having in their minds regarding the roads. Such a set of questions may be as follows:

- Why roads fail prematurely? What are the reasons?
- What are the failure modes, if explained in scientific terms?
- What are the critical concerns in the materials, design and construction which contribute to the failure of roads?
- What is the role of drainage in a road? How critical it is and why?
- What are the modern techniques to fight the battle of road going bad?
- What are the modern materials which can provide or contribute to longer life of the pavement?
- What are the design requirements to enhance the design life of the pavement?
- What are the construction related issues which will safeguard against premature failure of road?
- What are the factors required to be attended at the time of planning?
- What are the operation and maintenance needs of a road?
- What level of resources will be required to have good roads?

In spite of this long list of questions, it may not be exhaustive in any sense, but covers most of the doubts and dilemma of the engineers. This write up is not attempting to answer all these questions indicated above, but only to flag them, as there are large bodies of literatures addressing each of these questions.

## 2. WHAT MAKES A GOOD ROAD?

A good road involves executing methodically, a sequence of activities for planning, design, funding, construction, operation and management with the required level of high quality inputs at every stage. An ill planned road with every inadequacy cannot be a good road, even if an adequate amount of fund is spent on it. Serviceability of a good road becomes poor if it was ill-designed and/or poor quality control was exercised during construction. Roads with poor serviceability lead to higher fuel consumption. A 10 percent saving byway of better roads will mean savings of Rs. 6000 crores. Building and sustaining good roads needs a lot of systematic action from planning to maintenance.

### 2.1 Scientific Planning

The good features of the road are to be built in at the time of planning itself by aligning it through sound foundation soil as well as provision of adequate drainage and cross drainage facilities. A good road is to be also safe for road users in terms of curves, gradients and other geometries, This effort of careful selection of alignment makes a





paramount contribution in sustainability of the road in good condition for its entire service life. The project document has to give the detailed plans, standard specifications, special or supplemental specifications, and other special provisions.

## 2.2 Appropriate Design

Adequate design of a road cannot be over emphasized at any time. The road network in the country is over stressed due to lack of capacity as well as rampant overloading. The proper estimation of traffic load and the material properties are the fundamental inputs to the design, and they are to be attempted as rigorously as possible. Accuracy of these design inputs only determines the future of the road. Well designed road will serve the road users providing economy in the road users cost as well as for operation and maintenance. The age of stage construction is over and full design with its life cycle costing is required to be considered for a cost effective and sustainable good road.

## 2.3 Modern Construction

It was a misnomer that due to shortage of funds the roads had to be built in stages. The price that had to be paid, due to this under-designed and low-level construction along with very poor maintenance of those roads in the form of imposing high road user cost, has been much more than the total cost of fully designed good road. In the name of stage construction, even the compaction of the road layers was sacrificed which caused disaster to those roads and a total wastage of valuable resources. The choice of materials and construction technology available today along with the performance based specification do not leave anything to chance of not having good roads.

## 2.4 Operation and Maintenance

Although stage construction was considered as a philosophy in the past, these roads were never built again to complete the remaining stages, and these half-built roads were subjected to traffic in subsequent years many times higher than it could take with its partial design and poor construction. Moreover, due to lack of maintenance fund the upkeep of these roads with adequate maintenance was a last priority in road agencies which further created havoc for these roads.

## 3. MAKING OF GOOD ROADS

A good road can be defined as the one which has sufficient strength to carry designed traffic load and has good riding quality. A good road must be good to both road user by causing least road user cost as well as to the road agency in terms of its easy maintainability at minimum cost.

### 3.1 Planning for Good Roads

A good road can be planned only by a rigorous evaluation of alternative alignments to satisfy all the requirements in a most cost effective way. Of course, to avoid a marshy area or for having a bridge perpendicular in alignment with the flow line of the river current, a road is no longer twisted and turned in alignment. The modern techniques are available to tackle such situations, but it does not mean that normal design standards and specifications will be suitable for such special situations. These special sections of the road are to be tackled especially involving suitable specification, design and also cost. These are required to be so only to minimize the road user cost in terms of distance, operating cost and enhancing operational safety. The most important input for execution of a road project of any kind is its DPR (Detailed Project Report) which is the root of everything. DPR is supposed to expose all unknowns about the project and provide a convincing design and construction format so as to deliver a best product. It is only when the DPR is sacrificed, everything goes wrong and good roads cannot be built or sustained in good condition for the design life.

### 3.2 Design for Good Roads

The second stage of the journey is a good design, which of course, forms a part of the DPR and is supposed to project the requirement of the road (usage) during the design life and also account for all the inputs (material properties of available materials). It must be understood that poor quality of any available material must not be considered as a constraint for the engineer any more. There are plenty of techniques to improve the material quality or even replace the material. In extreme situation, the design may have to be completely changed; but there cannot be an excuse for producing poor quality road due to availability of poor quality material. Many a times it is the inadequacy of the design for which a road fails. This was the prevalent situation when the roads were designed with a strategy of stage construction, or simply not designed at all in view of the fact that sufficient funds were never available for a designed road.



The road pavements can be of two types - flexible and rigid. The flexible pavement is normally multilayered, the quality of the materials decreasing with the depth. The flexible pavement layers transmit the vertical or compressive stresses to the lower layers by grain-to-grain transfer through the points of contact in the granular structure. The vertical compressive stress is maximum on the pavement surface directly under the wheel load and is equal to the contact pressure under the wheel. Due to its ability to distribute the stresses to a larger area in the shape of a truncated cone, the stresses get decreased at the lower layers of flexible pavements. Therefore by taking full advantage of the stress distribution characteristics of the flexible pavement, the layer system concept was developed. CBR method for pavement design, developed by California Division of Highways in 1928 has been adopted as basis for Indian Roads Congress (IRC) method of flexible pavement design. Before 1984, IRC guidelines had different curves to determine pavement thickness based on the volume of the commercial vehicles. In 1984, the concept of cumulative standard axles was first introduced for design of flexible pavements. In 2001 IRC published the revised guidelines for the design of flexible pavements.

In IRC method, the design traffic is computed in terms of cumulative number of standard axle loads of 8170 kgs carried during the design life of the road. The commercial vehicles with different axle loads are to be converted in terms of cumulative number of standard axle loads, to carryout the design using these guidelines. The vehicle damage factor (VDF) is a multiplier for converting the number of commercial vehicle of different axle loads to the number of standard axle load repetitions. The main shortcoming in the present guidelines is with regard to indicative VDF values. VDF values of 5 to 10 have become most common on our highways. The indicative VDF values need to be revised to avoid under designing of pavements. A closely related issue is that of overloading on our highways. The engineers are required to understand the damaging effect of such overloaded vehicles (trucks), and then only the state authorities can be advised to arrest this menace to the roads. The overloading damages the roads in a fourth-power law, and therefore, the roads designed and built for 10 years may fail in even less than a year. While the legalities of enforcing axle load limit need to be looked into by the Government, the designer should take the realistic values of VDF after conducting the axle load survey in both directions of traffic. VDF should be evaluated direction wise to determine the lanes which are heavily loaded. Taking the higher VDF value for design in both directions would lead to uneconomical design for the lanes having lower VDF.

Cement concrete pavements (rigid pavements) offer many advantages over flexible pavement, such as, long life, minimum maintenance, lower life cycle costs and freedom from potholes and rutting. Recognising these advantages, concrete roads are staging a come back in NHDP works and also for city streets. The design of concrete pavements has been traditionally based on the classic formulae of Westergaard, who presented his results way back in 1926. IRC: 58-1988 'Guidelines for the Design of Rigid Pavements for Highways' was based on these formulae, making an adhoc allowance for traffic intensity. Since then, many changes have taken place in the design approach in various countries abroad. Taking advantage of these and performance of existing concrete roads in India, the Indian Roads Congress revised the guidelines last year and published IRC: 58-2002, 'Guidelines for Design of Plain Jointed Rigid Pavements for Highways'. The revised guidelines take into account effect of traffic intensity on fatigue behaviour of concrete. As long as the ratio of the load stress to allowable flexural stress is below 0.45, concrete road can take infinite axle load repetitions. As this ratio becomes equal to or more than 0.50, the allowable load repetitions get drastically reduced. The fatigue resistance not consumed by repetitions of one load is available for repetitions of other loads. The guidelines require that the spectrum of axle load be analysed and fatigue resistance to be consumed by various loads be accounted for, so that the thickness of the pavement so selected does not fail during its design life.

### 3.3 Materials for Good Roads

Material related factors play a decisive role in determining the serviceability of the road pavement. Many new materials have emerged recently which hold much promise for adoption in our country. To mention a few are emulsions, polymer modified binders, geotextiles, fibre reinforcement, high performance concrete, etc. There are several situations where such materials can be used with advantage in highway construction. Their adoption needs to be encouraged. Changes in existing codes and specifications and introduction of new clauses are needed to facilitate adoption of new techniques and materials.

Aggregates form the bulk of a pavement structure. The type and quality of aggregates available in different parts of the country vary very widely. Integrated stone crushing plants incorporating cone type crushers and vertical shaft impact crushers with a daily output of more than 2000 tons of clean aggregates of requisite sizes are now being used. Aggregates obtained from such crushers are devoid of flaky and elongated particles to a large extent. To keep the aggregates together in a well knit fashion, a binder is a must. The most popular binder for road construction is





bitumen which is also the most expensive binder used by highway engineers. Therefore its proper use has great bearing on cost of road construction as well as its performance. Vastly improved varieties of bitumen binder are presently available. In a country of India's size and diversity of climate, terrain and traffic conditions, grade of bitumen plays an important role. Unlike a few years back, when we had to be content with a single grade of bitumen, now we have several grades of bitumen available for road works. Based on R&D work carried out at CRRI guidelines have been prepared to help the designer to choose the right type of bitumen and appropriate grade.

Rubber and polymer modified bitumen provide a very effective binder for construction of roads under all climatic conditions to carry heavy traffic. This material is less susceptible to temperature and capable of providing road pavement of high durability. With the availability of refinery manufactured polymer modified bitumen, the quality of material is assured and it can now be used with confidence and pavement life can be increased considerably without any significant increase in the total cost of the work. The problem of premature cracking and rutting of bituminous surfaces can be effectively dealt with by using modified bitumen. Care should be taken to use only refinery/industry manufactured modified bitumen and site mixing of polymer with bitumen should be avoided.

The bitumen emulsion usage has been steadily increasing in India. The use of bitumen emulsions must be promoted because it leads to energy conservation, and its environment friendly nature, versatility of applications and possibility of application in adverse weather conditions as well as makes it a more preferred binder. The IS specifications on bitumen emulsions is recently revised, and it provides range of bitumen emulsions tailor made to suit particular applications like priming or tack coat application. It is expected that revised standards for emulsions would overcome many short comings that were experienced when only limited types of cationic emulsions were being produced in the country.

In recent years, there has been growing emphasis world over towards promoting the use of reclaimed and waste materials in road construction mainly from environmental considerations and to reduce over exploitation of good quality aggregates. Use of waste materials like fly ash, steel slag has been well established through laboratory studies and many successful field trials. Use of flyash has now been made mandatory upto a lead of 100 km around the vicinity of thermal power plants by the Government. Highway engineers must make determined efforts to incorporate such materials in road construction. Disposal of waste plastic bags from the domestic waste has become a major problem to the municipal agencies in cities. Such waste plastics mainly consist of low-density polyethylene. The laboratory performance studies conducted on bituminous concrete mixes containing waste plastics has shown promising results. Further waste plastic can be mixed with conventional grade bitumen to obtain a polymer modified bitumen with improved properties. Adoption of such materials for construction of test tracks to study their field performance is urgently required.

### 3.4 Construction Technology for Good Roads

The third stage of producing a good road is a right type of construction technology along with the thoroughly evaluated construction materials. While labour based construction techniques and use of conventional /locally available materials were found to be suitable for road construction till now, new technology products, methods and innovative materials are the need of the hour. Over the years, the technology for construction of flexible pavements has been steadily improving, combining the indigenous skills and modern art of construction. The modern road construction technology makes use of high output and high performance machines. The present approach focuses on user satisfaction, durability and speed of construction. These are pre-requisites for meeting the ambitious targets which we have set for ourselves. It is satisfying to note that mechanisation in road construction has been achieved to a large extent in the highway construction projects. Recent developments in pavement construction practices and use of high-tech equipment all over the world have brought in major technological improvements leading to improved performance, durability and productivity of working methods.

The conventional 20-30 TPH hot mix plants have been replaced by modern 100-200 TPH hot mix plants. Similarly, RMC (ready mix concrete) plants of 240 TPH are in vogue for making concrete roads using 9.0 meter wide slip-form pavers for simultaneous construction of multiple lanes. Vibratory rollers and pneumatic rollers are now a must in addition to conventional steel tyre rollers to impart high degree of compaction and to produce high quality of surface finish. Even in the construction of rural roads under PMGSY, mechanisation in road construction has made inroads in many ways. Until very recent time till the two giant road development programmes were launched by the Govt. of India, the road construction industry in the country was really in primitive condition except those few contractors who were involved in a few selected multi-laterally funded projects.



The required level of supervision of the construction work is required right from the making of embankment and subgrade. The under compaction in embankment and sub grade is probably one of the major causes of perennial problems in a major part of the total network of all types of roads in the country. The engineers must understand that embankment and subgrade together makes the foundation of the road; and there will be no second opportunity to correct any deficiency in them when the road fails due 'to it. Thus, the simple 'mantra' is that compaction cannot be compromised at any cost.

For constructing the base course, wet mix macadam has replaced WBM in all important road works. WMM is a better specification and has got improved compaction and strength characteristics than WBM. Even in case of rural roads, some of the states are considering provision of WMM instead of WBM. The other type of base course which needs our attention is crusher run macadam (CRM). It makes use of crushed aggregates into to instead of separating them into different fractions, and then blending them again. Wherever suitable type of binder material is not available for WBM or WMM, CRM 4 would be the best alternative.

The change of aggregate grading or increased binder content influences the performance of bituminous surfacing course more significantly as compared to the change in thickness of the surfacing. Considering the durability point of view, dense bituminous concrete would be about three times more durable than semi-dense bituminous concrete. Hence usage of SDBC should be restricted to conditions where traffic intensity is less than 1500 commercial vehicles per day. Pavements expecting traffic higher than 1500 cvpd, should invariably be provided with bituminous concrete wearing surface. Also compaction of bituminous layers at appropriate temperature should receive utmost attention. An increase in degree of compaction with adequate voids content of bituminous concrete layer is economically much more beneficial than an increase in layer thickness.

### 3.5 Quality Control for Good Roads

Quality is defined as the totality of features and characteristics of a product or services that bear on its ability to satisfy the stated or implied needs. Quality system includes all those planned actions that are necessary to provide adequate confidence that the product or service will meet the requirements and is essentially a system of planning, organising and controlling human skills to assure quality. The quality system being practiced currently all over the world is based on the ISO-9000 series, prepared and published under the aegis of the International Standards Organisation with the headquarters at Paris. Quality control operations are key to a quality assurance system. Quality control is an essential requirement for road construction for creating durable and long lasting roads. The little cost incurred on quality control operations, usually about 2 to 3 per cent of total construction cost, would result in direct and indirect returns to the order of 15 to 20 per cent or even more. The prerequisites of effective quality control in road construction are

- Making suitable provisions in the estimate/DPR
- Adequately trained staff and well equipped laboratory
- Periodic appraisal of quality control data

A few years ago, quality control through third party was unheard of. However today third party quality control and supervision have become the norm. Any number of quality control manuals is of no use unless all the personnel involved in the project are motivated to aim at excellence in place of any undue excuse for speed or economy leading to monetary gain. An important area which needs immediate attention is the acceptance criterion of quality. With the best of designs and construction practices, things may go wrong if there is any slackness in quality control. Though the contract conditions may stipulate that the work should be rejected, even then it is a national loss in the sense that both money and time have been spent on it. How to judge the degree of sub-standardness and to arrive at the appropriate reduction in payment to the contractor? A simple way is to arrive at the probable decrease in life of the pavement and payment reduced proportionately. However these questions still do not have simple answers.

### 3.6 Drainage Systems for Good Roads

Improper drainage of water from the pavement surface would result in problems like, pot holes and rutting of pavement, washed out shoulders, and even failure of complete sections of roadway structures. A majority of road failures (except in case of deserts) are due to inadequate drainage. Common pavement design methods that are adopted to determine the pavement cross section are based on different factors controlling design like the stress, strain, deformation, and fatigue under repeated loadings etc. Most of these methods ignore the dynamic effects of excess water, which can completely over ride the factors that are considered. Inclusion of effective drainage system



would increase the initial cost of the road or highway, but the omission may result in decrease in pavement life and increase in the cost of repair and replacements far in excess of the cost of the drainage system.

Ineffective surface and sub-surface drainage system on highways results in a variety of problems and damages. Though standards are available for camber required for different types of surfaces at localities with light and heavy rainfall, in practice due to variety of reasons, the actual camber available on pavement surfaces is often found to be inadequate, which leads to presence of water on the pavement surface. Wet pavement surface has lower skid resistance than the dry surface. Increase in moisture content in the subgrade soil, due to capillary rise, seepage from road side or percolation from the top, causes reduction in its stability. This would result in failure of flexible pavements in the form of waves and corrugations. Rigid pavements would fail by mud pumping due to poor drainage and excess moisture in subgrade soil. High moisture is one of the main causes for instability and failure of hillside and embankment slopes due to the increase in stress and simultaneous reduction in the strength of the soil mass. In places where freezing temperatures are prevalent in winter, the presence of water in the subgrade and a continuous supply of water from the ground water table can cause considerable damage to pavement due to frost action. Accumulation of water in the base or sub-base course may cause distress regardless of the thickness of the pavement. Hence good drainage is an important factor for the proper performance of a highway to withstand the effects of weather and traffic and to provide trouble free service over long periods of time. Effective drainage would also result in reduction in the need for frequent maintenance works and construction of overlays and would allow to maintain even riding quality of pavement surface. The complete and rapid disposal of all surface and sub-surface water from the pavement surface/structure and the foundation, has to be considered in the design and construction of roads. In fact, the provision of all drainage features are required to be made in the DPR itself.

Cracks and joints of very small widths in the pavement are capable of allowing surprisingly large quantity of water into the pavement. The amount of water that can enter a given pavement depends on the kind of mix used, its density, degree of cracking, the type and effectiveness of any sealers or joint fillers used and the age and condition of the entire system. Improper surface drainage on bituminous pavements results in their rapid deterioration due to (i) stripping of bitumen from the aggregate on the surfacing layer, resulting in breaking up of the pavement course under heavy traffic loads; and (ii) decrease in interface bond between the WBM base course and the bituminous surface course. This type of failure is predominantly found on pavements with thin bituminous surface course like that of pre-mixed carpet laid over WBM base course, with inadequate surface drainage.

The surface water from the carriageway and shoulder should effectively be drained off without allowing it to percolate to the subgrade. The surface water from the adjoining land should be prevented from entering the roadway. The side drains should have sufficient capacity and longitudinal slope to dispose off all the surface water collected. Flow of surface water across the road and along the slopes should not cause erosion or formation of ruts. Seepage and other courses of underground water should be drained off by the subsurface drainage system. Highest level of ground water table should be kept well below the level of the subgrade, preferably by 1.2 metre and at least by 0.6 metre. Altering the design of pavements in order to reduce the damages caused by the traffic on pavement structure containing excess water, without increasing drainability, does not remove the basic cause of deterioration. Provision of drainage system comprised of side drains and adequate number of cross drains at right locations are the basic requirements of hill roads. Hill roads without just appropriate drainage will not survive even for a day.

The rural roads manual has consciously given the stringent requirements in design for the sub-surface drainage. No doubt, the designed 100 mm thick drainage layer by a sand layer of specified grading will add to the cost of the road; but this will be cheaper option than to allow the pavement to fail prematurely in worst subgrade conditions or to allow it to deteriorate faster in other cases. Thus the manual clearly states that in case of subgrade with 2 per cent or lesser value of CBR with a combination of rainfall in the area higher than 1000 mm, there is no choice other than to provide 100 mm drainage layer of coarse sand. This sub-base/drainage layer should be extended over full width of the pavement. If lined drains are provided, these should have weep-holes at sub-base level. Many of the pavement failures can be traced to the failures due to poor GSB material, which instead of serving as a good drainage layer, gets choked. Moorum should not be used as a GSB material unless the quality of moorum is established adequately by wet sieve analysis and plasticity index test. It would be always better to use non plastic moorum unless it is a gravel road. Any wrong use of deficient GSB material with poor drainability will create havoc in the performance of the road pavement. It will be extremely costly to correct the situation once a wrong material is used without controlling its quality.





### 3.7 Maintenance for Good Roads

Adequate maintenance of a road is critical to sustain it in good condition. Most of the roads in the country are being used by illegitimate traffic for which it has not been designed both in terms of total volume of traffic as well as the axle load. The overloading on Indian roads is rampant and some states are exploiting the situation for making a business out of it both officially as well as unofficially. To some extent, this menace can be taken into account while designing the road as indicated earlier. However, the authorities should wake up to the ills caused by this malpractice and check this phenomenon ruthlessly. Otherwise premature failure of our well designed and constructed roads will pose a heavy burden on our economy. In addition to this, the added phenomena in Indian roads is that they are maintained with very scanty provisions of fund. The roads very well follow the principle of "a stitch in time saves nine", but the road authorities are not able to undertake the preventive maintenance for several reasons including the vested interests of several stakeholders. A road to be in good shape and to provide good level of service to the road users, requires preventive, periodic and renewal maintenance as routine process both timely as well as according to the maintenance management plan.

Most of the states and local authorities do not allocate the required funds for maintaining the road assets. Moreover, all along there has been an overemphasis on network expansion rather than the maintenance. There is not even a single PMD (Pavement Management System) in operation anywhere in the country for actual maintenance management of a network. All maintenance allocations as well as their utilisation in the network have been arbitrary/adhoc without any assessment of the actual need and decision about the level of maintenance that may be required. Inadequate design with low quality construction make it extremely difficult to maintain these roads at the required level of serviceability. Only at recent time in 2001 the MoRTH has evolved rational maintenance funding norms for uniform adoption for various types of roads along with the regional variations. It is experienced globally that adoption of rational maintenance management strategies using operational PMS is far more economic than any sub-optimal adhoc plans of maintenance. However such scientific method demands a minimum level of information on the condition of the network which has not been possible to be organised in any of the States nor at the Central Ministries, and also even in the local authorities.

### 4. MAJOR ROAD DEVELOPMENT PROGRAMMES - AN ANALYSIS

The main reason for bad quality of roads has been the steady decline of the Government's spending on the sector through the 1980s and early 1990s. Worse still, the bulk of the revenues raised through road taxes and related levies were diverted to other sectors instead of being ploughed back into road development. In contrast, vehicular traffic witnessed a sharp rise. However, the scenario began to change when the present Government started two national level road construction programmes - National Highway Development Programme (NHDP) and Pradhan Mantri Gram Sadak Yojna (PMGSY). The government has stepped up its investment through budgetary support and also through cess levied on each litre of petrol and diesel sold, being routed for road development. External aid is also flowing for Indian road sector. As a first step towards modernising National Highways, National Highways Authority of India (NHAI) was activated in 1995. The NHAI is now implementing the Rs.540 billion NHDP project which is by far the biggest infrastructure project to be taken up in the country. The NHDP involves four/six laning of about 14,000 km of national highways and is being implemented in two parts: one, linking the four metropolitan cities of Delhi, Kolkata, Chennai and Mumbai (called the golden quadrilateral), and the other, the north-south (Srinagar to Kanyakumari) and east-west (Silchar to Porbandar) corridor projects. Connectivity to 10 major ports is also being improved as part of NHDP. Sceptics had dubbed the NHDP as unrealistic and overambitious when the Honourable Prime Minister announced it in 1998. However the doubts have been laid to rest by the manner in which NHAI has gone about the task and has delivered a significant part of it by now. The NHDP is set to bring a sea change in road transport standards in India. Average speed of trucks is expected to double to 60 km per hour. Besides it will lower fuel bills, wear and tear costs and turnaround time. Savings in fuel costs alone is expected to be Rs.80,000 million every year on the golden quadrilateral only. In short, the country seems to be on the fast track to reach the international standards in road sector.

When such phenomenal improvements are taking place in national highways, the other roads cannot be left behind. State highways, district roads and rural roads which form rest of the network are also being improved. Several state governments like Madhya Pradesh, Punjab, Kerala, Karnataka, Tamilnadu and Maharashtra have taken up initiatives to improve state road network. This has been largely due to contributions from the Central Road Fund, loans from multilateral agencies like Asian Development Bank, World Bank, national banks and NABARD, and state coffers. The rural connectivity, which was till now neglected in India, received its attention in the recently launched PMGSY (Pradhan Mantri Gram Sadak Yojana) project. In India an estimated of 3,30,000 habitations (about 40



percentage of the 8,25,000 habitations in the country) are without all-weather road access. Lack of all-weather road access strains economic activities in the isolated rural areas, and prevent the rural communities from accessing essential social services such as health and education and also creates barriers for integrating into main stream of the country's economy. PMGSY programme aims to provide access to every habitation with a population of 1000 and above by the year 2003 and all habitations of greater than 500 people by the year 2007. The current estimates suggest that the total investment required to meet the PMGSY targets by 2007 is of the order of Rs.600 billion. Government of India made provision of 50 per cent of the diesel cess being collected, which has been about Rs.2500 million per annum towards this programme. The World Bank is also pitching in to lend loans to support the programme.

India never before built such roads as built in NHDP. These roads are designed for traffic of a given design life. Therefore, if these are constructed with due quality control, it cannot go bad within its proposed service life. If with all these planning, design and extremely elaborate construction programme through international contracting, and of course, at very high cost, the roads cannot be delivered at their best, there is simply no excuse. No doubt, a world class road can be constructed at world class cost only. Cutting corners with old notions or any scope for leakage will lead the project to a failure only. The actual cost of these roads are higher than what the road authorities used to build; but the effort should be to match the cost and the output. Moreover, there are so many ways to control and reduce costs of these roads while keeping their standards very high; (i) the land acquisition time is to be drastically reduced, (ii) very strict control and scrutiny of the pre-feasibility studies including planning, (iii) rigorous control and evaluation of the DPR including the design alternatives, and (iv) a very systematic construction schedule with best quality control arrangements. Thus, while higher costs are necessary for good roads, it does not mean that the country can waste for undue provisions or any kind of negligence. Further, the R&R (Resettlement and Rehabilitation) requirements of multi-lateral funding agencies often make the road projects complicated and extremely costly. In a country where the population is bursting at the seams and a majority of the R&R demands are legally illegitimate, this mandatory stipulation borrowed from other types of projects is not justified at all. The parallel projects funded locally never have this component in such a damaging way, but with due legitimacy. All such possibilities are to be contained by (i) a rigorous planning and pre-feasibility study, and (ii) accurate and detailed feasibility DPR. On top of all these, the non-performing and low-quality performance of the contractors and consultants must be punished and penalised for lapses and shortfalls.

The delivery of PMGSY has been designed in a completely different footing than all the earlier programmes including NHDP. The technicality of the programme includes preparation of district rural road plan (DRRP) along with the required core network to provide the basic minimum level of all weather connectivity to the target habitations for access to education, health and market facilities. A detailed project is prepared before implementation with due scrutiny of its accuracy. As the spread of the project is enormous unlike NHDP or the state level projects, and the states themselves are responsible for delivery of the individual road projects, in spite of the best efforts of NRRDA(National Rural Roads Development Agency) and clear availability of funds, the quality control in the works and the timely delivery continues to be serious casualty. It may be due to the fact that state engineers are not habitual of such rigor (of perfect quality) and time bound construction schedules with assured funds. The newly created capacity of contracting as well as the veterans of this industry alike have the capability of intimidating the NRRDA guidelines for quality where the executing state agency officials are weak in their commitment. However, NRRDA must not shy off from identifying those contractors, the states and the districts where it has not been possible to deliver good roads even with a massive system in place with a concern of quality.

## 5. SUSTAINABILITY OF GOOD ROADS

A road will gradually deteriorate in its serviceability (load carrying capability and riding quality) when it is subjected to traffic. A road deteriorates under the sky due to the environment even if it is not used by any traffic. But, this may be accelerated by over use of the road as it happens due to the overloading of the vehicles, particularly the trucks or additional traffic which was not envisaged at the time of design. Even under normal situation, a road is required to be maintained regularly to sustain it as a good road for the road users.

### 5.1 Design Life

Design life is defined as the number of years for which road is supposed to provide an acceptable level of service until the first major rehabilitation is anticipated. The flexible pavements are being designed for 20 years in the present NHDP program. In cases where the design traffic in terms of msa (million standard axles) exceeds 150, the thickness is being determined by extrapolation of curves provided upto 150 msa. Are these extrapolated values



acceptable? Alternatively, the design period has to be reduced to 10 or 15 years so as to limit the design value of cumulative standard axles to 150. CRRRI experience has shown that such extrapolation generally leads to over design of pavement thickness. The design guidelines need to be modified urgently to address this lacuna.

The principal criterion for determining the thickness of a flexible pavement with a thin bituminous surfacing is the vertical compressive strain on top of the subgrade imposed by a standard axle load of magnitude 8.17 kN (8170 kg). Excessive vertical subgrade strain causes permanent deformation in the subgrade, which is manifested in the form of rutting on the pavement surface. The maximum rutting that can be accepted in village roads may be taken as 50 mm before rehabilitation work is needed. For the purpose of structural design, only the number of commercial vehicles of laden weight 3 tonnes or more should be considered. To obtain a realistic estimate of design traffic, due consideration should be given to the existing traffic and its rate of growth. It is considered appropriate that roads in rural areas should be designed for a life of 10 years.

## 5.2 Maintenance

The roads under NHDP programme are being constructed as world class roads at a very high cost, and therefore, there is no choice other than to maintain them appropriately through provisions of adequate maintenance funds. The country cannot afford to allow these roads to deteriorate like others; and therefore, the government has decided to charge toll in these roads for funding the maintenance. The Rs. 20 lakh per kilometre toll revenue projected as toll collection on golden quadrilateral (GQ) is going to be used for maintenance/management of the road after construction. Many of the progressive states are also upgrading their state roads with heavy traffic using various methods of funding including borrowing from multi-lateral agencies. All such roads also are going to be tolled to generate adequate funds for their maintenance. In case of PMGSY programme, five years of performance guarantee has been incorporated at the stage of awarding contract itself. This is only to ensure a quality delivery which will demand minimum maintenance during its design life. Of course, the rural roads will also have to generate funds from agricultural productivity and marketability for their sustenance. A good road also needs the preventive maintenance to remain good.

## 5.3 Resources

Funding for road development has been increased by the Government. The non lapsable cess fund available as a dedicated fund from petrol and diesel cess in the form of CRFis being used for the NHDP and the PMGSY programmes. Funds will need to be mobilised through conventional and non-conventional sources like, user charges, betterment levies, employment taxes and most importantly private sector financing. Yet another option, which in fact is already in practice, for generating additional resources for highway sector is toll financing. Major attraction for toll financing is the quicker construction of facilities. The option of building of roads through non-recourse financing has turned the attention of Central and state Governments to throw open the road infrastructure to private sector for financing. Series of regulatory financing and legal measures have already been taken by the Government to attract private sector financing. Success has already been achieved in respect of small and medium sized projects. However factors like low rate of return, uncertainties with regard to amount of toll collection, etc are acting as inhibitors for large scale financing of private sector in road building. Some of the steps that can be taken up by Government to facilitate road users would be the stipulation of appropriate minimum distance between toll plazas so that the users are not made to pay frequently and provision of service roads to cater for local non toll paying traffic. Also one should think in terms of differential toll charges for peak period and off-peak period to relieve congestion.

## 5.4 Benefits

The goods transport (particularly the freight by trucks), affect the economy in a significant way as all the goods are to be transported to their place of consumption. Be it coal from the mines to the thermal power plants or a book printed in the press to be distributed to the markets all over the country, transport makes it possible. Therefore, any extra efficiency in goods transport makes the economy that much better. There are lots of multiplier effects of transport on the production and consumption patterns also. Therefore, the GQ (Golden Quadrilateral) is going to be the nation's pride and the effect will be more pronounced when the N-Sand E-W corridors are also in place. Similarly, the roads of PMGSY will convert the rural India to a huge enterprise for the country's economy, in addition to many more benefits. For example, the trucks at present are able to travel about 250 kilometers in a day (at an average speed of 30 kmph). These trucks will travel at double the present speed and will be able to cover some 500 to 600 kilometers per day through the new generation of roads of GQ, which means that they will have double the efficiency by reduction in travel time. Thus, the lower turn around time will enable a lower fleet size to deliver





the same output or the same fleet will deliver higher output. The country will also be highly benefited from enormous amount of time and fuel savings.

### 5.5 Research

The sustainability of these critical road assets and potential to enhance the know-how technology lies in how the knowledge gained through this road revolution is assimilated and put to use every time utilising their performance data and making them better every time. The revamped CRF is collecting Rs. 9000 crores every year. The research and training are the two areas which make things better in terms of economy and durability leading to sustainability of the assets. Only 0.5% of the CRF will make it Rs. 45 crores for every year which can make the research and training in their best. A majority of the road engineers are completely devoid of the critical knowledge of road which is vital for planning, designing and construction of good roads. It needs a systematic effort to train them, if we aim to sustain these valuable assets as good roads.

## 6. CONCLUSIONS

The globalisation of Indian economy 10-12 years back has very clearly demonstrated that nothing happens without infrastructure, and road system is the backbone of all infrastructures. Roads happen to be the most basic and critical infrastructure and forms a pre-requisite for everything else. Therefore, more systematic development of road network is called for starting from making of statewise 'road policy' leading to implementation of projects involving delivery of carefully planned and designed high quality roads. These, quality roads in turn will act as catalyst for the transformation of the present economy and the society into a developed nation. The age old perennial problem of short supply of funds seem to be handled through the dedicated fund concept and collection of cess and tolls as well as many other road sector reforms carried out over last one decade. However, a systematic re-engineering of the HRDsystem through complete revamping by training and re-training programmes with built-in strict norms of accountability and ethics is immediately called for. Therefore, till we sensitise our managers and workers of road (presently with age-old die-hard conceptions mixed with low moral), it is not possible to have good roads.

## ACKNOWLEDGEMENTS

The author is thankful to Dr. Sunil Bose, Shri Sudhir Mathur, Shri Stander Kumar, Dr. P.K.Jain and Shri U. K.Guru Vittal, all of whom are scientists of CRRI who have helped in preparation of the technical materials for preparation of the paper.



# Role of Civil Engineers in Earthquake Risk Reduction in India

Padmashree Dr Anand S Arya, *FNA, FNAE*

Professor Emeritus, Department of Earthquake Engineering, IIT, Roorkee  
National Seismic Advisor (EVR) GoI UNDP (DRM) New Delhi

## CHALLENGE OF EARTHQUAKE DISASTERS

- Loss of more than 100,000 lives due to earthquakes in India in 100 years.
- Loss of 20,000 lives in Kangra earthquake of 1905
- 13,000 were killed in 1934 in Bihar- Nepal in M 8.4 earthquake, again 900 killed in Aug. 1988 in M 6.6 Quake (M6.6 is 1/500 of 1934 Quake of M8.4)
- 13800 were killed in Kachchh earthquake of 26<sup>th</sup> Jan., 2001

### Recurrence

- In Algeria, AlAsnam 1,600 killed in 1954 earthquake, again 2500 killed in October 1980 in the Rebuilt city.
- Anjar in Kachchh was destroyed in 1819, 1956 and again now in January 2001.

## WHY EARTHQUAKE HAZARD BECOMES A SOCIETAL DISASTER

- Earthquakes don't kill, buildings do.
- Well designed & constructed buildings don't collapse, don't kill.
- Only badly designed & constructed buildings fail & kill.

## RISK OF EARTHQUAKE DISASTER

*Seismic Risk = f (Hazard, Exposure, Vulnerability, Location).*

**HAZARD-** occurrence of an earthquake of sufficient Magnitude and Intensity. *(No control of man)*

**EXPOSURE-** Objects and structures built by man which are exposed to the hazards. *(Existing one will only expand)*

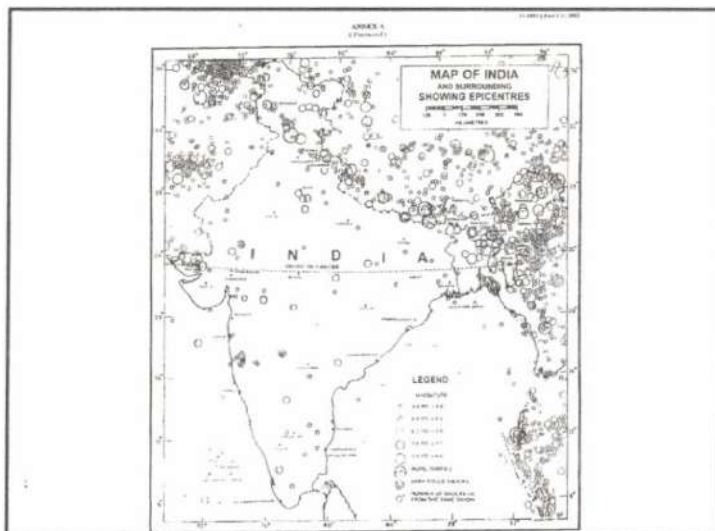
**VULNERABILITY-** Damageability of the 'exposure' under the hazard. *(Vulnerability can be controlled by us)*

**LOCATION-** (i) How far the 'exposure' is from the *Hazard* location and the site soil condition

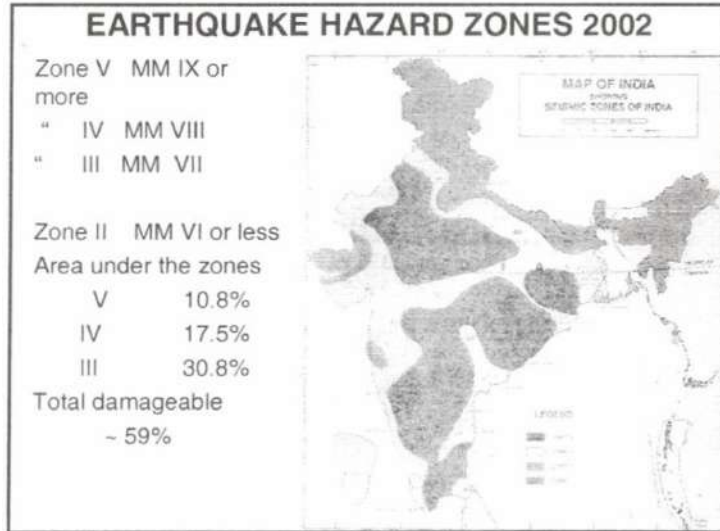
*Reduction of vulnerability of our buildings and other structures and systems, those existing and those being built or to be built, is the key to earthquake protection.*

It is here, the engineers have their most critical role to play.

## SEISMIC HAZARD IN INDIA







**Prediction studies** Precursory phenomena :

- Physical, chemical, electrical, etc.
- May define the Hazard and its location.
- Stimulate mitigation & preparedness measures .

***Prediction as a means of saving human lives in earthquakes is extremely unreliable at present***

***For saving economic losses it will be utterly useless***

**(Seismically weak buildings and structures remain liable to catastrophic behavior during strong earthquakes).**

*Seismic Zoning map is area wise maximum Intensity prediction map*

## SEISMIC RISK TO BUILDINGS



<b>BUILDING TYPES IN INDIA</b>							
Various Building Type by Wall Materials in India							
Wall Type	Number of Housing Units				Damage Vulnerability In MSK Intensity		
	Census 1991		Census 2001		VII	VIII	IX
	Millions	% of Total	Millions	% of Total			
Earthen Walls (mud, un burnt brick)	74.7	38.29	73.80	29.63	M	H	VH
Stone Walls	21.7	11.10	25.48	10.23	M	H	VH
Burnt Brick Walls	68.60	35.18	111.89	44.93	L	M	H
Concrete Walls	3.96	2.03	6.54	2.62	VL	L	M
Wood & Ekra Walls	3.12	1.60	3.19	1.28	VL	L	L
GI & Other metal Sheets	1.01	0.52	1.99	0.80	VL	VL	L
Bamboo Thatch, Leaves etc.	21.63	11.09	26.18	10.51	VL	VL	L

### **Non Engineered Building Construction**

*Non-engineered buildings* are those which are spontaneously and informally constructed in various countries in the traditional manner.

Such buildings involve field stone, fired brick, concrete blocks, adobe or rammed earth, wood or a combination of these traditional locally available materials.

### **Engineered Constructions including buildings and infrastructure.**

The *engineered constructions* include reinforced concrete and steel buildings and structures, which are normally designed by Architects and Engineers working together or Civil Engineers working in various Govt. departments or consulting organizations.

### **Building Types in India**

From the damage vulnerability consideration the buildings can be classified as follows :

#### **Masonry load bearing wall buildings**

Building Type	Description
A	Rubble (Field stone) in mud mortar or earthen walls
A+	As above but one storey only having light roof
B	Semi-dressed, rubble, brought to courses, with <i>through</i> stones and long corner stones; unreinforced brick walls with country type wooden roofs; unreinforced CC block walls
B+	As above of only single storeys and/or better quality of construction
C	Fully dressed (ashler) stone masonry or CC block or burnt brick walls built using good lime or cement mortar. Unreinforced walls but having RC floor/roof.
C+	As at C but having horizontal RC bands (IS: 4329, 13828).
D	Masonry construction as at C but reinforced with bands & vertical reinforcement, etc (IS: 4329), or confined masonry using horizontal & vertical reinforcing of walls.

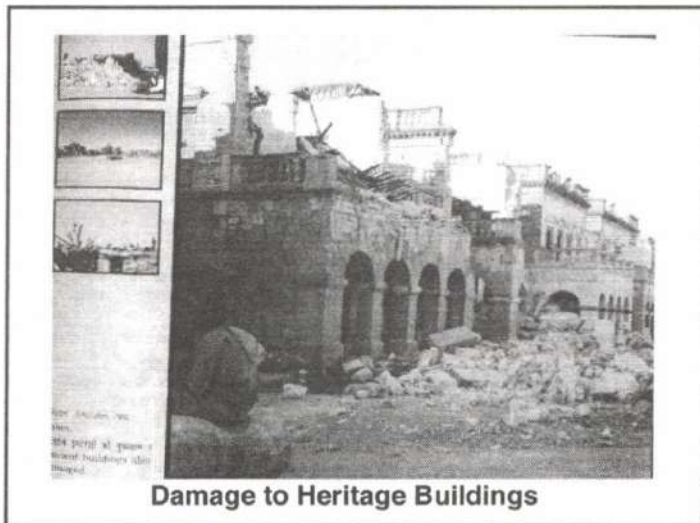
Reinforced Concrete Frame Buildings (RCF) and Steel Frames (SF)	
Frame Type	Description
C	RCF without ERD or WRD, built in non-engineered way; RCF with hollow plinth (open ground storey); SF without bracings having hinge joints; RCF of ordinary design without ERD or WRD, SF of ordinary design without ERD or WRD
C+	MR-RCF/MR-SF of ordinary design without ERD or WRD
D	MR-RCF with ordinary ERD without special details as per IS: 13920, with ordinary infill walls (such walls may fail earlier similar to C in masonry buildings); MR-SF with ordinary ERD without special details as per plastic design hand book SP:6(6)-1972.
E	MR-RCF with high level of ERD as per IS: 1893-2002 & special details as per IS: 13920/MR-SF with high level of ERD as per IS: 1893-2002 & special details as per Plastic design hand book, SP:6(6)-1972
E+	MR-RCF as at E with well designed infills walls MR-SF as at E with well designed braces
F	MR-RCF as at E with well designed & detailed RC shear walls MR-SF as at E with well designed & detailed steel braces & cladding; MR-RCF/MR-SF with well designed base isolation.

## SEISMIC BEHAVIOR OF BUILDINGS IN EARTHQUAKES




**Collector Office at Bhuj  
Collapse of Second Storey**





**Health:**

- 281 bed District Hospital and 16 bed Mental Hospital at Bhuj completely destroyed. (many staff and patients killed)
- 42 Primary health Centers, 227 sub-centers, 42 Community Health centers reduced to rubble.



**Collapse of General Hospital at Bhuj**

**Over 5,000 Health units damaged / destroyed**



*Bhuj General Hospital*

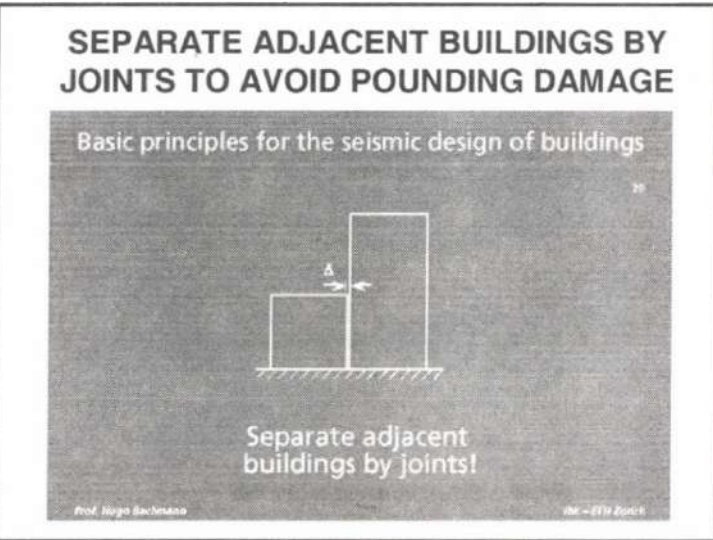
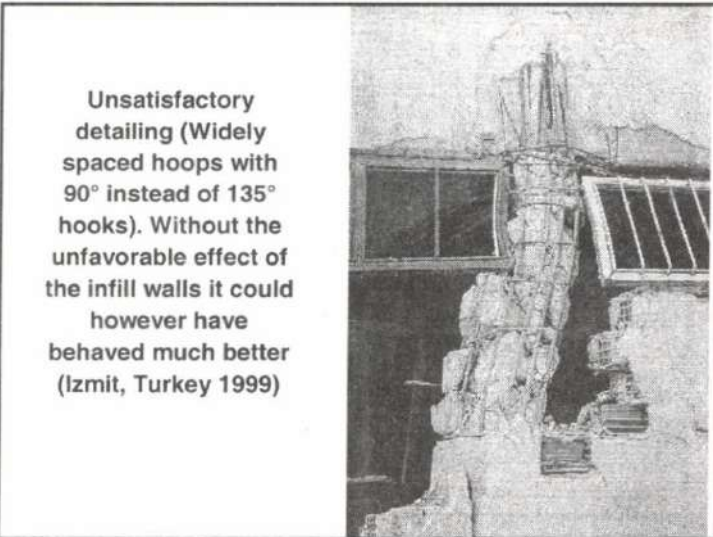
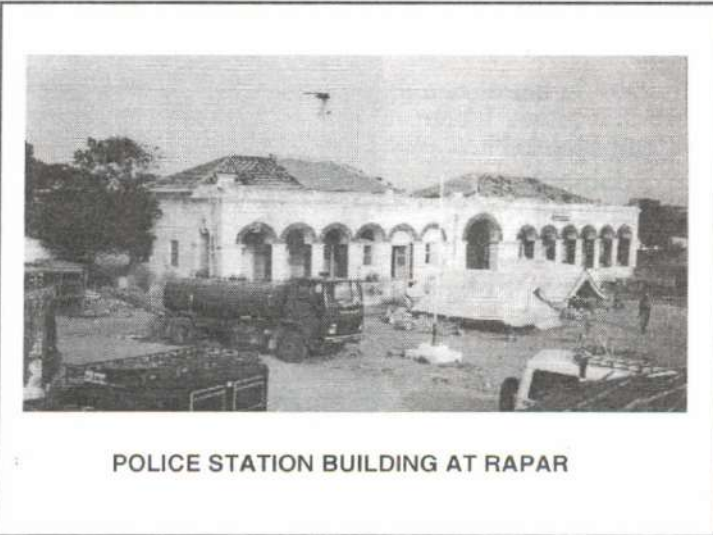
**Government Hostel Collapse (Bhuj)**



**OVER 50,000 SCHOOL ROOMS DAMAGED / DESTROYED**



*High School of Dudhai Village*





**Substantial damage resulted from the pounding of these two very different buildings (Mexico, 1985)**

**The modern reinforcement building was an extension of the older building to the left. Either the joint width was insufficient or the buildings were not connected properly. During the earthquake, the older sturdier building pounded against the new one and caused its collapse (Kobe, Japan 1995)**

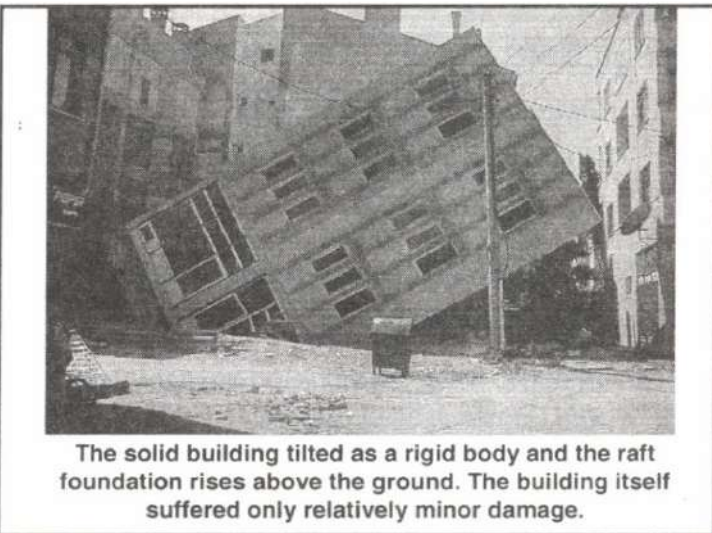
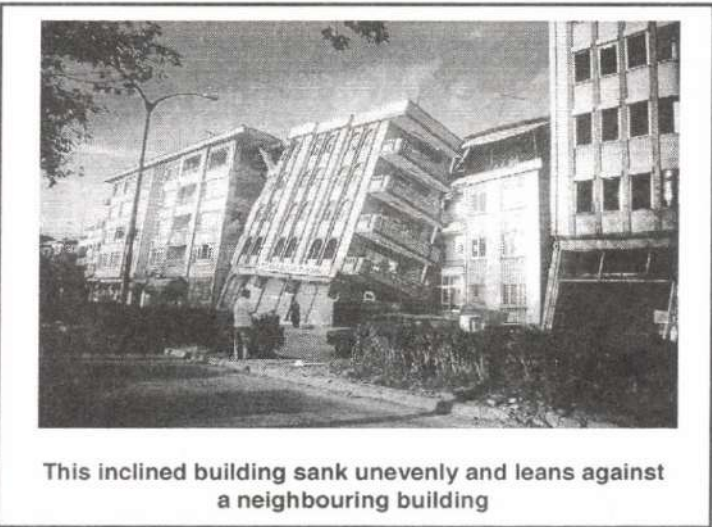
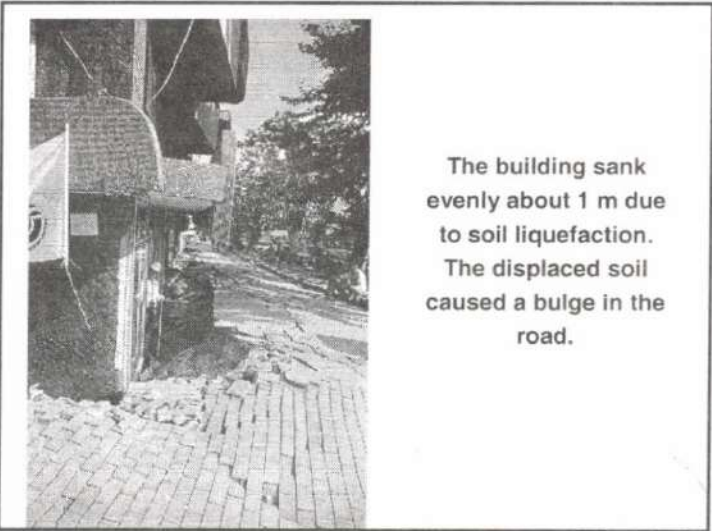
**ASSESS THE POTENTIAL FOR SOIL LIQUEFACTION**

Basic principles for the seismic design of buildings

**Assess the potential for soil liquefaction!**

Prof. Hugo Krawinkel IA - ETH Zurich







### R.C. FRAME BUILDINGS

- (i) Soft First Storey used without necessary design.
- (ii) Inadequate Design for Earthquake forces.
- (iii) Inappropriate configuration - torsion
- (iv) Long Period Effect.
- (v) Local Soil Condition. Foundation tie beams not used.
- (vi) Substandard Quality of Materials and Constructions.
- (vii) Inappropriate detailing
- (viii) Inadequate separation of blocks
- (ix) Intermediate soft storey
- (x) Inadequate design in long direction.

### IDNDR YAKOHAMA MESSAGE 1994

"The impact of natural disasters in terms of human and economic losses has risen in recent years, and society in general has become more vulnerable to natural disasters.

Those usually most affected by natural and other disasters are the poor in developing countries as they are least equipped to cope with them."

"Disaster Prevention, Mitigation and Preparedness are better than disaster Response in achieving the objectives of disaster reduction. Disaster response alone is not sufficient, as it yields only temporary results at a very high cost".

***"Prevention contributes to lasting improvement in safety and is essential to integrated disaster management".***

### Preventive Strategy for Damage Reduction



### NEW CONSTRUCTIONS

- Government Sector Buildings & Infrastructure:
  - Follow the E.Q. Resistance Codes Strictly.
- Public Sector and Private Undertakings
  - Mandatory use of Building Codes.
- Private Buildings in Local Body Areas
  - Improve Building Bye Laws with Earthquake Resistance Provisions and Ensure Effective Implementation & enforcement
- Private Buildings in Rural Areas
  - Demonstrative Constructions,
  - Building Technology Centres,
  - Awareness and Training to Artisans.

### BUILDING CODES FOR ENGINEERED CONSTRUCTION

1. IS: 1893-2002 "*Criteria for Earthquake Resistant Design of Structures, Part I (Fifth Revision)*" July 2002.
2. IS: 13920-1993 "*Ductile Detailing of Reinforced Concrete Structures subjected to Seismic forces - Code of Practice*" November 1993.
3. IS: 4326-1993 "*Earthquake Resistant Design and Construction of Buildings - Code of Practice (Second Revision)*" October 1993.
4. Many Good Books
5. Large Nos. of Conference Proceedings

### GUIDELINES FOR NON-ENGINEERED CONSTRUCTION

1. IS: 4326-1993: *Earthquake Resistant Design and Construction of Buildings – Code of Practice (Second Revision)* October 1993.
2. IS: 13828-1993 "*Improving Earthquake Resistance of Low Strength Masonry Building - Guidelines*" August 1993.
3. IS: 13827-1993 "*Improving Earthquake Resistance of Earthen Buildings- Guidelines*" October 1993.
4. Arya A.S. et al, *Earthquake Resistant Non-Engineered Construction*, Monograph Pub. by International Association for Earthquake Engineering, 1980, Revised 1986 (translated into Spanish for use in various Spanish countries).



(Continued)

5. Arya A.S., *Protection of Educational Buildings in Seismic Areas*, Digest 13, Pub. by UNESCO, Bangkok, 1987 (translated into Persian for use in Iran).
6. Guidelines—Pub. by BMTPC, Ministry of Urban Affairs & Employment, Government of India after Jabalpur and Chamoli Earthquakes.
7. Guidelines-Pub. By Gujarat State Disaster Management Authority, (GSDMA) Gandhinagar

#### **STRATEGY FOR IMPLEMENTATION**

1. Hazard Safety Cell in each Engineer in Chief's office (Design Basis Report).
2. Departmental Circulars
3. Standard designs for repetitive buildings

#### **STRATEGY FOR UPGRADING THE STRENGTH OF EXISTING CONSTRUCTIONS BY RETROFITTING**





## PRIORITIZATION OF BUILDINGS AND STRUCTURES

### (a) Buildings:

*The following and others to be identified:*

- (i) Instructional, laboratory and library buildings of educational institutions (schools, colleges, institutes and Universities).
- (ii) Hospitals including wards, dispensaries, clinics, etc.
- (iii) Congregation halls, temples, churches, cinemas, theatres etc.
- (iv) Residences of VIP's and top administrative officers in the districts (Collector, SP, CMO and the like needed for immediate Response).

(Continued)

### (b) Service Structures & Infrastructure:

*The following among others:*

- (i) Water tanks and towers.
- (ii) Telephone exchanges, fire stations, water supply pump houses.
- (iii) Bridges and culverts.
- (iv) Electric power houses and substations.
- (v) Monuments, Heritage Buildings, Museums.
- (vi) Critical and Hazardous industries.
- (vii) Railway stations, Airport buildings and towers.

*Priority may be given in order of Zones V, IV & III.*

## DAMAGE SCENARIO IN HYPOTHETICAL REPEAT EARTHQUAKE

(Example Kangra Earthquake, 1905)



## BENEFIT/COST OF SEISMIC RESISTANCE

(Hypothetical Repeat EQ of 1905 in H.P.)

	Case (a)	Case (b)	Case (c)
Seism. Resist. Cost	Nil	635 crores	1525 crores
Life Loss	65000	12000	12000
Physical Losses	5104 crore	1960 crore	1960 crores
Net saving as	-	2509 "	1619 "
Compared to (a)			
Indirect Losses & Trauma	A	20 – 25% of A	20 – 25% of A

Case (a) – Existing situation of buildings.

Case (b) – If all buildings were earthquake resistant initially.

## Extra cost in providing Seismic Resistance

Building in	Masonry in Cement Mortar	RCC framed Buildings 4-8 storeyed
Zone III	1.5 – 2 %	2.6 – 3.2 %
Zone IV	3 – 4 %	3.2 – 4.0 %
Zone V	5 – 6 %	5.0 – 6.0 %

Post earthquake retrofitting cost: 2 – 2.5 times the above

## CONCLUSION

- Carry out the engineering, architecture and planning measures
    - Land use zoning.
    - Planning of habitat,
    - Implementation of building codes in all new constructions, and
    - seismic retrofitting of existing buildings and infrastructure.
- Create the supportive structure of
- public awareness,
  - education and training
  - research and development about the safety from earthquake hazard.
  - Appropriate policy, financial and institutional support at national and state levels need to be provided for putting this strategy into a workable action plan.

**Role of Engineers is clearly seen in the Action Plan.**



**Thank you for your  
attention.**



# Infrastructure Development in Water Sector — Key to National Growth

Shri A.K. Ganju

Member (WP&P)  
Central Water Commission

Climatological, meteorological, demographic and socio-economic-environmental factors have accentuated several issues and challenges in the water sector. The severe spatial and temporal variations in water availability cutting across regions, declining per capita water availability, tremendous socio-economic development that has pushed for the increased multisectoral water demand, the emerging issue of climate change and its likely impact all indicate towards development of systems that are more controlled which will fare better than systems that are less controlled. In water resources sector, control means engineering infrastructure. that enables the water managers to store and transfer water with greater certainty, thus reducing the impact of uncertainty. Therefore, dealing with the above issues definitely need water resource infrastructure facilities.

Though water as an element is abundant on Earth, the pool of annually renewable fresh water is limited and is becoming increasingly scarce relative to needs. The water resources in India are roughly 4% of the World's fresh water resources, whereas the country's population is 16% of the World's population. The average annual water resources potential of the country is around 1869 BCM. Owing to topographical, hydrological, ecological and other reasons, the average annual utilisable water resource (surface and ground) is estimated as 1123 BCM of which about 690 BCM is from surface water and 433 BCM is from ground water.

There is also a large variation in rainfall both in space and time leading to considerable variation in water availability from region to region, season to season and year to year. Spatial variations are as high as 11000 mm at some parts in the eastern region to as low as only 100 mm in the western parts of Rajasthan. Temporal variations are evident from the fact that nearly 75% of the total precipitation i.e. 3000 BCM is concentrated during the monsoon season confined to only 3 to 4 months i.e between June and September when most of the rainfall in India occurs under the influence of south-west monsoon.

During the post-independence period, India has registered spectacular development of water resources mainly due to the planned development through successive Five Year Plans. In comparison to only 15.6 BCM of live storage created at the time of independence, presently 225 BCM of live storages has been created, 64 BCM is under construction and 108 BCM is being contemplated. The production of food grains in India which was just about 51 million tonnes (m.t.) in 1950-51 has increased to more than 210 m.t. at present. The irrigation potential created by the end of Tenth Five-Year Plan has gone upto approximately 102.77 m.ha. against 22.6 m.ha. in 1951.

Regarding urban water supply and sanitation about 91 % of the urban population has got access to water supply and 63% to sewerage and sanitation facilities. With a view to provide infrastructure facilities in the urban areas, the Government of India has launched two new programmes namely (i) Jawaharlal Nehru National Urban Renewal Mission (JNNURM) and (ii) Urban Infrastructure Development Scheme for Small and Medium Towns (UIDSSMT). The rural habitations have been provided access to safe drinking water from nearly 3 million hand pumps and stand posts and about 0.11million mini and regional piped water supply schemes. More than 85 percent of rural water supply is ground water based and consumes about 5 percent of the total annual replenishable ground water. '

The assessment made by the National Commission on Integrated Water Resources Development (NCIWRD) indicate that the total water requirement for multi-sectoral uses would progressively grow from 710 BCM in 2010 to 843 BCM in 2025 to 1180 BCM in 2050. Furthermore, it is also estimated that to meet the country's demand reasonably well, production of not less than 500 million tonnes of foodgrain by 2050 are to be planned.

It is therefore widely acclaimed that harnessing the available resources through the development / creation of infrastructure projects like dams, barrages, canals etc. forms a very crucial component of the overall strategy to simultaneously meet the rising multi-sectoral demand as well as to mitigate the droughtflood- drought syndrome due to spatial and temporal variations of water availability that might be further accentuated due to the impact of climate change. In fact, it is the development of water resources infrastructure projects that effectively bridge the gap





between availability and utilization. India through successive Five Year Plans has concentrated significantly on creation of water resource infrastructure projects, however, the per capita storage of India which is presently around 219 m<sup>3</sup> is significantly lower in comparison to some other countries in the World like Russia (6103 m<sup>3</sup>), Australia (4733 m<sup>3</sup>), Brazil (3145 m<sup>3</sup>), United States (1964 m<sup>3</sup>), Turkey (1739 m<sup>3</sup>), Spain (1410 m<sup>3</sup>), Mexico (1245 m<sup>3</sup>), China (1111 m<sup>3</sup>) and South Africa (753 m<sup>3</sup>) and the total storage is only 12% of annual average water resources potential of the country. A World Bank Report has noted that India can store only about 30 days of rainfall compared to 900 days in major river basins in arid areas of developed countries.

In India, post-independence, several dams and multi-purpose projects such as Bhakra-Nangal project, Hirakud dam, Ukai-Kakrapar project, Nagarjuna Sagar project etc. have been constructed to increase food production, energy generation, drinking water supply, fisheries development, employment generation, etc. In the long run, these projects have not only been successful in delivering the benefits that were contemplated prior to their construction, but has over the years, radically transformed the economic scenario of their command area to such extent that India today has evolved itself as a food-surplus nation from the days in the 1960s when it had to rely heavily on US scheme called PL 480 for importing its food grains. Records from the eighteenth century catastrophes reveal emphatically as to why these large dams and multi-purpose projects are so often regarded as 'temples of resurgent India'.

The implementation of the Bhakra-Nangal project has brought about dramatic improvements in the agricultural production in the states of Punjab and Haryana and presently these two states stand way above the National average as regards the productivity of rice and wheat. South-west Punjab and the adjoining Ganganagar region in Rajasthan, which now receive the benefits of irrigation from the Bhakra-Nangal project, were the scenes of severe droughts and devastating famines till India's Independence. Bhakra-Nangal project is perhaps the most glaring examples of hydro-electric development of our country. The project boasts of the largest hydro-electric complex and made the Bhakra Beas Management Board an important constituent of the Northern Grid catering to the heavy peak demand of the region. The Bhakra- Nangal project is also the source of raw water supply to the urban and rural people in the project area including the National capital, Delhi. Bhakra and Pong dams also absorb peak flood and help in moderating floods to a considerable extent. "

Hirakud dam project has proved to be a boon for the Bargarh, Sambalpur and Sonepur districts. During the pre-project period, agriculture was mainly rainfed and therefore entirely dependant on the monsoon. Since there was only a single crop during the monsoon, its failure invariably meant drought. With the construction of the project, assured annual irrigation has been achieved. Furthermore, Hirakud dam project contributes significantly to the hydropower generated in the state of Orissa. The project has also proved to be immensely beneficial to the Sambalpur, Bargarh, Jharsuguda, Burla and Hirakud townships, which have been provided drinking water either directly from Hirakud reservoir or from its canal system. As regards flood protection, prior to the construction of Hirakud dam, the Mahanadi delta used to suffer quite recurrently at the rate of almost once in every three years from the raging floods. With the construction of Hirakud dam, the swollen waters of Mahanadi in monsoon period have been tamed to a great extent. During the post-construction period, floods in the delta have been reported in much lesser number of years compared to that during the pre-construction period. About 10-30 % flood-moderation has been achieved by Hirakud dam historically.

In case of Ukai-Kakrapar project, due to assured water supply from Ukai, irrigation under Kakrapar command was augmented and perennial irrigation could be introduced. Area under paddy and sugarcane cultivation increased sharply. The power generated from the project has also greatly helped in reducing the power shortages. As abundant and assured cooling water is available from Ukai reservoir, a large thermal power station, is also set up and commissioned at Ukai since 1975. The project has also played a significant role for supply of drinking as well as industrial water. While on one hand cities like Surat is drawing sizeable amount of water for meeting its drinking water requirements, on the other, huge industries like Essar Gujarat, Reliance Petrochemicals, KRIBHCO, ONGC, NTPC etc. are direct beneficiaries as regards industrial water supply. Prior to the construction of Ukai dam, floods in the downstream areas were rampant. However, the situation dramatically improved after the building of Ukai reservoir as well as installation of a well established flood forecasting system.

The above are only a handful of the innumerable number of water resources infrastructure projects that are contributing heavily to the socio-economic development of the country. The most glaring example to justify this has been the year 1987-88, which though subjected to severe drought, the total agricultural production was 140 million tonnes registering a shortfall of only 11% against the peak production of 153 million tones achieved in 1983-84. In a World Bank report it has been mentioned that in irrigated districts the incidence of poverty is one-third of that in



unirrigated rural districts. The same report has further gone on to remark that 'the record is overwhelmingly clear - investments in water infrastructure in India have resulted in massive reductions in poverty, and it is actually the poor and landless who have been the biggest beneficiaries'.

Major irrigation projects have normal gestation period of 15-20 years while medium projects take 5-10 years for completion. Against these, a large number of major as well as medium projects are continuing as ongoing projects since the last 30-40 years or even more. Among them, a number of projects have already achieved 90% or more of the targeted potential since long, but not declared complete yet. Such projects should be taken out from the list of ongoing projects. Besides there are a number of projects which gets delayed on account of several reasons such as (i) pending environmental and forest clearance (ii) land acquisition (iii) R&H Settlement issues (iv) Contractual litigation, etc.

The Working Group on Water Resources has targeted to complete 72 major, 133 medium and 132 ERM projects out of a total number of 244 major, 367 medium and 175 ERM projects included for the XI Five Year Plan consisting of both ongoing and new projects. The target for creation of irrigation potential during the XI Plan through Major & medium Irrigation sector is 9.0 mha. For Minor irrigation sector the target is 7.0 mha.

For speedy completion of on-going projects in advance stage of construction, the Central Government launched "Accelerated Irrigation benefits Programme" (AIBP) in 1996-1997 to provide Central Assistance to approved major and medium irrigation projects to expedite implementation of projects which were beyond resource capabilities of a State or were in advance stage of completion. Since its inception, a number of relaxations in the criteria for AIBP have been made to facilitate expeditious completion of on-going projects. Till date, a total number of 257 major and medium projects are covered under AIBP. Out of these 100 projects have been completed so far and 157 are under progress. The Central Assistance released so far is of the order of Rs 30,690 Crore. The irrigation potential created through AIBP is about 52 lakh ha including minor irrigation while the irrigation potential created from major & medium irrigation is about 49 lakh ha. The Government of India has also decided to take up some projects as National Projects based on the following criteria:

- i) International projects where usage of water in India is required by a treaty or where planning and early completion of the project is necessary in the interest of the country
- ii) Inter-state projects which are dragging on due to non-resolution of inter-state issues relating to sharing of costs, rehabilitation, aspects of power production etc, including river interlinking projects
- iii) Intra-state projects with additional potential of more than 2,00,000 ha. and with no dispute regarding sharing of water and where hydrology is established

The Central assistance to be provided to these projects would be 90% of the project cost of irrigation and drinking water component of the project as grant. So far 14 projects have been selected as National projects.

The water resources availability in India is associated with wide ranging spatial and temporal variations. The problem is even more compounded with the phenomenal growth in population coupled with urbanization and industrialization. From the projected future water demand scenario, it is evident that even after Implementation of all the development as well as management strategies, the total utilizable water resources of the country may not be able to match the water demand by the year 2050. Therefore, exploration of newer concepts for augmenting the available resources is a vital area where the country needs to concentrate as a part of the long term strategy. The need to divert the excess water during the floods to the water deficit regions is therefore necessary for not only mitigating the drought-flood-drought syndrome but also fostering an uniform, balanced and cohesive socio-economic development across the country. The concept of interbasin transfer of water remind us of Dr. KL Rao, who way back in 1972 proposed for a National Water Grid which envisaged a Ganga-Cauvery link. Decades have past, the thinking, philosophy and concept refined and modified, yet, the relevance is eternal.

Ministry of Water Resources and Central Water Commission have formulated a National Perspective Plan for Water Resources Development in the country which envisages inter-linkages between various peninsular rivers and Himalayan rivers for transfer of water from surplus river basins to water deficit river basins for optimum utilization of water in the country. This perspective plan comprises two main components viz. (a) Himalayan Rivers Development, and (b) Peninsular Rivers Development. Out of the 30 links identified (16 under peninsular component and 14 under Himalayan river development component). Presently, five links namely Ken-Betwa, Parbati-Kalisindh-Chambal, Par-Tapi-Narmada, Damanganga-Pinjal and Godavari (Polavaramj-Krishna (Yijayawada) have been identified as priority links for bringing consensus amongst the concerned states to take up



th- work of preparation of their DPRs. Among the many schemes of interlinking of rivers, the best aspects are required to be consolidated in the shape of cost effective project reports and implemented in It mission mode. For Ken-Betwa link, NWDA is entrusted with preparation of DPR of the link and the work is likely to be completed by December, 2008. In case of Par - Tapi – Narmada & Damanganga - Pinjal links the signing of MoV is under advanced stages of finalization.

Since independence most of the activities for development in the water resources sector have taken place in the already developed areas of the country, i.e., where infrastructure was already available. Now, it is being recognized that most of the easy sites that could be developed have been exhausted and further work will have to be in more and more inaccessible and difficult sites, more so in the Himalayan region. In addition, natural calamities, hydrology, socio-politico-legal constraints such as resettlement of project affected families, environmental issues, law and order problems and legal interventions do have a larger impact in project implementation, for which innovative approaches are required.

In spite of offering remarkable benefits, water resources development projects particularly storage projects have been embroiled with controversies. Most of the opposition to creation of storage projects have centered around the Resettlement & Rehabilitation issues owing to submergence. Since the National Policy on Resettlement and Rehabilitation of Project Affected Families has already been drawn up, the same needs to be implemented in the right earnest for mitigating the sufferings of the Project Affected Families as well as setting the right precedence for allaying the fear of the future PAFs.

Fostering partnership among Government and end users for sharing responsibility in undertaking investigation, planning, designing, construction and maintenance of water resources schemes can be highly rewarding. The National Water Policy has also explicitly echoed the same theme and observed that management of the water resources for diverse uses should incorporate a participatory approach; by involving not only the various governmental agencies but also the users and other stakeholders, in an effective and decisive manner, in various aspects of planning, design, development and management of the water resources schemes.

The Government of India have organized several national and regional conferences and national level training programmes on PIM to sensitize the States about the need for enacting a new Participatory Irrigation Management Act or making necessary changes in the existing irrigation acts so as to put appropriate legal and organizational frame work for PIM in place. The issue of PIM being an integral component of the whole idea of sustainable development, it needs to be further intensified so that water development and management can be taken up in a co-ordinated manner.

In addition to the development strategies, special attention should also be given to the water resources management strategies that are also equally important. The management of water resources primarily aims at bridging the gap between creation and utilization. A wide array of programmes and activities like restructured command. area development & water management programme in States, modernization of water resources system, benchmarking of irrigation systems, conjunctive use of surface and ground water, selective lining of irrigation canal systems, improvement in water use efficiency etc, are being embarked upon from time to time to achieve the desired objectives.

The growing demand for water within a river basin / sub-basin necessitates that the planning, development and operation of the projects are carried out in an integrated manner so as to cater to the multisectoral needs on a sustainable basis. In this perspective, the setting up of appropriate institutional framework in the form of River Basin Organisations (RBOs) institutional framework plays a vital role. Efforts are on to establish RBOs in some selected river basins of the country and Mahanadi is one of them. The creation / construction of infrastructure facilities is not a mere end by itself but emphasis has to be given to the proper maintenance and performance improvement of the existing projects. For this allocation of sufficient funds for O&M requires to be given priority. The country spends Rs. 1.25 to 1.5 lakh (at 2006- 07 price level) to bring one additional hectare under irrigation, it is less than the cost of existing available irrigation coverage gradually by not spending Rs 600 per hectare annually for maintenance.

Another important aspect that deserves to be mentioned is the issue of climate change. Recently the National Action Plan on Climate Change released by the Hon'ble Prime Minister has laid down the principles and has identified the approach to be adopted to meet the challenges of impact of climate change. For the above, eight National Missions have been identified and National Water Mission is one of them. Several Sub-Committees have been constituted to deliberate on varied aspects with the ultimate objective of preparing a Comprehensive Mission Document.



While the exact shape of the future climate regime is uncertain, the weather experts have predicted that global warming may intensify the hydrologic cycle; more intense rainfall may occur in fewer spells; the floods and droughts both may become more intense; the floods may be more frequent; the rainfall may shift towards winter; and there may be significant reduction in the glaciers mass, resulting in increased flows in the initial few decades but substantially reduced flows thereafter. It seems that in the post climate change scenario, water resources infrastructure that enables to store and transfer water with greater certainty will be appropriate in dealing with climate change.

Therefore, creation of water resources infrastructure projects forms the backbone of the future endeavours to achieve the vision of equitable, optimal and sustainable development of country's water resources to match the growing demands. Some of the action areas that require focused attention are:

- Speedy completion of ongoing projects by providing sufficient funds
- Early action for seeking needed clearances in respect of all ongoing projects
- Increase of budgetary outlays for irrigation sector
- Taking up new projects only after clearances from all concerned
- The identified storage sites within a basin be harnessed and utilized to full potential from point of view of national perspective. Additional storages will even out the variability of availability of water resource due to climate change in the future
- Storage sites should not be lost to Run-of-the-River (RoR) schemes

Existing storages be augmented by raising the height of the dam and/ or by providing gated spillways, wherever feasible

- Participatory approach in planning, design, development and management of the water resources schemes
- Adequate maintenance of the infrastructure already created

Before drawing conclusion to this lecture, I would again like to recall the rich legacy of technological excellence and spirited commitment left by Dr. K.L. Rao. It is the solemn and collective responsibility of all the stakeholders to follow his footsteps and to carry forward the vision that he had in an atmosphere of cooperative participation.





# Some World Records in Structures Designed for India/Overseas

C R Alimchandani

Chairman & Managing Director, M/s Stup Consultant Pvt. Ltd., Mumbai, India; chairmanisstupmait.com

## INTRODUCTION

A good conceptual design requires an inventive mind, an excellent grasp and understanding of the main parameters which have to be optimized in order to achieve the best results whilst conceiving a structure. The best results are obtained when the structure fulfills its function at the minimum initial cost, minimizes carbon emission, has low maintenance cost, has the required durability of around a 100 years (with normal maintenance), has good aesthetics and utilizes technology which maximizes the use of less expensive local resources.

The construction environment in the developing countries of Asia and Africa varies considerably from that of developed countries. On the one hand we have the South Asian sub-continent and China with cheap and abundant labour, technicians, engineers and enterprising contractors, who aspire to take up work involving new technology, but need to be trained to utilize the same. These contractors in the South Asian Subcontinent have a comparatively low capital base and therefore need to be equipped with affordable specially designed enabling equipment which is in harmony with their construction environment. On the other hand we have the oil rich countries of West Asia where everything requires to be imported including labour, engineers, materials, and equipment - the high cost of personnel results in the adoption of more mechanized techniques, local contractors are however often new in this business, and the principal task is to train their labour and technical personnel. In South Asia the ratio of cost of labour and machinery to materials is respectively, 30%: 70%, (on some projects 35%: 65%) while in West Asia it is similar to Europe, that is, 60 %: 40%. The South East Asian environment lies somewhere between that of South Asia and West Asia. Africa presents especially difficult problems arising from a less developed construction industry and local administration. except in South Africa and Zimbabwe and some countries in North Africa - Indian Engineers have to make very light designs i.e. with the minimum consumption of cement and steel. If the world has now come to seriously worry about reducing these materials to reduce carbon emissions - please come to inspect the works of some of our most innovative designers in India, who continue to economize on materials because these materials still remain the most important component of construction cost (about 30 years ago the cost of labour to materials was 25%: 75% and the minimum mechanization was used).

The level of construction activity of India, which will within a few decades becomes the largest in the world, already throws up before the Indian Engineer challenging sizes of individual structures which might be the longest, largest or tallest in the world. I am going to speak to you on a few achievements of this type which have occurred over 49 years which our Company M/s STUP Consultants Pvt. Ltd. (STUP) had to design and get constructed.

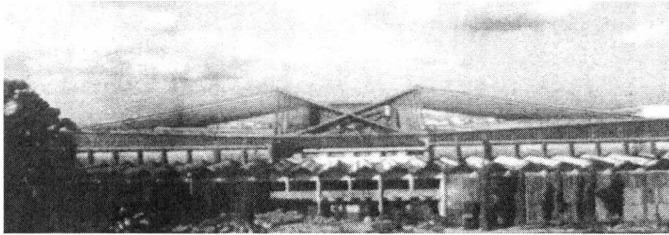
## INDIAN AIRLINES CARA VELLE AND BOEING 707 HANGAR ROOF

The roof of the Caravelle and Boeing 707 hangar for Indian airlines in Mumbai has a prestressed concrete stayed folded plate roof. It has two stayed cantilevers of 204' -6" (62.3 m) span on either side of the 90' (27.4 m) wide Central Service Complex. The stayed cantilever roof held and possibly still holds a world record for cantilever span for this type of construction.

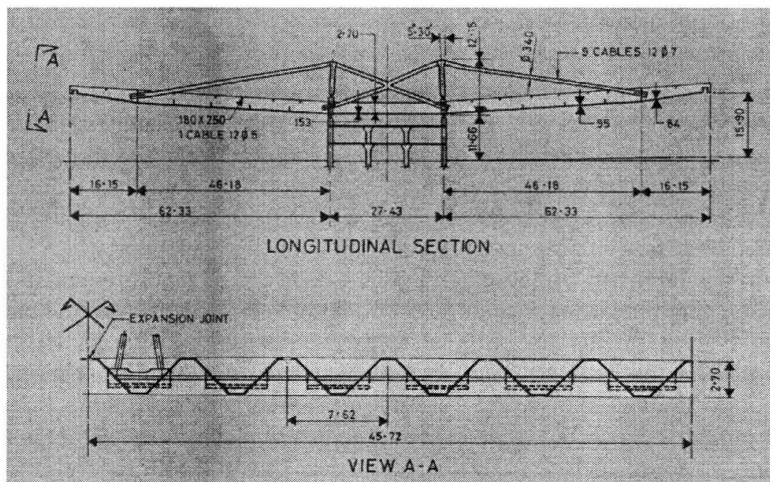
View 2 shows a typical cross section and a longitudinal section of the hangar. The roof proper consists of very thin folded plates of 25' (7.6 m) module with webs inclined at 45°. For the greater portion of the cantilever roof the thickness of flanges and webs of the folded plate are 4%" (10.80 em) and 3%" (8.25 em) respectively.

The continuous folded plate roof is stayed by prestressed concrete ties as shown. The overall economy and great slenderness of the structure becomes apparent, if one converts the total concrete used for the folded plate roof and Prestressed Concrete Stays in the, cantilever portion into a uniformly thick slab covering the same area, this works out to 8" (20 em) average thickness, which corresponds to the concrete usually consumed by a 12' (3.6 m) canopy at the entrance of a building. The forward portion of the roof beyond prestressed Stays is in R.C.C. and has a length of

57'-6" (17.5 m). The inclined struts supporting the P.c. stays are provided with Freyssinet hinges at the junctions with the roof in order to permit free rotations. The stays are anchored in inclined cross diaphragms provided for this purpose. The continuous length of each module is 499' (152 m) and each module is supported on two columns spaced 90' (27 m) apart through Freyssinet Concrete Hinges and which in turn are supported on RCC columns transmitting the load on internal columns running down the faces of the Central Service Complex and resting on pile foundations.



**View 1: Roof of the Caravelle and Boeing 707 hangar for Indian Airlines, Mumbai**



**View 2: Typical Cross Section and a Longitudinal Section of the Hangar**

View 3 shows the front view from the outside of the hangar with one Airbus 300 and one Caravelle (although there was space for 4 of the latter being serviced simultaneously). Aircraft of MIs Air India, however, used this hangar for servicing one Airbus 300 on each side as they purchased these wide-bodied jets instead of the Boeing 707s and the length of both these Aircraft was the same and requested STUP to modify one of the folds on each side of the hangar to accommodate the taller tails of the Airbus 300 on each side of the stayed cantilever portion which was also very challenging work.

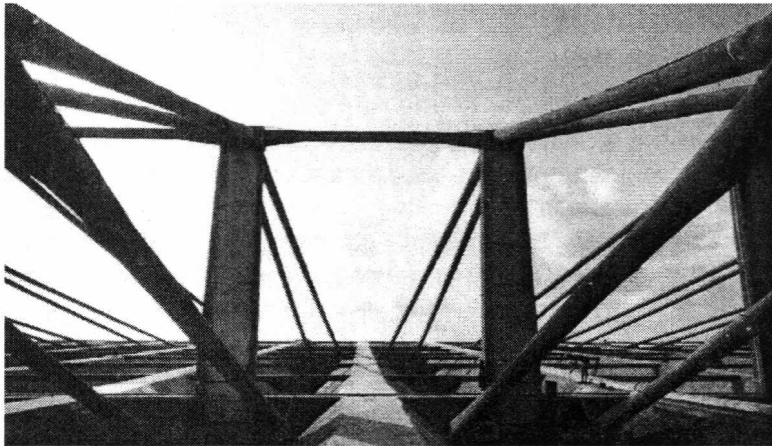


**View 3: Outer View of the Hangar with One Airbus 300**



The clear space between the side walls is 300 ft (91.4 m). An expansion joint at the center divides the roof into two units of 150' (45.5 m) each. The tip of the cantilever is expected to deflect by 11" (28 cm) under maximum wind effects plus maintenance and crane loads running over the width of the hangar and the safe movement of the door is ensured by the provision at the roof tip of a concrete channel section of adequate depth. Due to its long span and extreme lightness, the roof has a fundamental period of oscillation of 1 second. In consequence, the design of the structure had to cater for the dynamic effect of wind gusts during cyclonic winds touching speeds of 100 m.p.h (160 kmph). The hangar can be widened as required, as the side walls are independent of the roof.

View 4 shows a view of Prestressed Concrete Stays taken from the roof. Each Folded Plate module of 25' (7.5 m) is supported by two prestressed concrete stays of 13%" (33.5 cm) dia. provided with 9 Nos. 1207 mm cables and cast to a slight parabolic profile to minimize bending effects in the ties. The picture also shows thin prestressed concrete transversal ties provided at the level of the top flange of the folded plate in order to reduce spans of the edge beams.

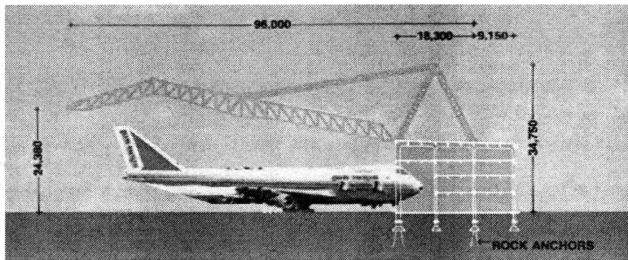


**View 4: Prestressed Concrete Stays from the Roof**

The roof of this hangar was designed for M/s Indian Airlines Corporation by STUP and constructed by B.E. Billimoria & Co.-this complex hangar was their maiden venture in prestressed concrete and was achieved in co-ordination with the construction Assistance Department of STUP. The hangar was completed in 1972.

#### AIR INDIA 747 JUMBO JET HANGARS

View 5 shows the cross section of the First hangar for Jumbo Jets designed for Air India at Mumbai. The roof is a giant structural steel cantilever truss suspended by structural steel ties, struts and backties. The overhang of the cantilever is 257' (78 m) and its total is 317' (96.5 m) which is believed to be a world record for this type of structure.

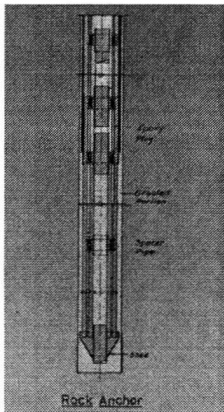


**View 5: Typical Cross Section of the First Hangar for Jumbo Jets, Mumbai**

Apart from the dimensions of the roof, this hangar is notable for the very interesting use of epoxy coated prestressed rock anchor cables for providing structural stability to this un-balanced cantilever. Each frame of the roof is connected at the rear to the reinforced concrete service building through cast steel bearings which are held in position by prestressing. In a vertical sense, since the weight of the building is inadequate, two sets of 3 Nos. 24Ø8

mm prestressing cables descend through the columns and are anchored in rock up to a depth of 50' (15.2 m) below rock level to anchor each cantilever at its rear end. Anchorage is also required at the support on the inner face.

A typical section through a 24Ø8 mm rock anchor at its lower end is shown in View 6. The anchor length is 15 ft (4.5 m) and the free portion above the plug is enclosed in a PVC duct filled with non-corrosive grease for protection. A water-tight epoxy plug is provided at the bottom of the PVC duct. The anchor portion of the cables is treated with a special epoxy coating completed by adding powdered quartz on the last coating when it is still tacky to improve its bond with grout in the anchor portion. The use of ungrouted cables permits periodic monitoring of prestressing forces in cables. These have been tested every year over 20 years, which is more than adequate to be sure of the quality of the anchorage system.



**View 6: Rock Anchor**

View 7 shows the completed hangar housing a Boeing 747. The hangar was commissioned on 10th July 1973 and gives the world's the longest stayed cantilever roof and the world's oldest epoxy coated rock anchorage system with epoxy grout to anchor such a roof. The largest steel cantilever was adopted because there were smaller existing hangars below the same and the lease for these hangars would expire and the small Hangars could be demolished only 3 months before the Air India Hangar had to become functional. There was no way of constructing this hangar without making it a stayed cantilever anchored to the Stores Building. The tip of the cantilever roof was very deformable H"2.4" (0.74 m) in service and doors had to be engineered to accommodate the same with a 1.5 factor of safety. The Hangar was designed to accommodate the future Boeing SSTs to compete with the Concorde. But the Boeing SST never got built because of the rapid rise in cost of Hydrocarbons at the beginning of the decade commencing 1970.

The hangar was designed for Air India by STUP and built by the Engineering Construction Corporation Ltd.



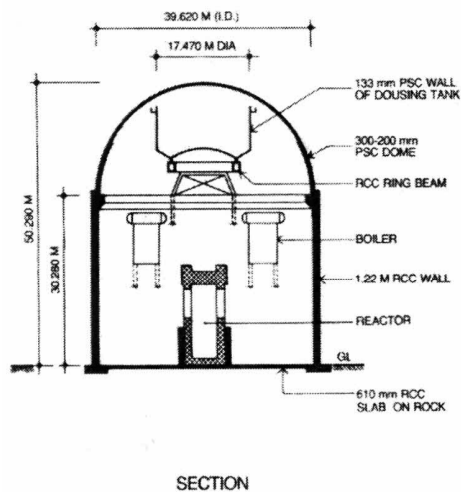
**View 7: Outer View of the Hangar**



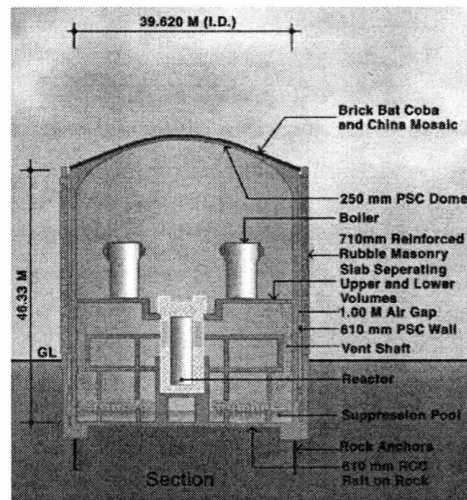
## MADRAS ATOMIC POWER PROJECT I & II

In the second generation of nuclear containments (1967), near Madras, MAPP I & II, and India achieved a quantum leap in safety by pioneering the concept of a double containment (View 8).

The inner prestressed concrete containment provides a leak tight environment which can withstand the internal pressures and temperatures it is designed for. The outer wall provides a second barrier and additional horizontal radiation protection. The annular space between the containments is constantly maintained at below atmospheric pressure (-0.2 Atmospheres) to aspirate any leakage occurring during an accident. The outer wall of the reinforced masonry also protects the inner containment from rain, wind and sun, reduces the risk of corrosion and provides a barrier for external objects such as collision with enemy fighter aircraft, missiles and wind borne objects in cyclones.



**Rajasthan Atomic Power Project I & II**



**Madras Atomic Power Project I & II**

### View 8: Double Nuclear Containment

The dousing tank was no longer required because the prestressed containment can take much higher pressures.

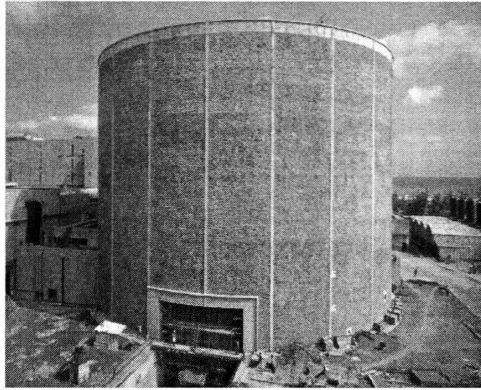
However an interesting safety aspect was the division of the reactor into two volumes by a horizontal slab so that during maximum / critical accidents, the initial pressure and temperature rise in the upper volume results in hot gases and steam being forced downwards through vent pipes to bubble through a pressure suppression pool at the bottom of the Reactor Building—a cheap and trouble free device which brings down temperatures and pressures rapidly—this has become a feature of all subsequent designs.

Another interesting aspect of this reactor is the roof surfacing. Instead of rock wool insulation with aluminum cladding as in the first 2 reactors built at Rajasthan near Kota, an inexpensive design using local materials was adopted; brick aggregate in lime concrete, faced with china mosaic. The painstakingly hand rammed brick bat concrete resulted in an excellent waterproof and insulating layer and the china mosaic provided a reflective surface which also helped distribute cracks to minimize the danger of seepage of rain through the China mosaic (View 9).

Note that there is extensive use of stone masonry in this structure—the entire outer containment is of reinforced masonry. This is because excellent granite is readily available in the area, a lot of which came out of the excavation for the Reactor Building itself. The outer containment is unique in that it is the only instance of a 35 m. tall, 71 cm. thick, free standing cylindrical shell made of reinforced masonry. This was possible because the local workmen are very skilled in stone work and were available at a very low cost per man day.

8 km away on the same shore, a temple in dry granite masonry, still stands against the sea wind and rain, since 12 centuries View 10.

Apart from their greatly enhanced quality and reliability, the MAPP I & II Reactor buildings were 25% cheaper than the modified RAPP I & II.



**View 9: Insulation & Water Proofing with Locally Available Material**



**View 10: View of Temple in Dry Granite Masonry**

This project is an example of improved performance and cost optimization obtained by utilizing an advanced design approach combined with development of construction technology suitable to the local environment. The double wall innovation has been adopted in all French and Indian reactor buildings constructed since 1967. It has also thereafter been adopted by all the countries in the world. India has 20 Reactor Buildings owned by the Nuclear Power Corporation of India limited (NPCIL) and all of them have been engineered by STUP in close cooperation with the owners Scientists and Engineers. India plans to add forty 1000 to 1650 MW Nuclear Power Stations running on imported Uranium, so that India produces clean Nuclear Energy in place of dependence on Hydrocarbons which will emit various pollutants.

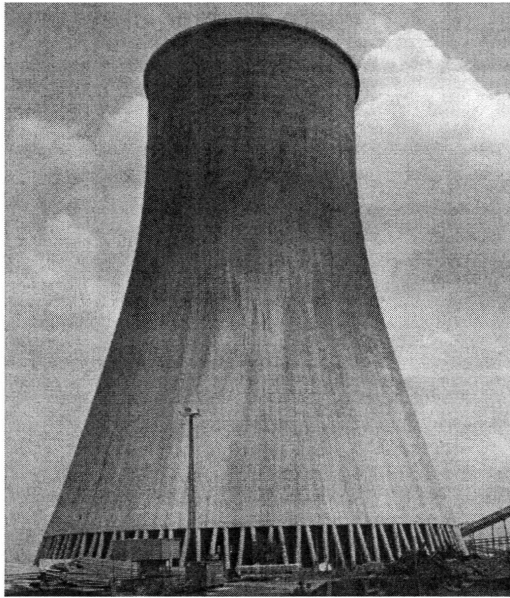
World's Tallest Natural Draught Cooling Tower-202m Tall in High Wind Velocity Zone in India

Two Natural Draught Cooling Towers of 202 m height are under construction for the  $2 \times 600$  MW Kalisindh Thermal Power Station at Jhalawar, in Rajasthan. The thermal sizing has been done by MIs GEA Cooling Tower Technologies (India) limited and BGR Energy Systems limited (BGRESL) are constructing the NDCTs. M/s STUP Consultants P. Ltd. (STUP) are doing the complete structural, civil and detailed electronic, electrical and lightning protection engineering of the NDCTs for BGRESL.

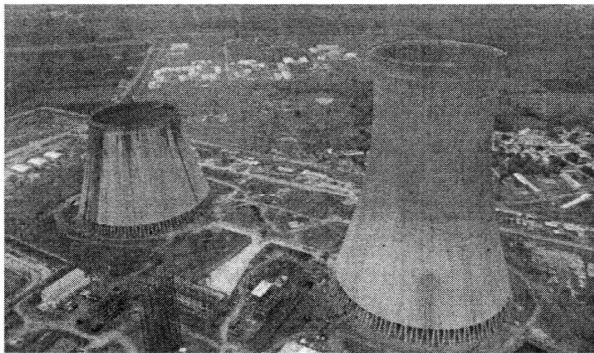
The shell of one tower is complete. This is how it looks from the ground (View 11).

The construction of the second tower is in progress. The sizes of the buildings in the background are dwarfed due to the large size of the Cooling Tower, which was photographed by ascending to the top of the 275 m high chimney View 12.

Each tower is designed for circulation of water at the rate of 75,000 cum/hr. The circulating water has turbidity more than normal water. The area is prone to high winds and the towers are designed for a wind speed of 181 kmph corresponding to a return period of 100 years. The size of the Cooling Towers can be judged from the dwarfed size of Buildings around them.

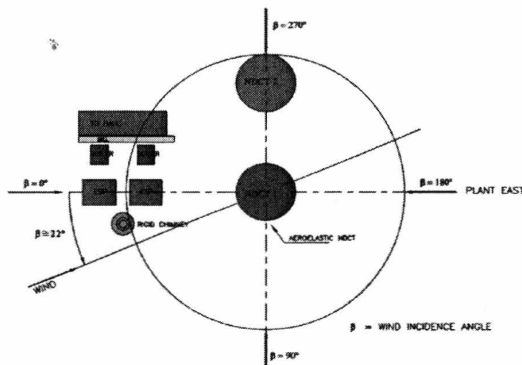


**View 11: 202 m High Natural Draught Cooling Tower, Jhalawar, Rajasthan**



**View 12: Construction View of Cooling Tower**

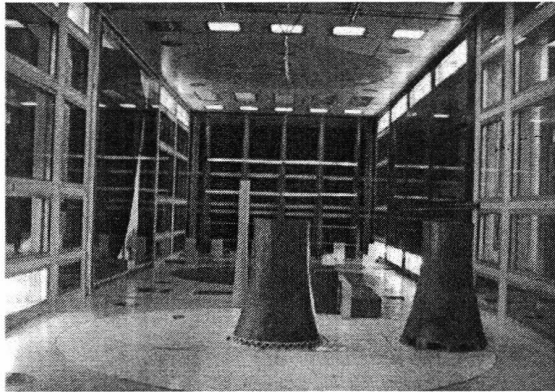
Enhancement of the wind load due to the adjacent cooling tower and all power plant structures shown here are based on wind tunnel tests carried out at the National Wind Tunnel Facility at the Indian Institute of Technology, Kanpur. A simplified layout of the plant containing all structures taller than 20 m is presented here View 13.



General layout during model study

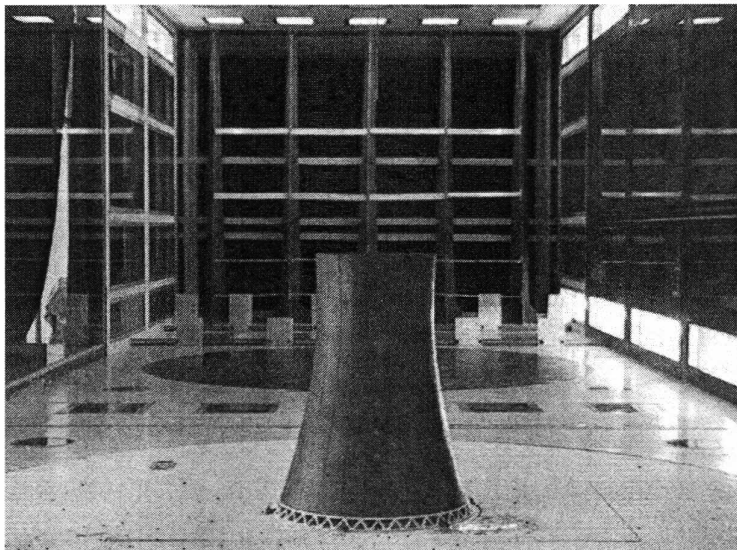
**View 13: Wind Tunnel Test of Cooling Tower**





**View 14: View Showing the Shells Inside the Wind Tunnel**

It is interesting to observe that one of the tower models was an Aero-elastic model provided with strain gauges which confirmed the tensions and compression which occurred on the outside of the shell while it was in service view 15.



**View 15: Another View Showing the Shells Inside the Wind Tunnel**

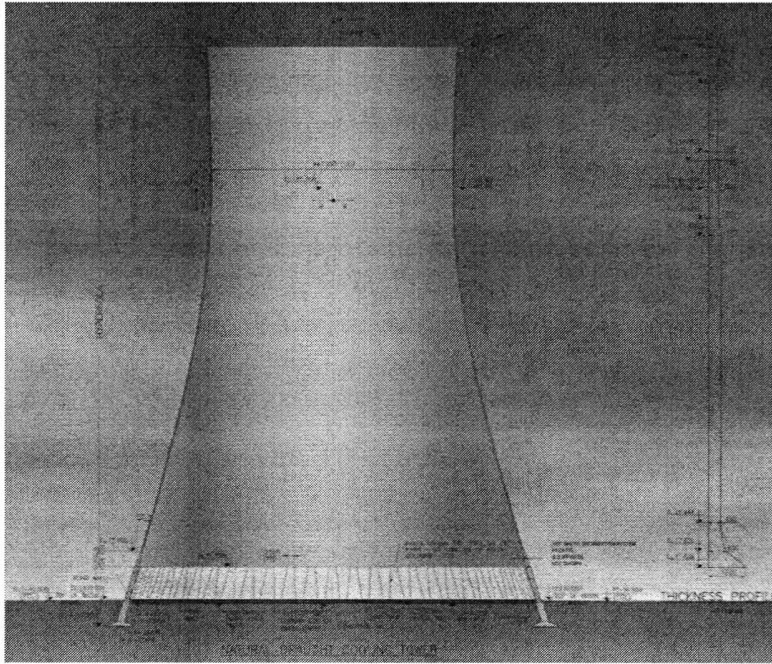
The shape and dimension are selected so as to be highly economical in consumption of cement and steel and therefore in cost to the contractor. The contractor observed that we had saved 30% cost as compared to their own structural design.

For the 202 m tall Cooling Towers, the ratio of height to sill diameter is 1.353 and the ratio of throat diameter to sill diameter is 0.583. The corresponding ratios in India are normally 1.2 and 0.50. The Aero-elastic model test carried out showed conclusively the safety of the shells under the enhanced wind loads plus the deadweight of the shell and thermal stresses View 16.

The salient dimensions are:

Total height of tower above finished ground level	: 202.0 m
Total height of tower above bottom of the foundation	: 212.0 m
Height above finished ground level at throat level	: 150.0 m
Diameter at sill level	: 149.35 m
Diameter at throat level	: 87.00 m





**View 16: Thermal Stress View of Cooling Tower**

The last two dimensions are at the centerline of shells.

The structural analysis indicated that load combinations including earthquake forces are not governing as compared to wind load combinations.

Critical design forces under wind load are determined as follows:

1. Analysis of tower considering wind load of 181 kmph as per Indian code IS 875.
2. Determination of critical wind pressure by conducting wind tunnel test with adjacent structures around.

The enhanced pressures are applied on the detailed FEM model of the NDCT using NISA and SAP-2000 software and the analysis is performed. The tension and compression on strain gauges fixed to the outer side of the Aero-elastic shells confirmed the design values.

Minimum factor of safety of 5.0 has been used against local as well as snap through buckling of the shell. Local buckling is checked as per BS: 4485. Vertical and horizontal reinforcement is calculated for the worst wind load case and provided along the full circumference.

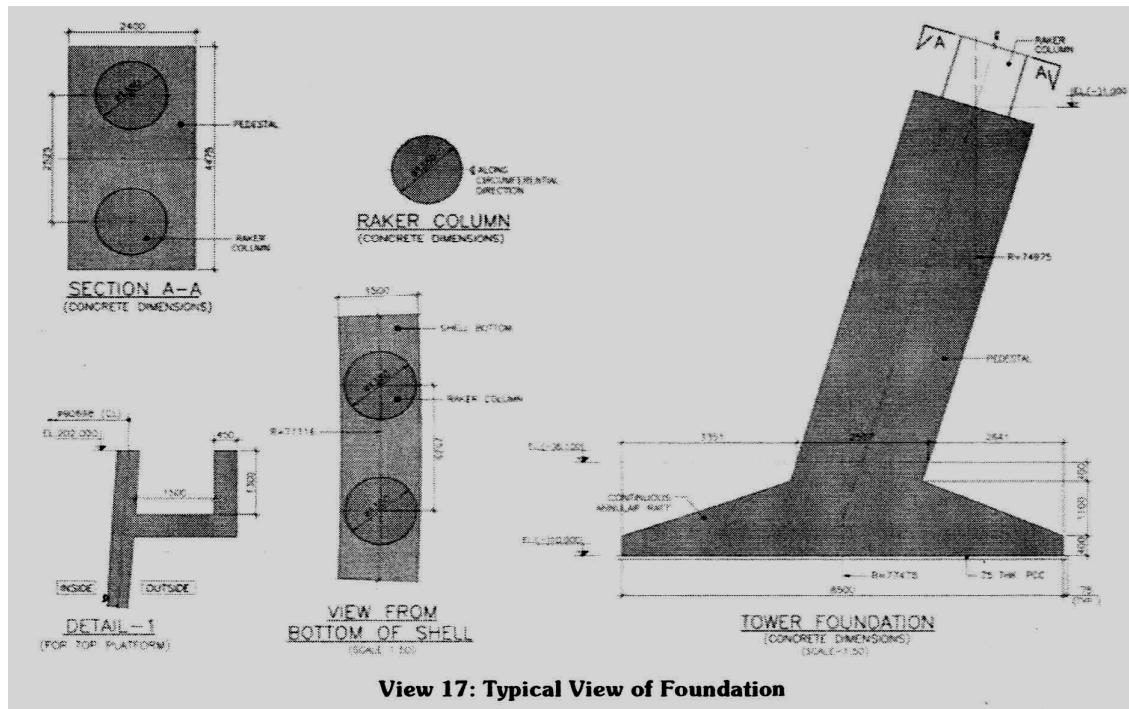
The foundation of the tower is an open annular foundation of 8.50 m width at 10.00 m below finished ground level. The uplift of the foundation under wind is checked as per BS: 4485 and it was decided that the foundation shall be engineered for uplift within a segment of 30 degrees in plan. The total height of the tower from bottom of foundation is 212 m View 17.

The following durability measures are taken for the severe environment at site:

1. Minimum concrete grade M 30
2. Minimum cement content 360 kg.cum.
3. Minimum cover to reinforcement 50mm for shell and 75mm for foundations.

These NDCTs are good examples of a new generation of NDCTs with higher ratio of total height to sill dia and smaller curvature in the meridional plane for better economy of materials.

The thermal sizing of these towers (presently done by M/s GEA on the insistence of the owners of the Power Station) could have been optimized to reduce overall size of the tower as checked by STUP's thermal design team.



**View 17: Typical View of Foundation**

## CONCLUSION

Challenges in Concrete Structures arrive in Developed Countries or Developing Countries within a short time after each other in the current World which is becoming a Global Village.

In Cooling Towers, the challenges will be larger for India due to smaller Thermal Approaches; Challenges are also greater in India because the Design Engineer, in addition, to innovation has to do more to lead contractors and workers to build such structures.

In the current World atmosphere of trying to reduce carbon emissions-the best Indian Engineers have something to contribute to the Developed World.



# Sesimic Vulnerability Assessment of Existing Buildings — Developments and Challenges

Prof Subrata Chakraborty

Department of Civil Engineering,  
Bengal Engineering and Science University

## ABSTRACT:

The efforts of evaluating seismic performance of existing buildings involve modelling of realistic behavior of structures and verification of these models with test data and/or the measured responses of real structures. The significant amount of research conducted on the subject and the subsequent advancements in the understanding and knowledge of earthquake resistant structural design provided a better recognition of the need for seismic vulnerability assessment (SVA) and retrofit of older buildings. The present article focuses on the development in the field of SVA of existing building. In doing so, a short glimpse of the need and relevance of SVA of existing structures are briefly introduced first. The fundamentals and various approaches of SVA and the recent developments in the field are subsequently discussed. Noting the increasing trend towards the use of probabilistic performance-based design methods in practice, special emphasis is given on the developments of probabilistic SVA of structure. Finally, the observations on the developments and challenges of SVA of existing structures are summarized.

## 1. INTRODUCTION

The impacts of earthquakes on infrastructures are relevant not only for the number of casualties, but also for the inflicted damage to the economy. The widespread damages of infrastructures have a substantial impact on the economy of the region in terms of both the direct and indirect losses. The direct losses are consequences of structural and non-structural damages. The indirect losses arises from the business interruption due to those damages, loss of utilities, transportation infrastructures etc. Particularly, when residential and public buildings are concerned, earthquakes represent a natural hazard that can trigger number of casualties. Moreover, suspension of production especially that of water and energy supplies facilities might magnify the dimensions of the catastrophe and impose more financial losses. Thus assuring safe performance of infrastructures is of paramount important.

The present earthquake design philosophy aimed to ensure life-safety by ensuring collapse prevention under most severe earthquakes and also to minimize the extent of damage and maintaining the function of building for moderate earthquakes expected to occur more frequently. This is usually achieved by limiting the lateral drift. The basis of collapse prevention requires the structural members to yield and deform well beyond elastic limits and are expected to withstand several cycles of inelastic deformation without significant degradation of strength and stiffness. To ensure such ductile behaviour during a major earthquake, current design provisions suggest special detailing of structural members and connections. Thus, structural systems designed according to current code provisions are expected to resist large inelastic deformations without collapse and thereby, provide good levels of life-safety and collapse prevention. However, the same is not the case for existing structures. It has been repetitively observed in the past that after severe earthquakes, the older building construction suffered extensive damage and the engineering profession, policy makers and government officials faces difficulty in assessing or deciding on what to do with the existing structures. The past researches have revealed that these old structures, particularly masonry and concrete buildings generally lack adequate strength and ductility due to inadequate detailing to meet displacement demands imposed by strong ground motions. Thus, along with the application of improved understanding of earthquake engineering in new construction, more efforts are increasingly focused on the assessment of seismic behaviour of existing structures. Normally, after every devastating earthquake, most of the countries issue revision of national earthquake hazard map and subsequent upgradation of the seismic code of practice. For existing structures, the earthquake actions causes problems, since at the time of design, a different set of less stringent regulations were enforced as per the old practice. Furthermore, it is important to recognize that the earthquake exposition of many locations is changing due to the developing knowledge-base in seismic exposition in terms of analysis of seismic signals, modern exploration of paleoseismic data and so on. Subsequently, the risks in some regions have increased



significantly. This problem is well reflected in the seismic hazard map published by the Global Seismic Hazard Assessment Programme. Thus, evolution of earthquake engineering practices essentially necessitates the vulnerability assessment of existing structures.

With the above in view, it is important to have a look on the scenario of seismic risk in India. In general, about sixty per cent of the land area of India is prone to moderate to severe earthquake ( $M > 5$ ) which makes it one of the most seismic risk prone areas in the world. It is heartening to note that more than 25,000 lives were lost due to eight major earthquakes in the last 20 years. Indian cities are growing at exponential rates. Some of the important cities like Delhi, Dehradun and Guwahati fall in the high seismic zone i.e. in Zone V. It is estimated that by 2025 the urban-population will be more than fifty per cent of the total population of the country. The very high vulnerability of urban India was starkly demonstrated during the Bhuj earthquake. Similar high intensity earthquakes in the USA, Japan etc. results not such enormous loss of lives due to collapse of structures. For example, less than 500 people were killed during M 8.8 earthquake in Chile on February 27, 2010 as the structures built with proper mitigation measures and earthquake-resistant features performed well during this earthquake. Here is the catch for making our built environment safe from disaster: ensure good governance leading to implementation of proper planning norms and development control towards preparedness for disaster management. This clearly justifies the need of seismic vulnerability assessment (SVA) of existing structures. In this regard it may be emphasized here that the North Eastern (NE) region of India is seismically one of the six most active regions of the world. It is placed in the zone of highest seismicity of the country. The region has experienced 18 large earthquakes ( $M \geq 7$ ) during the last hundred years including the great earthquakes of Shillong (1897,  $M = 8.7$ ) and Assam-Tibet border (1950,  $M = 8.7$ ). Various studies have reported a significant precursory decrease in the b-value in the NE region and indicated the probability of great earthquake ( $M \geq 8$ ) in the near future. But the big question is when and where it will occur and how big will it be? Seismologists have no specific answer to these questions as of now. On the contrary, there has been a phenomenal increase in the population density and infrastructural development programmes in the region. Furthermore, the region has witnessed a mushroom growth of unplanned urban centres in the previous two decades. These factors are further increasing the seismic vulnerability of the region. The earthquake hazards of NE region cannot be changed but the earthquake disaster can be mitigated. Thus, it becomes essential to assess the status of seismicity in the NE region realistically for an urgent and sustained mitigation measure.

The present article focuses on the development in the field of SVA of existing building. In doing so, a short glimpse of the need and relevance of SVA of existing structures are briefly introduced first. The fundamentals and various approaches of SVA and the recent developments in the field are subsequently discussed. Noting the increasing trend towards the use of probabilistic performance-based design methods in practice, special emphasis is given on the developments of probabilistic SVA of structure. Finally, the observations on the developments and challenges of SVA of existing structures are summarized.

## 2. FUNDAMENTALS AND VARIOUS APPROACHES OF SEISMIC VULNERABILITY ANALYSIS

In simple words, SVA can be defined as the expected damage of an existing structure or a class of structures as a function of the ground motion which the structure will be subjected to. To estimate such damage, the capacity of a structure required to be compared with the seismic demand on the structure. The underlying fundamental principle is schematically elucidated in Fig.1. The objective is to reduce potential damage through a comprehensive assessment of seismic risk followed by a package of relevant remedial measures namely, improving the assessment of seismic hazard, understanding the seismic vulnerability of the site and finally, to combine these results to elaborate risk scenarios. Thus, the seismic risk is fundamentally the convolution of vulnerability, exposure and hazard. Since nothing can be done to modify the seismic hazard to which existing buildings will be subjected to, or to modify their exposure, the most important studies from the structural engineer's viewpoint regard vulnerability as the key for reducing seismic risk. With the increasing computational effort and available database, broad consensus among the experts generally distinguished three levels of accuracy for SVA of existing structures, namely Level I, Level II and Level III approaches. The choice of a specific type depends not only on the objective of the assessment but also on the availability of data and technology. These are briefly elaborated in the following sub-sections.

### 2.1 Level I: approach of analysis

The Level I approach of SVA is based on simple empirical relationships between the damage and seismic intensity without performing actual structural response analysis. It requires only visual evaluation with limited additional information. It is recommended for all buildings of the region of interest. The various developments on Level I approach of SVA analysis can be studied under following sub-heads: Observed Vulnerability, Based on Expert Opinions and Scored Assignment. More details on these will be discussed during presentation.



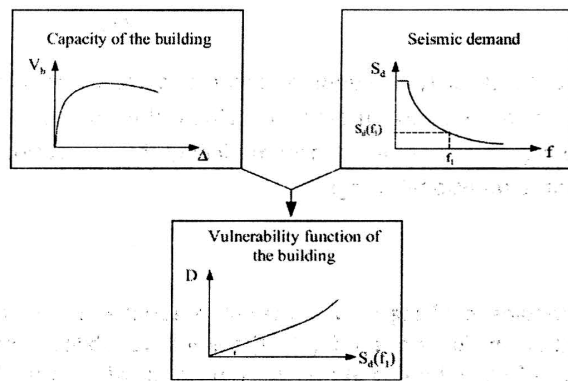


Fig. 1 : Fundamental of SVA analysis

## 2.2 Level II: method of SVA

The Level II approach of SVA is a simplified method which is one step ahead towards more reliable SVA that utilizes engineering information i.e. strength of lateral load resisting members, more explicit information on the ground motion data, structural member dimensions, on site material strength, spot check on reinforcement ratio, average stirrup spacing data etc. A simplified analysis to estimate the building drift is attempted to estimate potential seismic hazard of buildings. The results can be used to determine the potential status of the selected buildings, and for further short-listing of buildings requiring detailed assessment. The approach is useful for all buildings except critical structures where detailed SVA is always recommended. The analyses procedures follow either linear static and or linear dynamic analysis. The nonlinear static procedures for SVA are gaining momentum as a more realistic assessment following the development of the capacity spectrum method [1] and the displacement coefficient method [2]. Though, the non-linear response history analysis is the most rigorous procedure to compute seismic demands, professional prefers to use the pushover analysis for faster evaluation. It is generally used for site specific applications and is able to capture architectural features, material quality as well as detailing of the components to a certain extent [3].

## 2.3 Level III: Detailed SVA

The detailed SVA of a building requires carrying out comprehensive engineering analysis considering the nature of potential ground motions and the behaviour of the structural members. The detailed assessment procedure is highly specialised and requires extensive as-built information regarding a structure. The comprehensive engineering analysis involves considerations of (i) the nature of potential ground motions and non-linear behaviour of structure, (ii) the performance-based earthquake engineering (PBEE) involving explicit evaluation of system level performance utilizing extensive as-built information of structure as well as (iii) rigorous treatment of uncertainty due to earthquake motions, structural properties, physical damage, economic and human losses etc. The problem is basically a time dependent structural reliability analysis problem in which the limit state of interest is the difference between actions (seismic demand,  $D$ ) and resistances (capacity,  $C$ ) and can be mathematically expressed as,

$$Z(X_C, X_D, t) = C(X_C, t) - D(X_D, t) \quad (1)$$

In the above,  $X_C$ ,  $X_D$  are the variables governing the capacity and demand and  $t$  is the time parameter. The computation of probability that the limit state function is negative means to evaluate the seismic risk of the structural system i.e.  $Z < 0 \rightarrow$  Failed  $Z = 0 \rightarrow$  Limiting  $Z > 0 \rightarrow$  Safe. Mathematically, the evaluation of seismic risk is basically the evolution of following multi-dimensional integral,

$$P_f = \int_{\Omega} f_Z(X) d\Omega \quad (2)$$

Where,  $X$  is an  $n$  dimensional vector having variables involving seismic action, material and structural properties and also variables related to age of construction and/or codes,  $f_Z(X)$  is the joint probability density function (pdf) of the involved random variables,  $\Omega$  is the failure domain in the space of  $X_C$ ,  $X_D$  where the limit state function is not positive. The exact computation of the above is often computationally demanding. Various approximations are



usually adopted to obtain the probability of reaching/exceeding different states of damage for a given peak building response which is customarily termed as Seismic Fragility Analysis (SFA).

#### 4. SEISMIC FRAGILITY ANALYSIS

The generation of vulnerability function in terms of fragility function is a common approach for 5VA of existing building. The conditional probability of exceeding a particular damage state  $d_s$ , given the seismic hazard parameter  $y$  is defined by this function. The 5FA by PBEE in the probabilistic framework is performed by two approaches: (i) Analytical fragility based on probabilistic seismic demand and capacity model and (ii) Simulation based fragility based on non-linear PBEE using random field theory and statistical simulation. In either approach, one needs to deal with seismic intensity parameter, structural demand variable, structural capacity variable and various damage levels.

The seismic intensity parameter serves as an interface between the seismicity characterization and structural response. Various peak values e.g. peak ground acceleration (PGA), peak ground velocity (PGV), peak ground displacement (PGD), and spectral acceleration ( $S_a$ ), spectral displacement ( $S_d$ ) may be used. The PGA and  $S_a$  are the most commonly used parameters in SFA of structures. The structural demand variable is a displacement-based structural response representative of structural dynamic and nonlinear behaviour. The most common examples of demand variables for buildings include: roof displacement, inter-story drift, the maximum inter-story drift ratio or drift angle. The structural capacity variable is a threshold for acceptable structural behaviour. It describes the limiting value for the demand variable. Obviously, it will be represented all the same basis as the structural demand value. For example, FEMA 350 [4] specifies a drift ratio of 2% for onset of damage limit state. The damage levels are qualitative function of losses in terms of the economic and social terms. These are conveniently expressed by various damage states (light, moderate, extended or total).

In PBEE damage levels are describes as: Level 1 (Immediate Occupancy), Level 2 (Limited Damage), Level 3 (Enhanced Safety), Level 4 (Basic Safety) and Level 5 (Limited Safety)

##### 4.1 Analytical Fragility Relations

As already mentioned, mathematically the problem of SFA is to obtain the probability of exceeding a structural limit state i.e.  $P_{LS} = P[D > C]$ . The problem is usually decomposed into a more tractable one by introducing interface variables. The PBEE based approach developed at PEER Centre decomposes the problem of calculating the limit state probability into two sub-problems. The first step is to decompose the limit state probability with respect to the displacement-based demand (the first interface variable) i.e.

$$P_{LS} = P[D > C] = \sum_{\text{all } d} P[D > C | D = d] P[D = d] \quad (3)$$

The second step is to decompose the term,  $P[D=d]$  with respect to the spectral acceleration,  $S_a$  (the second interface variable) i.e.

$$P[D > C] = \sum_{\text{all } x} P[D = d | S_a = x] P[S_a = x] \quad (4)$$

Finally, the total probability theory is applied over all possible intensity to find the probability of exceeding a structural limit state i.e.

$$P_{LS} = P[D > C] = \sum_{\text{all } d} \sum_{\text{all } x} P[D > C | D = d] P[D = d | S_a = x] P[S_a = x] \quad (5)$$

It appears from Eqn. (5) that one first needs to calculate  $P(S_a = x)$  which is required to be obtained from a Probabilistic Seismic Hazard Analysis (PSHA) of the site. Spectral acceleration hazard curves are usually provided by seismologists for a given site which provides the mean annual frequency of exceeding a particular spectral acceleration for a given period and damping ratio of a SDOF structure. The second problem is to estimate the conditional limit state probability for the given level of ground motion intensity. The demand values are normally obtained from the result of structural time history analyses under various ground motion intensity levels. The demand variable  $D$  and capacity  $C$  is assumed to be lognormal and the conditional probability is evaluated by first order reliability method. More details on these may be seen in [5-6].

#### 4.2 Simulation based Fragility Analysis

The simulation based approach allows defining an approximate relationship between the failure probability and seismic intensity in the context of performance based SVA procedures by realistic modelling of seismic input, non-linear performance based analysis and use of random field theory in the framework of statistical simulation.

##### Modelling of seismic input

The procedure starts with choosing from among a number of future earthquake scenarios based on the analysis and interpretation of the available macro seismic data of the regions. Uncertainty in the seismic inputs is normally taken into account by the use of a suite of earthquake records. Four categories of approaches are used forth is: random processes, simulated accelerograms, recorded accelerograms and synthetic accelerograms. The suitability and limitations of various approaches can be found elsewhere [7].

##### Seismic Response Analysis

Based on the data available, a progressively refined mathematical model of the building under study is required to set up for determining seismic responses. The core of the procedure is to perform the non-linear dynamic analysis. A response measure that describes damage from seismic loadings is the so called demand parameters.

##### Statistical Simulation

To consider uncertainties in various parameters, a statistical approach is employed in order to obtain a large number of seismic responses of structures with random properties subjected to an ensemble of ground motions scaled to a specific intensity level. The probabilities of the chosen responses exceeding certain damage levels can be extracted from the Monte Carlo Simulation (MCS) outcome representing a point on the fragility curve. Repetition for several intensity of earthquake finally yields the fragility curves. A typical such curve is shown in Fig. 2.

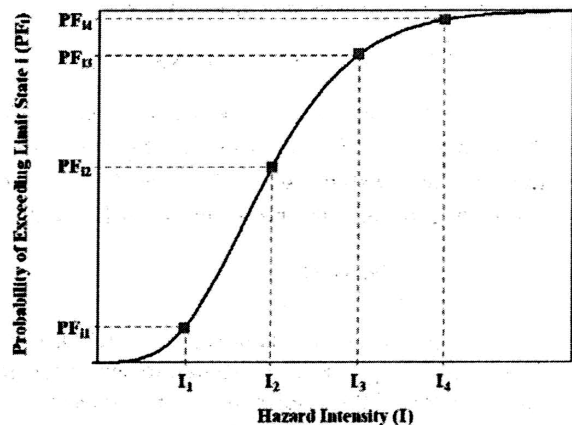


Fig. 2 : Example of typical fragility curve

#### 5. OBSERVATIONS ON THE DEVELOPMENTS AND CHALLENGES OF SVA

The traditional SVA studies of existing structures are primarily based on the empirical post seismic observations. In the recent past, developing methods for SVA of buildings was the subject of numerous research activities at international level [8-12]. Eurocode 8 [13], ATC40[1] and FEMA 356 [14] explicitly define the criteria for the assessment of existing structures. The national codes of our country do not address the issue explicitly. However, the importance of SVA of existing structures was well recognised after the Bhuj earthquake. Subsequently, the developments on SVA of structures at national level are exhaustive; but mainly simplified evaluation in deterministic framework and push over analysis based evaluation. The issue of system parameter uncertainty is not dealt with such works, except for few special structures. The developments at international level are notable in this regard. The FEMA-350 approach allows a new way of performance based SVA procedures considering parameters uncertainty and subsequent development at international level are enormous [15-21]. The PBEE has gained prominence as an approach that allows for more transparent choices about desired earthquake performance and assessment of structures accordingly. One of the most challenging aspects is the identification of relevant dimensions of performance i.e. public safety, reparability of a structure, usability of a structure and understanding the consequences and trade-offs among different levels of safety [22].



A comprehensive SVA study considering the feasibility of acquiring data from existing building is required for mechanical modelling of the system. The information about such parameters of existing building is normally derived from the measurement, test, visual inspection and opinion of experts. To consider the way in which the existing methods can be best incorporated into application, the case study for various regions by collecting data utilizing advanced non-destructive test (NOT) methods in addition to the usual NOT methods is important. Though the uses of advanced NOT methods are common in various countries, it is not so in India. These methods are expected to be more reliable and effective method for investigating RC structures, especially for older constructions.

Existing literatures of SVA generally characterize the important parameters describing the existing structure by statistical parameters such as the mean value and standard deviation. The question of representativeness (i.e. calibration of the values from a certain number of experimental results obtained in selected locations) is raised. The need to evaluate the degree of confidence is thus felt and modelling only as probabilistic variables poses serious restriction on the flexibility of realistic modelling of the input parameters. In reality, some of these parameters will be non-random type (e.g. bounded, fuzzy). Thus, the feasibility of seismic safety assessment of structures characterized by mixed uncertain parameters needs attention [23-24].

The enormous time requirement is the major hindrance of full simulation approach, otherwise a straightforward and best in terms of accuracy. The application of response surface method (RSM) to approximate implicit performance function which otherwise required to be obtained through complex structural analyses is found to be potential. The RSM is used to replace the complex mechanical model of structure involving repeated non-linear dynamic analysis of the mechanical model of the structure at each seismic intensity level. While the RSM has been sufficiently explored and used in time-invariant reliability problems, applications to cases in which random functions co-exist with random variables are very few. The first and the most comprehensive study of RSM on seismic reliability problem was by Veneziano et al. [25] and the subsequent developments for example dual RSM concept [15], mode-based meta model [26], comparison of different RSM in SVA [27], RSM with random block effects [28], high-dimensional model representation based RSM [29] are enormous. Generally, the RSM is based on global approximation of scatter position data, obtained by using the least square method (LSM). However, the LSM is one of the major sources of error in prediction by RSM. The moving LSM, basically a local approximation approach is found to be more efficient in this regard [31-31]. However, avoiding the repetition of intensity for complete generation of fragility seems to be still challenging.

For meaningful SVA, one needs to expertise in three disciplines: seismology, earthquake engineering analysis and structural reliability theory. Significant progress has been achieved between the first two; seismologists can provide realistic, physically justified ensembles of ground motions, with their associated probabilities of occurrence. The communications between the second and third have not proceeded with equal intensity and efficiency. The highly nonlinear dynamic structural response makes the application of well-established reliability methods both excessively complicated and expensive. It appears that the ideal approach for the future needs to be a combination of the positive aspects of different SVA methodologies. It is generally realized that large efforts are being made internationally on both aspects. It is encouraging that the profession is showing increasing consciousness about the importance of the subject and willingness to introduce it in common engineering practice. As there is no convenient way of experimental verification, one should employ at least two different approaches to complement and/or verify each other for reliable SVA of existing structure. The development of a professional guideline benefiting the community in general for SVA procedure enough generic in nature is the need of the hour. So that it can be adapted to different types of structures by suitable change in mechanical model and seismic input for the considered place of study utilizing readily available commercial finite element analysis software. This will encourage the professionals to utilize the developments in the field to provide possible assistance to the decision makers for feasible retrofitting alternatives. This is undoubtedly a mammoth task and there are enough opportunities for development both of fundamental and applied nature in the field of SVA.

## 6. ACKNOWLEDGEMENT

The financial support received in TSD Scheme No. DST/TSG/STS/2012/45, 21.1.13 from the DST, Govt. of India (for the project entitled "Seismic vulnerability .... with special emphasis to North Eastern Region") in connection with preparation of this article is gratefully acknowledged. I also sincerely acknowledge my former student Dr. Sudib K. Mishra, Assistant Professor at IIT Kanpur for his help.



## About Civil Engineering Division Board

The Institution of Engineers (India) has established Civil Engineering Division in the year 1954. This Division consists of quite a large number of corporate members from Government, Public, Private sectors, Academia and R&D Organizations. Various types of technical activities organized by the Civil Engineering Division include All India Seminars, All India Workshops, Lectures, Panel Discussions etc., which are held at various State/ Local Centres of the Institution. Apart from these, National Convention of Civil Engineers, an Apex activity of this Division is also organized each year on a particular theme approved by the Council of the Institution. In the National Convention, several technical sessions are arranged on the basis of different sub-themes along with a Memorial Lecture in the memory of 'Dr KL Rao', the eminent Civil Engineer of the country, which is delivered by the experts in this field. In order to promote the research and developmental work taking place in the field of civil engineering, the Institution also publishes Civil Engineering Division Journal quarterly in a year, where mainly the researches and its findings are focused. Due to multi-level activities related to this engineering discipline, this division covers different sub-areas such as

- Disaster Mitigation Engineering
- Advanced Construction Technologies
- Tunnel Boring
- Precise Design Criteria for High Rise Buildings in Tsunami-prone Areas of the Country
- Disaster Mitigation
- Mechanisation in Construction Industry
- Cost Effective and Eco-friendly Construction Technology
- Influence of Large Dams
- Rapid Transit System for Medium Cities
- Quality Management System in Construction

In order to promote the research and developmental work in the field of Civil Engineering, the Institution also publishes **Journal of The Institution of Engineers (India): Series A** in collaboration with M/ S Springer which is an internationally peer reviewed journal. The journal is published four times in a year and serves the national and international engineering community through dissemination of scientific knowledge on practical engineering and design methodologies pertaining to Civil, Environment, Agriculture, and Architectural engineering.





## *The Institution of Engineers (India)*

8 Gokhale Road, Kolkata 700020

Phone : +91 (033) 2223-8311/14/15/16, 2223-8333/34

Fax : +91 (033) 2223-8345

e-mail : [technical@ieindia.org](mailto:technical@ieindia.org); [iei.technical@gmail.com](mailto:iei.technical@gmail.com)

Website : <http://www.ieindia.org>