

IEI Centenary Publication

T S Narayana Rao Memorial Lecture

A Compilation of Memorial Lectures
presented in

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Background of T S Narayana Rao Memorial Lecture

T S Narayana Rao was born on the February 7, 1907 in a pastoral family at Arkera, near Mysore City. He graduated in Civil Engineering in 1931 from the Government Engineering College of the erstwhile Mysore State. As an apprentice engineer, he worked in Madras with M/s Gannon Dunkerley and Company and subsequently shifted to Bangalore to work under the personal guidance of the late Lakshmi Narasappa, a reputed Government Architect. He participated in the construction of the Town Hall, Municipal Offices and other highly acclaimed structures in Bangalore.

Backed by a few years of intensive experience in architecture and having an educational commitment to engineering, he felt that it was appropriate to fuse the complementary disciplines of architecture and engineering through private practice. He started practicing as a Consulting Architect and Engineer in 1933 and took the risk inherent in starting a new venture totally foreign at that time to the private sector.

Narayana Rao had the rare privilege of constructing buildings of which Shri Krishna Weaving Mills, Mysore Vegetable Oil Products, Rashtriya Vidyalaya and St Joseph's College Observatory deserve special mention. His work reflected a genetic blend of the architect and engineer in him. His success as a builder and architect was in no small measure due to his capacity to execute masonry, carpentry and plumbing works himself.

He was associated with several Engineering Institutions, ISI (now BIS), etc. As a man, he was highly principled and self disciplined. His honesty and integrity sought expression in his exemplary conduct and behaviour. His services as a man and as a professional are even remembered today with respect.

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

T S Narayana Rao Memorial Lecture

presented during National Conventions of Architectural Engineers

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An Integrated Planning for Safer Cities

Prof Santosh Ghosh

Honorary President,
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1. Introduction

Both natural and man-made disasters are causing extensive damage to life and property each year throughout the world. The culture of prevention has not been developed. Disaster reduction measures are not taken up seriously into urban planning and building design systems. As cities become larger they become vulnerable not only by natural disasters, earthquake, cyclone, flooding, land erosion etc. but man-made disasters are quite common in cities - fire, building collapse, violence, pollution etc.

The following are the unsafe practices of cities at risk identified (IDNDR, 1994).

- (a) Makeshift housing on unstable slopes with deforestation.
- (b) Inadequate emergency planning and working - unmarked evacuation routes.
- (c) Lack of urban planning, No safe measures and lack of open space.
- (d) Inappropriately built-and poorly maintained essential facilities and services.
- (e) Housing and industry too close to each other. Bad management of industrial wastes and technological risk locations.

The following factors make cities vulnerable to disaster:

- (a) Rapid growth and inadequate planning.
- (b) Ecological imbalance.
- (c) Dependence on infrastructure and services.
- (d) Concentrated-political, economic and other resources.
- (e) Inappropriate construction.

2. Disaster Issues

However, disaster issues are to be seen in a comprehensive way, These can be summarised as follows with main issues identified : (CBE, 1998)

i) Urban disasters

(a) Natural disasters affecting cities:

Cyclone - typhoon, floods, earthquake, land erosion, forest fires etc.

(b) Man-made factors affecting cities - external: Large dam, large irrigation projects, large industrial projects, silting of urban rivers etc.

(c) Man-made factors affecting cities - internal:

Urban transportation, accidents, pollution etc.

Sanitation and health hazards

Air, water and land pollution

Large construction incl. Highrise buildings.

Settlement planning and landuse.

The possible measures in preparedness and reduction in urban systems:

Urban disaster management



Crisis management

Integration with long-term planning

Civil Defence

Education and Training

Community awareness and actions

ii) Land and Building disasters

(a) Natural disaster affecting buildings

Cyclone, flood, fire, earthquake, solar radiation etc.

(b) Man-made factors affecting buildings

Structural failures, faulty construction, lack of safety factors, wrong siting of buildings etc.

(c) The possible measures:

Safety factors. Structural, fire, climatic, safety against wind, earthquake etc.

Development of temporary shelter structure, deployable and tent structure, safe hospital and school buildings, protection of museums and historic buildings, civil defence training and integration in planning and building, development of school and college curricula with culture of prevention.

iii) Ecological and Environmental Disasters

(a) Loss of agricultural, forest land and water bodies.

(b) Depletion of underground resources.

(c) Loss of flora-fauna and biodiversity.

(d) Air, water and land pollution affecting health and hygiene, biological - chemical effects.

(e) Traffic and industrial hazards.

(f) Urban waste disposal.

Environment management plan is essential which will include integrated planning, pollution control, ecological restructuring, education and training, participatory development of NGOs and CBOs.

iv) Social and economic disasters

Social disasters:

(a) Communal violences, crime and violence to women and children, terrorism/riots etc.

(b) Social & caste conflicts to individual & community, old-aged and handicapped persons.

(c) Absence of community facilities.

(d) Settlement pattern in vulnerable areas.

Economic disasters

(a) Urban poverty, unemployment etc.

(b) Economic disaster: non-physical.

(c) External effect on lack of productivity, labour unrest, deficiency in relief and welfare measures.

3. Disaster Management

The International Decade for Natural Disaster Reduction (IDNDR) 1990-2000 has created awareness for reduction of disaster in different regions of the world and policy guidelines for safe cities include (IDNDR, 1995) :

(a) Encourage development policies that reduce vulnerability to disaster- landuse, Risk assessment, Disaster Impact Assessment, Design, Construction, Maintenance, Integration.



- (b) Prepare city Managers to cope with emerging situations – emerging Management Planning, Institutional strengthening, Communications channels and warnings.
- (c) Prepare community members to address emergency situations, public awareness and education, community based programmes and solutions.
- (d) Have special programmes for high risk situations - Informal settlements, essential facilities, high risk groups, cultural treasures, and building with hazardous substance.

Landuse planning and now more effectely environmental/ecological planning is essential for disaster prevention and mitigation. In an earlier report the United Nations office for Disaster Relief Coordinator, Geneva outlined the measures such as : (UN, 1977)

- (1) Planning new development away from hazardous areas.
- (2) A vulnerability analysis is to be part of all project evaluation and pre investment studies.
- (3) Vulnerability analysis techniques can be applied to landuse planning.
- (4) Landuse planning / legislation to include disaster prevention and mitigation.
- (5) Multi disciplinary training and education programme.

There are several aspects of landuse zoning in earthquake prone areas, micro-zoning for vulnerable area, flood plain landuse zoning, building codes and other development control regulations. Government Departments very often overlook these. In Calcutta public housing has been constructed on drainage basins. Highrise buildings on poor soil make the soil porous and become vulnerable in earthquake as happened in Mexico. Building collapse has become an annual event in most of Asian cities.

Modem mapping system - remote sensing and Geographical Information System has become helpful in the preparation of disaster prone map.

The Local Authorities Confronting Disaster and Emergencies (LACDE) Association has the motto of 'you are not alone' for safer city (LACDE, 1999). Some of the programmes are:

- (1) To foresee potential environmental and other weaknesses so as to prevent disaster, where practicable including Landuse and Building Regulations, inspection of structures and equipment.
- (2) To provide the residents with advance warning of any potential disaster and advice as to the measures.
- (3) To take every practicable measure to mitigate the effects of any disaster.
- (4) To have an emergency coordinator and trained staff, who are responsible that all the rescue and lifeline services - water, electricity, communications, gas, sewage, roads, ambulances, hospitals, security etc. are prepared for emergencies and react quickly and efficiently.

4. Recommendations

The recommendation of International workshop on disaster - cities, buildings and environment organised under the chirmanship of the author by the Centre for Built Environment, Calcutta in January, 1998, are as follows: (CBE, 1998).

- (1) With the rapid urbanisation and growth of cities both vertically and horizontally and with hapazard and ill-conceived development the cities have become vulnerable to various kinds of disasters. A comprehensive and long range vision is necessary for preparedness and reduction of the such disasters-natural, man made and environmental.
- (2) The United Nations declared the International decade for natural disaster reduction 1990-2000. There were various types of awareness campaign and various conferences were held and technical research studies were conducted. Both the Agenda 21 of the UN conference on Environment and Development and Habitat Agenda of the UN Conference on Human Settlement Habitat II emphasized these aspects. The reduction of vulnerability to disaster is the key objective. Disaster preparedness, prevention and mitigation are to be incorporated in every urban development plan.
- (3) During the last decades over a bilion people have been affected by the natural disasters. These have affected the cities also - cyclone, flood and earthquake. People have become homeless also due to the construction of large



dams, due to famine and civil war and also due to urban development. The process and methodology of integrating disaster reduction into sustainable development have not been given due consideration. Rehabilitation is often considered a crisis management with temporary solution. But a permanent solution through proper disaster management should be aimed at.

(4) In recent times, many buildings have been collapsed due to fault construction and poor people's houses have been damaged due to landslides. Large urban development like underground rapid transit, a large bridge or highway have become responsible for damage to surrounding areas. Environmental impact analysis before the construction has become theoretical exercise. Housing estates especially for poor people are planned in disaster-prone areas and people themselves build houses in areas subject to flooding, soil erosion and insanitary areas. Building rules in many cities do not have adequate provision for fire protection. Proper landuse planning and building regulations are necessary.

(5) Cities are often ill-equipped to prevent and to reduce fire hazards, seasonal flooding and other disasters like crime and violence. Developing a culture of prevention, education and training in civil defence is important. Community preparedness with the help of nongovernment organisations and community based organisations are equally important.

(6) Emergency services in health, safety and hygiene with safe hospitals and health centres especially in disaster prone areas are necessary. Protection of important structures especially museums, historical building, removal of debris in case of earthquake, draining of water in case of flooding or protection from fire hazards require new education and training.

(7) Modern scientific methods in collecting data and mapping using modern techniques like remote sensing, geographical information systems etc. should be applied. International help from the United Nations and other agencies should come to the nations.

(8) Ecological and environmental disasters are often realised after a long period. Water and air pollution are causing health hazards. There are serious consequences due to discharge of effluents and smoke from the industries and the pollution caused by the vehicles. The ecology of cities is damaged by ill-conceived exploitive urban development. Waterbodies have been filled up and rivers are getting silted and many flora and fauna have become extinct. The ecological restructuring is required.

(9) There are social and environmental disasters - unemployment, poverty, drug use at one hand and crime and violence, insecurity of women and children, old and handicapped, lack of facilities etc. on the other hand., This is multidisciplinary and multi-dimensional problem which can only be solved by the participation of all stakeholders.

(10) Education and training in disaster in schools, colleges and professional curricula is important. Here community participation is essential.

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Architectural Engineering — Perspective 2020

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1.0 ARCHITECTURAL ENGINEERING — A REVOLUTION

'In every revolution there is a period of upheaval and extremism, followed by a period of consolidation.' - Toffler; Power Shift

The Indian Architectural Scene is exposed to the world market today. This exposure has brought in rapid change in the entire scenario. It means competition from within and outside and from unknown quarters. It means new technologies, new skills and new workers and unexpected economic conditions. This has actually resulted in turbulence in the entire professional scene requiring a stream of innovative disciplines, products, machines and services. The traditional ways of designing and execution are matter of past and the present exposition has really made them obsolete.

Out of 'Roti, Kapra and Makan', the shelter used to be the third priority of an individual to house himself. This priority concept has also changed and today a shelter can be made for housing any of the uses be it educational, commercial, health or recreation. The complexities are really changing fast and so the uses of the shelter. It is common experience that the shelter for humans (house) gets changed to commercial uses for augmenting the family income. This use may also change very often as per the market demands.

The buildings of the date are getting more and more complex day by day. There is an increasing involvement of different kind of specialist right from the designing stage. The world of knowledge is open to the Indian designers also and with increasing complexities of the building typology, construction methodology or equipment availability one is being forced to involve these specialists also.

With increasing knowledge base about the mother earth there is a growing concern and sense of appreciation of the fact that the fossil resources are limited, that there is global warming and the causes of the same could be known, that the subsoil water is reducing day by day and that there is greater necessity to re-charge the same, that there is greater demand of electricity for running our systems and maintaining the buildings but the production is limited demanding use of alternative sources of energy. Because of faster availability of information, it has really become easier to be aware of what is happening around the world and how to best utilize our resources.

This is both making the job of today's designer easy and equally difficult. It is easy to collect information, interpolate the same for your own use, interact with the experts and have their opinion. It is really making it difficult for the designer to be updated and be-equipped with the world of available information and resources and may be equally difficult to be able to cope up with the intricacies of the use of available information or resource.

This revolutionary stage is really demanding a team of expertise and a person knowing more of engineering of architecture shall certainly be having an edge over a person having expertise in only design. This fact has very well been understood by the team of experts involved in the process of revision of the National Building Code of the Country. It has very well been understood by the experts that the building of the 21st century involves more than 70% of engineering skills than the designing. This realization has resulted in the fact that a separate trade of 'Architectural Engineers' has been included in the list of professionals dealing with the buildings.

2.0 MOTHER EARTH

"Man is the product of earth's surface. This means not merely that he is a child of earth, dust of her dust, but the earth has mothered him, fed him, set him task, directed his thoughts, confronted him with difficulties that have



strengthened his body and sharpened his wits, given him his problems of irrigation and navigation and at the same time whispered hints for their solutions." (E. C. Sample, 1910).

This almost a century old saying amply justify that earth is the mother of all activities and we have total dependence on her. During past few decades enough research has been done to understand the systems of the earth. All architectural activities are also performed on the earth's surface. Many a times we forget the system of earth and in a process of personal gains we perform activities that are totally against the natural systems and akin to the mother earth.

Architecture leaves permanent marks on the Earth, as such the present revolution must understand the systems of earth and its 'whispers' clear and loud, in much better way so that it create only marvels like 'Taj' for which India is proud and not the scars. With broad base of information, there is much more of responsibility on the architects, engineers and architectural engineers to ensure better living conditions and environment on this planet earth.

3.0 GLOBALIZATION OF ARCHITECTURE

History teacher while telling 'HIS-STORY' has largely been depending on the architecture of the time as this would provide major evidence for working out inferences. The architectural remains have been telling about the bygone era as to how people were living, behaving. What was the governance system, how the climate was or what the technological level was and how, the same was incorporated in the architecture of the time to provide for human comforts? Indian mythological scriptures such as Ramayana and Mahabharata have narrations that indicate the level of development of society of the period, unfortunately there is no material evidence to prove the same. The modern scientists accept the narration only when they themselves are able to achieve that level.

Unfortunately the architecture of present times is bound to lose this significance. This is largely because of the impact of globalization and the impact of sales gimmick of the multinationals that have forced the designers of the day to adopt 'modern materials' without any logistics or reasoning. The result is that we have similar typology of buildings world over. The sense of belongingness of buildings to a place or time has been lost. We no more have Gothic or Roman; Mughal or Colonial architecture that used to take us to the nostalgic times. It has also forced the modern designers to 'forget' the climatological impacts on buildings and human being. We need to have a greater caution. The modern technology has opened up greater avenues and we need to perform our role with greater caution, care and diligence.

3.1 Irrational use of Material

There is a race for use of glass, stainless steel, ceramics, plastics, copper and similar other materials that not only consume high energy in their manufacture but also on their construction, upkeep and maintenance. During recent times glass is being used irrespective of its functional utility but for the craze of its use. We are providing glass wall on the western facade inviting more of sun and heat there by increasing the cost of air-conditioning, consuming more of the scarce energy. This vicious cycle goes on and we find it difficult to come out of the trap laid down by the firms who are trying to push their product by allurements.

Functional use of glass cannot be overruled. It need be adopted. We need not keep on designing stone buildings of Pala or Ashoka period. We need to move with the times adopting modern technology and materials in a diligent manner to provide better buildings that are not only good to look at but that take care of the functional requirements and provide comfort for the user without wasting scarce resources.

3.2 Energy Conservation

India is a tropical country. We have hostile sun but still we have good brightness round the year. We have good wind flow that is good for achieving comfortable living. The sun's energy can both be used for providing light and heat the interiors during winters. Unfortunately we are forgetting the study and use of macro and micro climate and use the same in our buildings for human comfort. We are just trying to ape the glass in our buildings to produce global architecture and trying to place the same irrespective of local conditions. This is resulting in high energy consumption for achieving comfortable living conditions within the buildings.

In a move to encourage lesser use of energy consumption, Japan government ordered that there is no necessity to visit offices wearing suits and tie; instead it recommended that such practices be reduced to cut down the air-conditioning cost. Mind it, Japan is one of the developed countries that have no power cuts and they cannot think that electricity can go. Their rapid transit system moves underground on electricity and need forced ventilation. If power goes for a few seconds there shall be manmade catastrophe. Many people shall die of suffocation



underground. They have assumed electricity as replacement of sun as a permanent source of energy. Unfortunately the scientific studies have proved this assumption contrary. Japan has realised this fact and has initiated corrective measures.

We need to think again and again if we need to repeat such mistakes. In a situation that our country is can we avoid such dependence on manmade systems while shunning the natural alternative that are easily available and that do not disturb nature and add to enlarging the 'black hole'?

3.3 Built Environment-Socio-Psychological Impact

All)" architectural activity results in creation of built environment which in turn results in urbanization. Unfortunately today we are adding de-humanized built spaces and centres of anonymity. 'Unrelated neighbours' live' lonesomely together'. 'Human to Human relation' is an obsolete concept. Centres are devoid of Humanized life and environment. There is loss of 'Identity' which used to be the key of any known and classic built environment. The residents do not have a sense of belongingness or ownership. This has resulted in in-different attitude towards the spaces- indoor as well as out-doors.

The sense of belonging and ownership is very very important. One keeps ones belongings with utmost care and affection but has different view if it does not belong to one. We keep our eyes shut if it is happening to a neighbour but get concerned if it happens to him or one known to him. We clean our homes and leave garbage on the road to be cleaned by others. This is impact of our urbanization.

Singapore made a novel effort in this direction. Today every Singaporean owns a house. This effort has made them proud resident of the Country. This impact has made this Country as one of the most beautiful counties of the world. We need to learn lessons and adopt best in our efforts.

3.4 Smart Buildings

If you could work in building where you could keep your office as you like it, icicle-cold, while your neighbor turns hers into sauna hot. If only your office lights and computer could flicker on every morning when you swiped your security card in the building lobby, so that you could be ready to work when to sat down with first cup of coffee. And while we are on this flight of fancy, wouldn't it be reassuring to know that your building would shield you from harm in the event of earthquake, or even a chemical or biological attack? We in an era of such structures and We need be prepared to face the challenges.

Yes such buildings are a reality today. Technology shall let the future buildings minimize damage when earthquake hits by automatically adjusting way the weight is being earned by the structural members. Detecting harmful/chemical substances in the buildings air ducts, the system would seal them off and intimate the administration.

Systems can now cut down the running cost of building operations like air-conditioning, lifts and lighting by 4-8% per square meter. Efforts are being made to operate systems through remote control via Web, from a far away building control point, even located in a different country. It is possible to set up to 16 levels of priorities. Priorities can be enforced based on the set 'protocol.' Fire might have highest level of priority level-I, 'comfort- 10' and 'energy management-5'. So if it is cool outside a program shall start fan and draw out side air to save energy. But if there is a fire, the fire safety message will stop the fan.

Smart buildings are being designed today and the team of designers and executers of the design always has greater number of engineers than the architects.

3.5 Structural System

The structural systems are becoming more and more complex. The technology today is demanding fast changes in the spaces as the space requirements are changing very fast due to changes in the functions. This is demanding more and more flexible spaces meaning thereby larger span structures. The technology and software available today helps you to analyze any difficult situation with much less of difficulty. This is the area that is beyond the scope of and architect and an architectural engineer has to play vital role both at the soft ware development level and design level.

3.6 Construction Management

With increasing complexities in the design of buildings, execution of projects is also becoming more and more challenging and complex. Experts at all the levels are required to work out the execution sequence, matched with the supplies required, keeping minimum of inventories. A close watch is necessary over the wastages, finances and the



time of completion. With increasingly complex materials being used especially of larger sizes and with larger size of and taller building, use of intricate machinery has also increased. This demands involvement of specialists at all levels at the level of mechanics and machine operators. This again is an area to be taken care by the engineers rather than the architects.

4 ACTION PLAN FOR 2020

The world is changing very fast so is the building trade. To be updated one need to be regularly be brushing his information backup. The Information technology is helping you to achieve this goal. The amount of information available at click of a mouse is tremendous and we need to make use of this technology to the fullest benefit of mankind. The technology also need be given its fullest due for making human life more comfortable, economical, flexible and safe be it in the form of making efficient use of energy, materials or for making the buildings safe against the natural calamities. We should be ready to face any kind of 'tsunami', earthquake or cyclone. In case our technology is still not ready to give sufficient safeguard or warning then the designers must give alternatives for the same.

In spite of this high-tech era I would emphasize on use of local material and indigenous techniques that even today is labour intensive and not mechanical. Encourage use of materials consuming less of energy in manufacture and application and designs structures that need lesser energy in its running and maintenance. The materials such as bricks require 1.2 to 4.75 Giga Joules per ton for production while gypsum only 0.8 to 4.6 , glass 11.9 to 21, concrete 30 to 300, steel 25.8 to 64.5 Giga Joule of energy. Aluminum consumes 261 to 270 and the cement consumes 350 to 3300 Giga Joule of energy. We cannot think of any construction worth naming modern, to be constructed without use of cement but we can certainly make its efficient use.

Similarly the trend of construction of buildings on agricultural lands and in ecologically inappropriate areas be discourages. Use of recyclable materials need be encouraged to reduce enlarging dumping grounds.

'NATURE SHOULD NOT BE SEEN AS AN ENEMY TO BE CONQUERED IT SHOULD BE TAKEN AS BASIS OF ALL THE LIFE AND A MILEIU TO WHICH ARCHITECTURE CAN AND MUST PERFORM HARMONIOUSELY'. We are product of nature and can be happiest with the nature. This fact has been recognized time and again by one and many. We need to appreciate this fact and try to incorporate in our actions and designs.

It is a matter of fact that the complexities of the present time have better possibility of being solved. The process requires involvement of a number of the specialists. It is the co-ordinated effort of all the specialists that can produce desired results i.e. a 'master building' or a piece of architecture that could be a 'matter of joy for one and the all'. The future is bright and really lies in the co-ordinated effort of one and the all. The 'architectural engineers' have made a beginning. It is the time that they must prove their worth and establish their utility; their niche is bound to expand and there would be no looking back.



Material & Technology for Sustainable Development

Shri Promod Adlakha

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Human settlements is intimately concerned with several environmental issues, such as prevention of water, air & land pollution, conservation of conventional sources of energy and sustainable development for maintaining ecological balance. Environmental planning is therefore, a critical factor in economic and social planning.

Sustainable Architecture, in broad contest, seeks to minimize the negative environmental impact of building by enhancing efficiency and moderation in the use of materials, energy, technology and development of space.

The technology development in the building material & building construction section is considered as a vital input for making housing and construction sector responsive enough to participate in the Nation building activities.

The building materials may be categorized broadly as conventional and modern building material, comprising of 40% which are manufactured in formal sector and the rest 60% include materials like bricks, aggregates, puzzolona, timber based products etc. are produced in informal sector. The quality which has a direct bearing on cost effectiveness is practically absent in the informal sector.

While the products from informal sectors require both the improvement of its process, technology and its appropriate use in construction, the materials, which are manufactured in formal sector, require efficient application techniques under strict supervision in order to achieve desired results.

The aim for sustainability lies in adopting materials & technologies that cover environmental protection and energy conservation. The aim of this selective

Approach is

- ❖ Identification of needs for technologies to reduce the cost of construction so as to make the housing affordable
- ❖ Characterization of the needed technologies, which are practicable under the conditions in India
- ❖ Assessing the potential of each of these identified technologies
- ❖ Training needs and R&D required for development and application of low cost building materials & technologies

Various Research Institutions have developed new and innovative building materials and technologies, based on local raw materials, industrial and agricultural wastes. Such materials & technologies fall in two categories:-

(A) Those, which can be utilized for production at small & medium scale units

(B) Those, which are capital intensive and require highly developed machinery and equipment.

However, for sustainability, the criteria for selection lies in the following factors :-

- ❖ Technology evaluation
- ❖ Standardization
- ❖ Performance & durability
- ❖ Substitution of scarce materials
- ❖ Reduction in pollution
- ❖ Economic feasibility
- ❖ Compliance of National Building Code
- ❖ Validation for application in geo climatic regions
- ❖ Conservation of energy
- ❖ Utilisation of waste



Some of the alternative materials & technologies, which have withstood the test of time, include: -

- ❖ Brick Arch Foundation
- ❖ Granular Piles
- ❖ Brick Piers
- ❖ R.B. Footings
- ❖ Undereamed pile foundations for load bearing walls
- ❖ 190mm thick Load Bearing Brick Wall (stretcher bond)
- ❖ 230mm Rat trap Bond (Row-lock Bond) brick wall
- ❖ Precast Stone Blocks Masonry Walls
- ❖ Precast R.C. Hollow Panel Walls
- ❖ R.B.C. Piers
- ❖ R.C. Ribbed Slab
- ❖ Precast Channel Roofing
- ❖ Precast RC Plank Roofing
- ❖ Precast RC Ferrocement Panel Roofing
- ❖ Precast RC Hollow Slab Roofing
- ❖ Cast-in-Situ Hollow Slab Roofing
- ❖ R.B. Filler Slab Roofing
- ❖ R.B.C. Roofing
- ❖ Precast R.B. Panel Roofing
- ❖ Precast R.B. Arched Panel Roofing
- ❖ CRF Sections and Ferrocement Panel Roofing
- ❖ Precast Ferrocement Segmental Shells Roofing
- ❖ Precast RC panel roofing
- ❖ Funicular shell roofing
- ❖ Precast R.C. Cupboard & Kitchen Shelves
- ❖ Precast Ferrocement Sunshades
- ❖ Precast R.C. Lintels
- ❖ R.B.C. Lintels
- ❖ Precast Ferrocement steps
- ❖ Precast concrete door & window frames

The Rajiv Gandhi Housing Project of the Govt. of Delhi is one of such projects comprising of 3164 dwelling units constructed alternative materials and technologies on a large scale. Infact, this project is among the First:-

- ❖ First Mass Housing scheme with cost effective alternative technologies.
- ❖ The Largest Industrial Workers Housing scheme in organised sector in Asia.
- ❖ The First Housing Project to use fly ash and fly ash products on a large scale.
- ❖ The First Housing Scheme with largest number of precast concrete & ferrocement elements (more than 3 lacs elements).
- ❖ The First Low Cost Housing ISO - 9001 Certified Project.

The Project has the largest ever number of precast elements used. The precast elements casted are :-

RC Planks	=	2,33,258 Nos
RC Joists	=	22,148 Nos
Lintel beams	=	7,992 Nos
Sunshades	=	4,828 Nos
Ferrocement Stair case steps (tread & riser unit)	=	8,380 Nos
Ferrocement Kitchen Shelves	=	3,164 Nos
Ferrocement Water Tanks	=	458 Nos
	=	<u>2,80,228 Nos</u>

The focus has been made on use of low cost "Cost Effective" and "Space Effective" housing resolved by:

- a) Low rise high density concept
- b) Usability of green areas, by sensible planning and optimization of areas.



c) Maintaining ambience and generosity of the residential clusters.

Urban Design Concept

The concept of the layout has been evolved integrating economic & social factors, ideas and innovations so as to meet with functional, recreational, aesthetic, environmental and futuristic aspirations.

Integral Community Housing

This project explores the varied relationship integral to community living. Continuing presence of life and movement in the spaces are the guiding factors, that have shaped this 'creativity project'. The interaction between group of families as new comers is extended into the built environment. The inside - outside, the personal-intermediate - public spaces, the movement respite, the built - void, are all reflections of the same interaction.

Cluster Courts

The dwelling units are arranged in cluster pattern of courts inspired by traditional courtyard housing of urban forms of north Indian climate. This pattern also generate diversities of urban form to allow, like the traditional, the integration of different housings and at the same time, incorporate traditional living pattern.

Use of Bricks — State of Art Technology

The project develop a strong language of exposed brick work moulded with brick bands, in a load bearing wall system of naturally expressed materials. The expression of natural material, both inside and outside in the load bearing wall system reveal in expressionistic form a strong physicality to this architecture.

Street Picture

By planning combination of housing blocks of 3 and 4 storeyed along the roads, an attractive street picture is obtained.

Thus the design has a combination of soft and hard landscape, use of previous paving e.g. (inter locking tiles), use of light coloured paving, shaded hard paved surfaces, plants trees and bushes adequately to help to minimize the heat island effect.

Diffusion of Traffic

Clusters have been planned and judiciously distributed around roads in all directions to encourage balanced distribution of traffic on all roads in various directions.

Pedestrian Paradise

Continuous flow pedestrian with centralized green linkage is an important feature of the concept. At nodal points, that is intersection of roads, 'kiosks' have been planned in each cluster.

Green Effect

The architecture in this hot dry climate has been solved by the duality of building blocks with open parks and totlots like the body and soul. Here the units represents "the body" and open courts its "soul". All the modulations on the outside are the natural responses to peripheral conditions, establishing a strong relationship with the "earth". The trees, plants, grass and vegetation, the soft pathways allows free flow of soothing air.

Native indigenous plant species & trees are planned which require less maintenance and water as compared to exotic species. They also adapt to local conditions, while maintaining the character of landscape.

Resource Management

Resource efficiency features adopted in this project include:-

- ❖ Community parks, cluster parks, courtyard tot lots
- ❖ Cluster courts as well lit source of light and ventilation
- ❖ Energy optimization
- ❖ Water conservation
- ❖ Perforated - high - strength bricks
- ❖ Flyash Bricks - climatically
- ❖ Blended cement - flyash mortar



- ❖ Precast thin sections
- ❖ Minimum steel
- ❖ Practically no shuttering
- ❖ No external finish required - natural finish. Atmospheric actions such as rain, temperature changes, humidity, abrasion from dust and wind, chemical reactions, pollution, the drying & fading effects of sunrays, account for the deterioration of the facades. Instead of the expensive paints and cladding – we have crystallized on strength and quality natural materials.

Resource Conservation

Proper light, ventilation and "Integrated Environment Design" minimised the use of artificial means of energy. The savings concept in cement, steel, bricks have saved tremendous amount of natural resources of the country.

Energy Saving Concept

- The consumption of scarce materials such as cement, steel and bricks is about 20% less than conventional.
- Use of flyash as blended mortar saves energy
- Minimum consumption of steel (300 kg per dwelling unit) in comparison to conventional construction (960 kg per dwelling unit) results in saving of energy.
- Use of perforated bricks provides better insulation and improve thermal performance.
- Use of precast construction techniques with "medium technology" requires less energy use.
- Low rise dwelling units do not require lifts & escalators and thus save energy.

Low Energy Materials

Use of low energy materials and methods of construction have been aimed at. The energy conservation objectives also include reduced transportation energy, efficient structural design, reduction of use of high energy building materials, such as glass, steel etc. Environmentally sensitive construction materials and techniques which reduce embodied energy content of buildings have been adopted. Some common products used are :

- Flyash bricks
- Blended mortar (mix of cement & flyash)
- Ferrocement precast components such as shelves, stair case steps, sunshades, lintels, water tanks etc.
- Precast thin roofing elements

Appropriate Technologies

Conventional

Conventional construction has many drawbacks besides high cost longer schedule of construction, such as bad quality workmanship requiring high maintenance

- Bad Quality
- High maintenance

Hitech

The Hitech construction such as slip form construction, large panel precast construction suffer from stigma of:

- High Skilled workers
- High Investment
- High Cost
- Suited to only Metros with High Volume Turnover Projects
- Require continuity of works to offset idle period of heavy plant & equipment

Intermediate Technology (Best Practices Adopted)

This technology require only small equipments, which are portable & available at very small investment and has many positive features :

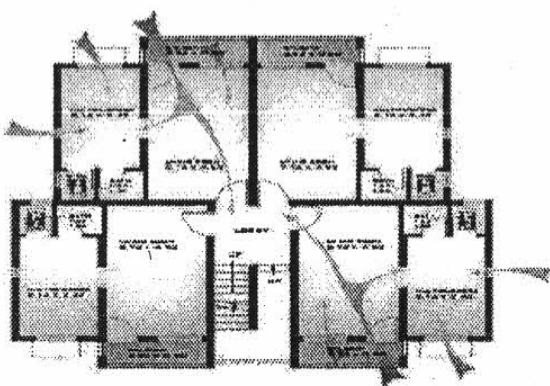
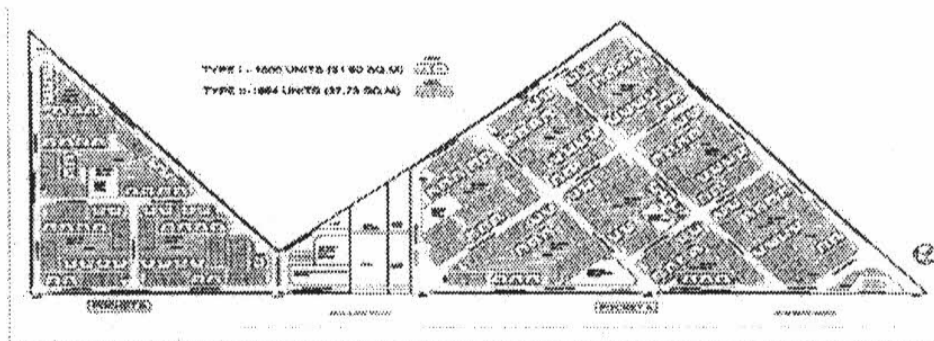
- Partially precast
- Skilled & non-skilled workers
- Generates employment

LAND USE PATTERN

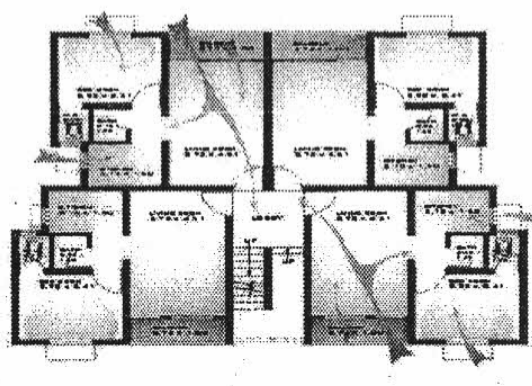
Total Plot area	=	1,05,556 sqm (10.55 hact.)
G.F. coverage achieved	=	25.3 Acres
Total FAR achieved	=	29.91%
Total number of dwelling units	=	105%
Density in terms of D.U's/Hac. of land	=	3164
Total number of units Type-I	=	300
Total number of units Type-II	=	1500 dwelling units each having plinth area as 31.60 sqm.
	=	1664 dwelling units each having plinth area as 37.73 sqm.

Community Facilities

* Kiosks	=	16	Nos.
* Community halls	=	3	Nos.
* Local Shopping cum Facility centre	=	1	Nos.
* Women's, Welfare Centre	=	1	Nos.
* Security Check posts	=	5	Nos.
* Play School	=	2	Nos.
Area under Roads & Parking	=	27%	
Area under green tot lots/parks	=	15.56%	



TYPE-I
(31.60 sam)



TYPE-II
(37.73 sqm)



INNOVATIVE COST EFFECTIVE TECHNOLOGIES ADOPTED (+ SAVINGS)

Item	Conventional	Alternative technology used	Advantages	Savings In Cost
Foundations	Isolated and step footings	Under-reamed piles In load bearing Structure	Economical as well as speedy construction	10%
Walls	230 mm Brick wall in English bond (using conventional FPS, Clay Bricks)	200 mm thick brick wall in Flemish bond (using machine made modular perforated bricks) and flyash (Fal-G) Modular brick.	<ul style="list-style-type: none"> Reduction in wall thickness due to high strength bricks No plaster on external faces Heat & Sound resistance 	20%
Intermediate floors & roof	Cast-in-situ RCC slab	Precast RC Plank system	<ul style="list-style-type: none"> Saving in cement, Steel & shuttering 	21%
Stair case	Cast-in-situ RCC joist slab	Precast ferrocement steps 25 mm thick (tread & riser unit)	<ul style="list-style-type: none"> Cost effective (no Plaster required) 	30%
Sunshades cum Lintels	Cast-in-situ RCC slab	Precast RC	<ul style="list-style-type: none"> Controlled conditions 	25%
Kitchen platforms	Cast-in-situ RCC slab	Precast ferrocement 25 mm thick	<ul style="list-style-type: none"> Speedy construction 	30%
Water Tanks	RCC, PVC	Ferrocement	<ul style="list-style-type: none"> Better finishes & Aesthetics 	20%

TECHNOLOGY EXPLAINED

Under reamed Pile Foundation for Load Bearing Structure

Under-reamed piles are bored, in situ concrete piles with one or more bulbs formed by enlarging the bases of the bore-holes by means of an under-reaming tool.

Arising from the additional bearing capacity and anchorage derived from the bulbs, these piles provide safe and economical foundations in soils of poor capacity overlying firm strata.

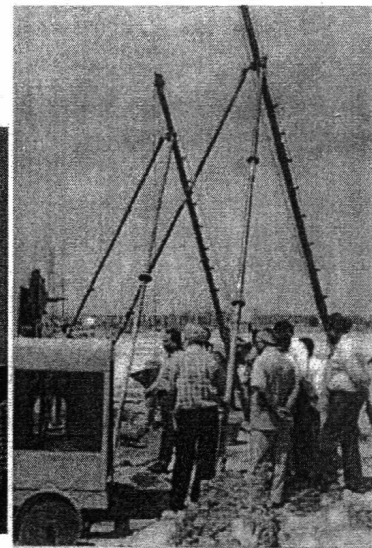
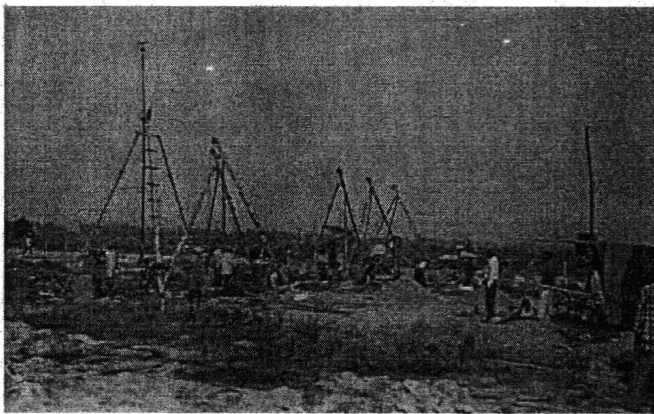
The economy in the foundation cost is about 20% - this is over and above the other advantages such as structural safety, and speed of construction. For load bearing structures, the grade beam has been provided which rests on the ground.



CASTING THROUGH TREMIE



REINFORCEMENT CAGE IN PILE



AUGUR BORING IN PROGRESS

Load Bearing Walls

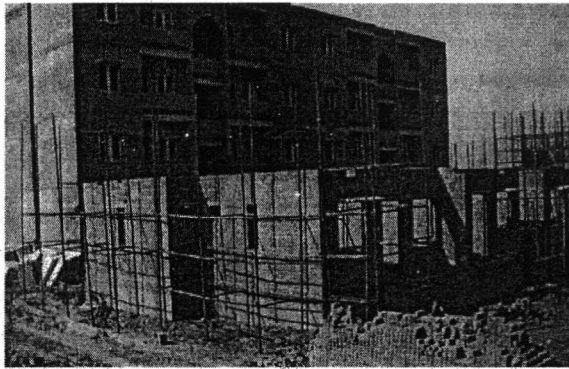
A. Perforated Modular Brick Walls

The Conventional load bearing walls are 230 mm thick. The conventional bricks have non-uniform shape, size and strength. The modular bricks are of 200 mm thick thus saving about 15% of brick walling. The machine made perforated modular bricks are intended for both structural and facing bricks for architectural effect. They have high compressive strength and low water absorption lesser size variation, lesser distortion and chip page and are thus more-durable.

The bricks are manufactured with cores by extrusion and wire cut process. The cores not only provide better insulation but also aid in mechanical bond in a wall and easier laying of the units;

B. Flyash (Fal G) Bricks Masonry

Fal-G is a cementitious material which has a composition of flyash 70%, lime 1.5% and calcinated gypsum 15%. With this technology mechanised bricks are being manufactured using -60% sand, 28% flyash, 6% lime & 6% calcinated gypsum. The lime content can be varied to achieve higher strength of bricks.



Load bearing walls with mechanised perforated modular bricks and flyash bricks

Precast R.C. Plank Roofing & Intermediate Slab

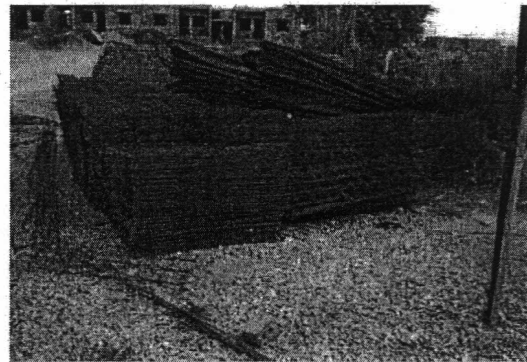
This scheme consists of precast R.C. planks supported over partially precast RC joists of 150 mm width and 150 to 200 mm depth with stirrups projecting out on the top. To provide for Tee-beam effect with the joist, the plank is made partly 60 mm thick. A 100 mm wide tapered concrete fillet is provided for strengthening the haunch portion during handling and erection. The planks have only 3 Nos 6 mm dia bars as main reinforcement and 3 mm dia mild steel wire @ 150 mm dc as transverse reinforcement. The in-situ concrete at every joint with 2 no. 6 mm dia as negative reinforcement form the flange of the tee beam along with the joists and provide monolithic effect. The scheme is suitable for intermediate floors and roofs or lightly loaded buildings and upto a span of 4.2m. For larger spans main beams, shall be provided at suitable spacings to support the partially precast joists.

During the construction, the joists are first erected and propped at mid span. The planks are placed over the joists side by side. After placing reinforcement across the joist, concrete is filled over the joist and the haunches of planks are finished level. After the in-situ concrete has attained strength, the props are removed. No structural deck concrete is provided over the planks.

The maximum weight of a panel is 60 kg, which can be easily handled manually. The roof is designed for composite section. The partially precast joists are designed as Tee beam. The reinforcement in joists is provided as per design depending upon the span, spacing, load and end conditions. This system has, been found very economical. It saves about 14% steel, 27% concrete and 20% in overall cost of roofing besides saving in time-as explained in through photo pictures :-

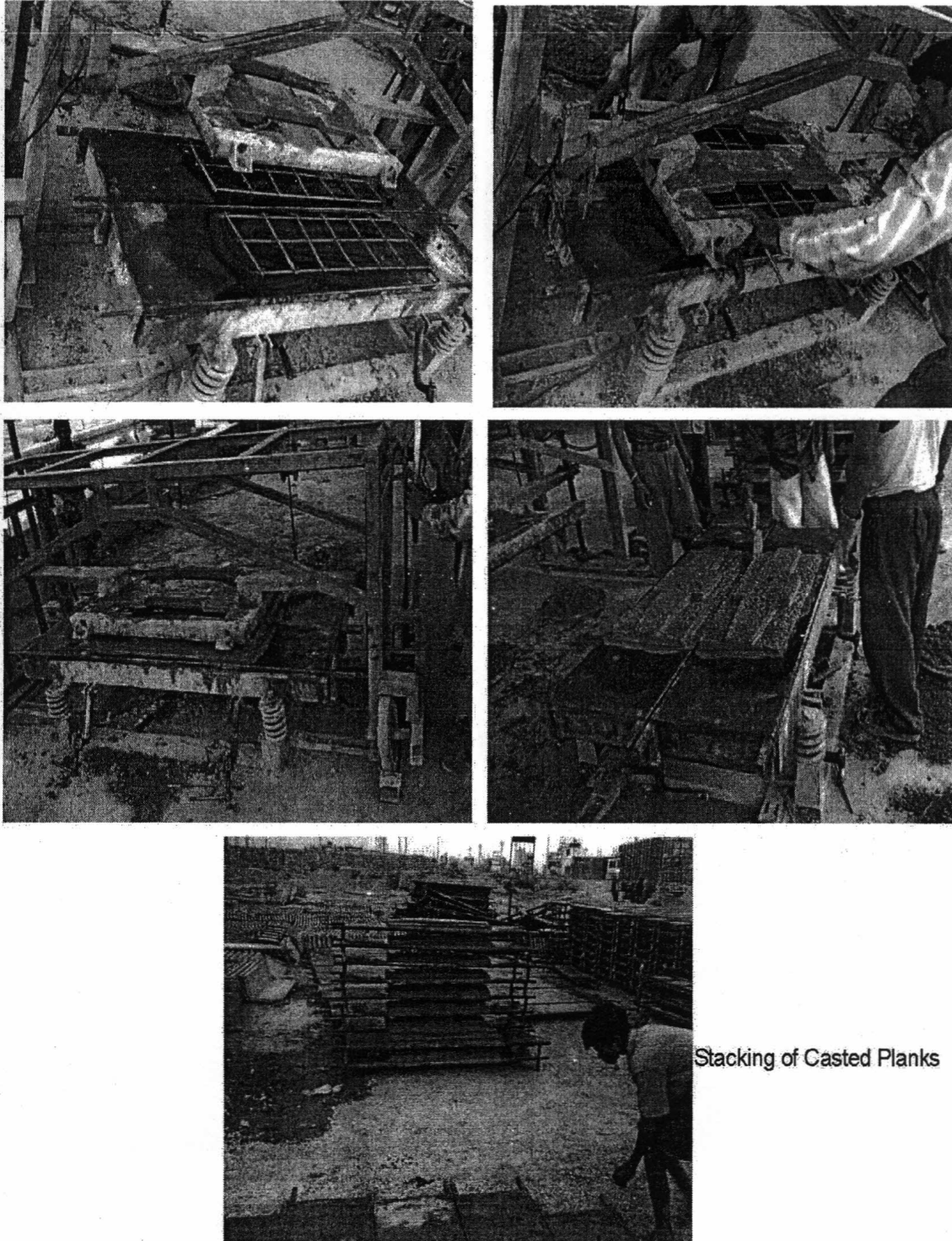


Precast components- Casting Yard



Reinforcement for planks & joists

SEQUENCE OF MECHANISED PRECASTING RC PLANKS



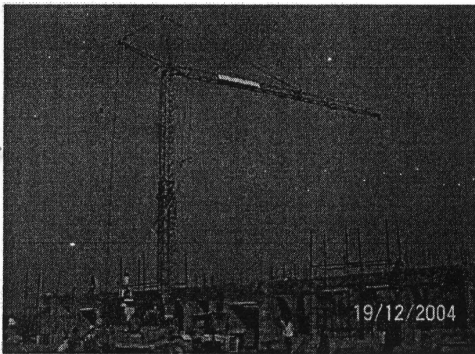
Stacking of Casted Planks



Precast Joists Being Casted



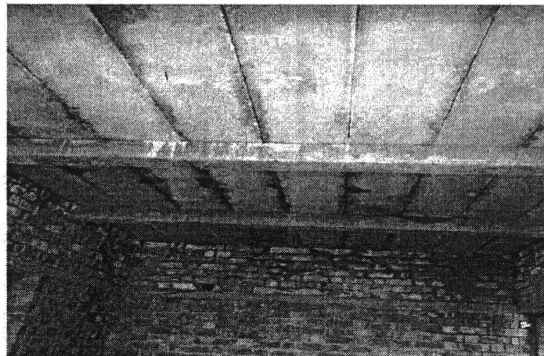
Joists



Mechanical Lifting of Precast Elements



Concreting of Haunches



View of Ceiling

PRECAST FERROCEMENT ELEMENTS

Ferrocement is a form of reinforced mortar in which closely spaced and evenly distributed thin wire meshes (welded or woven) are filled rich cement-sand mortar. Ferrocement structure's can be constructed in any desired shape and thickness (as thin as 12 mm) without framework. The other main advantages of ferrocement include:-

- High strength to weight ratio compared to reinforced concrete
- High crack resistance and impermeability to water
- Lightweight structure due to relatively small volume of material required
- Ease in maintenance and repair
- Easy provision of accessories, conduit holes-etc.

Ferrocement comprise of cement, coarse sand and wired mash.

Ferrocement Shelves

The cooking platform is 15mm thick with one layer of welded mesh 25×75 mm of 12 mm gauge and two layers of chicken mesh 23 gauge

Precast Ferrocement Step

Stair case is an essential part of any building. The cost of stair case is always more than the built up area of rest of the building, due to treads and risers railing, baluster etc. An economical method of stair case waist slab is to use precast steps (tread & riser unit). The unit is precasted in ferrocement and simply supported on walls. A saving of 30 to 40% is achieved.

The steps are 25mm thick and do not require any plaster or flooring.

Ferrocement Water Tanks

Ferrocement tanks of 1200 litres & 1600 litres are being provided, having a dia of 1.5 m. The tank has a separately casted base and the walls are 25 mm thick. Two layers of chicken mesh along with GI wire in helical shape are provided in walls.

Thin Precast R.O.C. Lintel cum Sunshade

Normally lintels are designed on the basis of the assumption that the load from a triangular portion of the masonry above, acts on the lintel. Bending moment of $WL/8$ where W is the load coming on the lintel and L is the span of the lintel assumed for the design purpose. A thickness of 15 cm is required by this method.

Thin precast R.C.C. lintels are designed taking into account the composite action of the lintel with brick work. It is applicable only when the load on the composite lintel is uniformly distributed. The thickness of the lintel is kept equal to the thickness of brick itself having a bearing of 100 mm on either supports. The sunshade is casted along with the, lintel. The projected reinforcement of lintel beam is tied with cast — in-situ lintel band.

Use of precast lintels, speeds up the construction of walls besides eliminating shuttering and centring. Adoption of thin lintels results in upto 50 percent saving in materials and cost.



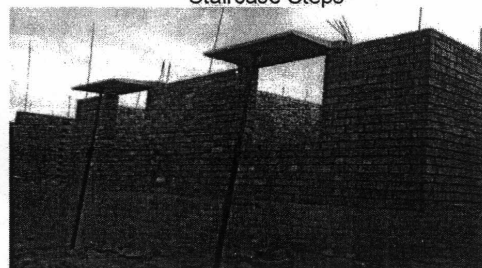
Precast Ferrocement Shelves



Staircase Steps



Ferrocement Water Tanks

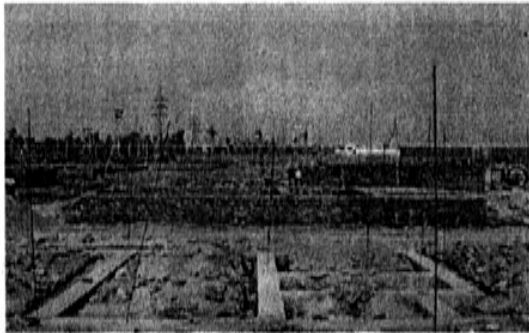
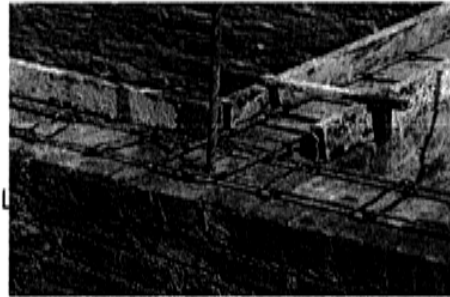


Lintel-cum-precast Sunshade placed over window openings



EARTHQUAKE RESISTANT FEATURES

Lintel-cum-Sunshade casted

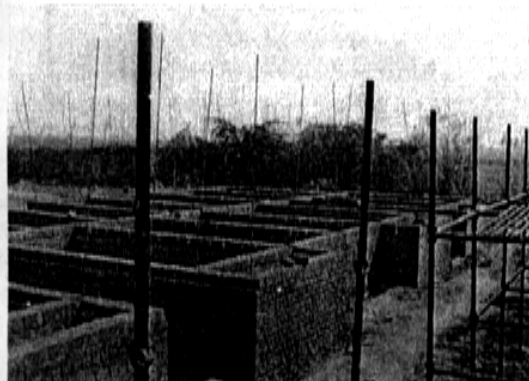


Grade Beam & Vertical Reinforcement
(for Earthquake Resistance)

Plinth Band T Junction



Plinth Band L Junction



Plinth band & Vertical Reinforcement
(for Earthquake Resistance)

Plinth Band & Vertical
reinforcement





Strength and Durability of High Performance Concrete Structural Elements

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1.0 INTRODUCTION

Normal Conventional concrete has been widely used as a construction material throughout the world because of the advantages of mouldability, durability, and resistance to fire and energy efficiency. However, the major deficiencies in conventional concrete are its poor tensile strength, low ductility, dimensional instability etc. Hence, in order to improve the tensile properties, several new materials have been developed in the recent past such as high performance concrete, high performance fiber reinforced concrete, polymer modified concrete, self-compacting concrete, steel fibre reinforced self-compacting concrete etc. Any concrete that gives high workability, high strength and high durability could be called as high performance concrete.

In this paper an attempt has been made to introduce the High Performance Concrete, and discuss in detail the effect of addition of steel fibres to HPC.

2.0 HIGH PERFORMANCE CONCRETE

The term high performance concrete was first used by Mehta and Aitcin [1] for concrete mixtures possessing three characteristics, namely high strength, high workability and high durability. Thus, a primary distinction between high strength concrete and high performance concrete was the mandatory requirement of high durability in the case of HPC. High performance concrete can be made by using mineral admixtures (e.g. micro-silica, fly ash, blast furnace slag, metakaolin, etc.) and, chemical admixtures (e.g. plasticizer, super-plasticizer, retarder, etc.) to the conventional concrete.

The main ingredients of HPC consist of i) cement ii) fine aggregate iii) coarse aggregate iv) mineral admixtures v) chemical admixtures and vi) water.

Cement: Ordinary Portland cement of 43 grade or 53 grade or Portland pozzolana cement is generally used.

Fine aggregate : River sand and crushed stones can be used as fine aggregate. Generally sand conforming to grading zone I and II of IS 383-1970 are preferred because fine and very fine sand increases the water demand of concrete.

Coarse aggregate: In any concrete coarse aggregate is the strongest material and it is highly impermeable. The coarse aggregate should conform to IS 383-1970. In HPC by restricting the maximum size of aggregate and also by making the interface between cement matrix and coarse aggregate stronger by the usage of mineral admixtures, such as silica fume, fly ash, metakaoline etc., the strength of concrete can be enhanced significantly.

Mineral Admixture: Micro-silica (also called silica fume), is a mineral admixture and is a by-product of the industrial manufacture of ferrosilicon alloys and silicon metals in high-temperature (approximately 2000°C) electric arc furnaces. Silica fume is composed of mainly ultra fine solid, amorphous glassy spheres of silicon dioxide (SiO₂). Most of the silica fume particles are less than 1 micron in diameter, with particles ranging in size from 0.01 to 0.3 micron with an average diameter of 0.1 micron. Specific gravity of silica fume is 2.2, lower than Portland cement (3.1 to 3.23) and fly ash (2.5 to 2.7).

Some of the advantages of use of silica fume in concrete are given below:

- i. Increased strength - significant increase in compressive, split tensile, flexural and bond strengths.
- ii. Reduction in bleeding and segregation of fresh concrete.
- iii. Reduction in permeability of concrete,
- iv. Reduction in alkali silica reaction.



- v. Reduction in sulphate attack, chemical attack and corrosion attack, leading to increased durability of concrete.
- vi. Reduction in heat of hydration of concrete.

Chemical Admixture: Super plasticizer (also called high-range water-reducing admixture) is a chemical admixture and is capable of reducing water content to the order of 30 percent and at the same time result in improvement in the desirable properties of concrete. Some of the advantages of use of super plasticizers in concrete are given below:

- i) By adding super plasticizers to the concrete, workability can be increased. Such concretes can be used at places where the reinforcements are congested such as beam-column joints, etc.
- ii) By adding super plasticizers, (a) concretes having high strength with less water content without sacrificing the workability, and (b) concretes having normal strength with lesser cement content can be produced.
- iii) The addition of super plasticizers to the concrete helps to reduce adverse effects due to shrinkage.

3.0 STUDIES ON CONFINED STEEL FIBRE REINFORCED HPC

In recent years High performance concrete (HPC) has gained broad acceptance among engineers and contractors. The addition of fibres to concrete has been shown "to increase strength, ductility and fatigue strength of concrete. Steel Fibre Reinforced High Performance Concrete (SFRHPC) can be effectively used in RCC members subjected to extreme loading conditions such as seismic loading, blast loading and impact loading. For the rational design of such structures the knowledge of complete stress-strain curve of SFRHPC is essential. It is generally accepted that the presence of fibres improves the performance of concrete in compression. The main functions of the fibres in members subjected to compression are to resist the opening of cracks due to micro-cracking, increase the ability of the composite to withstand loads, and to allow larger strains in the neighbourhood of fibres. Literature shows that large number of studies were conducted in the area of confined normal concrete [13-20]. But only limited studies were conducted in the area of SFRHPC and confined SFRHPC. Hence an attempt has been made to study the effect of confinement on the behaviour of SFRHPC at NIT Calicut.

Effect of confinement and influence of steel fibres on the strength and ductility of high performance concrete were studied. Based on this study, the following conclusions were arrived at.

1. Increase in the volumetric ratio of transverse reinforcement, increases the ultimate strength of HPC and SFRHPC. However the percentage of increase is higher for SFRHPC specimens than for HPC
2. Peak strain was found to be higher as the confinement increases. Addition of steel fibres improved this peak strain further.
3. The addition of fibres improve the dimensional stability of the structure to a great extent.
4. The improvement in the values of strain at peak load could be used for modifying the existing stress block in the case of limit state design.
5. Since the combined effect of confinement and fibres improve several engineering properties such as strain at peak load, strength and ductility, energy absorption capacity etc. the confined SFRHPC appear to be a useful technique in case of structures subjected to seismic/impact dynamic loading.

4.0 STUDIES ON THE EFFECT STEEL FIBRES ON THE SHEAR STRENGTH OF HPC

Shear failure of reinforced concrete beams occur when the principal tensile stress within the shear span exceeds the tensile strength of concrete and a diagonal crack propagates through the web of the beam. This type of failure will be sudden and without any warning due to the brittle nature of plain concrete in tension Literature indicates that large number of studies have been attempted by several researchers on steel fibre reinforced normal strength concrete (Naaman, 1991[23]; Swamy1981[24]; Barros, 1999[25]). However, only few investigations are reported on the effect of steel fibres on high performance concrete (Pilar Alaljos, 1996[26]; Habib et.al, 2002[27]; Aitcin, 1998[22]). These are limited to investigations which involve proportioning of HPC mixes and testing of small scale specimens. In actual practice concrete structures are rarely subjected to increasing monotonic loading. In fact they are subjected to repeated loading such as varying imposed loads, wind load and other dynamic loads. However a comparison of SFRHPC beams subjected to monotonically increasing load and repeated load has not been attempted. Considering this, an attempt has been made to study the behaviour of SFRHPC beams under repeated loading and compare it with that of monotonic loading.



Findings

1. The HPC specimens without fibres suffered small deflections at ultimate load. This indicates the sudden failure of specimens due to shear cracks.
2. Addition of fibres was found to improve the first crack strength appreciably and this may be attributed to the increase in the tensile strain of concrete in the neighborhood of steel fibres.
3. The ultimate load was also found to increase as the volume of fibres increases. This increase was found to be marginal. However deflection at ultimate load was found to increase significantly when fibres were added to the specimen. This indicates that failure mode of the specimen changes from brittle type to ductile one as the fibre content increases.
4. The energy absorption capacity of HPC specimens were found to increase with the increase in percentage of fibres.
5. Comparison of specimens with stirrups which has been reported elsewhere (Ganesan et.al) [30] indicates that partial replacement of stirrups by steel fibres is possible.
6. The envelope curve obtained for repeated loading case did not compare satisfactorily with load deflection curve of specimens subjected to monotonically increasing load. Hence attempts have to be made to develop expressions for predicting the envelope curve of repeated loading.
7. The ultimate strength of specimens in the case of repeated loading is found to be higher than those subjected to monotonically increasing load.

5.0 STUDIES ON PERMEABILITY OF SFR - HPC COMPOSITES

As permeability is an important durability factor, an attempt has been made to study the permeability of High Performance Concrete with and without fibres.

This experimental investigation consists of two phases. In the first phase, the effect of addition of micro-silica on the permeability characteristics of high strength HPC has been investigated, and the optimum dosage of micro-silica to improve its impermeability was found. In the second phase, the effect of addition of both micro-silica and steel fibres on the permeability characteristics of SFR-H PC composites has been investigated.

Findings

Based on the experimental investigations reported in this chapter, the following conclusions are drawn:

1. Addition of 7.5 % of micro-silica to the high strength HPC reduces its permeability by about 64 % and further addition of steel fibres having an aspect ratio of 100 and a volume fraction of 1.0 %, reduces the permeability again by about 74 %. Thus, addition of both micro-silica and steel fibres to the high strength HPC reduces its permeability by as much as 90 %.
2. For a given aspect ratio of steel fibre, permeability of SFR-HPC composites decreases as the fibre content in the composite increases. The rate of decrease of permeability, however, decreases with increasing fibre content.

CONCLUSIONS

The findings of the above studies indicate that the addition of steel fibres to high performance concrete improve not only the strength characteristics but also the ductility, energy absorption capacity and durability significantly. Hence steel fibre reinforced high performance concrete appears to be a useful composite in the case of structures which are subjected to seismic! impact! blast loadings and expose to severe environment. Studies on Steel Fibre Reinforced SCC indicate that additional steel fibres to SCC improve many of the engineering properties of conventional SCC. By using SFRSCC spacing of hoops provided in columns can be increased without reduction in the strength and ductility. This reduces congestion of reinforcement in beam column junctions, which in turn eases the construction difficulties.

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Architectural Engineering Education — An Emerging Scenario

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National Institute of Technology Calicut, Kerala

1. Introduction

Architectural Engineering is a sunrise profession in India. Training programme for Architectural Engineers shall synthesize the best elements of engineering and architectural education, as taught in modern institutions globally. It shall also incorporate the essence of traditional building science and technology unique to India and evolved over centuries. Only such a synoptic approach will suit the gigantic building needs of vast rural and urban areas of India. This paper presents an approach for such an emerging scenario for Architectural Engineering Education.

2. The Magnitude of the Building Activity Construction activities provide infrastructure for socio-economic development. The outlay for construction forms practically 50% of the plan expenses. Almost half of this goes for building construction. Infrastructure construction and Architectural Construction thus form two equal components of the construction sector. The rate of house construction in India is about 4 units /1000 population/year. If we take a small town like Calicut having 5 lakhs population, 2500 houses are built in a year or 8 houses are built in a day. If each house construction entails an expenditure of 25 lakhs, 1 crore is spent in the city in a day in the housing sector alone. We can extrapolate the total spending in all the towns of India which holds about 20% of India's population. No wonder Architects and building engineers flock to towns for rendering services as consultants and supervisors. As the availability of qualified professionals do not match with the need for quality services, this field also attracts many unqualified and under qualified practitioners.

3. RURAL VACUUM OF BUILDING PROFESSIONALS

The total volume of construction in the rural sector is almost 4 times that in the urban sector. However as the area is spread over, as the per unit cost of dwelling is small and the material and techniques of construction are traditional, this sector does not attract the formally qualified architects or engineers. The curriculae of architectural or engineering courses, cover the traditional further, do not technology which support the rural construction. Truly those who hold university degree in Architecture and Engineering are ill equipped to 'practice profession with design concepts, materials and techniques of traditional systems and are thus unqualified to practice in rural setting. In other words educational inputs in our University education in civil engineering and architecture intended for the training of building professional, ignore 80 percent of the target group of Indian population even in the matter of providing their basic need of shelter. This results in lack of quality up gradation in rural housing inspite of overall technology development in engineering education.

4. REGIONAL NATURE OF ARCHITECTURAL CONSTRUCTION

The scope of Architectural Engineering Education is to be seen in this perspective. Infrastructure construction is global in nature, whereas Architectural construction is regional in content. It is clearly tied with geographical, social and cultural contexts. It is based on availability of materials and indigenous skills. The forms of Architectural constructions are adaptive of regional climate and ethnic symbolisms. Hence the training of Architectural engineers shall be founded on traditional knowledge of design, material, construction techniques, craft skills in theory and practice. It shall then incorporate regional setting and socio-cultural needs and evolve to absorb modern analytical theories, and technological tools. Finally it shall grow into futuristic trends of efficient and intelligent buildings.

5. ARCHITECTURAL ENGINEER AS A GENERALIST

How this emerging scenario of Architectural Engineering Education can be made pragmatic? Here we have to redefine the conflicting goals of training. Our difficulty in attracting people to become Architectural Engineers arises in the context of viewing him as a generalist in building profession. We have so far taken the view that



architectural engineering will unify the best of architecture and civil engineering. It will be a fusion of the key subjects of the two disciplines with many more inputs such as environmental control technologies and services. This would emerge as a new discipline free from the deficiencies of Civil Engineering and Architecture in building related subjects. Consequently there will be three building professions; Civil engineer, Architect and Architectural engineer.

6. HOW THEY WILL DIFFER PROFESSIONALLY?

From a pragmatic view point, a client finds no distinction between the three building professions. According to a judicial point of view Uudgment on Writ petition 123 & 125 of 1985 in this High Court of Judicature at Bombay, Panaji Bench, Goa), "00. there is no substantial differentiation in the technical qualifications of Architects and Engineers and both such professionals are qualified and have the necessary knowledge and expertise to engage themselves in building construction and development activities". The academic programmes of Civil Engineering and Architecture are well established in India during the last 100 years. In this context the introduction of a third stream of generalists in the building profession was perhaps a hurried, unwanted and untimely decision. It was not necessarily with the broad goal of achieving quality in buildings; but with a narrow view of professional interests. The IE(I) which started Architectural Engineering as a separate division in 1978 conceived it as an independent discipline of a generalized nature. Those who became corporate members of this division were civil engineers practicing building profession as designers or builders. IE(I) also initiated the examinations in this discipline, but it was not continued with perseverance. B.Tech. course in Architectural Engineering was started in NIT Calicut in 1985 as a separate generalised building professional course. Subsequently it was also discontinued owing to academic interests. Decision to restart the AMIE (Grad IE) examination in Arch. Engg. is yet to be taken. In short we have not made any progress in establishing the division by the IE(I), in giving on a firm footing even after 32 years of initiating it. The only Architectural Engineers, trained in the concept of IE(I) of 1978, are those who hold B. Tech. degree in Architectural Engineering and continue to render professional service in a variety, of fields.

7. ARCHITECTURAL ENGINEERS AS A SPECIALIST

Let us take an alternate view of Architectural Engineering as one of the specialized sector of Civil Engineering. A review of the curriculum of Civil Engineering course which existed 50 years ago will show that it is loaded with subjects related to building design, building drawing, materials, construction, estimation and maintenance. It covered practically 50% of this engineering course content. Today it does not account even 20% the total subjects of Civil Engineering curriculum. Additional emphasis has come in Structural Engineering, Environmental Engineering, Geotechnical Engineering etc. replacing building related subjects. Hence as todays Civil Engineering syllabus is richer in analytical subjects, it has become deficient in designing, detailing, estimating and construction subjects.

The result of this shifting emphasis in subjects is reflected in the building profession of engineers. The early generation of Civil Engineers have easily adopted to Architectural Engineering profession. Infact more than 90% of the corporate members of Architectural Engineering division are senior Civil Engineers. But younger entrants to Architectural Engineering field are few. They are not confident in architectural design or drawing or other building related subjects. Consequently they start playing subsidiary roles as structural designers or construction supervisors in Architectural projects. If we reorient our view of Architectural Engineering as a specialized division of Civil Engineering concerned with Architectural construction and provide facility for this specialization, it will attract increasing number of Civil Engineers to this division. In fact American society of Civil Engineers has Architectural Engineers as one of its specialized division, at par with other specialities like Structural Engineers, Environmental Engineers. Transportation Engineers, Urban planners etc.

8. TRAINING STRATEGY

It is far easier to plan for the education and training of Architectural Engineers as a speciality division 'bf Civil Engineering, rather than as a diversified, generalized, undergraduate course.

There are two options for this;

1. To offer a professional oriented post graduate diploma in Architectural, Engineering and
 2. To offer an academically oriented post graduate degree in Architectural Engineering.
- a) Post Graduate Professional Diploma Scheme



The general requirement of a post graduate diploma in engineering disciplines, cover 4-5 subjects with a total of 300 contact hours and a field project at the end of the course. The following 5 subjects are suggested for the P.G Diploma in Architectural Engineering.

1. History and theory of architecture
2. Landscape architecture and interior design
3. Acoustics, lighting, ventilation and air conditioning.
4. Traditional Architectural Engineering (Vastuvidya)
5. Settlement planning and management

The project can ideally be design or field oriented one under a senior Architectural Engineer. Such a programme could be offered directly by local centres having resource persons in these areas or such' other educational agencies. P.G. Diploma in Arch. Engg. could be approved by ARDB as a desirable qualification for new entrants to the division.

b) Post Graduate Academic Degree Scheme

The P. G. Degree in Arch. Engineering, M.Tech (Arch. Engg.), could be offered by Academic Institutions. Such a programme could be of multi-disciplinary in nature and admit Architects also. It could have the above 5 subjects and elective 'subjects in Architectural Engineering which can be taken by civil engineering and architectural entrants. The academic programme in Architectural Engineering can thus be an integrative course for Civil Engineers and Architects.

The thesis of M.Tech. course could cover topics in Architectural Engineering subjects. Such a course would produce resourceful faculty for undergraduate courses in Civil Engineering and Architecture in building related subjects.

9. CONCLUSION

The professional P.G Diploma programme for civil engineers and Academic masters degree programme for civil engineers and architects are suggested as possible steps to strengthen the Architectural Engineering division. These programme can be offered by The Institution of Engineers and academic institutions respectively with out any procedural constraints. Specially the P.G Diploma can be offered by local centres of IE(I) under Continuing Professional Education Programme, converting the centres into meaningful promoters for professional development.



A City can be Only as 'Smart' as its People and its Planners

Prof Devdas Menon

Professor, Department of Civil Engineering, IIT Madras

What kind of architectural engineering needs to be done to serve the government's proposal of building 100 smart cities? While discussing this important theme, it is necessary to keep in mind the larger philosophical context what does it really mean to be smart? Making the physical infrastructure of a city 'smart' (like making a smart device, such as a smartphone) can be tremendously helpful for efficient functioning, but by itself, cannot be expected to make the end users (the city dwellers) truly smart, in the sense that they live fulfilling lives and enjoy holistic well-being. This calls for a larger shared vision that aims high - beyond materialistic terms. A city can be only as 'smart' as its people and its planners.

It is therefore necessary for planners and policy makers to proceed with caution and wisdom. Especially in a country like India, in which truly smart cities were built in ancient times, as in the Indus Valley Civilization, dating back to some 6000 years, and in later periods. It is important to remember this, as our current education seems to suggest that true smartness and civilisation perhaps began only some four centuries ago, with the advent of science and technology in the Western world. Technology is a double-edged sword. While it has contributed much to providing greijlter comforts in living, it has also done much to make humans more and more dependent on (and addicted to) technology, and irreparably damaging an increasingly fragile eco-system. If the objective of the Smart Cities Mission is ultimately "to improve the quality of life of people", then we need to adopt a more holistic approach and improved understanding of what really

constitutes quality of life. Surely, it is something more than applying "smart solutions" to "enable cities to use technology, information and data to improve infrastructure and services"?

But even if we restrict our vision to providing basic amenities, such as adequate water supply, electricity, sanitation, affordable housing, efficient transportation, health and education, safety and security, and governance, the challenges are enormous. These are simply basic requirements that we seem to have not paid adequate attention to in the past. Use of sensors and digital technology can certainly help, but cannot be seen to suddenly make us smart and magically solve all our problems. While we need to arrive at innovative and sustainable engineering solutions to these problems, we also need to reckon with the harsh reality of associated non-technical issues that compound these problems: such as corruption and lack of integrity at various levels of our society, including professional service providers. Truly, we need a major restructuring and transformation, which ideally must begin within ourselves. We cannot rely on smart sensors to make us better human beings and thereby truly improve our quality of life. We need to aim for a more comprehensive approach, with integral education having a key role in it. The city should ideally reflect and express the inner qualities and aspirations aimed at by its people and planners, and be in harmony with Nature - as, for example, in the case of Auroville, which is continuing to evolve as a "place of unending education, of constant progress, and a youth that never ages".

This talk will give examples of how such a holistic approach to smartness can be invoked through the practice of architectural engineering and integral education.



Environmental Planning through Architectural Practice

Dr Soumyendu Shankar Ray

Founder Director

School of Architecture & Planning, KIIT University, Bhubanesar

I feel truly honoured and privileged to present the T S Narayana Rao Memorial Lecture instituted by the Institution of Engineers, India on 'Environmental Planning through Architectural Practice'. Narayan Rao's contribution to architectural profession matches his unique career. He pioneered architectural Practice in India and his work exhibits integrity between Engineering Innovations and architectural sensibilities. The architectural expressions he created true to their purposes. His work was in continuity with the Indo-Saracenic Revival, an architectural style movement by British architects in the late 19th century in British India. It drew elements from native Indian architecture and combined with gothic revival and Neo-Classical style. The confluence of Victorian Britain favoured styles and Indian exoticism gave rise to an aesthetic direction to major architectural projects. I am delighted by this rare opportunity to honour his memory.

I am glad this workshop is being conducted in Bhubaneswar, whose master plan was envisioned by a climate responsive architect, Otto Koeningsberger, and its architectural character was shaped by a passionate revivalist architect Julius Vaz.

Otto Koeningsberger, known for his treatise on tropical Architecture called 'Manual of tropical housing and buildings', a text-book on climate responsive design for tropics. He conceptualized Bhubaneswar to be a modern progressive city with a mix of cultural diversity. The Master Plan he proposed was based on Pandit Nehru's vision of transforming traditional India into a modern Welfare State. He emphasized, "A good master Plan must provide for unlimited expansion, but at the same time organize the town in such a manner that it forms an organic and healthy structure at each stage of its development". A linear settlement pattern with flexible neighbourhood units became the framework of his proposal. The neighbourhood units became self-contained units flexible to accommodate the population growth as the city grows in size. Realising the dearth of public transportation with the exception of cycle-rickshaws, the units were designed to limit the distance between a common man and his work place. The square shaped units spanned three-fourth of a mile, a distance which can be comfortably covered by bicycle. The houses were arranged considering the topography of the land and prevalent wind flow patterns to capitalize on the cool south-eastern breeze and were aligned at a convenient distance from the railway station. All the homes were to be within half a mile of a bus station.

Julius Vaz tried to inculcate in Bhubaneswar a convergence between the scientific ideas from the west and traditional heritage of the east. In the modern buildings he created, he infused architectural elements of the past to create iconic Indian forms. He authored some of the most influential buildings in the new capital of Odisha including the Secretariat and Assembly building. Vaz's designs had simple underlying principles of climate consciousness and modern design sensibility. This humble and dignified approach became the character of modern architecture of the young state Odisha.

Climate responsive design constitutes an important phase in the development of passive technology, solar architecture and green architecture from the early 1930s to the end of 1960s. Climate responsive design matured as a global phenomenon, developing as 'Bio-Climatic Architecture' in the United States and 'Tropical Architecture' in Asia and Africa.

Environmental Planning is the process of facilitating decision making to carry out land development with consideration given to the natural environment, social, political economic and governance factors and provides a holistic framework to achieve sustainable outcomes. Architecture is a process not a product. Unlike Industrial manufacturing process designing is non-linear and intertwined. A scientific process of climate responsive design is to modulate the conditions such that they are close to comfort zone. In climate responsive design, climate has to be a parameter of design in every aspect of building and built environment.

Laurie Baker's innovative work is an outcome of his simplicity and directness. A chance encounter with Mahatma Gandhi at the beginning of the career had a huge impact on Baker's Architecture. In his own words "One of the



things he said that impressed me and has influenced me more than anything else was that ideal villages will be built of materials which are all found within a five mile radius of the house. What clearer explanation is there of what appropriate building technology means than this advice of Mahatma Gandhi."

Buildings need to be simple, true to their purpose, devoid of aesthetic manifestations and contextual. A true architecture of the sun and wind is more than the sum of passive strategies, technological systems and ecological engineering. Each building is an intervention in the nature's process. The best building is one, which has minimum intervention and strives for democratic and peaceful co-existence with its surroundings.

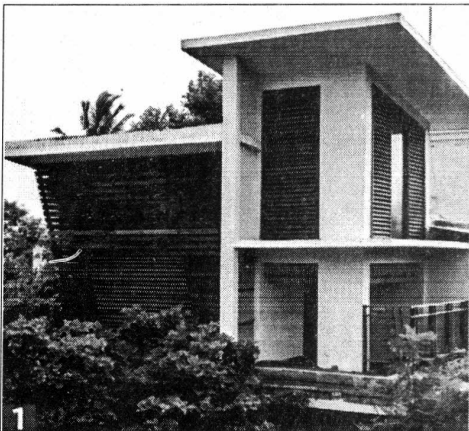
Own Interpretations:

1. Vastukar Design Studio, Bhubaneswar:

Small Buildings, which have relatively small individual environmental foot-prints, however have enormous cumulative effect on climate change. With a design intent of 'Contemporary building with traditional soul' the built outcome substantiates itself with nature. The building is responsive to the prevailing wind pattern, solar movement and sensitive to warm humid climate of Bhubaneswar.

2. Kalinga International School; Adaptive Reuse:

The School is built out of an existing factory shed. Geometry plays a very important role here. Creation of interesting shapes and forms through interpolation of various shapes has been experimented through a generative approach. Built from locally available blue basalt stone the school shows care and concern for children.



Vastukar Design Studio

Bhubaneswar, Odisha, India 2011-13

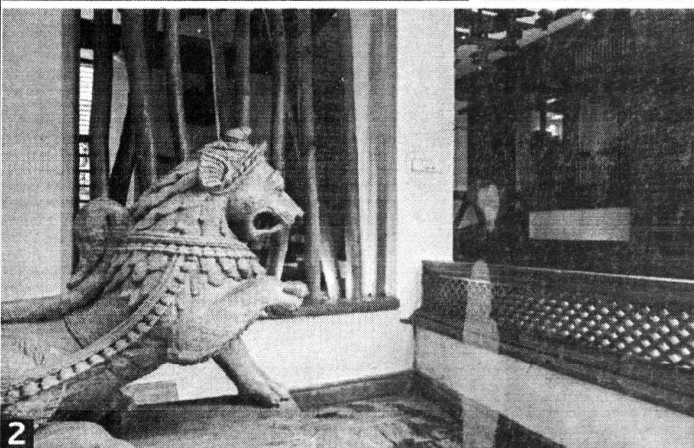
Submission Category: LIVING SPACES : WORK (Office Building Design)

1. A contemporary building with a traditional soul
2. Building houses architecture studio and also space for research foundation
3. The building is contextual and representative of traditional temple architecture of Odisha.
4. Located in Old town Bhubaneswar, the building draws inspiration from traditional architectural values of Mukteswar temple, Lingaraj temple and Bindusagar lake.
5. The building recognises all passive features in terms of use of materials, planning concepts and energy consciousness. It has been rated five stars under SVA-GRIHA by TERI, the first and only building in Odisha to have this status.

- Vastukar
- Temple
- Bindu Sagar
- Water Body



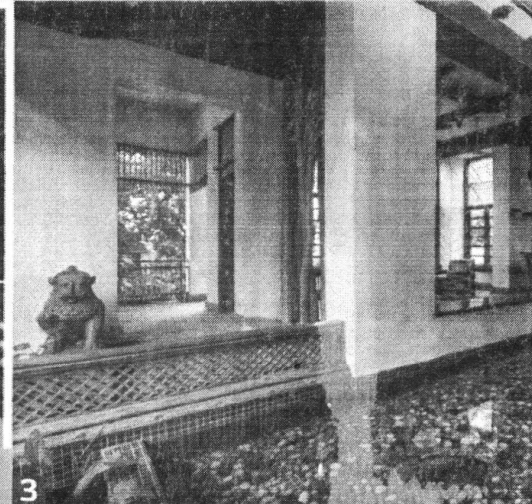
Location : 20° 14'



2

Design Elements & Features

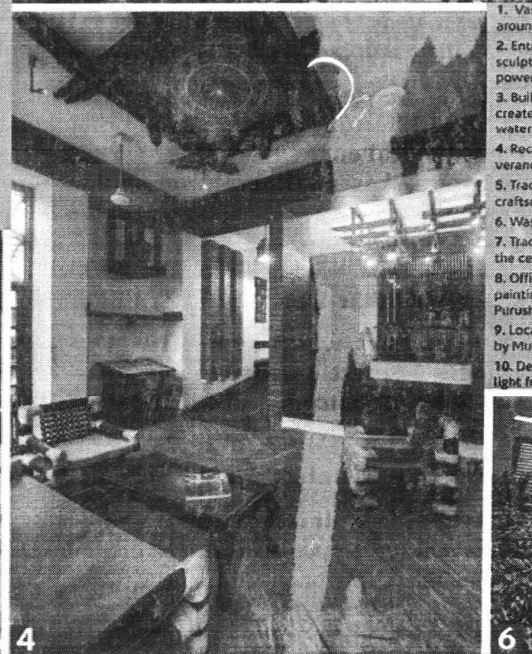
- Double Height
- Narrow Floor Plates - Minimise artificial lighting
- Front and Vertical Louvers for Maximum Day-Light
- Open Verandah replaces Lobby
- Central Water Body
- Visual Links
- Devoid of aesthetic pretensions
- Clear Storey
- Visual link with green
- Low Surface Area to Volume Ratio



3



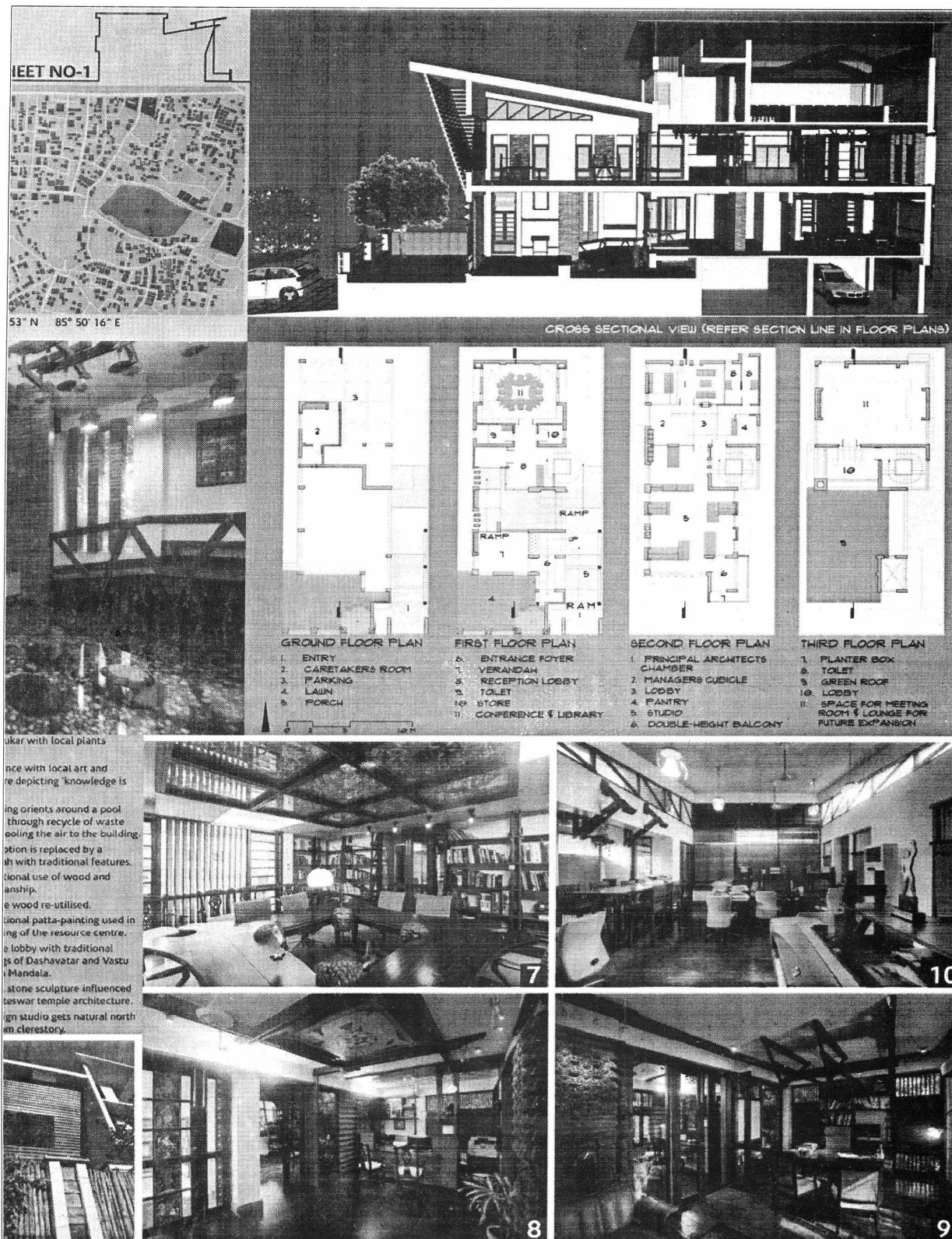
5



4

1. Vastu around.
2. Extra sculptural power
3. Build created water c
4. Recei veranda
5. Tradit craftsm
6. Vastu
7. Tradit the ceil
8. Office painting Purusha
9. Local by Muk
10. Des light fro

6



The Institution of Engineers (India)



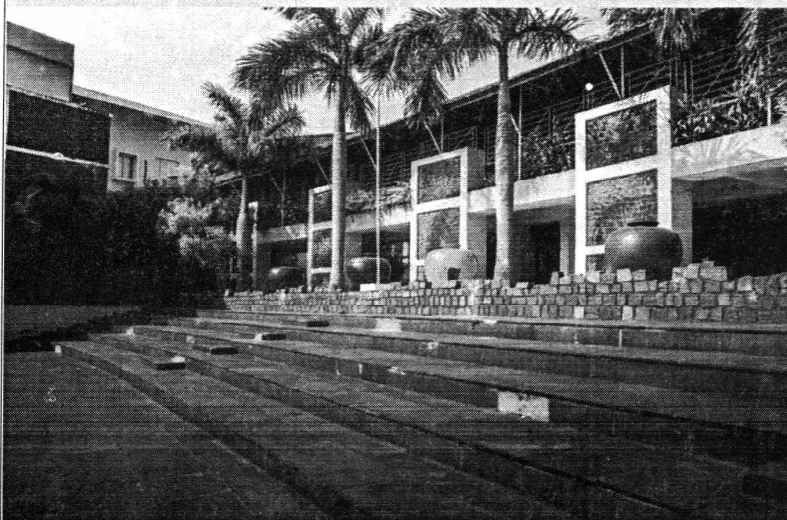
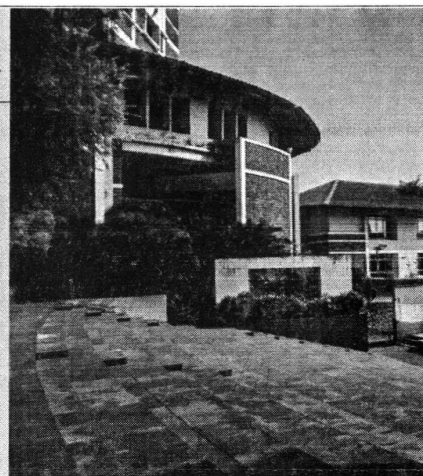
Kalinga International Public School

Bhubaneswar, Odisha, India 2012-14

SHEET NO-1

Submission Category: LIVING SPACES : LEARNING INSTITUTION (Campus Design)

1. Kalinga International Public School is an adaptive Re-use of old factory building.
2. Built in the downhill of Shikhar Chandi Temple, the campus is responsive to the topography of the land and the building blocks are placed at various levels along the terrain.
3. The design of the building reflects care and concern for children.
4. The buildings have been built out of locally available Blue Basalt stone, a form of Granite.
5. Geometry plays a very important role in creation of interesting shapes and forms through interpolation of various basic shapes have been experimented through a generative approach.

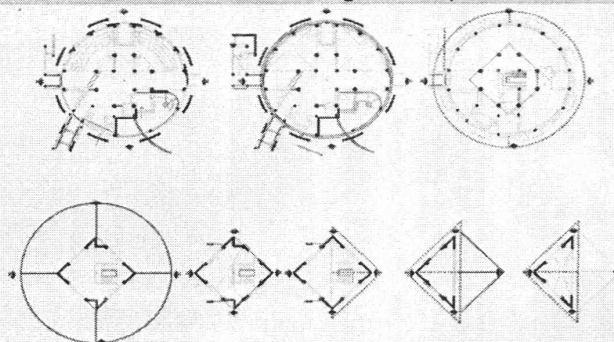


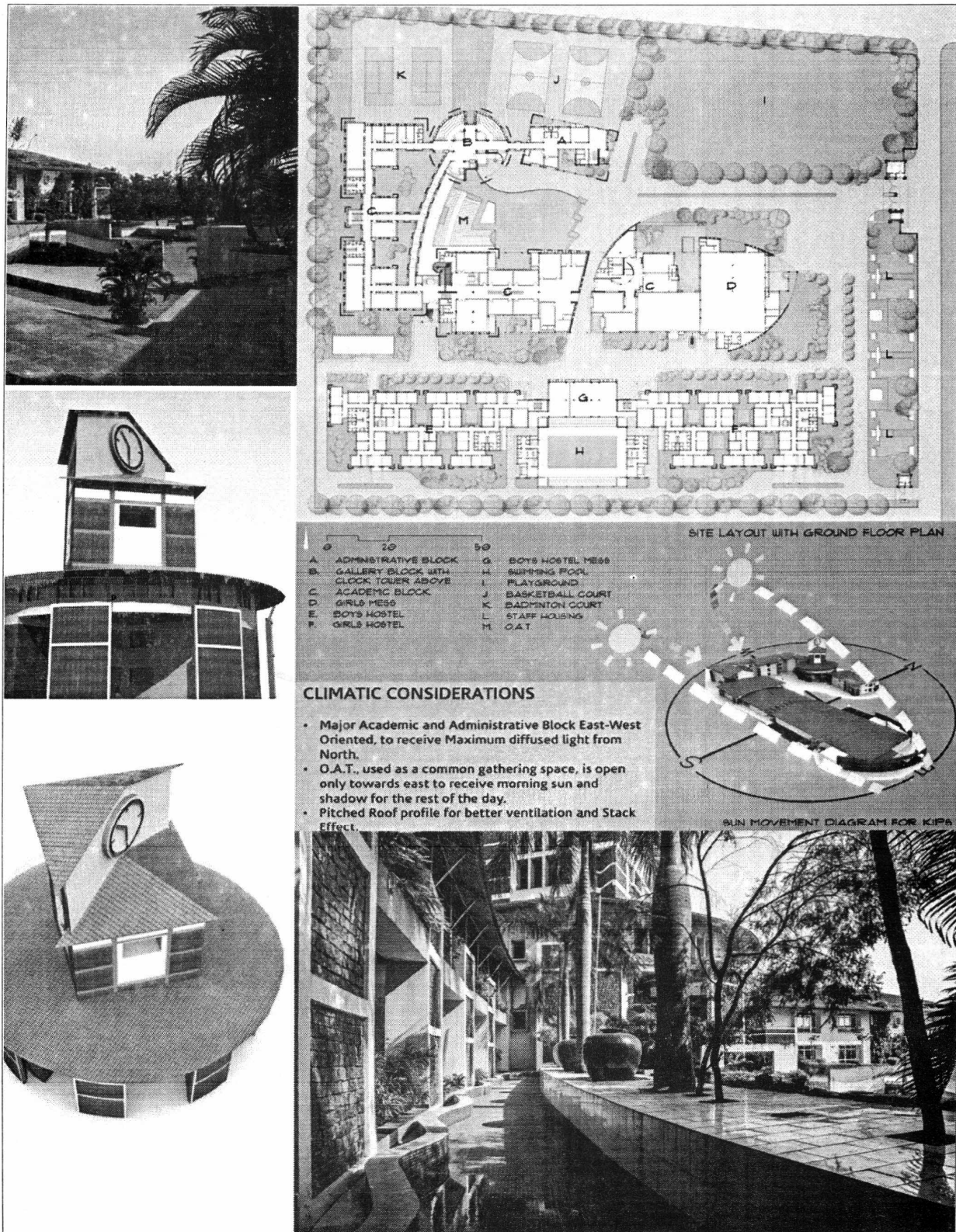
Above
View of O.A.T. serving as the connecting space in between the blocks

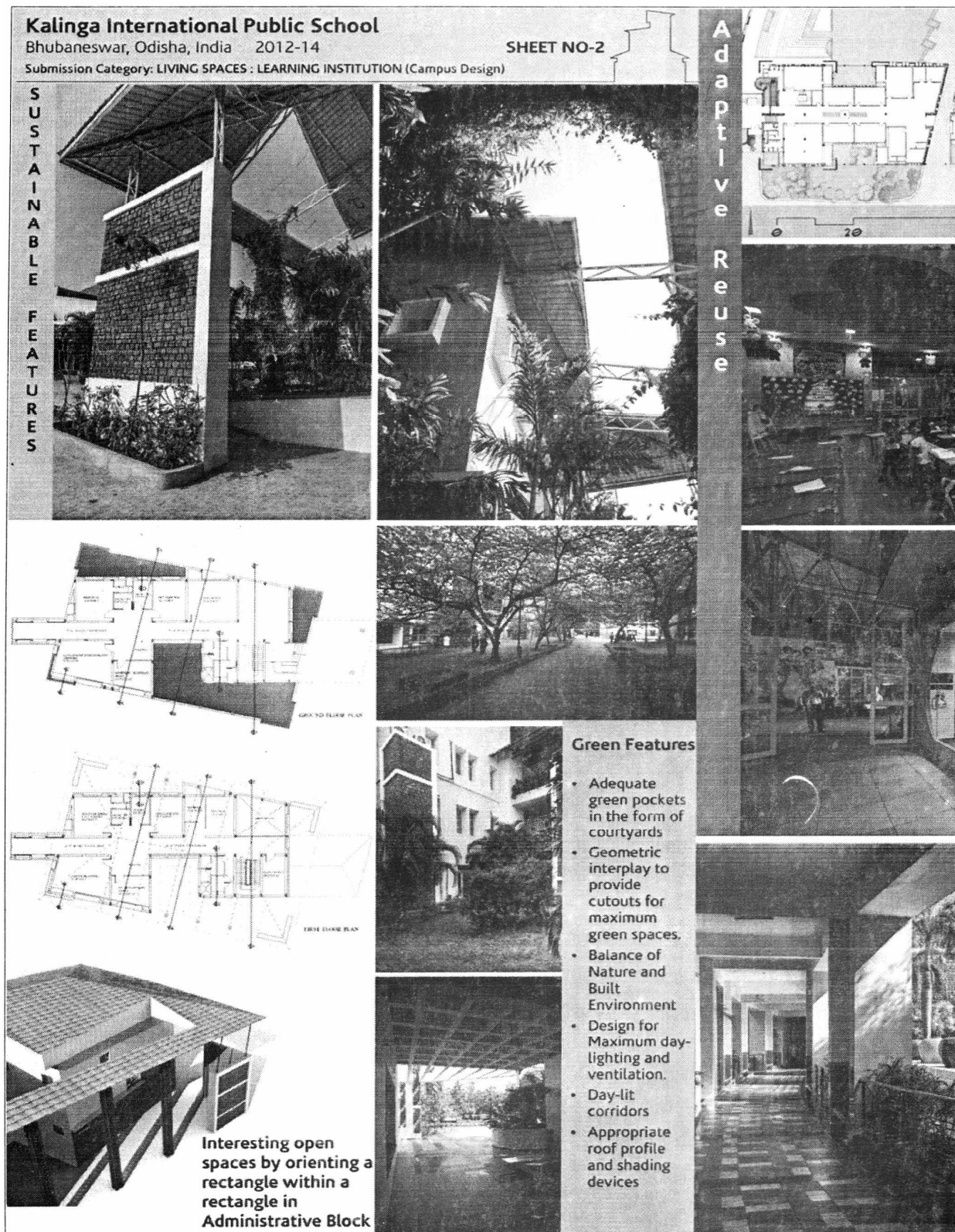
Above
Triangular cutout in the roof of administrative block for additional day-lighting

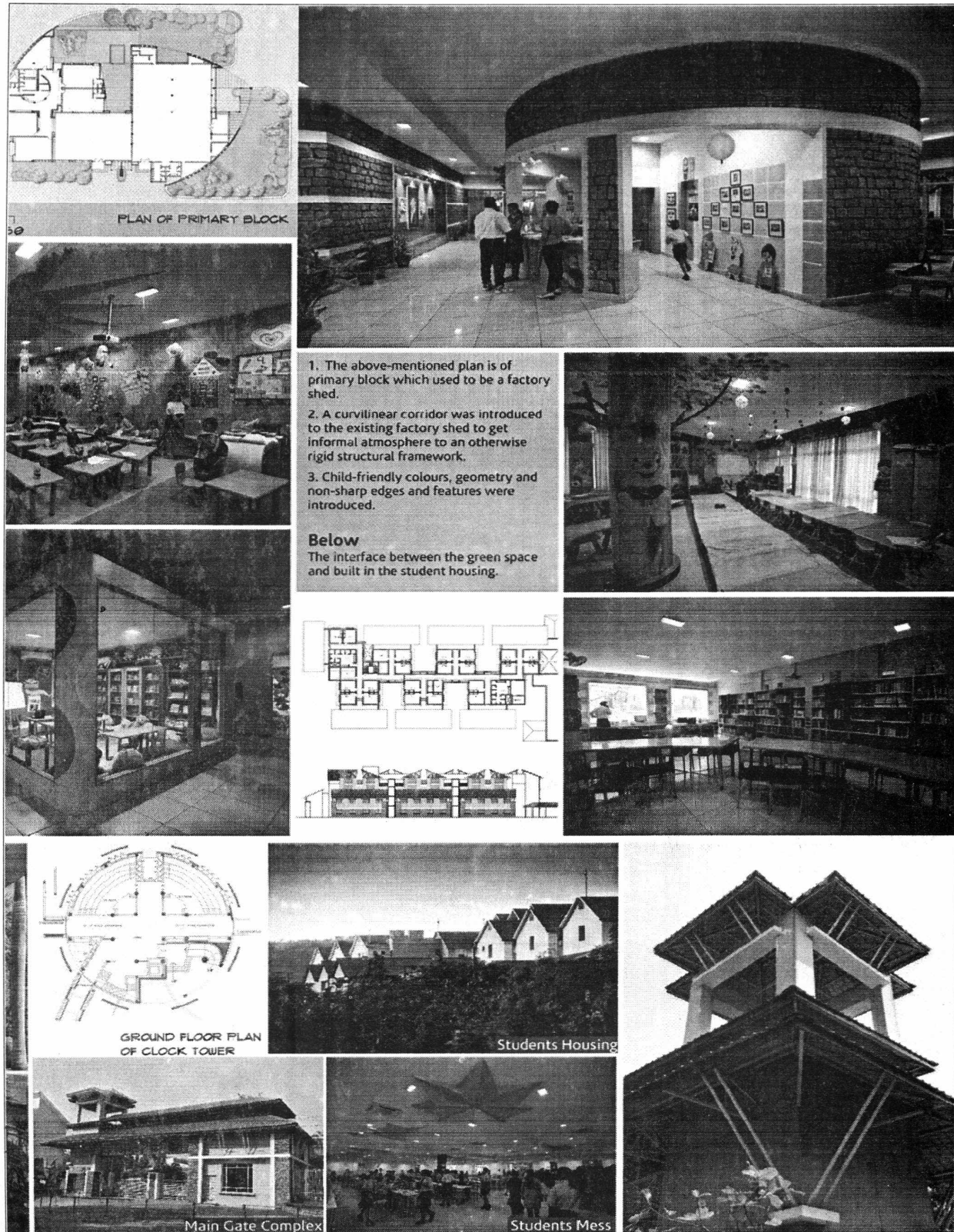
Left
A view of the iconic clock tower from O.A.T.

Right and Below
Geometrical transformation of clock tower from a circle on ground floor to triangle in the top floor











Er T S Narayana Rao Memorial Oration

Dr Balagopalan T S Prabhu, *FIE*

Respected members of the dais, honourable members of the organizing committee of this national convention of Architectural Engineers, esteemed guests, delegates and fellow engineers,

It is a great honour to stand before you and deliver this Er. T.S. Narayana Rao memorial oration. Er. T.S. Narayana Rao was a doyen in the Civil Engineering field, who put up a flourishing Architectural and Engineering consultancy in Bangalore and who inspired many generation of engineers to serve the society through ethical professional practice. However his contribution to the society will be remembered more for his concept of integrating architecture and engineering in the creation and delivery of building and taking initiative to start the Architectural Engineering Division in 1978 in the Institution of Engineers (India). Karnataka can take pride in lasting contribution to society in many areas, like the Karnatic music, the culmination of Indian temple architecture and the blending of Engineers with Statemanship demonstrated by Er. M. Visweswaraya. The concept of Architectural Engineering, I am sure is a similar concept in which the tradition of crafts and the wisdom of creation and governance can synthesise in building the humble homes of the poor or the grand edifices of the nation.

Er. T.S. Narayan Rao was just a name in the list of Architectural Engineering directory of IE(I) with No. FIE 000227/1, when I joined this division in 1982. After my graduation in Civil Engineering in 1962 and after taking up various assignments like design engineering at Heavy Engineering Corporation, Ranchi, a short spell in teaching, post graduation in Architecture and Town Planning at College of Engineering, Pune, Ph.D. in City Planning in IIT Kharagpur and the work of a Town Planner at GCDA, Kochi, I had returned to REC Calicut as an Assistant Professor in Civil Engineering Department with the seed of Architectural Engineering in my mind. In 1984 I was deputed for discussion to set up a Building Science Lab in Civil Engineering Department jointly with Building Technology Division of Civil Engineering Department of IIT Madras. This was a positive stimulus and I presented a report on starting a Architectural Engineering course at REC Calicut as a diversified course of Civil Engineering. The entire credit of following up this proposal at Delhi and in the Board goes to Dr. S. Unnikrishna Pillai, FIE, who initiated this novel course at REC in 1985 under CED. I was put in charge of this division in 1989. Unfortunately, in 1999, soon after his retirement, the course was discontinued, owing to "internal politics of the college, university, government and some professional body" as described by Er. T.R. Krishnan in his Inaugural address of 31st National Convention of Architectural Engineers held in Calicut in 2015. He adds ".... In 2000 AD Govt. of India decided to transform all REC's as autonomous bodies with administration set up similar to that of IITs. Had this change been made a few years earlier, this would not have happened". Some 400 Architectural Engineers have come out during the 10 years of the existence of this course and they occupy high position in various sectors of India and abroad.

I stand here today as a soldier who fought a lost battle. But I am happy to note that NBC 2005 recognised Architectural Engineer as at par with Civil Engineer. American Society of Civil Engineers approve this as one of its specialised division. All over the world Architectural Engineering is viewed as a multi disciplinary profession concerned with every aspect of design, delivery and maintenance of buildings. In this term the concept of Architectural Engineering as an integration of Architecture and Engineering becomes more relevant today. Here with technological advancement, even architecture of building is viewed only as a subsection of Design Engineering and hence Architectural Engineering can be truly viewed as a multi disciplinary field incorporating all branches of engineering – Design Engineering, Infrastructure Engineering, Mechanical Engineering, Electrical Engineering etc.

What is the position of Architectural Engineering today? The IE(I) have already a national membership of about 175000. The corporate membership of ARD is less than 500 or only 0.3 percent - only 3 out of 1000. There is no B.Tech. or M.Tech. course in this subject. The section B AMIE exam started in 1984 was discontinued in 1989 and although it was restarted in 2010 then are no taken. Even the Diploma holders in Architectural Engineering courses run by all Directorate of Technical Education of State would prefer to join B.Tech Civil by parallel entry rather than write section B of AMIE. Civil Engineers applying for ARD are directed by IE(I) to join in CED and then request for division transfer. All these have to change if ARD is survive the closure of division.



IE(I) has always been an open for any aspirant from the level of matriculate to rise up to PE. It served its purpose when technical institutions were few in the country and provided facility for professional development in core areas of engineering and sharing ingenuity for social and economic development of the nation. It was also amenable for changes. When ARD was started it admitted Civil Engineers and Architects.

Today there are more than 3500 engineering colleges admitting some 16.70 lakhs students. Among them only NITs, IITs and few Institutions of Eminence are having full strength and almost 1400 colleges have filed application for closure to AICTE. The turnout of graduates is about 40% of the admission and employability is only for half of it. Increasingly the options for graduates will be self employment. Building sector will be the largest sector in this context. It is also one sector with increased inputs from other disciplines for building services, comfort engineering and competitive economic production.

Professionally, ARD can take a note of this and expand its admission criteria open to graduates of all branches of engineering and also architects to the division to really have an integrated approach as conceived by Er. T.S. Narayana Rao. Similar professional approach can be adopted to welcome corporate members of IE(I) from other divisions who are engaged in areas related to any aspects of building to change over to ARD. In both the above cases, short term professional development courses may be offered in subjects such as

1. Theory and design methodology of buildings
2. Advanced building service engineering
3. New materials and techniques of construction
4. Ekistics and landscape engineering

Pedagogically, there are two solutions, one will be to start M.Tech. (Arch. Engg.) courses with multi disciplinary admission. This scheme is presented in detail in my paper in another session. The second solution will be to introduce Architectural Engineering as one of the several mandatory professional track in the Civil Engineering course as indicated in the AICTE model curriculum 2018 at U.G level. Students who opt for this track can take electives in this track for subsequent semesters to get an honours degree in Civil Engineering with minor in Civil Engineering. Both these options can be easily adopted by NITs, IITs or other institutions of eminence.

I hope and pray that the dream of Er. T.S. Narayana Rao will be realised starting from Karnataka State. This will put this State as a pioneer in innovation in Engineering Education in the whole of the nation.



Reengineering of Buildings — An Exploration into Timber Technology

Dr P Gireesan

Superintending Engineer, Kerala Water Authority

ABSTRACT

Re-engineering has been evolved as a techno-managerial discipline from the early concept of fundamental rethinking and radical redesign of the business processes to achieve dramatic improvements in performance of an industry or organization in critical areas of cost, quality, service, and speed. When applied to building industry, reengineering takes up more challenging and versatile nature owing to the varied practices evolved from even before the beginning of human civilization and settled life. The process envisages optimization of various activities leading to value addition, energy savings and meeting utilitarian needs of the masses. For achieving this goal, it requires a holistic approach integrating development and adoption of the new materials and products by reengineering of production process and optimization of construction process. In building industry the material plays a key role in addressing the functional needs, strength requirements and aesthetics. Clay, rocks, sand, and wood, the natural materials form the domain of building materials either in raw or engineered form supplemented by synthetic materials. However the materials and products of natural origin occupy the core of the industry and novel products and forms are entering industry with promising potential to meet the needs of the contemporary social life.

Of the natural building materials, timber plays a dominant role in Civil as well as Architectural Engineering constructions all over the world with varied applications. Timber has been evolved as the most acceptable and sustainable building material. Over the years varied and fine techniques have been developed in processing this material to fit construction in different contexts in structures and utility items. Timber finds its place in superstructure and even in foundation. The potentiality of timber in auxiliary uses such as doors, windows, ceilings, floors, claddings etc is immense. Though several alternative materials have been introduced in recent times, timber continues to be a versatile material in its natural or reconstituted states.

The prospects of furthering the use of timber by reengineering timber technology in the context of its immense potentiality as a sustainable material are explored here.

1.0 INTRODUCTION

Construction forms the infrastructure for socioeconomic development for the sustenance of the quality of life of the people. Materials form the basic resource for construction along with man power, equipments, finance and time. Timber has been traditionally used as a structural material in its pure form from time immemorial. A great deal of techniques has been developed to improve the properties of this natural material forming the realm of reconstituted timber technology. Timber having the advantages of universal availability in variety of forms, technological properties to resist axial flexural or torsional loads, good serviceably and potentiality of conservation to increase life and scope of recycling retains its status as a promising building material. The challenges posed in reengineering timber technology are (i) the need to address the anisotropic or heterogeneous nature (ii) amenability to decay owing to attack of insects, fungi and bacteria, (iii) substantial variation in properties depending on factors like moisture content, temperature, exposure to natural phenomena, loading condition etc. and (iv) extreme variation in properties in regions and amongst varied types making it difficult to standardize. However, with the modern developments of seasoning techniques, conservation treatment, structural strengthening and quality control, the disadvantages of timber can be overcome to a large extent. The strong craft base provides a strong technologic input for reengineering timber technology.

2.0. TRADITIONAL KNOWLEDGE BASE OF TIMBER TECHNOLOGY

Use of wooden structural elements in construction dates back to the primitive life when man used fallen trees to bridge natural water courses. Timber technology has got a vast evolutionary history to the current times. Wood had primacy in the building of houses and has influenced the evolution of architectural forms. Secondary timber,



bamboo, bough of trees, branches and leaves were used for making walls and roof of huts, sheds for temporary uses, rural houses, cattle sheds etc. More sturdy trunks as such were cut and jointed to make log houses, for more durability and thermal insulation especially in cold climates. Timber logs were also used as stiles driven in the earth to form early pile foundation. The working platform of timber was directly constructed over these styles, eliminating the need for a basement and plinth. This type of construction was specially adopted near river banks, marshy areas and paddy fields. In places amenable to seismicity, timber framed walls were put up with posts embedded into the ground to form a flexile structure. The openings in the frame were filled by stone in mud mortar to serve as shear walls. The traditional knowledge base was developed addressing various needs and adversities and it is capable of addressing the disadvantages narrated above to reasonably good extent. Consideration of sustainability with due regard to protection of nature, optimum utilisation by means of identifying and adopting in areas of secondary structural importance, fine techniques for providing aesthetic appeal to the exposed surfaces, development of different joinery to suit for the structural behavior, preservation techniques to improve durability etc have been the key elements of the traditional knowledge base in timber technology. Because of this, the traditional practices still enjoy adoptability in rural regions all over the world. Re-engineering timber technology become easier for the same reason, at the same time it poses challenging avenues to elevate status of timber to a modern building material.

3.0 DEVELOPMENT IN TIMBER TECHNOLOGY

Timber technology embraces the studies on the biological structure of wood, physical and mechanical properties, the behaviour under changing environment, degradation by insects and bacteria and preservation for durability of timber elements. It encompasses wood anatomy, processing of timber, seasoning and chemical treatment, industrial processes and end use management. The structure of wood varies with species, age, growth and climate. Its properties vary with the directional planes - transverse, radial or tangential. The use of timber is dependent on the physical properties - appearance, density, strength, dimensional stability, penetrability and durability. As these properties are influenced by moisture, seasoning is an imperative process in timber technology.

Timber is anisotropic in character. Being an organic material, it is the food for insects and bacteria. Control of insect attack is hence an essential preservative process for timber. Chemicals are commonly used for preventing the damage by decay, fungi or insects. They may be water soluble like Borax, Copper Sulphate or Copper Chrome Arsenic mixtures, or water insoluble like mineral oils or Penta Chloro Phenols in Kerosene. The chemicals may be applied under pressure or by brushing.

Durability, fire resistance, thermal and acoustic properties are also important in the engineering application of any material. But, by far the most important considerations are the mechanical properties of timber - under axial loading, shear, flexure, impact and torsion. Standard test procedures have been evolved for studying the mechanical properties of timber on clear specimens. SP: 33 of 1986 summarize the code provision regarding the structural timber. It includes.

1. Classification of timber for structural uses.
2. Selection and identification of structural species.
3. Design stresses and their variation along different planes.
4. Timber design methodologies for beams, columns and trusses.
5. Floors, Ceiling, Wooden stairs and doors and windows and
6. Fire retardant treatment and anti-termite construction

4.0 DESIGN PHILOSOPHY FOR REENGINEERING

Timber has occupied its place in varied structural forms and systems such as framing. It takes up the role as a versatile and capable part in various building systems. The use of timber elements in conjunction with concrete and steel elements has been a recent development. Of late, timber is being used in framed form in various types of claddings (eg brick, render and timber). However, the integration of materials, such as steel and concrete, into floor and wall elements of timber frame construction requires special consideration as to the movement of timber with changes in moisture content.

In the context of re-engineering timber technology the design philosophy shall consider the following:

- Designing within the limits of standard timber components (eg joists)
- Using optimum sizes of timber and engineered wood products
- Designing within the limits of transportation, lifting and manual handling\



- Designing to coordinate the timber frame with the frame work of other materials (building heights, widths, openings etc)
- Avoiding changes in load lines and planes
- Adopting dimensional grids to suit standard sizes
- Keeping the wastage of materials to minimum
- Predetermining the service voids at the preliminary design stage
- Avoiding interfacing with other forms of construction that have different characteristics
- Minimising the amount of cross-grain timber
- Using specially conditioned timber
- Incorporating provision for differential movement to improve structural performance
- Adaptation of modern techniques and use of reconstituted timber

5.0 ADOPTION OF RECONSTITUTED TIMBER

Over the years there has been great development in processing secondary timber varieties, agricultural wastes, and wood industrial residues and making reconstituted timber of higher strength and durability which contribute to the process of reengineering timber technology. The products such as (i) Plywood for structural and decorative uses (ii) Fibre boards or hard boards for decorative or insulation uses (iii) Particle boards for structural purposes, (iv) Block boards with veneers for paneling and shutters and (v) Glued laminated (GLULAM) structural members for large span uses etc. offer a great deal of scope for efficient buildings with timber. Variety of products being manufactured and marketed today find application in Thirty Fifth National Convention of Architectural Engineers flooring, cladding, doors paneling, ceiling work, thermal insulation, acoustic purposes, cabinet making, furniture, interior decoration and such other uses when strength, lightness, resilience and aesthetics are needed ..

'GLULAM' manufactured by bonding planks of wood together has attained wide range of applications recently. It is formed by planks bonded together on their wide face. Bonding is carried out using adhesives. This process has the advantages such as (i) possibility of making members in virtually any size and shape, (ii) Increased strength obtained by dispersing strength reducing characteristics throughout the member, (iii) Better dimensional stability achieved since produced from dry lumber.

By research and development, it has been possible to manufacture many new products like bamboo boards, coconut wood panels and rubber based boards, in India However, using the extensive variety of timber species not being exploited so far for their potentialities still leaves down ample scope for research and development for meaningful adaptation in potential building industry.

6.0 DEVELOPMENTS IN JOINERY

The emergence of metal fasteners in varied configurations to connect two or more timber members is a welcome development that gives a promising future for reengineering timber technology. This may be by simple butting of timber ends and the use of bearing or lapping plates at the joints for bolted connections. Toothed rings can be fixed on the members to resist shear. Metal fasteners have simplified the timber joints and they are extensively used to day in USA and Europe. The main advantage of metal fasteners is that they can be designed or selected as per design strength of members.

An off-shoot of metal fasteners is the lamella construction. Vast domes, or space frames can be fabricated using small length of timber, bent and connected in the required configuration. The short curved timber members are joined together by bolts at an angle through another member bored through its centre. Lamella roofs are used for assembly halls, pavilions etc. Depending on the span the individual lamella units can be fabricated in workshops and erected at site conveniently on buttressed columns or foundation blocks.

7.0 HARDWARE IN JOINERY

Hardware in timber joinery consists of fasteners used to connect two or more timber members. It provides continuity to the member as well as strength and stability to the system. Of the two basic types of connections viz. Lateral and withdrawal types, lateral (shear) connections transmit force by bearing stresses developed between the fastener and the members of the connection while withdrawal connections transmit load by pull-out resistance.



The following form the popular hardware in timber joinery

Bolts: Used in both lateral and tension connections where moderately high strength is required. Nuts and washers are applied to maintain tightness and transfer load. In lateral connections, load transfer takes place as bearing between the shaft of the bolt and the timber member. In withdrawal connections, load transfer takes place as bearing between the bolt head or washer and nut.

Timber Connectors: A steel ring or plate is bolted between laterally loaded members. They provide high strength due to their large bearing area. Load transfer takes place as bearing between the plate and the member.

Lag screws: Similar to bolts but provide lower strength. This type of connection is used both in lateral and tension connections. In lateral connections, the strength mechanism is bearing between the shaft of the screw and the timber member. Lag screws are typically used where access to the connection is convenient from only one side.

Nails and spikes: Driven fasteners are used primarily for non-structural applications. This type of fastener is susceptible to loosening due to vibration and moisture change.

Drift bolts and drift pins: Long unthreaded bolts or pins driven into pre-drilled holes. These are typically used for lateral connection of large timber members and are not suitable for withdrawal connections due to low resistance to withdrawal.

8.0 CONCLUSION

Timber provides vast scope for employment in construction of modern buildings. Timber is the only replenishable structural material, available all over the world, in a variety of species and with different properties with a wide scope of improvisation. Although timber is one of the earliest building material, not much attention has been paid to its potential use in the form of built-up sections in beams and columns, trussed rafters, space frames etc. Potential areas of use in composite form are also left ignored. The advent of metal fasteners has furthered the scope of application. Thus, engineering applications of these techniques are very vast, both for temporary, permanent and floating construction. Timber structures are eco friendly and energy efficient. Emphasis on this technology will also promote scientific practices in timber plantation; wood preservation, and recycling of timber. For countries like India which has a great tradition in timber craft, this engineering input will be an invaluable contribution to realisation of the modern concept of sustainability.

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