SUSTAINABLE BUILT ENVIRONMENT IN HIGH SEISMIC ZONE: CASE STUDY OF A MODERN TOWNSHIP IN THE NORTH EASTERN REGION OF INDIA

[1]Prof. (Dr.) Thiruvengadam V., Department of Building Engineering and Management.
[1]Email: thiruspa@rediffmail.com

[2]Prof. (Dr.) Mehta Rommel, Department of Landscape Architecture.

[3]Wason J.C., Visiting Faculty and Structural Engineer.
School of Planning and Architecture, I.P.Estate, New Delhi-110002 India.

Abstract

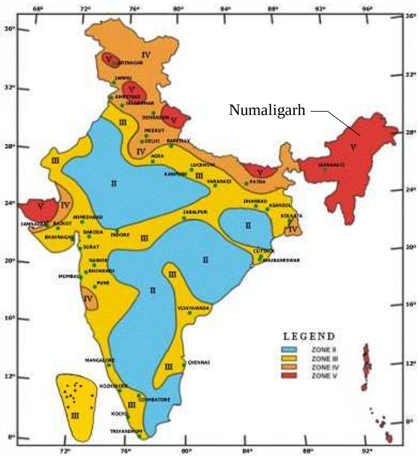
The paper presents the details of sustainable aspects related to earthquake safety measures adopted in a recently constructed modern township in the high seismic prone north east region of India. This medium sized township constructed for the employees of Numaligarh Refinery Ltd is situated near Numaligarh, a small town in the Golaghat district in the state of Assam. The site is ecologically sensitive, densely vegetated and with steep undulating topography with deep valleys and background moderate hillocks. The site falls under severe seismic zone in the seismic map of India.

A seismic and sustainability conscious approach has been adopted in the planning, design and construction of the township. Site and landscape planning, building Architectural configurations, Structural and foundation systems and Infrastructure services are done to ensure safe and sustainable built environment with specific emphasis on earthquake safety and maintaining the natural landscape and ecology of the site.

Keywords: *Sustainability, built environment, seismic region, earthquake safety.*

1. Introduction

This paper brings out the planning and design concepts adopted for the establishment of a modern medium sized township located in an ecologically sensitive and very severe seismic zone in the north east region of India. The township is situated on the bank of the river Kalyani near Numaligarh, a small town in the Golaghat district of Assam. The site falls under severe seismic zone in the seismic map of India. Comprehensive architectural services including site and landscape planning, structural engineering, infrastructure services, construction specifications and cost estimates were carried out by the School of Planning and Architecture, (SPA) New Delhi, a premier educational institute in the field of Planning and Architecture.



Seismic Map of India

The Original Site Condition
Still Retained in Areas within the Site

The main aspects covered in this paper are the planning, design and detailing for earthquake safety and various measures adopted for ensuring minimum impact on the environment and protecting the natural landscape of the area to achieve a safe built environment in an earthquake disaster prone region. The environmental protection was secured by strict adherence to damage prevention measures for existing landscape during execution and by ensuring that the proposed landscape is low maintenance.

2. Built Facilities and Infrastructure Services

The township is built to cater the residential requirements with associated facilities for the staff of the Numaligarh Refinery Ltd Assam. The refinery complex is located at about 4 km from the township location. The gross area of the township is about 250 acres including the non buildable hill slopes, natural valleys and drainage channels. The built facilities comprise of about 600 residential units in five categories of built-up areas, guest houses, recreational facilities in the form of club houses with swimming pools and play fields, primary and secondary school, hospital, community centre and convenient shopping, township park. The civil infrastructure services provided are; road network, water supply storage and distribution, sewerage collection and treatment, electrical substations and power distributions, street and area lighting and close circuit cable TV system.

View from the site towards the rive

NRLTownship Site

3. Site Characteristics

3.1. Site Topography

The eastern part of the township overlooks the scenic and meandering Kalyani river flowing adjacent to the eastern boundary of the site. The northern and western sides are hills with few identifiable low peaks. There is a general slope of the site towards the south. The valleys originate from the central ridge line draining out towards all the sides. The edges of the valley are at times having greater than 80% gradient but are well protected by dense natural vegetation against erosion. The undulating contoured land profile consists of ridges and natural valleys with dense vegetation.

The valleys divide the land into plateaus of undulating topography generally used for tea plantations. The elevation variation within the site ranges from 83 to 94 meters. The topographic survey was a difficult task due to steep slopes and with dense moist evergreen natural vegetation and tea gardens covering the entire site. The site rises abruptly above the flood plains of the river and proposals for reclaiming of some low areas adjoining the flood plains were not recommended for building activities.

3.2. Geotechnical Parameters: Subsurface Soil Conditions

The geotechnical technical investigation of the subsurface conditions showed varying soil conditions at different pockets of the township site. The soil conditions are generally medium type silty clay or clay with medium to high plasticity. The groundwater table is encountered at 2 to 5 m below the natural ground and the chemical analysis of subsoil water showed higher iron content. The allowable bearing pressure of soil is governed by settlement considerations and varied from 75 kN/Sqm to 120 kN/Sqm determined based on field and laboratory testing of the soils. The soil characteristics not being saturated loose sand have no potential for soil liquefaction under earthquake vibrations

3.3. Site Seismicity and Climatic Conditions

The township site located in the north east region of India which falls under seismic zone V, a very severe seismic zone category in the seismic map of India. The expected seismic intensity is IX on MSK 64 scale with potential for heavy damage. The seismic parameters used in the design are as per IS 1893-2002 (1). This Assam region has experienced two major earthquakes in the past, one in the year 1897 with a magnitude of 8.7 and another in the year 1950 with a magnitude of 8.50 indicating the severe seismic vulnerability of the region. The region experiences heavy rainfall from south west monsoon and falls under tropical hot and humid weather prevailing most of the summer and monsoon months. Total average annual rainfall is 1300 mm. and the heaviest rainfall in 24hours is 167mm. Maximum precipitation occurs in June and July. Maximum temperature is 38.0°C in June and minimum temperature is 10.0°C in December. The region falls within the 'Humid Subtropical' climatic zone of India.

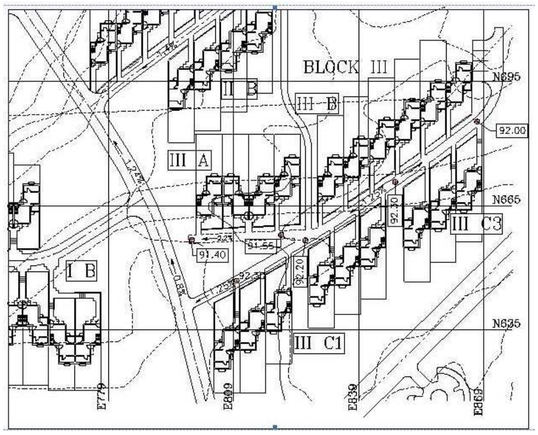
4. Site Planning and Landscape Design

The design programme emanated from the relationship amongst existing landscape, proposed design and sustainability. The basic goal of the design program was to protect and maintain the ecosystem of the site and ensuring least disturbance to the regional environment. Four components of the design were: environmental protection and perpetuation of bio-geo-chemical components, protection of existing vegetation, maintaining the prevailing hydrological systems – particularly the surface drainage discharge rates and routes, prevention of environmental damage during execution and maintaining the visual characteristics of the unique site. All this was achieved even after installation of the infrastructure services, the construction of buildings, and the vehicular and pedestrian circulation systems. The direction taken in realizing these program goals was a direct product of the alignment of design philosophy and approach of the client and the consultant. An integrated relationship, of pedestrian and vehicular circulation system with the sites storm water functions, has been achieved. Natural systems of existing plant communities and tea plantations were retained to a large extent to improve site sustainability. Substantial parts of site, on completion of project, were retained as low maintenance landscape zones.

A number of sustainable features are incorporated in the site and landscape planning aspects of the township. Buildings are avoided on hill slopes and near to the edges of the deep valleys. The existing land profiles of the plateau were left practically undisturbed without resorting to large scale cutting and filling and land reclamations. Minimum site grading surrounding the buildings are done to enable the location of the services and smooth flow of the storm water to the nearest valleys. The natural drainage paths of the site are left undisturbed and the existing landscape with dense vegetations is maintained. The alignments of the roads generally restricted to ridge lines are carefully planned and geometry suitably designed to achieve minimum earthwork. Crossing of the deep valleys are avoided eliminating the need for heavy bridge constructions but managing the storm drainage with few culverts. Unstable slope conditions are protected with low height breast walls with proper drainage arrangements. During construction operations restrictions were imposed not to dispose construction wastes in to the natural valleys.

5. Building Typology

The building typology adopted is low rise two storeyed constructions with light roofs. The form, height and roof lines are designed without dwarfing the tree heights and naturally vegetated landscape. For better utilization of buildable areas and community living residential units are designed as medium sized clusters scattered on the plateaus surrounded by ravines and drainage valleys. Topography determined the placement of the clusters resulting into aesthetically pleasing built environment. Due to contoured ground profile, varying plinth levels are adopted within the same clusters to avoid heavy site grading. However such situations complicated the structural aspects and roof forms which are resolved through careful design and detailing. Individual clusters are provided with small garden space in the front and with vehicular approach.



Type B Cluster Plan

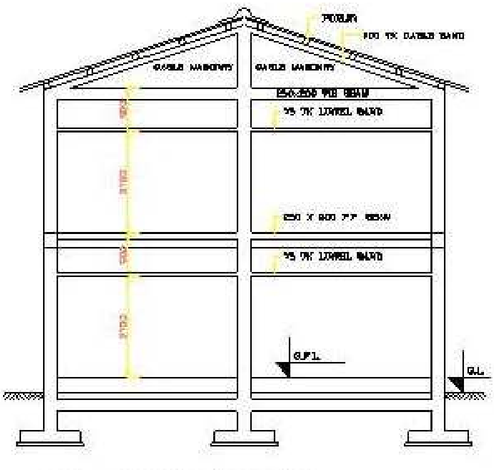
Type B Cluster

6. Building Architectural Configurations

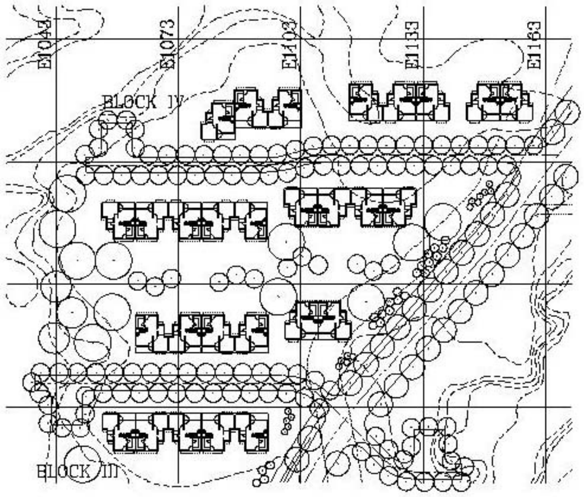
Compact building forms in terms of size, proportion and mass provided seismic resistant architectural configurations. Long building clusters for residential units are divided into compact lengths with the provision of seismic joints which also serve as expansion joints. Non residential buildings with unsymmetrical plans due to functional planning and site constraints are converted into simple and compact rectangular blocks with the provision of the seismic joints at appropriate locations. Buildings with open ground storeys are completely avoided. Due to high rainfall conditions, sloping roofs are adopted with light corrugated galvanized iron sheets in tune with the local construction practices. The light roofing systems provided the advantage of reducing the building mass that would result into reduced inertial forces during earthquakes. Buildings are mostly oriented in North-South directions from the considerations of better ventilation and thermal comfort.

Type C Unit

Type C clusters integrated with existing vegetation



Typical framing arrangement



Type B Cluster Plan

7. Building Structural Systems

Besides adopting suitable overall built forms and individual building configurations for reducing the vulnerability for earthquake damages, efficient structural system that could safely withstand severe earthquake forces are used. Special moment resisting reinforced concrete frames with ductility detailing are adopted to ensure the essential requirement of ductile behavior to avoid major damages and collapse situations under severe seismic conditions (2). The ductility detailing essentially provides adequate beam-column sizes for improved joint rigidity, adoption of closely spaced stirrups near as well as within the beam-column junctions as confining reinforcement, anchorage of beam bars into column members, 135^0 hooks for the effective anchorage of stirrups, adequate compression reinforcement and richer concrete mix. Although the brick masonry filler walls are treated as non structural elements, they would participate in the earthquake resistance as shear panels. The lintels over the doors/windows openings are made continuous between the columns and cast over the masonry filler walls and act as their horizontal stiffeners for improved seismic behavior. The top ends of the columns in the upper storey at in the roof tie levels are also connected with tie beams for the complete frame action.

As stated earlier, the material for the roofing system is light corrugated galvanized iron sheets fixed over steel tubular purlins supported over steel tubular trusses properly anchored with anchor bolts on columns/roof tie beams. The geometrical shapes of the roofs are as per the plan configuration of the buildings and are generally hipped roof system avoiding masonry gable ends which are susceptible for earthquake damage as observed in the past earthquake damage studies. However, in situations where gable ends are provided, such free standing walls are properly confined with reinforced concrete bands which are tied to the main structural frame. The trusses are provided with diagonal bracing to improve the diaphragm action at the roof tie level. For the external shading elements over the window openings, reinforced concrete chajjas are avoided due to the problem of rebar corrosion of these exposed elements in such moist high rainfall conditions. Instead, shading elements with corrucated galvanized iron sheets over steel tubular members are provided which also enhanced the aesthetic appearance of the building elevations. From durability considerations the thickness of galvanizing coating was specified as 0.80mm.

Senior Secondary School *School Hostels*

Both Represent an Architectural Expression of Sustainability

8. Foundation System

With the adoption of two storeyed constructions with light roofing system in moderate soil conditions, the foundation system with simple reinforced concrete isolated footings under the individual columns are adopted. For the integral action of the footings under earthquake motions and also to take care of possible differential settlements, grade beams connecting the individual footings in mutually perpendicular directions are provided. These grade beams, generally provided at 150 mm below the final ground level, also support the internal partitions and external enclosure brick masonry walls of the buildings. Due to undulating topography, placement of the footings of the adjoining columns at different levels are improved by taking the upper footing at a deeper depth so that the level difference between the founding levels of the footings is not more than half the distance between the edges of the footings. The buildings are carefully located at site so as to keep minimum distances between the foundations and edges of valleys.

9. Infrastructure Services

9.1. Water Supply Storage and Distribution System

The source of water to the township is from the river Kalyani and raw water is treated for the removal of suspended solids and other impurities in a water treatment plant located near the refinery site. The treated water is received in the township site in an underground storage tank of 16 lakh liters capacity catering about one and half days storage of the township requirement. The underground storage tank is located carefully on firm ground away from the valleys. The tank projects above the ground about 900 mm and merged with the landscape. The pumping station and chlorination equipments are kept as part of the tank below the ground so as to provide positive suction head to the pumps. The structural design of the tank has taken into consideration the soil characteristics and earthquake parameters. The water proofing of the tank is made as external tanking method with integral water proofing system.

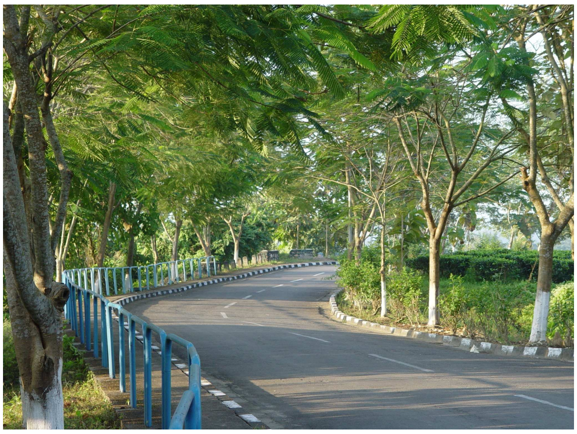
The water is pumped to an overhead tank of 5 lakh liters capacity from which water supply distribution is made through gravity flow to the individual buildings. During the conceptual design of the township, a conscious decision was made not to construct any tall conventional overhead tank in conflict with the subdued and low rise constructions. The presence of the hillocks on the northern boundary of the township enabled to construct a ground supported tank on the hill top without any staging structure which provided the required elevation for the hydraulic gradient to ensure for the gravity flow. The location of the tank was carefully selected to ensure stability and avoid cutting of slopes.

The water supply distribution network using cast iron and galvanized iron piping materials was designed taking into consideration the varying plinth levels of the buildings due to undulating site topography. All the piping networks are made with closed loops for better pressure distribution. Special care was taken to support the piping system over the valleys and depressions. The locations of the air relief valves, sluice valves and scour valves positions are carefully decided as per the site topography. For fire fighting operations, fire hydrants are provided at appropriate locations. In order to conserve the treated potable water, separate unfiltered water supply is being considered for nondomestic usages. An effective water conservation and management system with alternate source of water in emergent situations are under consideration.

9.2. Road Networks

The environmental uniqueness of the site led to the design of curvilinear alignment of vehicular roads. This is based on sound engineering practices and relates well to the topography of the site. This resulted in aesthetically pleasing and non environment safe circulation system. The curves and lack of formal geometry in the layout of roads and the resulting alignments, which evolved from the site itself, has contributed substantially to sustainability. The three dimensional aspects of all elements were suitably resolved; including various combinations of horizontal and vertical curves, cuts merging smoothly with fills, and side slopes blending well with the terrain.

The main spine road runs along the ridge lines almost in the middle of the township. Alternate routes were examined on site. These included considerations of avoiding deep valley crossings with major bridge constructions and heavy retaining structures. The road geometry is carefully designed to avoid large scale cutting and filling and ensuring proper storm drainage. An aesthetically pleasing alignment merging with the natural landscape of the site with minimum disturbance to the site topography could be achieved although this has marginally increased the length of the roads. Any conventional solutions in such an undulating site would have involved extensive earthwork, bridges and retaining walls resulting increased construction cost and time and destructions to the natural features of the site. Such situations were carefully avoided. The width of the main, sub main and cluster roads are 7.3 m, 5.5 m and 4.5 m respectively with foot paths on one side of the main and sub main roads. Each of the cluster roads serving the building units are carefully designed in relation to the plinth levels of the buildings to enable smoother approaches.




Curvilinear Alignment of Roads Relates to Site Topography

9.3. Storm Water Drainage

Although the site falls under heavy rainfall area, the storm water drainage did not pose problems due to significant topographic advantage with self draining nature of the site with the presence of natural channels and valleys around the plateau of the built-up areas. Storm water could ultimately find its path to the Kalyani River. However with careful planning with nominal site grading as a part of landscape design was carried out to direct the storm water to the nearest valley as sheet flow without the possibility of top soil erosion with the presence of dense vegetation.

9.4. Sewerage Collection and Treatment

The township site being a virgin land with contoured topography, it has been a challenging exercise to design and implement the sewerage network and treatment system for the cluster of buildings with different plinth levels. The main objectives of the design were to ensure gravity flow with minimal pumping, minimum disturbance to the natural landscape by avoiding deep sewer lines and manholes, avoidance of conventional septic tanks that would pollute the subsoil and vegetation, sewer treated to acceptable pollution control standards and the treated effluent is safe to discharge into the natural streams or used for gardening/horticulture purposes. Several alternative routes were examined at the site and an optimum alignment was chosen that involved only one pumping station in the entire township avoiding deep sewers. The sewerage treatment in done through extended aeration process and the effluent is subjected to filtration and chlorination to achieve the biochemical oxygen demand content to a level of 10 to 15 mg per liter and suspended solids less than 20 mg per liter. The location of the sewerage treatment plant is kept at the lower end of the township keeping in view the prevailing wind directions.

10. Township Plantations

The plantation systems are broadly categorized into road side planting, boundary planting, plantation in residential and public areas and plantations for protection of ridges and valley slopes. The plants selected are entirely from the existing regional indigenous plant species in consultation with the local horticulturists. Native flora is used to avoid the import of exotic species. In parts of the township the original tea plantations are also maintained as a pleasant reminiscence of the original tea gardens.

11. Summary

The case study presented in this paper brings out the various measures adopted in the planning and design of this medium sized township project in an ecologically sensitive and high seismic prone area. These efforts have led to the smoother functioning of the township and serve as an example of a safer and sustainable built environment. These measures are broadly summarized as under:

(i). Maintaining the natural undulating topography and landscape elements of the site
(ii). Avoiding construction activities on the hill slopes and protecting the vulnerable land profiles.
(iii). Natural drainage systems maintained without any kind of obstructions on realization of their environmental significance.
(iv). Existing vegetations, dense and prominent in the valleys, was protected during construction and construction wastes were carefully disposed at predetermined locations preventing the same from entering the valleys. Large scale additional plantation schemes were implemented.
(v). Adoption of low rise two storied construction with light roofing system suitable for high seismic zones.
(vi). Seismic conscious architectural and structural design and detailing of buildings and infrastructure services to provide earthquake safety.

The experiences and data gained from the long and comprehensive involvement in the project has proved to be very useful in teaching and research. This included the multi disciplinary technical as well as the contract related management and administrative experiences. All this has, over the years, been disseminated in the academic programs.

References

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