CONSTRUCTION AT EXCEPTIONAL SITES - SOME INNOVATIVE SOLUTIONS

THESIS

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BY

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CERTIFICATE

This is to certify that the thesis entitled CONSTRUCTION AT EXCEPTIONAL SITES - SOME INNOVATIVE SOLUTION and submitted by SODHI RAJINDER SINGH ID No. 89 PHX F-016 for award of Ph.D. Degree of the Institute, embodies original work done by him under my supervision.

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CONSTRUCTION AT EXCEPTIONAL SITES - SOME INNOVATIVE SOLUTIONS

1. OBJECTIVE

As a consequence of accelerating developmental processes, there is an increasingly felt and inescapable necessity to take up construction activity in remote areas of the country, which have generally remained inaccessible so far in the sense that surface transportation facilities are not well developed. Such areas present a wide diversity of climate, geology and terrain and are characterised by a lack of modern skills and often material resources, including materials for modern construction.

Some of the forces that are compelling this inexorable movement of construction activity to remote areas can be listed as follows :

* Demographic compulsions and imperatives of equitable development.
* Strategic and Defence compulsions for opening up new areas and locating specialised projects.
* Burgeoning affluence of a small section of the populace which wants scenic and serene retreats far from the pollution, congestion and stresses of a city.

Irrespective of what factors compel construction activity in difficult far off places, difficult in resources and skills the demand for such construction is going up and one has to meet the challenge and find solutions.

As an Architect author proposed and offered a solution by evolving standard modules for creation of spaces that would offer flexibility in configuration and designing versatile structural components that could perform several functions - as beams or walls, or columns, or doors or windows, or elements of floor & ceiling.

While the concept of standard space modules has been tried and as per design practices which offer flexibility in orientation or expansion of a building by addition of standard space units with the design of multi-function, structural components. However, author has analysed the traditional Indian architecture in Rajasthan which displays structural elements that are with some modifications capable of variety of functions.

The evolution of standard modules and versatile elements has lead to great economy and speed of construction, and has in no way affected the variety or individuality of any structure or complex.

2. BACKGROUND

Ready built shelters or systems have emerged as an alternative to meet the client needs, pose limitations in creation of spaces as per individuals' needs and design parameters. Efforts have been made in our country to popularise, pre-fabricated building, pre-stressed building components for building units. To the best of our knowledge, no work has been done for developing versatile building elements which could be effective in a variety of functional roles.

"SHILPSASTRAS" have scientifically described each type of buildings and location of each usage on the basis of "Vastupurushamandala". Building layouts were based on scientific analysis and were developed on grid-pattern. Traditional Indian Architecture in Rajasthan displays structural elements which are capable of variety of functions with slight modifications. An element can perform as roof, walls, beams, columns and cantilevers. Developing this idea further, author presents a minimum elemental components capable of versatile use.

This could be of particular use in creating built-up environment in difficult and relatively inaccessible terrains and also terrains where skills and resources are deficient. This will be possible because the construction technology could be based on mass production and assembly-line, yielding much quicker and easier construction.

3. THE APPROACH

The Research work had started with examining the existing construction Methodology in remote and relatively inaccessible areas where skills and resources are deficient. Prevailing construction techniques of a region have been analysed and adopted to meet the specific requirements. Development activities including specialised building and other support infrastructure has been created to achieve the enormous task of development process. During the process it was realized that lack of resources at particular locate the process has suffered set back.

Author has reviewed and surveyed number of documents in the form of books, literature, technical papers, publications to evolve the theory of standardization of building elements. Various types of sandwich panels available and in use globally were studied and analysed and accordingly the design of standard panel was arrived at.

Existing construction techniques prevailing in various difficult, inaccessible terrains were examined to identify the concept underlying the building process.

The changing requirement of building needs and client's requirement have been examined to delineate clearly the objectives and the situational characteristics that uniquely characterise the Indian building environment.

4. WORK IN THE THESIS

The New Methodology and innovations have been described and the important such executed projects by **author** at different locations such as :

"Pokhran" the Desert of Rajasthan : The site is situated at "Chandan", which is 180 Kms from Jodhpur and 40 Kms from Pokhran on Jodhpur - Jaisalmer Highway. The entire complex is planned covering an area of 1670 sqm, to accommodate Research Scientist for testing war heads, in shortest span of less than 4 months. Water was scare, population was sparse & scattered & no local skilled labour were available. In this kind of situation one could think only about prefab panel technology where the factory made insulated panels with provision of doors, windows, electrical & plumbing could be brought, assembled & finished with concrete internally & externally, whereas locally available stone putty could be used for flooring & roofing.

The Baralachla : The high altitude area of Leh : The site is situated at "Baralachla" on Leh - Manali Road at an altitude of 4890 m above mean sea level, generally found snow bound over eight months in a year & wind speed upto 100 km/hr. Extreamly hostile environment having temperature down to - 30 degree C, standing snow of 2 to 3 metres and extream drift snow condition. The Accommodation was to be planned for Snow Avalanche Study Establishment, Manali of Defence Research Development Organization which conducts studies on avalanches at high altitudes to provide data to ministry of defence.

The accommodation and laboratory were to be planned to accommodate field teams within the limited period of two and a half months. Because of the time constraint only factory made solution was possible which means maximum work away from site and only assembly of components at site.

The precut insulated sandwich panels having cement based wood particle board on internal & external skin with provision of insulated hermetically sealed laminated glass in window panes and raised floating floor using insulation and particle board supported on adjustable metal jacks.

The powder coated Corrugated Galvanised Iron (C.G.I.) sheet roof were supported on trusses and having Particle Board and Poly Urethene foam insulation above the false ceiling.

Defence Institute of Work Study, Mussoorie : The site is located at Landour, which lies almost 300 m higher than Mussoorie. It has steep terrain and the congested sketch of developments through which roads are laid out, restricts the transportation during peak hours and regulates during peak season and very difficult to carry material even in the small trucks due to winding roads.

The favourable time for construction clashes with the tourist season and scarcity of water hence restricts the construction time.

Due to scarcity of water during tourist season when the weather is most favourable, the local Government body restricts the construction activities and monsoon is followed subsequently.

Defence Institute of work study a premier teaching institution of Defence Research & Development Organization with the growth of establishment it became necessary to provide additional hostel accommodation & recreational facilities.

Due to shortage of buildable land only possibility to accommodate the requirement was to build multi floors.

Due to non availability of skilled and unskilled local labour, scarcity of water, problem of mechanical transportation, precut factory made insulated panels including Doors and Windows panels were made and assembled at site and finished with concrete on external and internal skin. Steel stanchions were used for structural system with the help of nuts and bolts to erect the structure up to four floors and after laying powder coated C.G.I. sheet roof, the work on internal and external walls were commenced. Particle board with sound insulation was laid in ceiling and floors.

CHAPTER I

CONSTRUCTION AT EXCEPTIONAL SITES

1.1 INTRODUCTION

The necessity to create a built-up environment for existence is as old as the mankind itself. In the primitive societies it was more or less a question of survival, However as civilization progressed consideration of comfort & aesthetics gained importance, further with increasing complexity of Social Organization the functions and activities in a society proliferated, throwing up needs for building structures to meet specialized requirements e.g. schools & universities, theatres, hospitals, R&D laboratories, factories, offices etc. Thus in today's buildings security is taken for granted and what one looks for is functionality, comfort and aesthetics achieved through a structure of adequate strength constructed economically.[10]

For functionality and economy one can very profitably look at the **'Vernacular'** building traditions of various people who under very different geo-climatic conditions have over the centuries evolved very sensible, often brilliant solutions, based on local resources in terms of materials and skills, which on the one hand serve the demands and needs of the life style and the culture of the people, and on the other hand ensure that man is no intruder into the nature's sanctuary but an integral part of the whole natural.[7] Such brilliance of solutions is in evidence in all cultures and all locations whether it be the igloo of the Canadian Eskimo built in a few hours using snow blocks as the material of construction with its ingenious arrangement for sky light, or heating, or the houses of the tribals of the North - East India who build a house in two to four days through community effort, using locally available material, lengthy bamboo, timber and stone, in a practically cost free non-money mode.[6]

The vernacular architecture of the region responds to the land-form and climate. It makes use of material available in the vicinity. It also takes into account the life-style of the people.

Vernacular construction methods are the outcome of experience of the people based on available local construction materials, climatic and geological condition as well as construction techniques extensively adopted for generations. Ecological balance is prime consideration to safeguard environment for human beings, flora and fauna. During the process of developing appropriate construction technology for a region architect seek solutions to meet the vagaries of weather and geological characteristics of the region.[3]

Some day architecture may well be able to take on more directly a good part of human expressive needs, so become itself an expressive art. It is also possible that the computers yet to be designed will be able to take note of both the deterministic and analogical, and so will be able to help in more than the purely pragmatic challenges of architecture, helping to corelate and fuse together both the practical and emotional.[14]

New building projects could suggest a new image of something the world has not yet seen, but which, it is beginning to shift towards a decentralized, sustainable culture, underpinned by a sophisticated and ecologically sound technology. By building something genuinely new, and not just a watered down version of current international fashions, local pride can be stimulated. When people build for themselves, working under different constraints and limiting local conditions, they respond directly to the situation and as they find them and achieve rich and expressive forms.[19] This directness of approach leads to a natural and contextual order which eliminates superfluity. This approach is not restricted to the house form alone, but permeates each and every element of the living environment, from a house to an entire settlement.

During the early years after independence, building profession in India was too enamoured by the modern architecture in the West. Now at least the time has come when we are finally trying to get back to our own roots. Contempory materials are getting translated into varnacular forms and idioms. We are slowly but surely are in the process of evolving our own architectural language. It is in this context regional architecture deserves a closer look. This regional and varnacular architecture shall be as diverse as our country itself, bonded together with the common threads of culture bequeathed to us by ancients.[12]

The conventional region specific housing technology and building techniques deserve a closer look both for learning how to build in specific regions & for identifying how to better the traditional approaches by introducing modern, technologically superior techniques of construction and construction systems & use of new and improved building materials from the locally available raw materials, using as far as possible local skills.

Development in construction technology itself has been relatively faster in developed countries of the world for it has been their requirement that a built facility be made available in the shortest possible time. The development was also aided by the relative paucity of manpower and limitation of human skills in matters of finish & durability.[9] Human errors had to be eliminated by mechanical processing. However the Construction Industry continues to be faced with problems of increasingly larger sizes of project and complexities of execution under difficult situation like **High Altitude** area and **Hilly Terrain** where the means of communication & the period of construction impose their own limitations.

1.2 NEW CHALLENGE IN CONSTRUCTION : BREAKING NEW GROUND, LITERALLY

As a consequence of accelerating developmental processes there is an increasingly felt, and inescapable necessity to take up construction activity in remote areas of the country, which have generally remained inaccessible so far in the sense that surface transportation facilities are not well developed. Such areas present a wide diversity of climate, geology and terrain and are characterized by a lack of modern skills and often material resources, including materials for modern construction.[1]

Some of the forces that are compelling this inexorable movement of construction activity to remote areas can be listed as follows :

i) Demographic compulsions & imperatives of equitable development.

ii) Strategic and Defence compulsions for opening up new areas and locating specialized projects.

iii) Burgeoning affluence of a small section of the populace which wants scenic and serene retreats far from the pollution, congestion and stresses of a city.

Irrespective of what factors compel construction activity in difficult far off places, short of local resources & skills, the demand for such construction is going up and one has to meet the challenge and find solutions.[2]

Building a structure consists of collecting materials of small size and assembling them in to the desired shape at site. In this process the materials required, approximately 700 kg/cum of space enclosed, are handled several times horizontally and vertically.

Delays occur due to the inherent qualities of materials like brick and concrete which demand sufficient time to set and also due to the need for erecting scaffolds and form work. In India mechanization in these activities has not gone beyond the stage of using mixer and vibrators for concreting. Employing large blocks of standard size shuttering elements and plants for concrete mixing and laying use of ready mixed concrete, concrete pumps, medium sized handled equipment and `insitu' steam curing can be treated as mechanization. This however does not remove the inherent delay of setting time except when steam curing is used. One then thinks of a system with non conventional construction technology, wherein all components of the building have to be fabricated **off the site** & numbered to facilitate the easy assembly in shorter span of time. The concept of using minimum amount of material and minimum number of precut structural elements saves the time.5

It is evident that construction techniques appropriate to meet the staggering demands of climate, terrain, location and end-use are to be developed to cope with the demand and supply of built-up environment. It is essential to plan and construct the buildings within the planned period to avoid escalation of cost. It is estimated that every year the cost escalation is about 15%. In addition to the burden on the exchequer, non-provision of facilities results in retardation of the progress of the nation.

At the international level one finds that in the building industry standardization of building components has been carried out to a considerable extent, However at the national level, such standardization is a far cry. Unless the mass production of standardized components is resorted to our goal would seem to remain beyond reach.13

1.3 SEARCH FOR SOLUTION

SOME INNOVATIVE CONSTRUCTION BY THE AUTHOR

Nature and scope of architecture has undergone tremdous change during the travelogue of time. Monarchy and religion depended on monumentalism to create their impact on people as the heights of the buildings increased, so did the scale of proportion which assumed gigantic magnitute which required special skill. This aspect brought in varied and complex solutions to the building problems. Solutions to building problems thus historically used man kind into new era of advancement to create new problems for itself and to solve them successfully.

The author in his professional life has been privileged to handle several large construction projects at sites beset with exceptional problems and has delivered innovative and perfectly satisfying solutions in record time adhering to highest standards of quality. **The thesis** pertains to construction at three of these exceptional sites. In coming up with his own solutions for the structures and has drawn and improved upon the rich vernacular traditions of Rajasthan and The Northern India.

Regional construction methods adopted in Rajasthan utilize pre-fabricated/pre-cut components for buildings. Traditional Indian Architecture in Rajasthan displays structural elements which are capable of performing a variety of functions with slight modification (Plate 1.1). An element can perform equally well as a component of roof, walls, beams, columns & cantilevers. Developing this concept further the author has perfected a versatile, composite, sandwich panel in the nature of a "**minimum elemental component capable of versatile use**" and developed a system of construction, which makes creative use of it. Apart from the versatile panel several other innovative, original ideas have been successfully developed and implemented by the author at his unusual and difficult construction sites as shown in subsequent chapters. **The innovative solutions pertain both to the elements of construction & technical solutions, & the organisation & management of project delivery systems (construction - tasks)**. The result invariably has been completion of highly satisfactory complexes substantially ahead of schedule though **the sites presented formidable difficulties, including near absence of any infra structural facilities, and in some cases low-oxygen, practically water-less, environment.**

The evolution of standard modules and versatile elements leads to great economy and speed of construction, and in no way affects the variety or individuality of any structure or complex.

1.4 ORGANISATION OF THE THESIS

STRUCTURE

The account in the following pages is the **author's** own tryst with various difficult terrains, sites and locations during the course his experiments with the built form at all these places.

The thesis concerns itself with the problems of construction at "**Exceptional Sites**". The meaning of exceptional sites is explained in the **Chapter II**. Suffice it to say here that for our purpose the exceptionality lies in extremely unfavourable natural conditions either of climate or terrain or of infrastructure or of any other kind, which make construction activity almost impossible to organize. Subsequent three chapters (**Chapter IV, V & VI**) deal with construction in exceptional sites of Desert, High Altitude area and the Difficult Hilly Terrain.

LIST OF PLATES

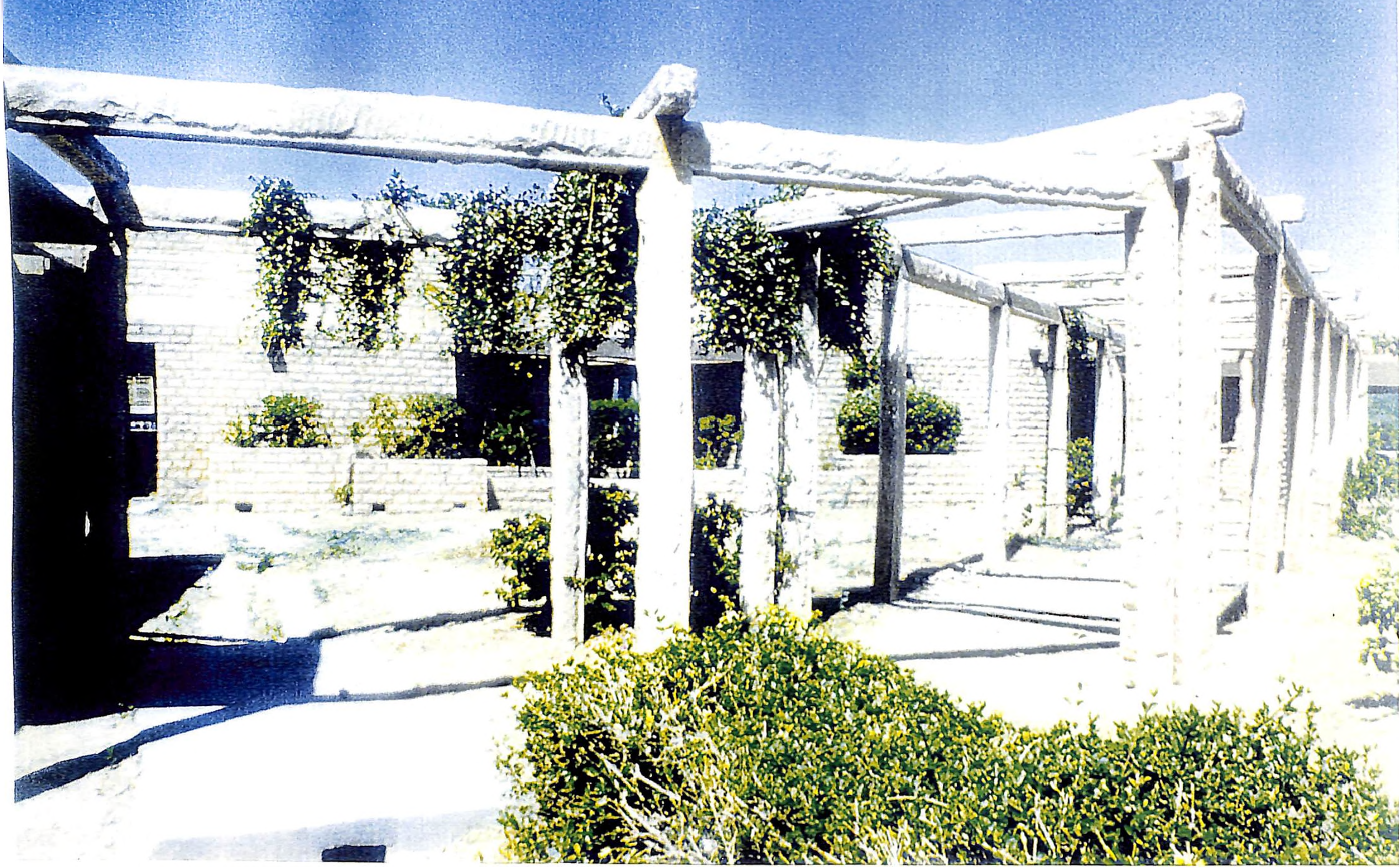

PLATE 1.1 SANDSTONE - VERSATILE ELEMENT - VARIETY OF FUNCTION

CHAPTER II

DEFINING EXCEPTIONAL SITES

2.1 INTRODUCTION

As suggested in the preceding chapter an exceptional site for our purpose is one which is characterized by extremely unfavourable natural conditions either of climate or Terrain or infrastructure or any other kind which present formidable obstacles to the organizing of modern construction activities. Examples of such exceptional sites can be found in : **Hot Desert**, where hot, sandy winds and absence of water are hostile to any human activity, and very **High Altitudes** where dry climate, low-oxygen environment, short duration of days, non-availability of water etc., coupled with **Hilly Terrain** and near absence of infrastructure make it extremely difficult to carry out construction activity particularly for transportation and communication.

In this chapter we discuss the characteristics of the regions of three projects at such exceptional sites where the author has carried out successful construction, in an attempt to identify the major common characteristics which can satisfactorily define an exceptional site from the point of view of the exceptional difficulties related to construction activity.

2.2 THE THAR DESERT (THE POKHRAN SITE, RAJASTHAN)

The North Western parts of India largely consist of the desert, known as the Thar Desert, which lies to the North - West of the Aravalli mountain range, 650 Km long, running from South - West to North - East across Rajasthan. It accounts for about half of the area of Rajasthan.

The Indian Desert lies between 22 degree to 28 degree North latitude and 69 degree to 76 degree East longitude. The area is very sparsely populated due to its arid climates, scorching heat and erratic rain fall. Apart from occasional rock outcrops, and plains of dry clay, the desert is characterized by sand dunes interspersed with patches of prickly grass and brushy plants.

The North Easternly wind blowing from the direction of the Arabian sea and the Rann of Kutch sweep across the desert landscape for nearly eight months in the year, carrying with them a considerable bulk of sand particles. With no moisture or vegetation to hold the soil, even moderate wind gain momentum as they travel, ultimately turning into powerful sandblasts. Sand dunes form a peculiar feature of the desert landscape, (Plate 2.3.4) frequently rising to a height of 30m, Towards the Rann of Kutch more or less permanent dunes may rise upto 60 m above the sandy surface.[8]

The average annual rainfall is about 380 mm but towards the western boundary of India it is only about 12 to 15 mm. It is highly erratic variability from the mean being 30%. The range of temperatures, both diurnal and annual is very large : January nights may see temperatures of 20 degree C & maximum day temperature in July may touch 53 degree C. There are no perennial rivers worth the name. The desert is probably underlain by the crystalline complex of the Indian peninsula.[4]

The greater part of the desert surface exhibits sands, silts and loess like material. Water is thus evidently a scarce, and highly priced commodity. Small wells and natural depressions are the only source of water. The desert therefore supports only small population. the density of population of the Rajasthan as a whole is less than half the national average (128 vs. 267 in 1991) The development of infrastructural facilities road net work, communication, electricity, etc is minimal.[19]

2.3 HIGH ALTITUDE AREAS OF THE LESSER (OR MIDDLE) HIMALAYAS

2.3.1 >3500 M (BARALACHLA, BEYOND MANALI IN HIMACHAL PRADESH)

The Himalaya mountain ranges make the northern boundary of India. Widthwise the Himalaya is not one continuous chain of mountains, but a series of three parallel mountain ranges viz.

i) **The Greater Himalaya**, the northernmost range, with an average height of 6000m and the breadth between 120-190 km, consisting of perpetually, snow clad mountains;

ii) The Lesser or **Middle Himalayas** with average height of 3500 m to 5000 m, and width between 50 km to 80 km,

iii) The **Outer Himalaya** (foot hills), 1000 m to 1500 m in height and width 15 km to 50 km.

The Middle Himalaya contains a number of well known hill stations like Nainital, Almora, Simla, Manali, which besides being densely populated townships are large tourist attraction centers. The region also is the seat of a large number of scattered villages, which do not yet possess the transport and communication links as available elsewhere in the country. Presently, this is the area that is the centre of our attention.

Large parts of our Northern borders remain snowbound for over six months in a year. Due to poor communication system and the fear of frequent avalanches, development of these areas has suffered. Generally, the development activities have taken place around the historical and populated regions in the country. Hilly region, particularly the highest reaches & the interiors have remained relatively undisturbed; There are areas full of scenic beauty and they are virgin and no modern facilities are available. The need for mineral and scientific exploration and defence of the borders and linking them to national networks for transport and communication has brought forth the need for increasing construction of roads & residential accommodation in the mountains.

The infrastructural facilities particularly roads and information and communication are generally deficient in the hill region as a whole, with the possible exception of a few major hill stations like Nainital, Mussoorie and Simla, but only a few kilometre into the interior from these centres, the life could be tough indeed without even minimum facilities including arrangements for drinking water, domestic heating or sanitary systems. At about 3500 m or more the life is very much on its own, coping with a beautiful yet unbearably harsh nature. (Plate 2.3.1, 2.3.2, 2.3.3)

Understandably the sites at these altitudes are snow bound for better part of the years; icy and fearsome wind rage, the period when working at site is possible is confined to about 2-3 months in a year of the summer season and even then the working is limited to 4 hours in a day (in western sector) as the day light is short. The site is practically uninhabited, water may not be available and would tend to freeze, construction material would have to be brought from some distance and no roads would be available, storage sites would be difficult to get, hill range may not often permit sufficient ground width to plan a normal structure, the foundation bed is fragile, possibly on unstable slopes, concrete will not set in extreme cold and housing the labour at site can be an intractable problem.

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Such was the site Baralachla, beyond Manali in Himachal Pradesh (vide chapter V) where we were required to design and construct a sensitive complex project in 3 months time.

2.3.2 < 3500 M (LANDOUR, NEAR MUSSOORIE IN .

The problems of transport and communication, restriction on sp.

fragility of ground remain similar to those mentioned earlier, the cl.

shade less.

The foregoing descriptions of the **Desert** and the **High Altitude** Himalayan sites would help to indicate what we mean by exceptional sites in the context. Broadly the sites present the following features :-

(i) Extremely hostile climate / environment.

(ii) Grossly underdeveloped or absent, infrastructures, particularly for transport and communication.

(iii) Away from human habitat.

(iv) Peculiar technical constraints / problems, e.g. restricted availability of space, unstable and fragile ground.

In chapters IV, V & VI we take the specific projects and construction problems at each of these sites presenting the specific features of project design and management that achieved, very satisfactorily, solutions in time and cost effective manner. However, as the development of versatile, sandwich panel & its effective use by the author has been a common feature, alongwith prefabrication & remote controlled organisation of construction activity and project management which required only minimal supervisory staff to be posted at site and yet insured perfect quality control, the next chapter deals with construction methodology.

2.3.2 < 3500 M (LANDOUR, NEAR MUSSOORIE IN UTTAR PRADESH)

The problems of transport and communication, restriction on space and instability and fragility of ground remain similar to those mentioned earlier, the climatic severity is a shade less.

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PLATE 2.3.1 STUDY AND BEHAVIOUR OF HEAVY SNOW ON STRUCTURE
INACCESSIBLE HEAVY SNOW BOUND REGION

PLATE 2.3.2 INACCESSIBLE HEAVY SNOW BOUND REGION

PLATE 2.3.3 INACCESSIBLE HEAVY SNOW BOUND REGION

PLATE 2.3.4 THE THAR DESERT

CHAPTER III

CONSTRUCTION METHODOLOGY - VERSATILE ELEMENT / PRE FABRICATION

From the time immemorial, the building material has always played a dominant role in shaping-up the human environment. As the building industry took strides of progress, the innovations in the field of material was only natural outcome. The conventional material continued to hold away and perhaps shall continue in future, but as the preservation of ecological balance and other relevant issues took a centre stage, a search for new material stated in new urnest. Simultaneously need for quick methods of construction became a necessity. All these factors brought forth a whole new set of materials to suit the varying and complex needs of the building profession. Some of these are discussed here.14

3.1 THE SANDWICH PANEL - DEVELOPMENT OF A VERSATILE ELEMENT

Three types of panels are generating a lot of interest today. They are:

(i) Exterior insulation system panels,

(ii) Glass fiber reinforced concrete panels,

(iii) Ceramic tile panels.

But the economy of these panels lies in their use of steel stud framing (as structural element, installing the steel stud frame) is simple and quick, and the interior stud face can sometimes be used as a back-up for a finished dry wall partition. Prefabricated panels eliminate the need for elaborate scaffolding, and become most economical on buildings over four stories high.

Metal panels and precast concrete panels have been well established in the construction industry for many years. The prefabricated brick and tile panels introduced in the 1960's never enjoyed a large market. The energy crisis and economic pressure are combining to create a favourable market for today's generation of panels.[15]

3.2 EXTERIOR INSULATION SYSTEM PANELS

The basic components of the system as a prefabricated panel are steel stud framing with gypsum sheathing, a layer of insulation (typically expanded polystyrene) that is adhered or mechanically fastened to the sheathing, and thin veneer coats of either synthetic plaster, modified portland cement, or both. Another element is reinforcing mesh or fabric embedded in the veneer. The veneer is available in many different colours and finishes simulating other cementitious and masonry veneers. (Fig. 3.1)

The primary advantages of these systems are their thermal properties, light weight and low cost. Because the insulation is placed outside the framing, the studs do not act as a thermal bridge and the expansion and contraction of the structural frame is reduced because the insulation protects it. The weight of a panel varies depending on the type of veneer and reinforcing used, but averages about 15 kg/sqm for veneer and insulation.

Exterior Insulation System (E.I.S.) did not immediately win advocates in the architectural profession. The use of EIS has increased dramatically in recent years. These panels are now used primarily in light commercial buildings, hotels and residential projects.

The classification of systems is by veneer type (polymer based or **PB** which is entirely synthetic and polymer modified or **PM** which is latex modified cement) and by reinforcing type (usually glass fabric, wire mesh or glass fibers mixed into the matrix). PB veneers are colourfast and flexible, requiring few control joints. They are very vulnerable to impact damage unless adequately reinforced; PM veneers perform more like conventional plaster. Some manufacturers use a combination of coatings, with a PM base coat and a PB finish coat.

The controversies at the heart of the industry's code problems are questions about the fire performance characteristics of the assembly & questions about the use of adhesives to secure the insulation to the sheathing.

The fire resistance controversy centers on the flammability and toxicity of the veneer and insulation used in the system. None of these systems have received fire resistance classification. According to fire tests for exterior walls. These tests measure fire endurance, hose stream effects & heat transmission. The exterior systems may not be required to meet fire endurance codes in any event if they are part of a non-bearing system.[15]

3.3 GLASS FIBER REINFORCED CONCRETE PANELS

Glass Fiber Reinforced Concrete Panels (GFRC) panels are thin, lightweight cement panels consisting of portland cement, silica sand, water and alkali resistant glass fibers. The cement ratio in GFRC is very high, compared to normal architectural precast concrete. The cement slurry is sprayed in place in a form in combination with glass fibers. The form can be moulded into any shape, aggregate or tile can be placed in the mould prior to spraying and other textures or finishes can be introduced. (Fig. 3.2)

A typical GFRC panel is 20 mm or less in thickness and weights 30 to 70 kg per Sqm excluding structural back-up. They require only seven days to cure sufficiently to allow erection & accelerators can be introduced in the mix to reduce cure time to as little as one day. If the building floor slab is not designed to carry the weight of the curtain wall and the panels must be connected to the columns, the length of panels required to span between the columns may need more structural bracing than just a steel stud frame. While the studs may be able to carry the panel weight from columns to column, a truss type frame is required to resist the wind loads over long spans. Another potential problem is warpage of the panel.[15]

3.4 CERAMIC TILES PANELS

Gail's Brickplate Panel uses a one coat mortar bed on metal lath over the sheathing & steel stud frame. The tile installation is similar to the time-tested Tile Council of America (TCA) Method W201 for installing exterior tile. Replacing the masonry substrate in the TCA section, the steel frame with drywall diaphragm is used replacing the standard three coat portland cement mortar bed, and a one-coat latex modified portland cement is specified to increase bond strength and water resistance. The panel weighs approximately 100 kg/sqm including steel stud framing. (Fig. 3.3)

The Buchtal system uses Buchtal's Keraion tile, a 155 sq cms unit, and employs structural silicone adhesive & foam tape to adhere it to a metal deck and steel tube substrate with steel stud structural framing. The tile joints are grouted with silicone sealant. The resulting panel is very flexible since every joint acts as in expansion joint and differential movement between the steel frame and the tile veneer is absorbed by the silicone. The adhesive used in test panels in Dow Corning's 795 Sealant which has been used for years for structural butt-glazing applications. The panel weights about 35kg/sqm excluding steel stud framing.

Tile Panels using GFRC back-up are formed by laying the tile in the form and spraying GFRC in successive layers to produce a 12 mm thick panel. The resulting tile panel has perfectly located tile. Tile joints can be grouted before or after the concrete backing is in place. Since these tile panels are so new, their performance in the field is difficult to evaluate. Theoretical concerns then take the place of actual problems.[15]

3.5 VERSATILE SANDWICH PANEL DEVELOPED BY THE AUTHOR ENGINEERING A SOLUTION - INNOVATION AND INGENUITY

3.5.1 THE SANDWICH PANEL

The Panel is a versatile element which can be factory made as per required design. It consists of polyurethane foam having welded mesh reinforcement on either side. This insulated panel retains interior temperature thereby reducing need of desert coolers/heaters. These panel are light-weight. Electrical conduits are in-built in the panel to facilitate concealed wiring.

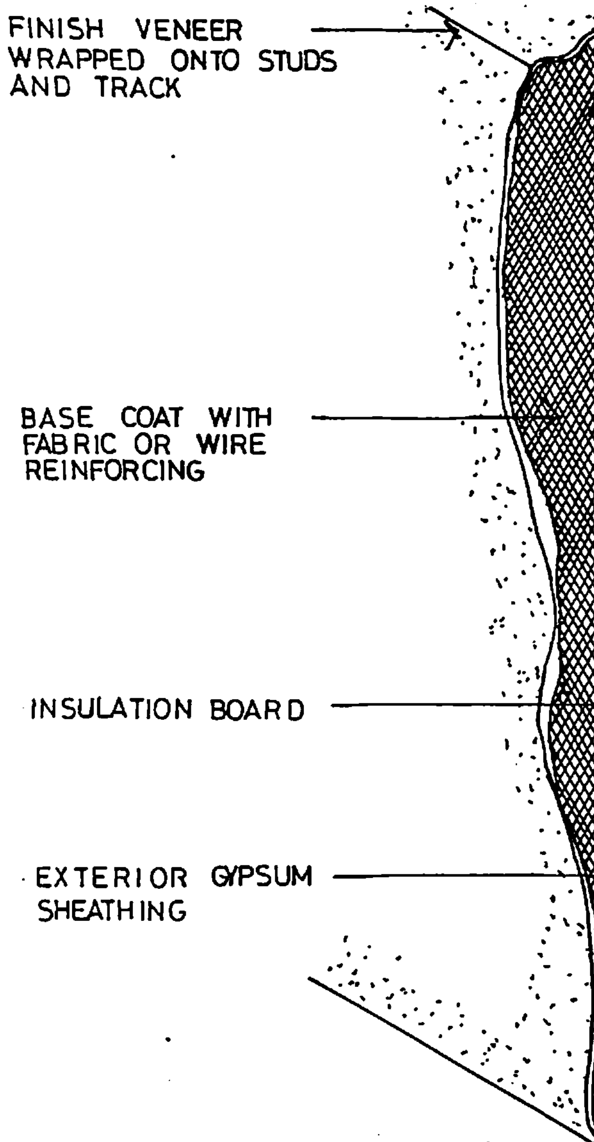
Doors, windows, plumbing etc. are also inbuilt in the panel thereby minimizing activities and the manhours required for construction/ erection at site. Being factory made under strict supervision of technical staff, the panels have the necessary precision and quality control. Singular material utilization eliminates participation of a number of agencies in the construction activity, thereby reducing duration of construction. All the panels of the enclosure are numbered in the factory which are to be assembled at site as per design. This activity takes very little time compared to the continuous supervision by Technical staff required for monitoring the normal construction activity.

3.5.2 PROJECT MANAGEMENT - THE REMOTE CONTROL MODEL

Besides the absence of water, power supply, local labour & construction material, another complicating factor at one of the sites was the "Test Flights" that were commissioned in the vicinity, and therefore, no habitable dwellings were permitted in that area in order to avoid bird hits. This necessitated merging of activities into different groups. We adopted an unconventional model for managing this project, where a remote central office located in Delhi, provided all functions and services (designs, stores, prefab. components etc.) enabling construction activity at site to be pursued, supported monitored and controlled satisfactorily from a distance and ensuring the perfect communication & optimum movement of personnel.[28]

In the following chapter, we discuss in some detail specific cases of three exceptional sites where the author was commissioned to design and execute special projects giving for each site the specific project requirements and architectural/engineering solutions and methodology of project management.

LIST OF FIGURES



EXTERIOR INSULATED PANEL

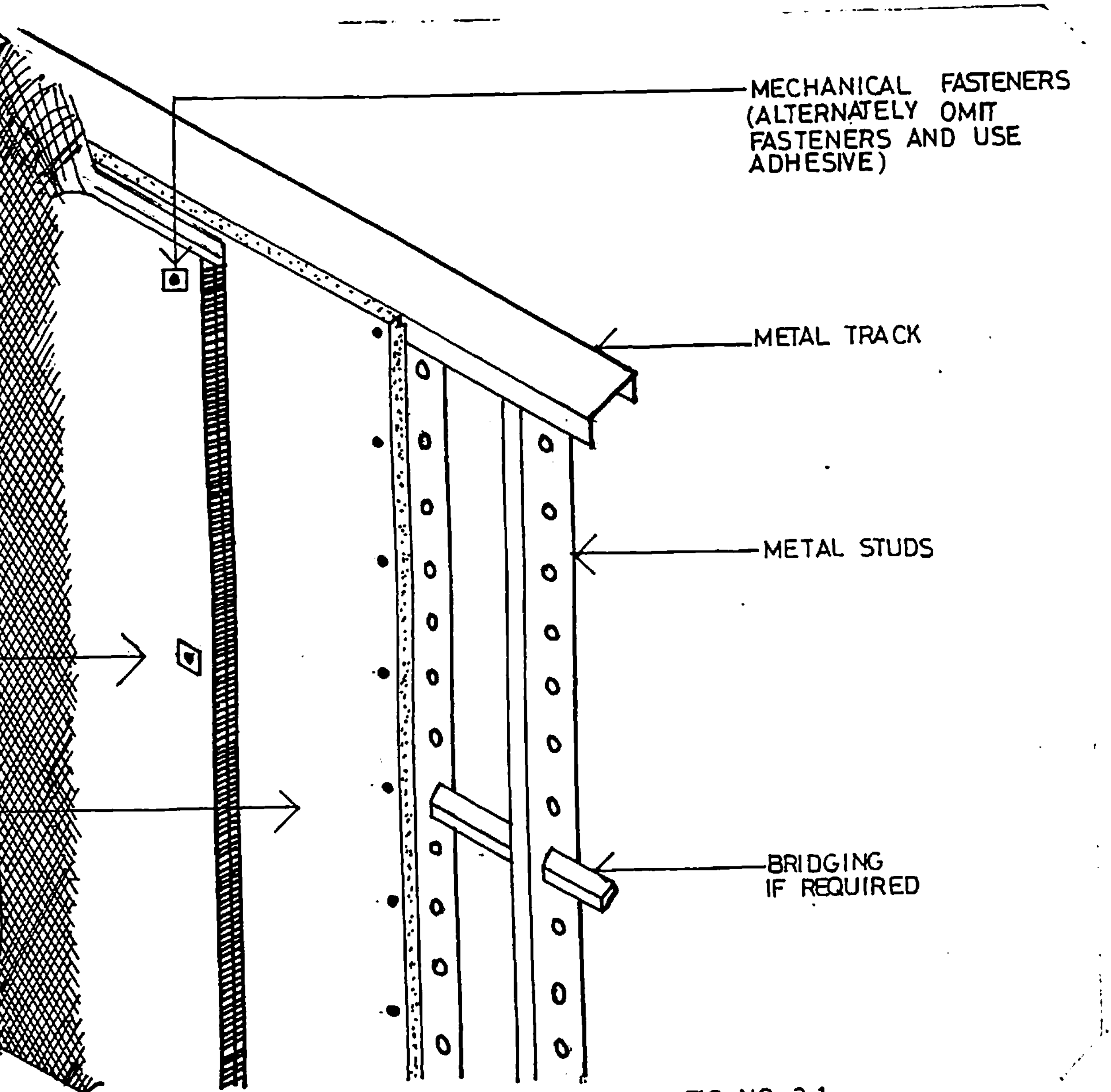
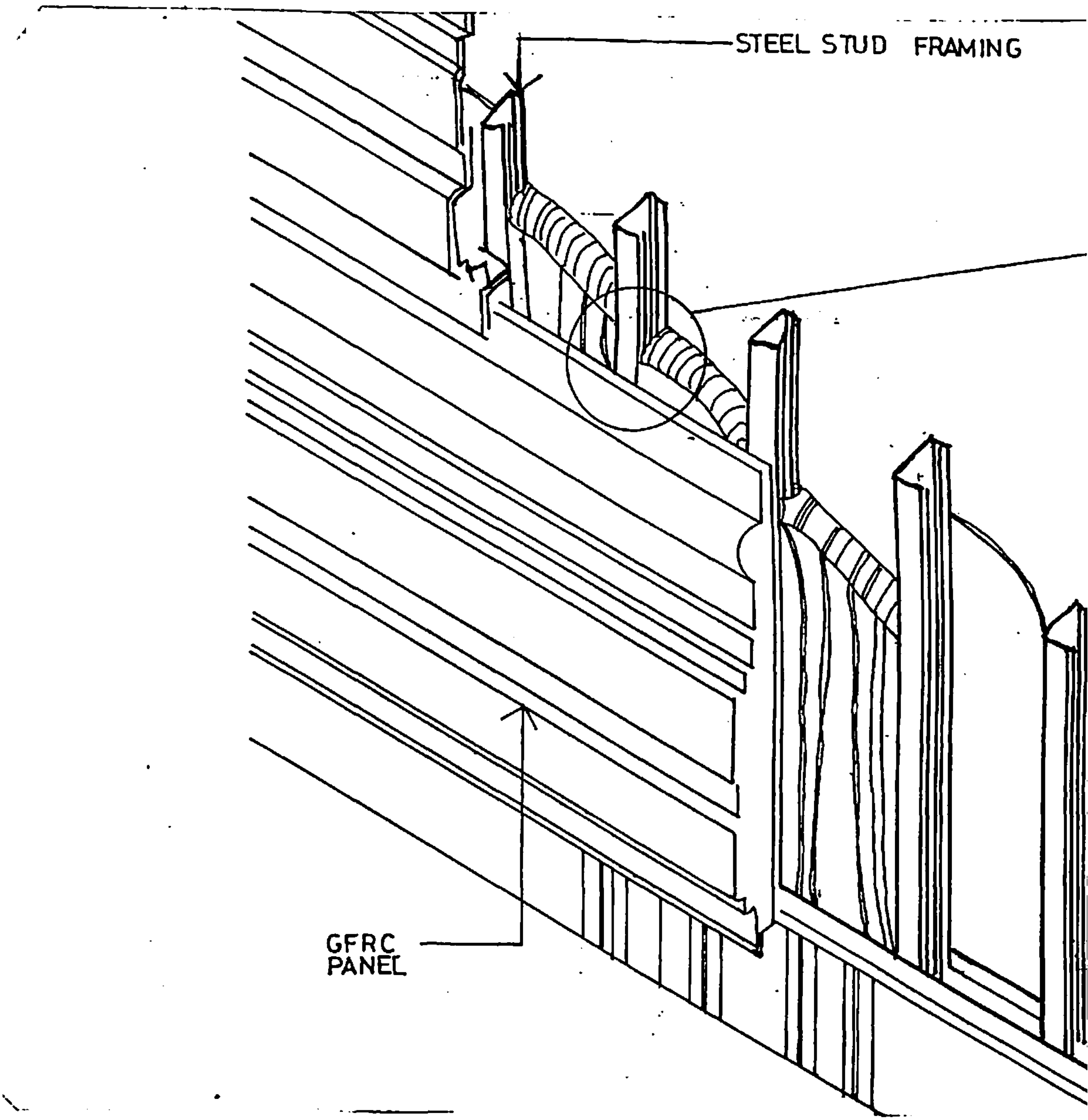
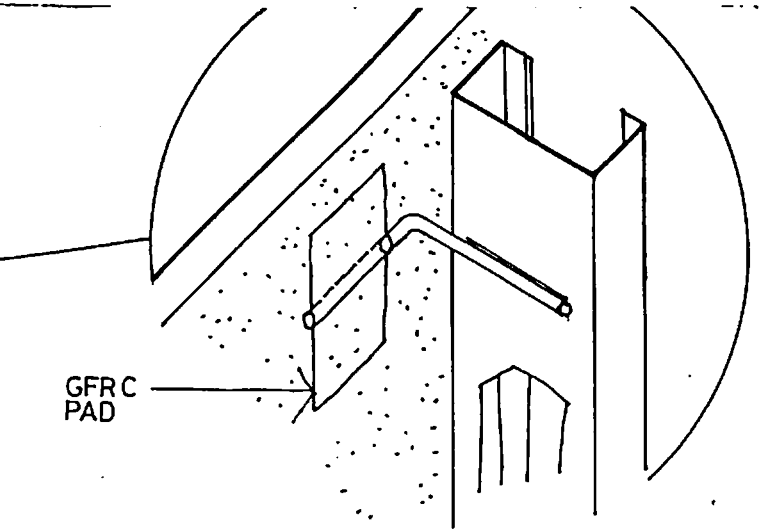
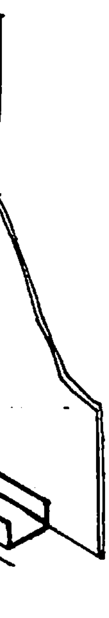

MECHANICAL FASTENERS (ALTERNATELY OMIT FASTENERS AND USE ADHESIVE)
METAL TRACK
METAL STUDS
BRIDGING IF REQUIRED

FIG. NO. 3.1


STEEL STUD FRAMING
GFRC
PANEL

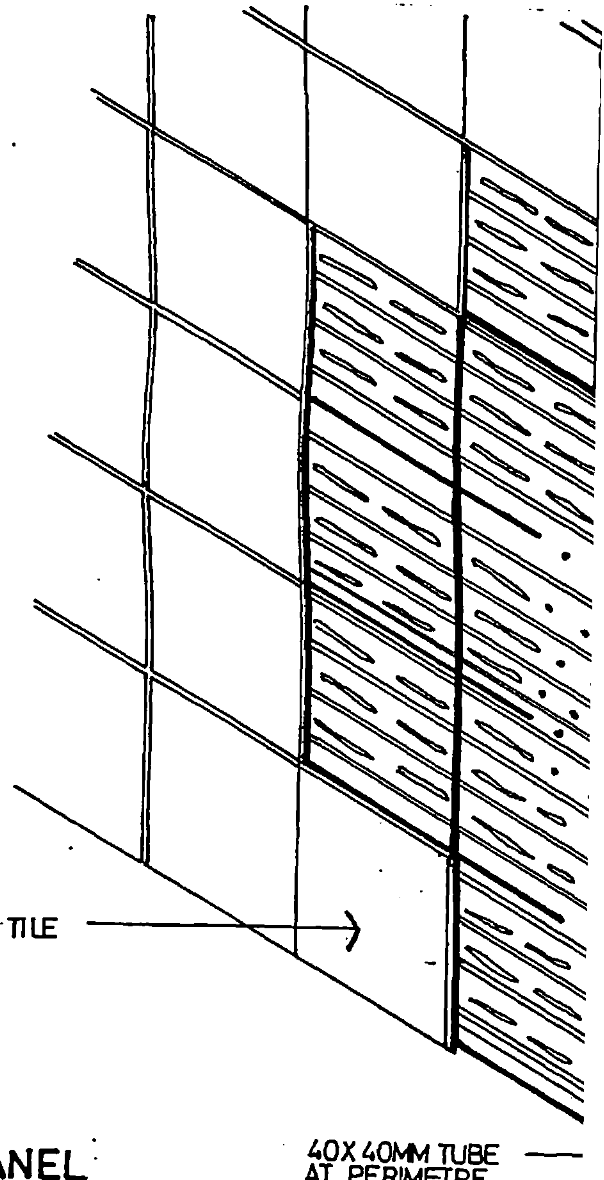


CONNECTION DETAIL
(BEHIND PANEL)



GLASS FIBER REINFORCED CONCRETE PANEL

FIG. NO. 3.2



CERAMIC TILE PANEL

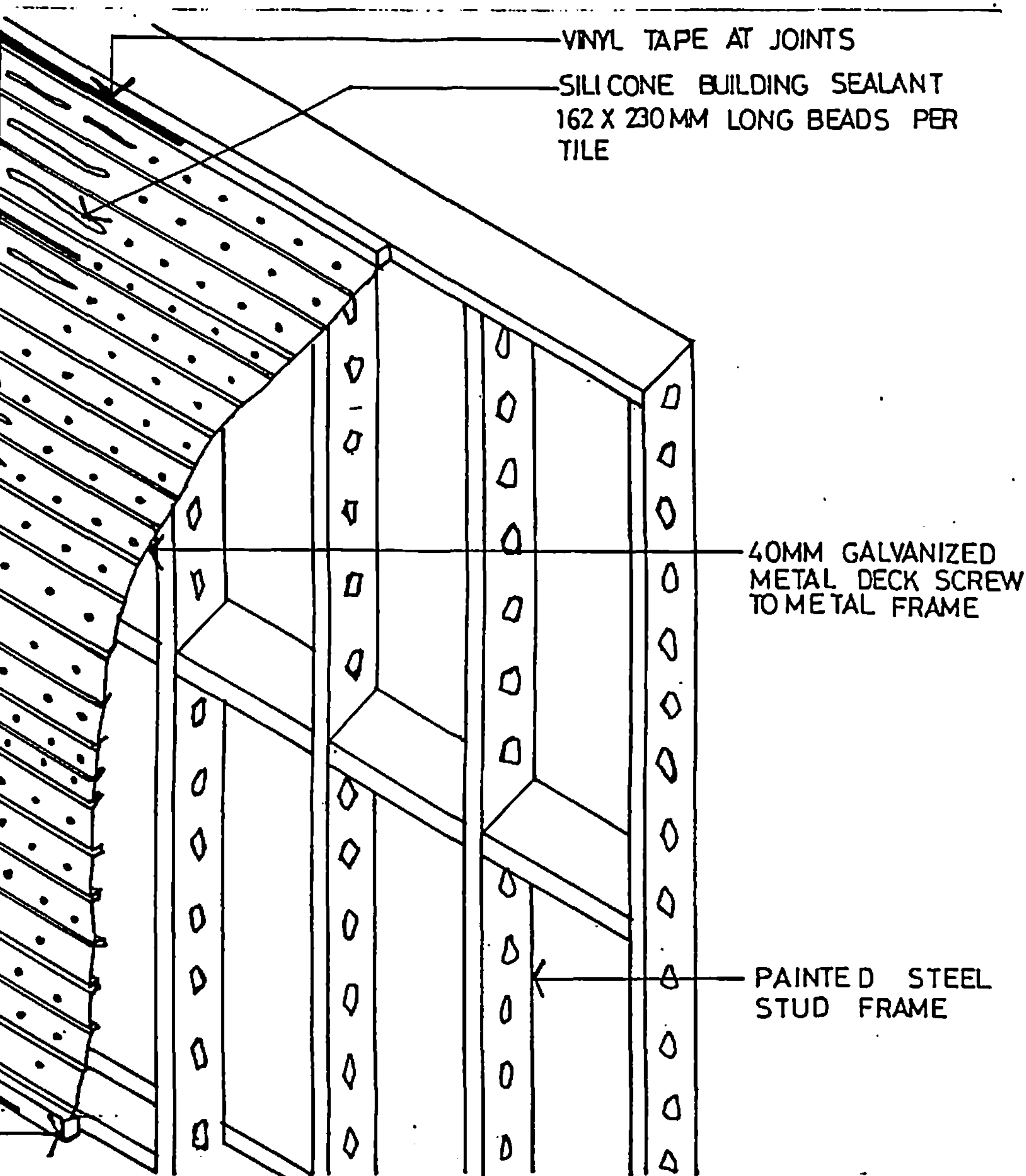

VINYL TAPE AT JOINTS
SILICONE BUILDING SEALANT
162 X 230 MM LONG BEADS PER
TILE
40MM GALVANIZED
METAL DECK SCREW
TO METAL FRAME
PAINTED STEEL
STUD FRAME

FIG NO. 3.3

CHAPTER IV

CONSTRUCTION IN DESERT - THE POKHRAN PROJECT

The author had an unique opportunity to work on a strategic defence project related to testing of war heads, located in desert. It was a residential project meant to accommodate 15 senior scientists & 25 junior scientists & 75 supporting staff. (Plate 4.1, 4.2)

4.1 THE SITE

The site is situated at "CHANDAN" which is 180 km from Jodhpur and 40 km from Pokhran in Rajasthan. The site lies in the Thar Desert & the soil is sandy, the nearest available source of water for day-to-day construction activity is 40 kilometres away from site.

4.2 DESIGN PARAMETERS

The entire complex is planned in an area admeasuring 30,000 Sqm. The project complex is designed to have a total built up area of 1670 sqm. Which includes 950 sqm for accommodating 15 senior scientists, 25 junior scientists and 75 supporting staff; 310 sqm for a common dining area, a kitchen & a store complex and technical accommodation in test range covering an area of 410 sqm. **The entire complex was to be set up within a period of four months.**

(Drawing No. 4.1, 4.2, 4.3, 4.4, 4.5, 4.6)

4.3 PROBLEMS OF THE SITE

All the problems/difficulties associated with a desert site were encountered in full measure, vide chapter II. Besides the scorching heat and gusty, sandy blasts, water & material could be brought only from a site 40km away. Water was scarce and road non-existent. No local labour was available as,

(i) The population was sparse & scattered,

(ii) Construction skills for modern construction were unknown.

4.4 THE CHALLENGE FOR THE ARCHITECT

The Right Material Doesnot Exist

An ordinary stone masonry wall construction, with normal type of load bearing walls would have involved large quantity of stone & the normal course of construction would have needed huge quantity of water for curing etc. This would have aggravated the problem of transportation of material from 150 km away & water at 40 kms away from site. Water being one of the major components of construction activity. Its consumption was minimised by using "**Dry Wall**" construction concept.

Prevailing practice of local stone slabs was considered for the construction of wall which would have consumed much less water and involved much less transportation. But local stone slabs being thin and smaller in size, its construction was time-consuming and thus it was not suitable due to the time constraint of 4 months. Also with the local stone slab it was not possible to run the electrical conduit or Galvanized Iron (G.I.) pipes as also to fix doors and window frames.

Further, Stone has the property of heat retention and the extreme variation of temperature in Rajasthan causes cracks at the joints of the stones which weakens the bonding. Also stone being heavier, more number of trips are required for transportation of material from distant places.

4.5 PROBLEMS OF ENGINEERING DESIGN

Apart from the problems of the choice of strategic materials, design of structural element and project management, there were specific problems of engineering design of foundation and super structures, as discussed below which were solved with ingenuity.

4.5.1 SALIENT PROJECT STATISTICS

To get an overall idea of the magnitude of the task vis a vis the cost & the time available one may consider some of the project statistics :

*	Area of the Complex	:	30000 Sqm
*	Total Built Up Area	:	1670 Sqm
*	Project Cost (Year 1991)	:	68 Lacs (Excluding Cost of Road, Area Development & External Services)
*	Time for Completion	:	4 Months

The innovative design and unorthodox approach to organize construction at the inhospitable and difficult site led to successful completion of the strategic project strictly within the stipulated tight time frame of 4 months.

4.5.2 FOUNDATION

As the soil strata over entire site is sandy, therefore simplified technique was followed for footings. The light-weight panel construction has permitted the depth of foundation to be kept minimal & the design, simple. At certain places where foundation was required for load bearing structures or for the main members of the structural frame, a stone slab was kept under the vertical load carrying member instead of having normal Plain Cement Concrete (P.C.C.) below the footing bed and the concreting was carried out for the panels, whereas stone slabs were used as dwarf wall. (Drawing No. 4.7, 4.12)

4.5.3 WALLS

Walls consist of modular sandwich panels and are light weight. The composition of the sandwich panel includes welded mesh on both faces of Insulation material (Poly Urethene Foam) maintaining a gap of 15mm on either side firmly secured by means of press metal channel frame work which also holds the service conduit to run electrical cable (Plate 4.4). These panels are standardized to the dimension of 1.2 m x 2.7 m, weighs approximately 4.5 kg/sqm, irrespective of the nature and type of panels i.e. window panel, door panel and wall panel etc. In the modular concept it is found that construction and operating cost are lower, additions can be more easily and hermoniously planned. Space is more flexible, which is immensely important in view of the largely unpredictable and changing space requirement.

The incremental nature of modular planning has enough flexibility to do addition & alteration, horizontally, vertically or any direction and still forming a good geometrical form supporting its function and need.

To continue with this modular approach, the structural members which are light weight & economical and are arranged in grid. Vertically and tied up with the help of steel members horizontally at the roof level to support the stone roof slabs. After erection of these structural network the modular sandwich panels are placed in position.

On positioning of these panels (Plate 4.5), concrete is mechanically sprayed over welded mesh and finished with trovel to give a smooth and ultimate finish over external and internal skin of the panel (Plate 4.6). The foam cores are composed of Polyurethane of required thickness carefully selected to achieve higher degree of insulating properties (Annexure 7.1). This also acts as shuttering for the concreting. These panels are manufactured off the site, at the factory. After analysing the building plan, various types of panels are identified with the help of fabrication drawings for manufacturing each panel to precise dimension including opening (Plate 4.7) & odd geometries. Edges, angles, & all other configurations are checked and cut in the factory. All the panels required for the entire building are then packaged and transported to the construction site. **Panels being quite light weight are mostly installed manually.** Being stressed skin panels, their cores of rigid plastic foam provides shear strength, while the exterior skins of structure of the panel provide tensile as well as compressive strength.[16]

Structural composition of the panel is comparable to that of an `I' beam. The panel skins are analogous to the flanges of an `I' beam, while the foam core is comparable to its web. The complete assembly, with exterior and interior faces laminated to the core with glue under pressure, allows for a system that is structurally comparable to and straighter than conventional stud frame structure.[17] (Drg. No. 4.8, 4.9, 4.10)

4.5.4 SUPER STRUCTURE FRAME WORK

Design solution of the entire structural system (Plate 4.8) is a steel frame work consisting of M.S. tubular columns supporting I.S.M.B (Indian Standard Medium weight Beam) Girders (Plate 4.9), local stone slabs are used as structural slab. Roofing consists of a coarse of average 75 mm thick lime concrete overlaid by a layer of water proofing having insulation properties.

Sliding of local stone slabs over the steel frame due to horizontal forces such as wind/earth quake is resisted by the provision of M.S. bolts (acting as "shear keys") welded to steel girders.

Diagonal bracings are provided in the outer frames to resist the wind/earth quake. These bracings are provisioned in the panel to give an aesthetically even appearance. Where the structure require more height due to its functional need, the super structure is raised in the similar modular form to suit to any required height after due consideration for the seismic, wind, live and dead loads. (Plate 4.3), (Drg. No. 4.7, 4.11, 4.13)

4.5.5 FLOORING

Standard size, readily available, sand stone flooring were laid over lean concrete in the entire complex which is the local practice and found to be very economical.

4.5.6 ELECTRICAL SERVICES

Electrical wiring conduits are provided in the panels in order to accommodate electrical wiring. These conduits are inbuilt in the panel along predetermined route. Spaces in the vertical joints of the panel are utilized for providing electrical conduits. These panels are identified as per fabrication drawing. (Drg. No. 4.8, 4.9, 4.10)

4.5.7 PLUMBING SERVICES

The water supply pipes and the brackets for holding the sanitary fixtures were in built in the pre determined panels and sleeves were kept for running water supply pipes.

4.5.8 ENERGY EFFICIENCY

The foam core of sandwich panels provides thermal insulating properties. The thickness & density were carefully selected by virtue of which there was a saving of thermal energy between 12% to 17% during peak duration.

LIST OF PLATES

PLATE 4.1 VIEW OF THE COMPLEX

PLATE 4.2   VIEW OF THE COMPLEX

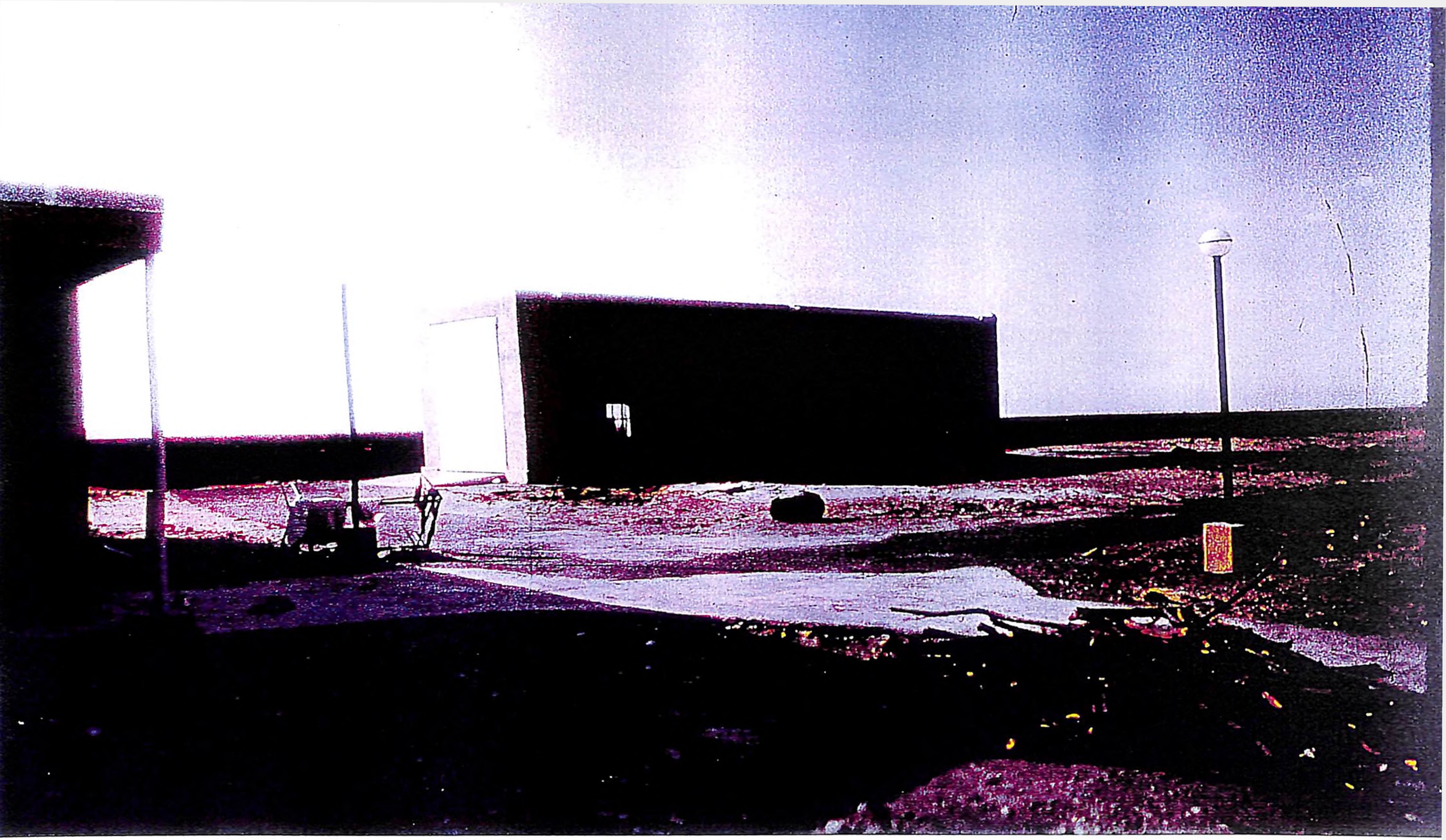


PLATE 4.3 VIEW OF STORAGE BLOCK (6.0 M HIGH)

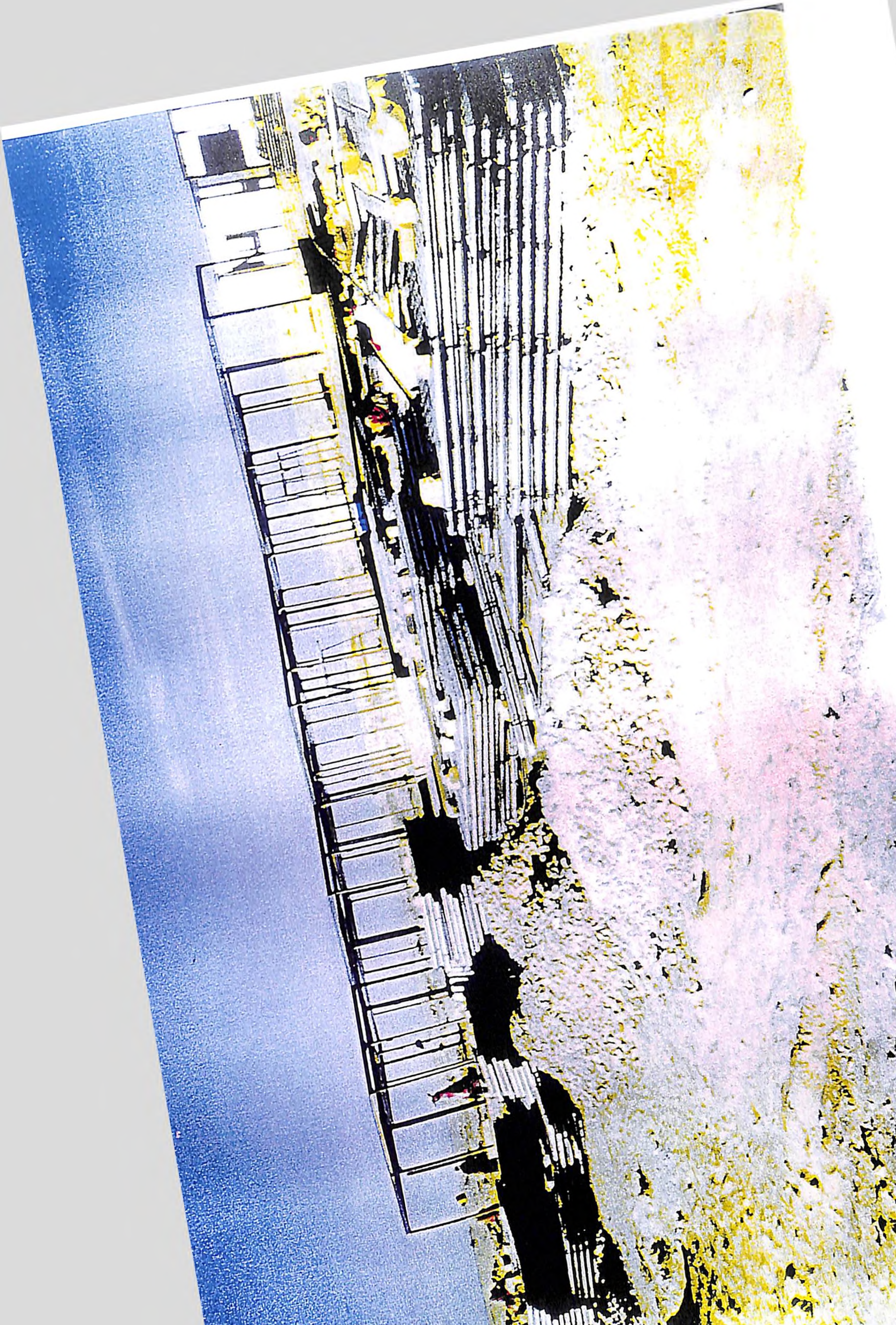


PLATE 4.5 SANDWICH PANEL ASSEMBLY AND ERECTION

PLATE 4.6 COMPLETION OF INTERNAL AND EXTERNAL SKIN OF THE PANEL

PLATE 4.7 DOOR WINDOW AND WALL PANELS

PLATE 4.3 ERECTION OF VERTICAL STRUCTURE SYSTEM

PLATE 4.9 ARRANGEMENT OF VERTICAL AND HORIZONTAL STRUCTURAL SYSTEM

CHAPTER V

CONSTRUCTION IN HIGH ALTITUDE AREA

Snow Avalanche Study Establishment - Project At Baralachla, Beyond Manali, Himachal Pradesh. (>4800 M)

5.1 INTRODUCTION

Snow Avalanche Study Establishment **(SASE)** since 1969, has been working on projects on study of snow & avalanches along a number of axes. Such studies are carried out over a number of years deploying independent field investigation teams on high altitude, snow bound regions on a self-contained basis. These teams remain cut off from the rest of habitats for almost nine to ten months in a year.

One of the **SASE** study projects is along the road axes connecting Leh with Manali and Srinagar. A study complex was required to be set up on this axis.

5.2 THE SITE

The site is located in a place called **"Baralachla"** on **Leh-Manali Road** (Fig. 5.1) at an altitude of 4890 M. above mean Sea Level (MSL). Being in high attitude area, generally it is found snow bound over eight months in a year. In these area the average wind speed recorded in the year 1985-86 was 60.6 km/hour and (Fig. 5.2) the lowest 3.7 km/hr; the highest wind speed recorded during snow storm was 150 km/hr. in the year 1988-89.

5.3 PROJECT REQUIREMENT

The accommodation needs have so far been met by either resorting to hiring or creating improvised pre-fabricated shelters (Plate 5.1) at selected sites. Various kinds of shelters (Plate 5.2) built over a period of time at various field locations neither serve the functional necessities nor remain usable for long periods under extremely severe winter conditions and could not sustain the severe snow conditions (Plate 5.3). Although some kind of insulation had been provided in the shelters, yet the shelters have not been able to meet the user needs.

The scientists and the staff involved in cold region studies have to work in extremely hostile environment having a temperature down to - 30 degree C, wind upto 100 Km/hr, standing snow of 2 to 3 Mtrs and extreme drift snow conditions. Thus, the field teams are, to be provided with adequate living accommodation in the field location in addition to the transient accommodation, where apart from living and working (research) spaces and environment, storage are to be created for stocking rations, fuel, clothing and other items.

To approach a functional architectural solution the Author studied in great depth and detail the diverse requirements of the project at exceptional sites. Such as, the method of day to day communication (Plate 5.4) existing structure during snow (Plate 5.5), light weight tubular structure (Plate 5.6) and a model structure created by Author (Plate 5.7). These included requirements of research and study to be carried out, at and from the site, besides the problems of engineering and organisation of construction activities. Thus, the studies dealt with avalanche forecasting and avalanche control, which in turn call for an indepth understanding of the physics and mechanics of snow. A cold Lab provides such facility where simulated studies on various aspects of physics & mechanics can be carried out simultaneously throughout the year, thereby, telescoping the overall time frame of technological advancement.

In particular studies on the following aspects were to be carried out round the year in this laboratory :

Metamorphism, Crystallography, Mechanical properties of snow.

The study complex was required to be provided with the following facilities :-

a) Snow Physics and Mechanics Lab.

b) Snow Sample Room.

c) Recording Instruments Area.

The accommodation was to be provided with adequate insulation appropriate electrification and other ancillary facilities so as to provide the field team workers a minimum level of comfort.

Two kinds of field study teams are deployed for studies viz **Major Teams** and **Minor Teams.** Major teams generally consist of 2 officers, 3 Junior commissioned officers (JCO) and 10 orderlies (ORs); and Minor teams consist of 1 officer, 1 JCO and 06 ORs.

In addition to data collection the field teams are also required to undertake recce during peak winter months for over long stretches. However, on account of the inability to transport all logistic facilities like tentage and ration with the recce party, transient facilities are created and stocked.

5.4 DESIGN RATIONALE

The construction sites available at the field team locations are such that it would not be possible to get large flat terraces of ground to construct long building units. Multistorey construction was also not advisable in view of seismicity, wind activity and the need for snow clearance from the roofs. This led us to suggest buildings in single storey modules. The layout was designed to provide closed, interconnecting corridors, so as to protect the shelter from the severe cold and winds. Provision of Insulation, Central Heating and Airlocks (for changing snow cloths & snow shoes) was unavoidable to comb at the vagaries of weather.

5.5 DESIGN PARAMETERS

This project has been planned on a piece of land area of about 1000 sq. yards. The major component of the building consists of living accommodation for Junior and Senior Scientist & laboratory facilities. Since it was located in the remote area, even the facilities of kitchen and dining hall were provided in the building. The availability of electricity solar energy (Plate 5.8) was utilized for generating electricity and water heating which had the stand by arrangement of generator and boiler respectively.

(Drg. No. 5.1, 5.2, 5.3, 5.4, 5.5)

5.6 DESIGN APPROACH

After comprehensive study and analysis of the problem and the information available on ground following were identified :

* Limited period is available for construction.
* Acclimatization of climate is essential. (Refer Annexure 5.2 of this Chapter)
* Skilled and unskilled labour is not available locally.
* Power Supply is not available .
* Due to inclement weather conditions insulated structure need to be provided.
* Due to remoteness of the place transportation cost of material from Kulu or Manali will be phenomenal.
* Trucks can't reach the project site for transporting the material, cartage by means of smaller vehicles is the only alternate, to be effected thereby increasing cost of transportation.
* Thus, only factory made solution was possible which means maximum work away from site and only assembly of components at site.

Due to heavy Snowfall in this region it was desired to have single story structure with sloping roof of Corrugated Galvanized Iron (C.G.I.) powder coated sheet roofing. The total accommodation have been planned covering an area of 500 Sqm. (Drg. No. 5.2)

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5.7 DESIGN PROCESS

The site being in heavy snow bound region, very limited period, barely two and a half months from mid July to September was available for construction. During the peak season from December to February, standing snow of 2.4 M height is found. Earlier the use of stone for construction of structure was studied but the study in that area revealed that extreme variation in temperature of day & night leads to the problem of setting of cement. The water in cement mortar turns to ice bubble, which contracts at night and melts during the day time and expands, resulting into disintegration of concrete. Even the quick setting cement also does not help. (In addition to these even the normal code for concreting in cold weather requires working which is difficult even for an ordinary site vide Annexure 5.1 of this chapter).

In these areas one could only think of some material which does not have use of cement as binding material. Thus the solution to this problem could be the use of either metal sheet or wooden panels or cement base wood particle panels which come in various thicknesses and sizes.

5.8 SALIENT PROJECT STATISTICS

*	Total Built up area	500 Sqm
*	Project Cost (Year 1992)	35 Lacs
*	Time for completion	3 Months

5.9 DESIGN COMPONENTS / SOLUTION

5.9.1 FOUNDATION

Several innovative features have been incorporated in the foundation design making a virtue of the compulsions and restrictions imposed by the site.

Considering the heavy snow fall in that region the level of the plinth has been kept considerably high (Plate 5.9, 5.10, 5.11). The basic idea is to isolate the structure (living area) from the ground and insulate it from the surroundings. The foundation wall upto plinth height is designed as a retaining wall to take care of the standing snow load.

The elevated portion of the area under floor has not been filled up but utilized as natural insulation, besides the available space has been utilised for the services catering to the building. (Plate 5.12)

Precasted foundation bed blocks, having provision of nut and bolt arrangement in which the structural member is positioned. Local available stone was used within the column bed block for construction of foundation / retaining wall upto plinth. (Drg. No. 5.6, 5.21)

5.9.2 SUPER STRUCTURE

The structure consists of frame work of steel members & the size of the member is carefully selected after evaluation of the wind load & snow load etc (Plate 5.13). After properly levelling of the concrete precast bed block, the vertical structural member which consists of Indian Standard Medium Channel (I.S.M.C.) having arrangement of a base plate with necessary holes to secure it with precast bed block in vertical position with help of nuts and bolts. These channels also are provided to receive the placement of steel plate, cut at an angle to suit to the angle of inclination of truss and to align & match the predetermined holes of the truss. All these vertical members are then placed in position as per the drawing.

The vertical channel also have holes at required internal to secure the sandwich panel in position by nuts and bolts. The truss comprises of I.S.M.C. and is divided in two parts to facilitate easy mobility to the work site. The trusses are then placed in position over the vertical structural members and secured by Nuts and bolts and both at the ridge level and the column level. The cross bracing as per the structural requirement is provided at desired location to cater for the prevailing wind and seismic forces.

(Drg. No. 5.5, 5.7, 5.17, 5.21)

5.9.3 WALLS

Insulated sandwich wall panel which are thin, light weight weighing approx. 18 kg/sqm easily transportable consisting of frame work of G.I. stud and channel, externally and internally finished with 12 mm thick cement based wood particle panel & the space in between is lined with 100 mm thick rigid polyurethene foam for insulation.

A variety of panels meets different requirements (Plate 5.15). For example, there are window panel and door panel with a built in window / door frame. Due to the extreme climatic conditions the use of insulated hermetically sealed laminated glass panel in window shutter is preferred in comparison to normal glazing.

These doors & windows also form the part of the panel. The electrical service conduit is drawn within the G.I. frame work of the panel. The modular approach is followed which is already explained in Chapter 4.5.3. Special kind of Hardware were selected for doors and windows. Due to extremely cold condition no metal hardware were used instead it was all fluropolymer coated including the gaskets. These wall panels were numbered and assembled at site as indicated in drawing along the vertical structural member with nut and bolts and necessary precaution has been taken to isolate structural steel members used on internal & external sides of the sandwich panel to prevent "Thermal Bridge" formation to prevent as this is very essential in the areas where the difference in inside & outside temperature is considerable e.g. inside maintained temperature is 27 degree C where as outside temperature is as low as - 40 degree C.

(Drg. No. 5.7, 5.8, 5.9, 5.10, 5.11, 5.12, 5.13, 5.14)

5.9.4 FLOOR

The raised floating floor are supported on adjustable metal jacks resting on precast cement concrete blocks having built in arrangements of nuts and bolts to secure the jack in firm position. Existing ground contours were not disturbed due to the flexibility provided in the adjustable jacks. The steel grid frame network is laid over these jacks to support the particle board flooring finished with epoxy coating. The insulation is sandwiched between the steel grid network & the particle board. The space between the existing ground and floating floor also acts as insulative area and all the services such as water tank disposal system water supply pipes, airconditioned pipes are accommodated within this area. All the services and the water tanks is further insulated for the ultimate effectiveness. (Drg. No. 5.15, 5.16)

5.9.5 CEILING

The area between the C.G.I. roof and the false ceiling being very valunarable which have to bear the difference of the extreams in temperature. The false ceiling panels are engineered as insulative panels out of cement based wood panel internally and externally fabricated on G.I. studd with polyurethene insulation sandwiched in between providing the required thermal control. The electrical cable and conduit which connects the lighting system which are planned in the false ceiling has been routed under the false ceiling due to variation of temperature above false ceiling which could otherwise call for maintenance frequently. Provision has been made to maintain the air circulation in the space between false ceiling and C.G.I. sheet roof to avoid condensation. (Drg. No. 5.18, 5.19)

5.9.6 ROOF

The structure has the powder coated C.G.I. sheet roofing on M.S. channel Truss and the purlin which is designed to suit to the snow load and the wind pressure prevailing at that site with the angle of inclination of truss to cater to the snow fall of that region. The joints of the C.G.I. sheet roofing have been given the preventive covering from water seeping through by virtue of capillary action and resulting in damaging the ceiling and the insulation thereof. (Drg. No. 5.3, 5.5, 5.20)

5.9.7 PLUMBING

Extra care has been taken to avoid bursting of water supply pipe and design the plumbing system in these high altitude area. As the Ph. value of snow being very high, it was not possible to melt the snow and use water for drinking purpose hence the source of water is identified and specific arrangement are being made to bring it to the storage point. Within the raised floor the pipes are insulated and placed at 1.2 m below the ground level (below freezing point), it is connected through the prefabricated concrete pipe positioned at the source to draw water. Specially designed water pumps to suit to high Altitude area used to maintain the regular water supply. Under ground water storage tanks were housed, within the space under floating floor. These tanks are supported over insulated platform and encased by the insulated sandwich panel from all sides and top to avoid freezing of water. From this main storage tank water is distributed in to the loft tanks placed within the toilet. Due to extream weather condition even the toilet areas were also conditioned and all the internal distribution pipes were properly insulated.

The entire disposal system is designed 1.2 m below ground level to take care of vagaries of weather and all the connecting pipes from toilets to the disposal tanks are insulated. The man hole is connected with the soakage pit located outside the plinth however below 1.6 m from lower terrace.

5.9.8 ELECTRICAL

In the absence of regular electric supply lines diesel generator set has been used to meet the load demand for the building which generally comprise of lighting system and general convenience socket outlets.

Standard DG set design do not envisage any derating upto 38 degree celsius temperature and 1500 m altitude.

However, for any change in ambient temperature and/or altitude the following derating, have to be considered, as declared by the manufacturers :

Every 11 degree celsius ambient	:	2%
Every 300 m above 1500 m altitude	:	4%

The DG set rating was thus arrived at by considering overall derating of 35% in the power output.

Furthercome, at Subzero temperatures an antifreezing compound need to be added with the fuel, being diesel in this case to have smooth starting of the engine.

As far as possible Polyvinyl Chloride (PVC) material is to be avoided for use in subzero temperatures as it tends to loose its hardness and turns brittle.

Wires generally used for wiring of lighting fitting, socket outlets etc. have copper / aluminium conductor with PVC insulation do not find much use in this situation for the reason stated above. Hence wires with copper conductor and insulation of fluropolymers which are thermoplastic with excellent weatherability are made use of. This particular insulation can withstand temperature as low as - 200 degree celsius.

Similarly, in place of PVC conduits galvanised iron conduits are used, for encasing the wiring.

LIST OF PLATES

PLATE 5.1 IMPROVISED G.I. SHEET STRUCTURE

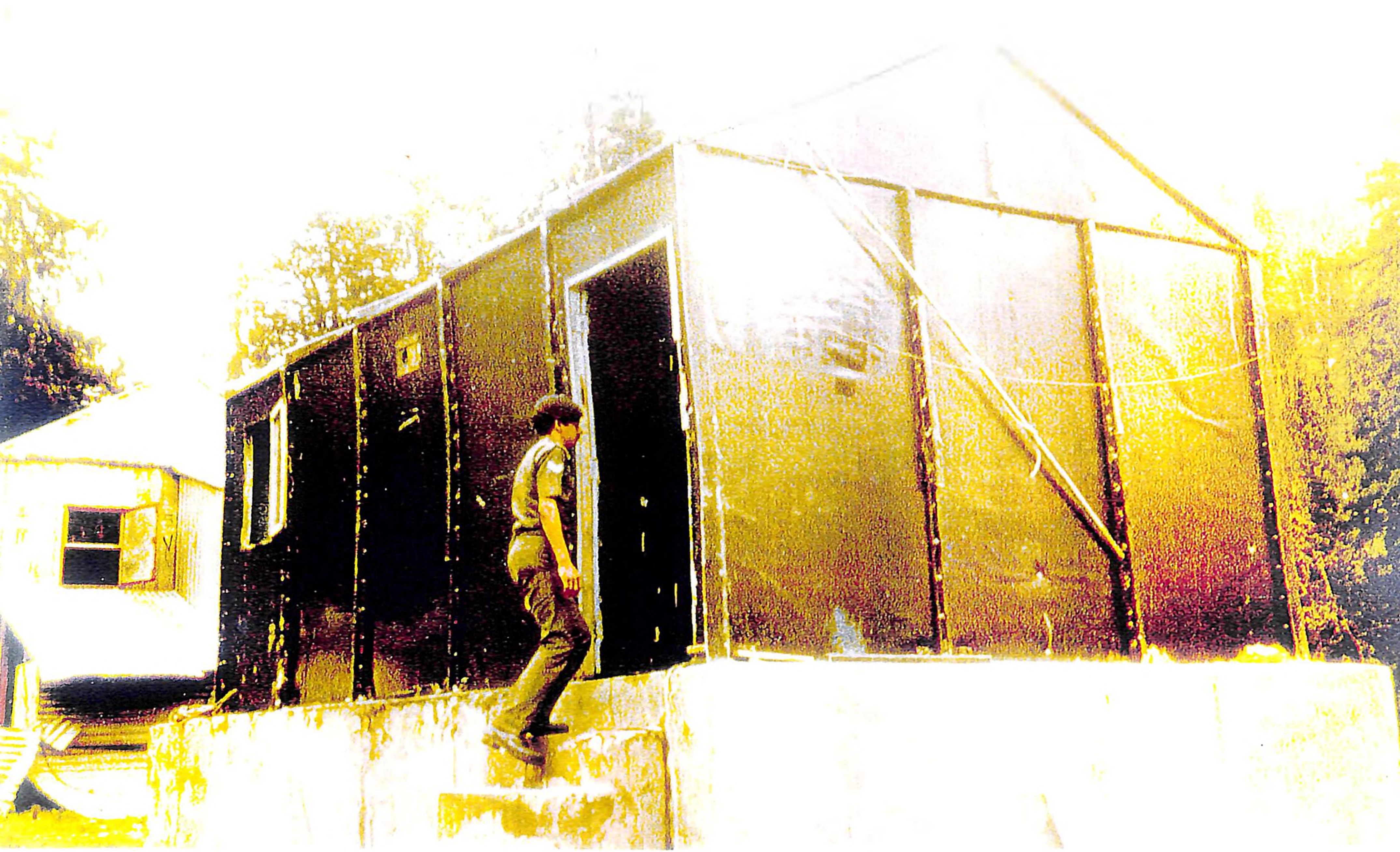


PLATE 5.2 IMPROVISED PORTABLE STRUCTURE

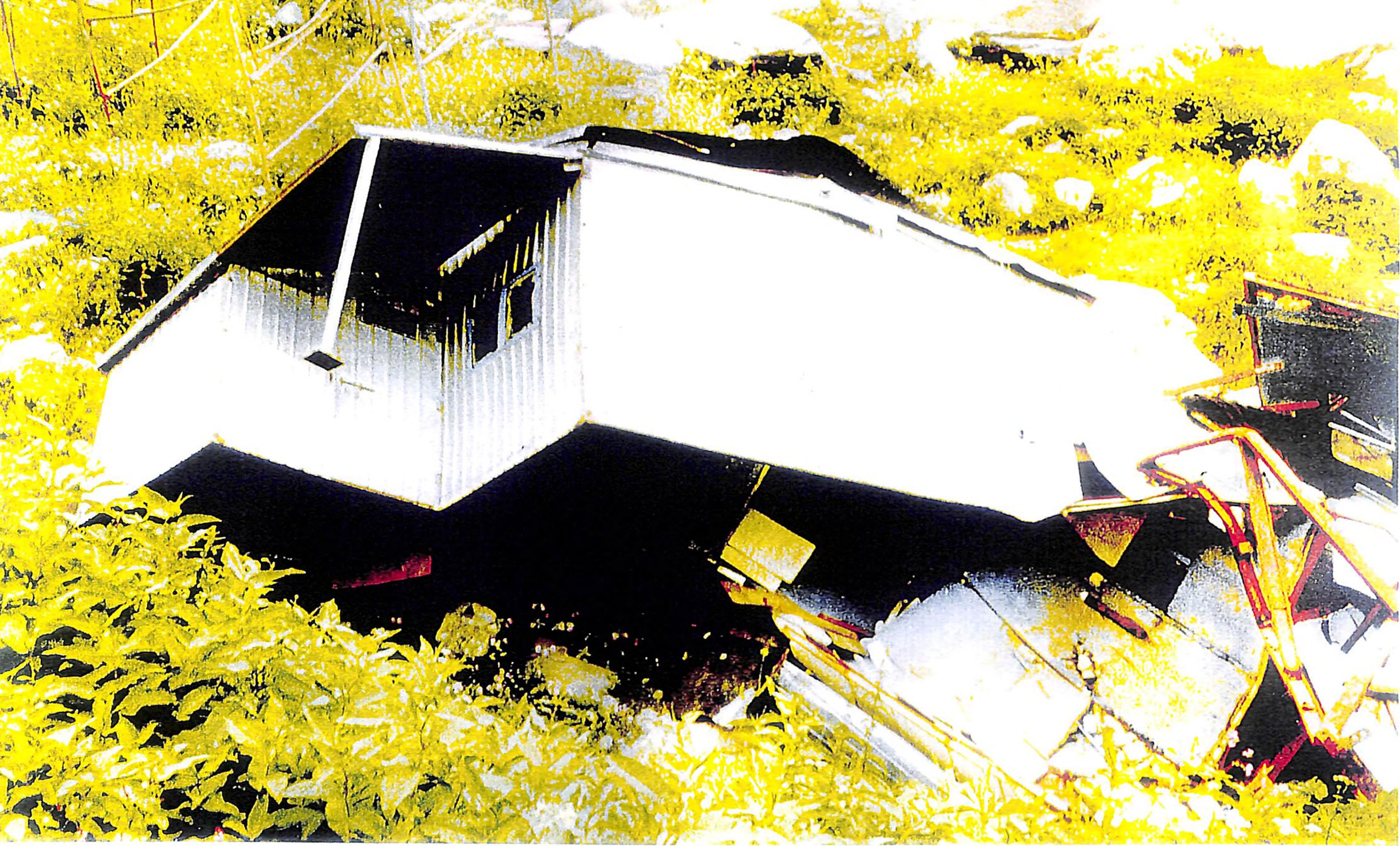
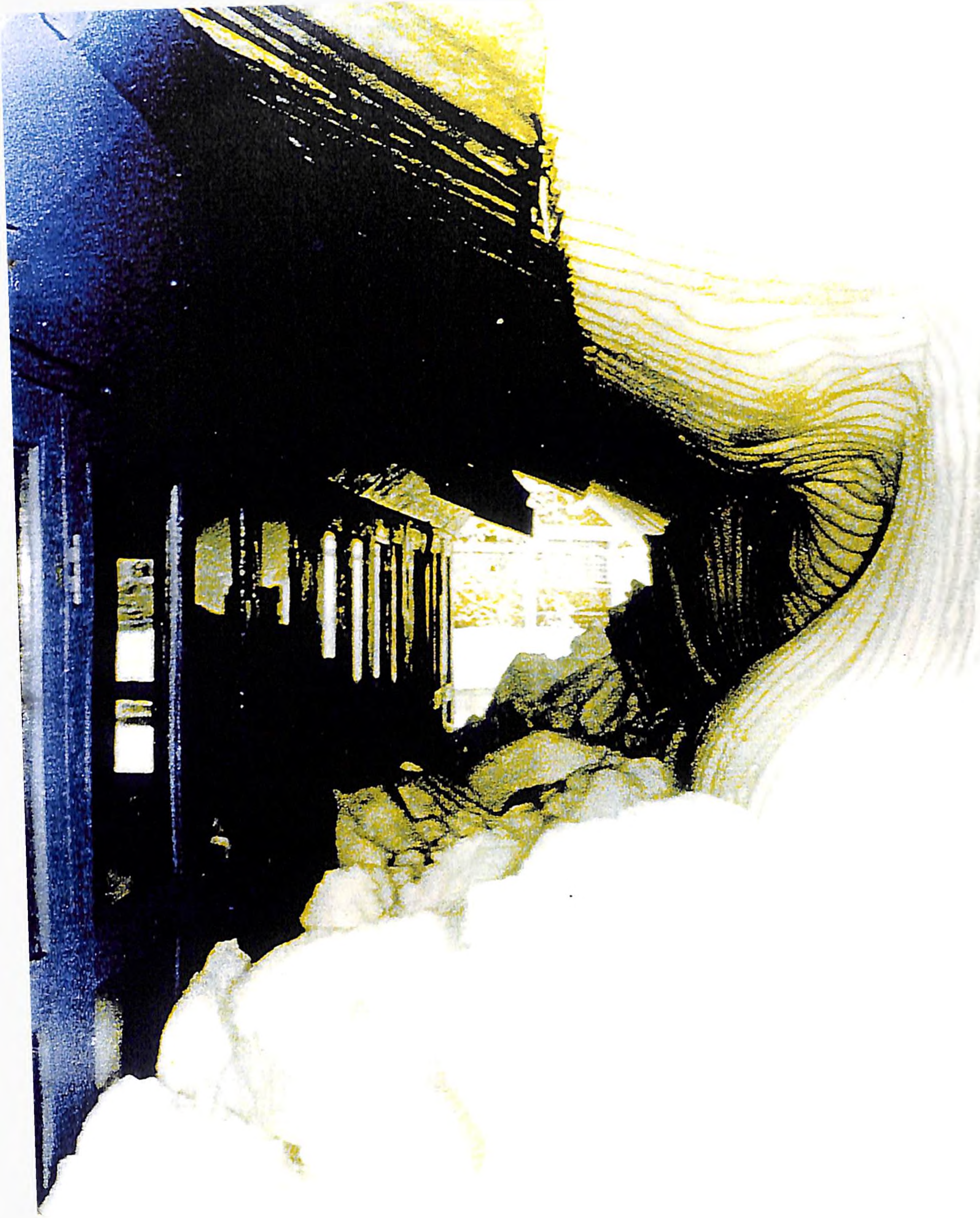


PLATE 5.3 FAILURE OF IMPROVISED STRUCTURE

PLATE 5.4 IMPROVISED BRIDGE FOR COMMUNICATION



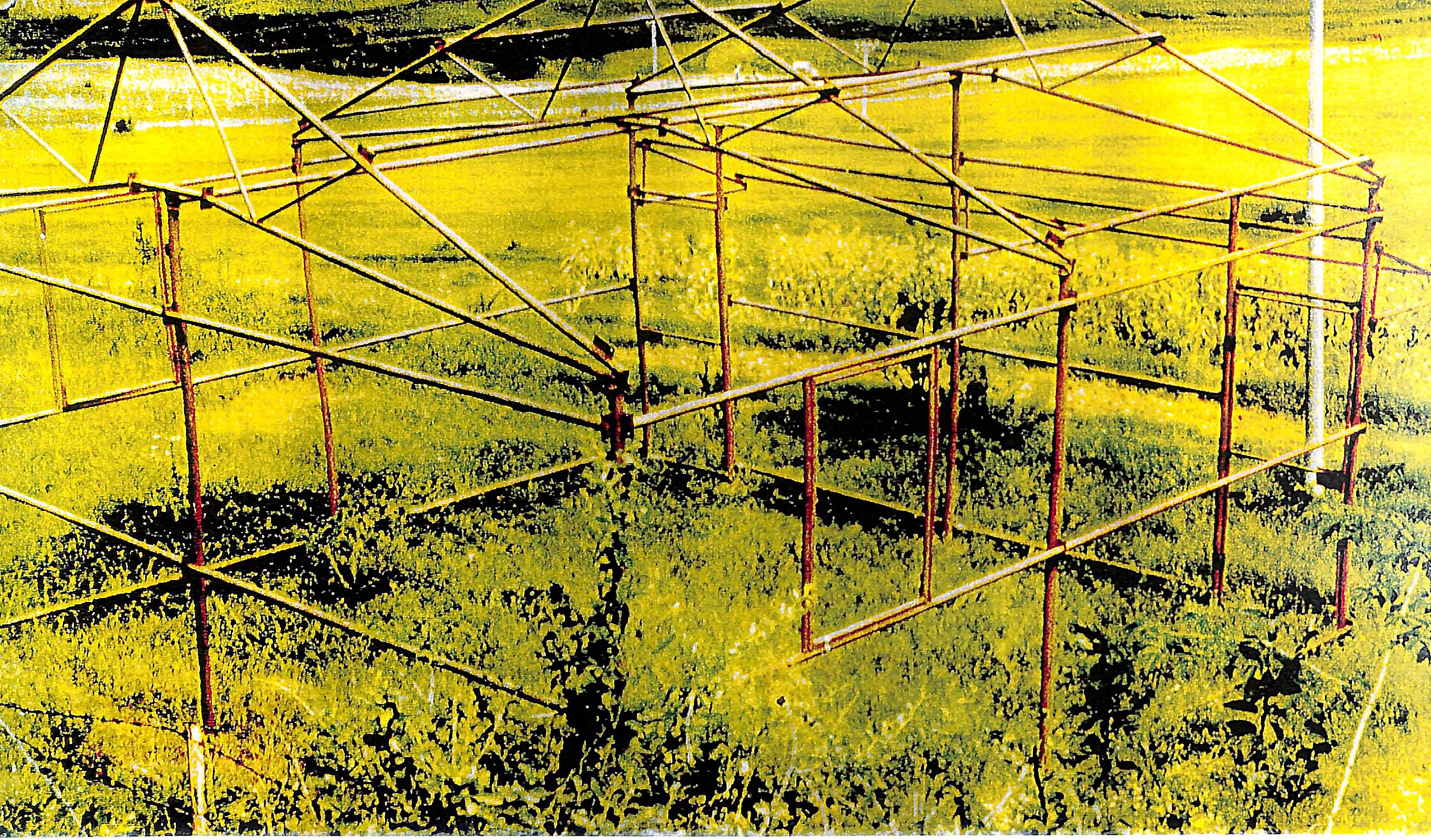


PLATE 5.6 IMPROVISED EXPERIMENTAL LIGHT WEIGHT TUBULAR STRUCTURE

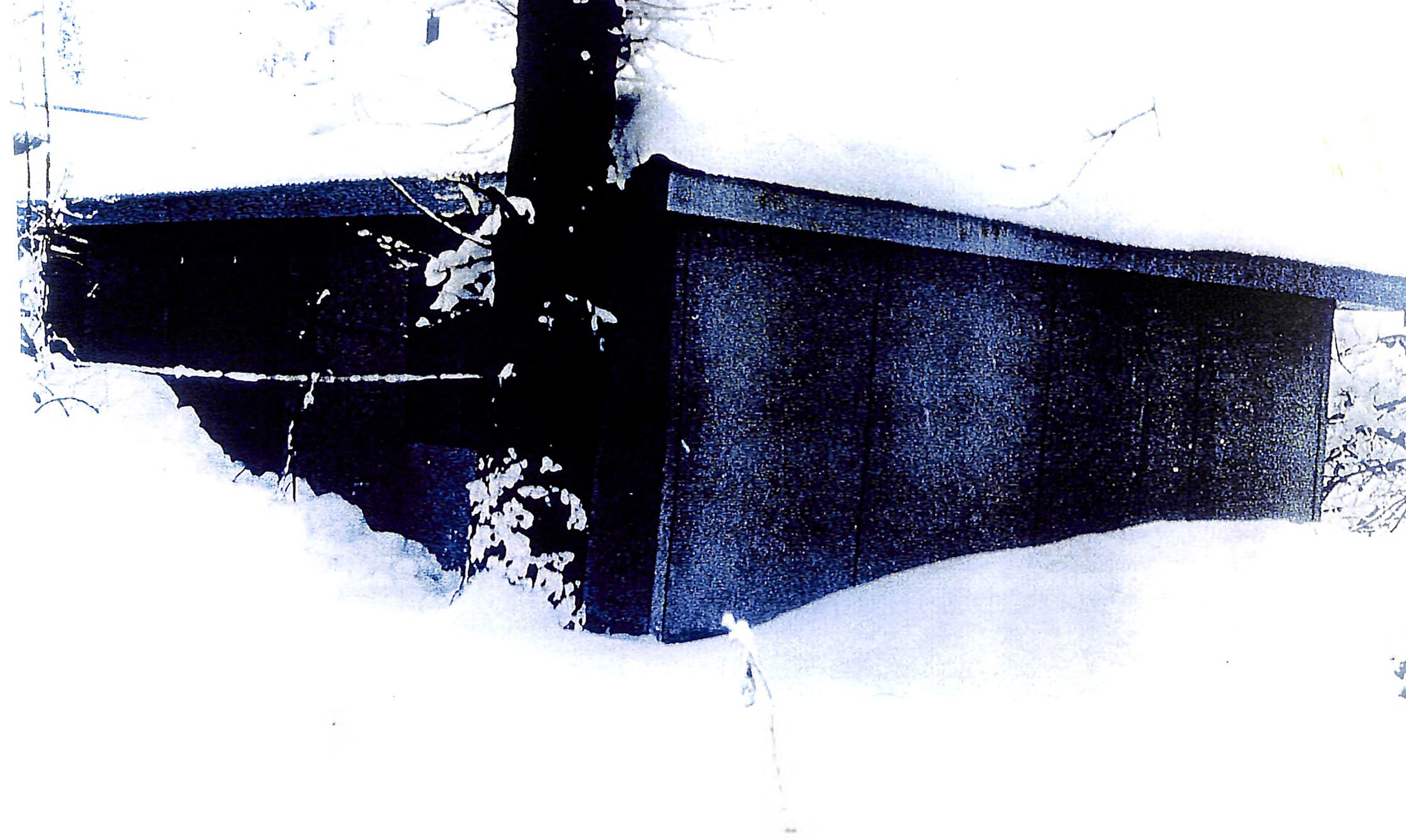


PLATE 5.7 STUDY OF MODEL STRUCTURE DESIGNED BY AUTHOR

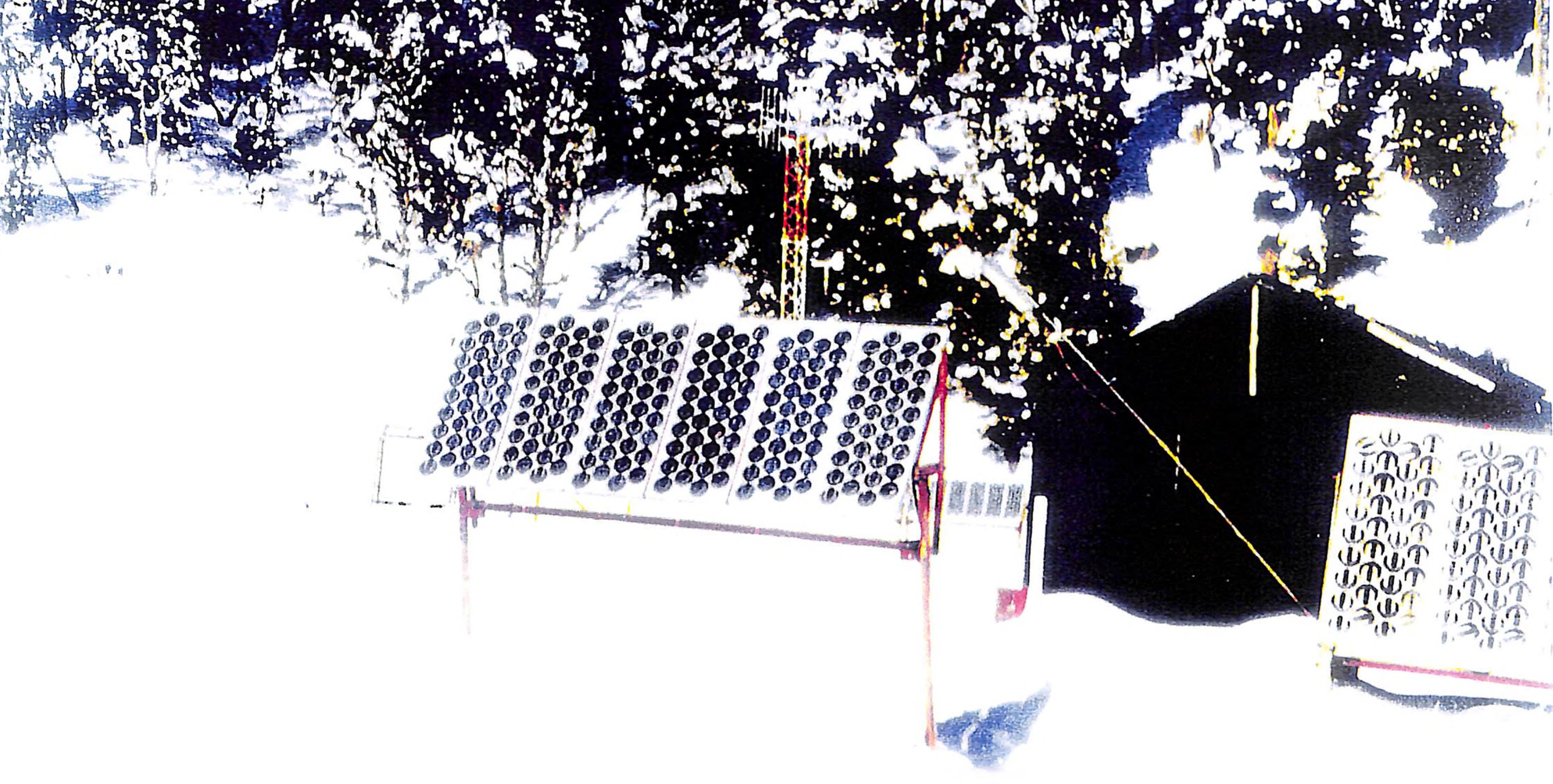


PLATE 5.8 SOLAR ENERGY UTILIZATION

PLATE 5.9 PLINTH OF PROPOSED BUILDING (VIEW DURING SNOW)

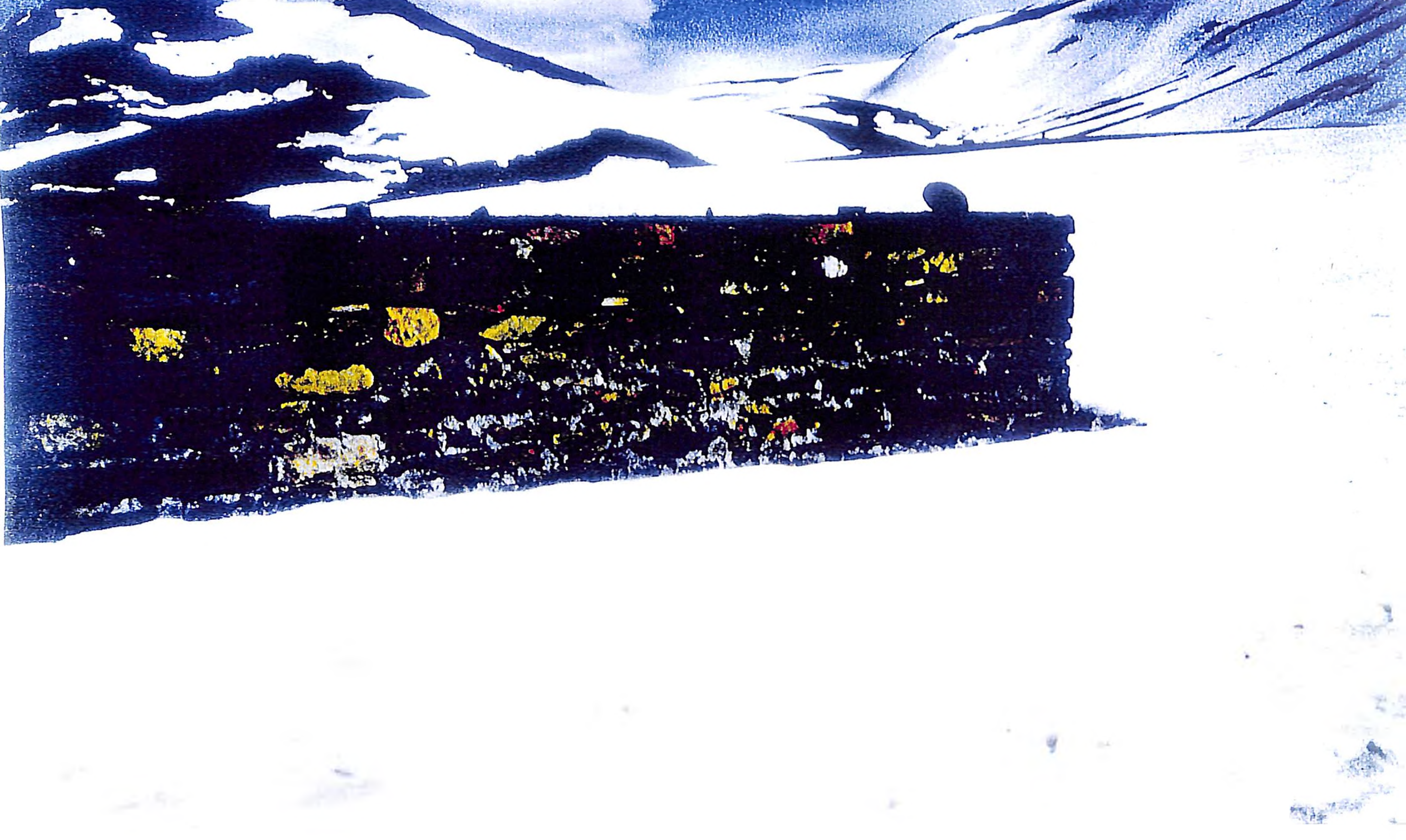


PLATE 5.10 PLINTH OF PROPOSED BUILDING (VIEW DURING SNOW)

PLATE 5.11 PLINTH OF PROPOSED BUILDING

. PLATE 5.12 PLINTH OF PROPOSED BUILDING (UNDER CONSTRUCTION)

PLATE 5.13 ASSEMBLY OF STRUCTURE

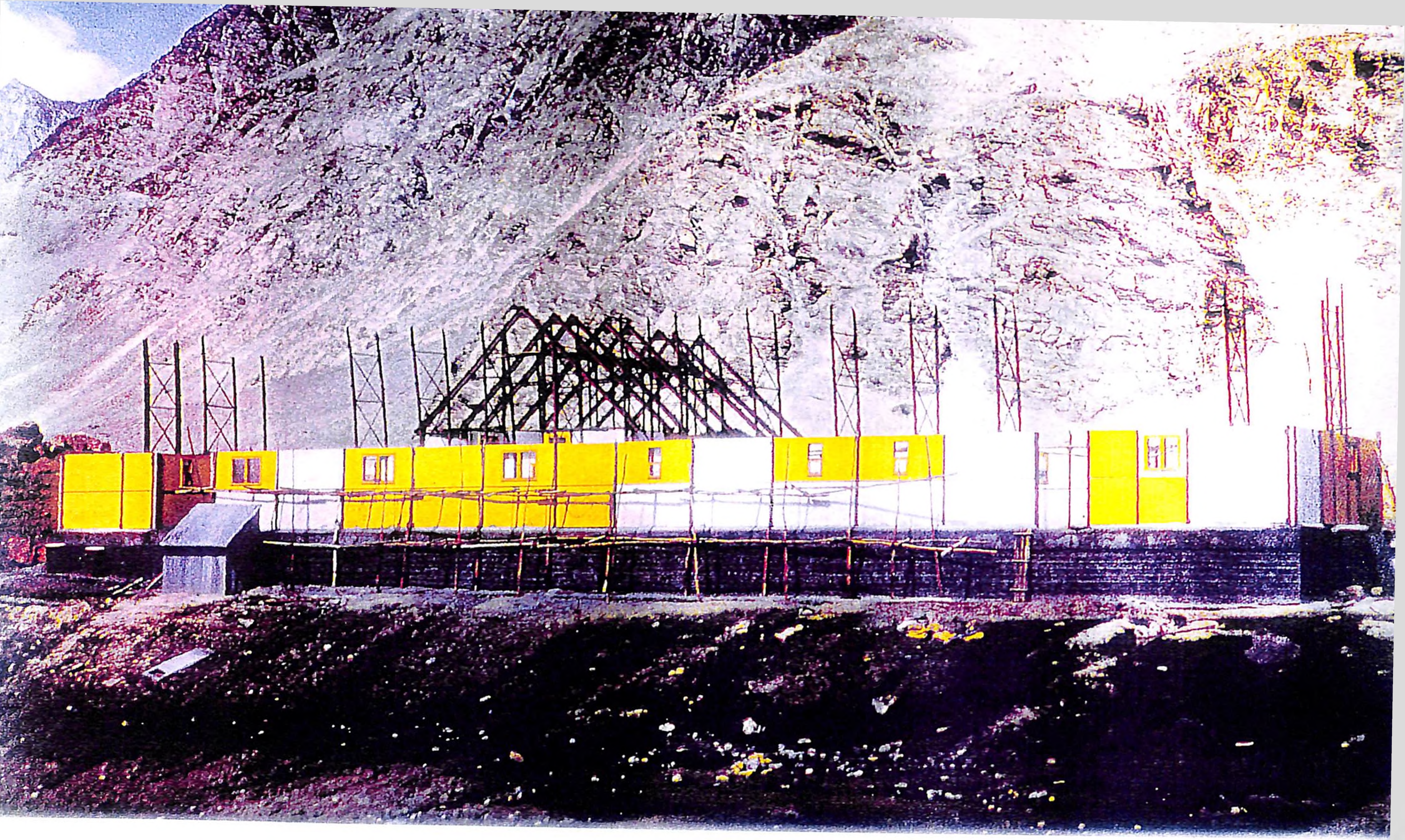


PLATE 5.14 ASSEMBLY OF STRUCTURE AND SANDWICH. PANELS

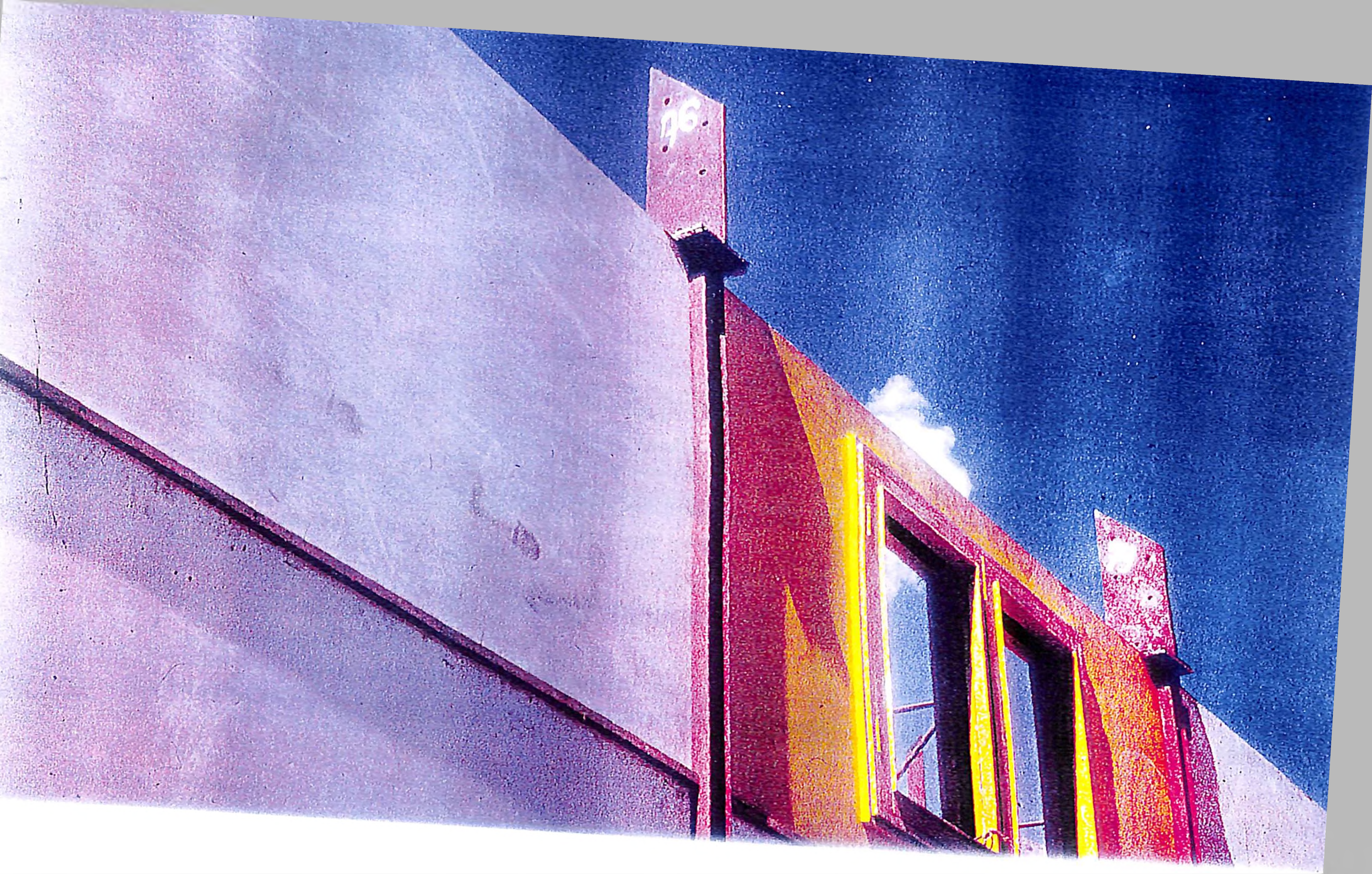


PLATE 5.15 WALL AND WINDOW, SANDWICH

LIST OF FIGURES

TEAM DEPLOYMENT MANALI - LEH
(SCALE - 1: 250,000)

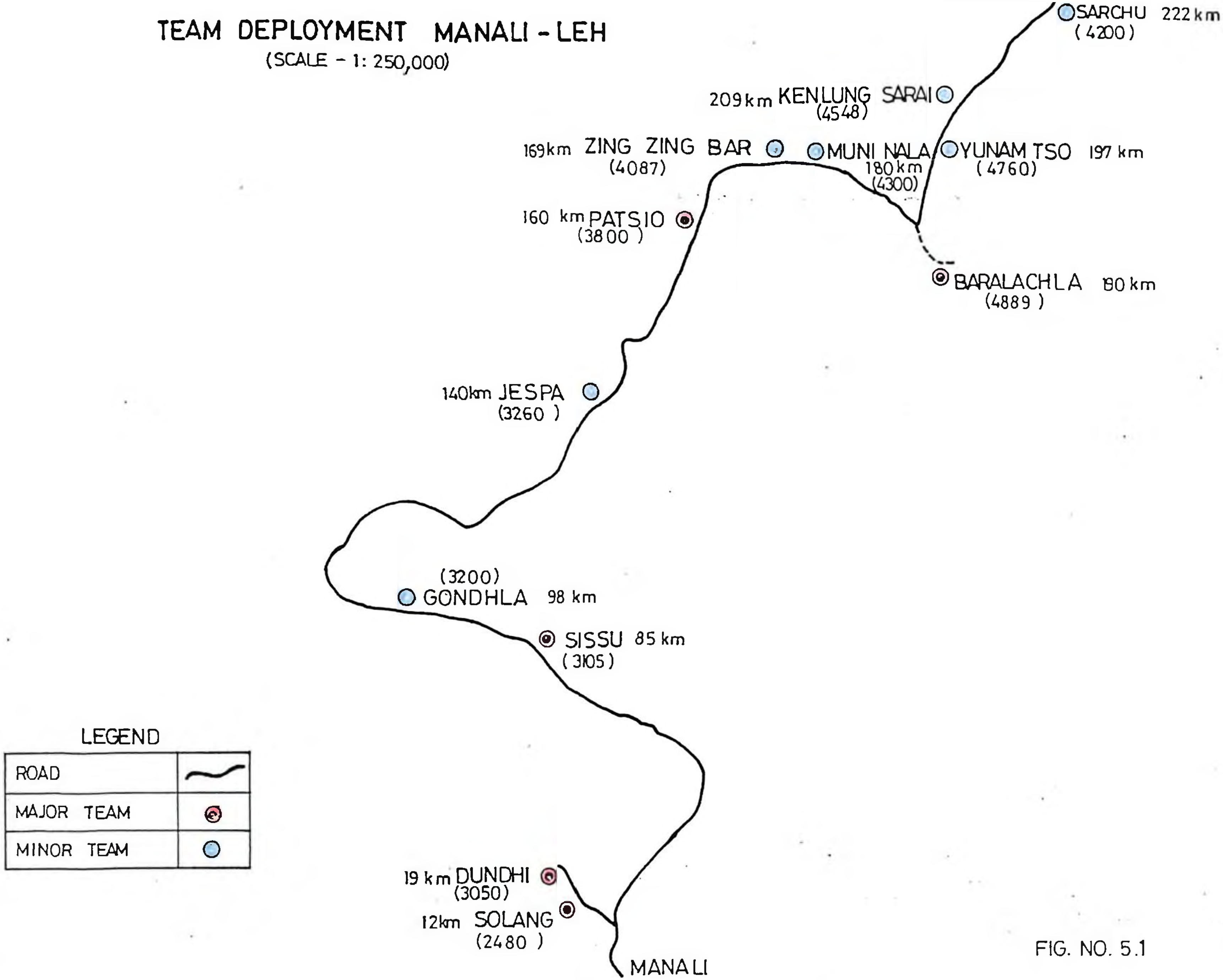


FIG. NO. 5.1

WIND DATA

	SISSU LOCATION ALTITUDE 3105 MTR (MSL)			PATSIO LOCATION ALTITUDE 3800 MTR (MSL)			BARALACHLA LOCATION ALTITUDE 4890 MTR (MSL)		
YEAR	AVE WIND SPEED (KMPH)	DIRECTION PROMINENT	HIGHEST WIND SPEED DURING SNOW STORM (KMPH)	AVE WIND SPEED (KMPH)	DIRECTION PROMINENT	HIGHEST WIND SPEED DURING SNOW STORM (KMPH)	AVE WIND SPEED (KMPH)	DIRECTION PROMINENT	HIGHEST WIND SPEED DURING SNOW STORM
1984-85	HIGHEST AVE 9.6 KMPH	SE & GENERALLY CALM	36 (NE) KMPH	-----	-----	-----	-----	-----	-----
1985-86	HIGHEST AVE (24 HRLY) 12.2 KMPH HIGHEST AVE HRLY 40.2 KMPH	SE & GENERALLY CALM	12 KMPH (SSE)	HIGHEST AVE 263 KMPH (S) LOWEST 1.4 KMPH (SOUTH)	N,NINE SE, S & E	40 KMPH GUST 60 TO 80 KMPH DURING STORM	AVE HIGHEST 60.6 KMPH LOWEST 3.7 KMPH	E, SSC, SE, N, W	66 KMPH
1986-87	HIGHEST 20 KMPH	N T O E & GENERALLY CALM	16 KMPH	-----	-----	-----	-----	-----	-----
1987-88	-----	-----	-----	-----	-----	-----	HIGHEST AVE 38 KMPH	-----	40 KMPH (SW)
1988-89	HIGHEST AVE 10.2 KMPH	GENERALLY CALM SE, N	9.7 KMPH	HIGHEST AVE 26 KMPH LOWEST 1.7 KMPH	SE, S, NE, N	AVE 33.5 KMPH 40 60 KMPH DURING STORM	HIGHEST 41.7 KMPH LOWEST 1.6 KMPH	NE, ENE, SE, SWNW, NW	150 KMPH

FIG. 5.2

CHAPTER VI

DEFENCE INSTITUTE OF WORK STUDY - MUSSOORIE, UTTAR PRADESH

6.1 INTRODUCTION

Mussoorie rises on a horse shoe shaped foot hill that overlooks on the one side, the great plains sweltering in their pestilential heat the holy river gauges sluggishly oiling its way across them and on the other side, the vibrant, magnetic silhouette of the Sivalik Hills of Himalayas. At an altitude of 2000 meters and 35 kms beyond Dehradun Mussoorie is a popular hill resort.

Its History dates back to 1827 when captain Young, an adventurous military officer explored the present site and laid the foundation of the British Military Hospital.

Mussoorie one of the most popular hill station in northern index is famous for its scenic beauty with an area of 64.25 sq kms and climate having summer temperature and winter temperature :

Summer	Max	26 degree C to 31 degree C
	Min	7 degree C to 13 degree C
Winter	Max	7 degree C to 2 degree C
	Min	1 degree C to 4 degree C

"Landour", which lies almost 300 m higher than Mussoorie was first developed as a Military Station but gradually an integral part of the hill resort.

The steep terrain & the congested sketch of development through which the roads are laid out restricts the transportation during peak hours and regulates during peak season. During peak season material transportation is permitted only during late night hours very narrow & winding road also restricts the size of the truck. Infact one has to have the base camp where the materials are stacked and subsequently transported to the site as per the restricted time schedule by smaller truck since the vehicle has to travel through very populace and congested area.

Very restricted and limited time period is available for construction activities. When there is good weather for construction at that time the tourist season starts hence restricting the construction time and activity and monsoon is followed subsequently and concreting during this period is very difficult and hence the preferable type of construction should have minimum usage of such material.

Usage of steel and precut system is acceptable alternative.

The labour for the construction activities generally comes from lower Mussoorie area and the material for construction are generally procured from Dehradun or Rishikesh.

Defence Institute of Works Study is a premier teaching institution of Defence Research & Development Organisation (DRDO) located at Landour Cantonment, Mussoorie. With the growth of establishment and revision of the charter of duties, it became necessary to provide additional accommodation for hostel and recreational facilities for scientists. A study was conducted to examine the feasibility of the proposal.

6.2 PROBLEM DEFINITION

After detailed study of the problem and information available on ground, the followings features were evident:-

* There is considerable shortage of buildable land in the complex.
* Skilled and unskilled labour is not easily available locally.
* There is shortage of water for construction purposes.
* Power supply is inadequate and not dependable.
* Due to inclement weather conditions the structures would need to be insulated.
* Due to remoteness of the place, cost of transporting material from Dehradun, 35 km away, will be very high.
* Trucks cannot reach the project site for transporting the material. Cartage by means of smaller vehicles is to be effected thereby increasing the cost of transportation.

Thus the only solution was to do maximum work away from site and only assembly of prefabricated / pre-cut component to the maximum possible extant to be done at site.

6.3 DESIGN PARAMETERS

The proposed project is designed in a land area of approximately 2500 Sqm. The total complex consists of Residential Accommodation for Senior Scientists and Visiting Scientist of the Institute and Ministry of Defence. It has recreational facilities for the inmates of the complex as well as for the Members of the Institute.

The facilities include : Table Tennis, Badminton, Squash court, Carrom and Card Room. It has also a Seminar Hall having a capacity to accommodate eighty persons.

As flat land is scarce, the entire complex has been designed in four storeys covering an area of 1280 sqm in the Residential Block while the sports complex has been designed in an area of 780 Sqm and seminar hall of 140 sqm.

(Drg. No. 6.1, 6.2, 6.3, 6.4, 6.5)

6.4 DESIGN PROCESS

The roads in these areas being very narrow and winding, transportation of the construction material became the major factor for consideration. Accordingly, selection of building material became principal component of this project.

Stone or brick is available from the out skirts of Dehradun, which is the nearest source 50 kms away from the site, transportation of the same is very difficult.

Since there is scarcity of land area, a multistoried construction is necessary but the site falls under a high seismic **zone** IV, Thus steel framed Structure was preferred for the following reasons :-

* Quicker construction
* Lack of adequate water supply.
* Steel Structure is light weight structure, thus reducing the earthquake forces.
* Steel is ductile compared to brick masonry/reinforced cement concrete structure giving advantage in situation of extreme weather condition.

Walls consist of light weight sandwich panels and do not require foundation to support weight; just toe wall is adequate to keep the panel in position.

6.5 DESIGN APPROACH

After preparation of building designs to meet the requirements in relation to available plot of land, building construction methodology and techniques were studied. In view of the non-accessibility of this remote location through trucks use of non-conventional building components which could be transported in smaller vehicles or through mules were considered for the proposed project. Walls form a major portion of the enclosures, sandwich panels were used having welded mesh & rigid polyurethane foam sheet in between the mesh. Other structural members viz. steel stanchions and girders etc. are also precut to reduce transportation problem and ensure quicker assembly of the building components at site. It is estimated that the carting cost with this innovative method was reduced to about 50% of the total carting cost in the case of conventional stone masonry construction. These sandwich panels were then concreted using substantially less amount of water than conventional building construction. Prefabrication results in saving construction time. This techniques have resulted in an overall saving of considerable time required for the conventional construction techniques.

Planning of bathrooms and kitchens in the proposed block has resulted in considerable saving in the cost due to optimum utilization of services viz. water supply, sewage and waste water. A central heating system has been installed using solar thermal technology in view of inclement weather conditions to save the cost of heating of each room separately. Walls & ceiling have been insulated to contribute towards consumption for heating purposes & thus enable its utilization for other requirements.

Sports Complex was planned as an integral part of the complex using the existing higher terrain of site. The specific requirement of spaces due to the nature of the sports, was met in the same system without disturbing the style and character of structure.

6.6 SALIENT PROJECT STATISTICS

*	Total Built up area.	2200 sqm
*	Project Cost (Year 1990)	95 lacs
*	Time of Completion	6 months

6.7 DESIGN COMPONENTS

6.7.1 FOUNDATION

Isolated footings have been provided with R.C.C. pedestals upto ground level to support super structure. The foundations are designed for vertical loads (dead load+live load) from the floors as well as strong lateral forces due to wind and earth quake. Horizontal forces are resisted by diagonal bracings of one bay width each at required locations along the peripheral walls.

The resultant Horizontal force at the top of pedestal due to wind/earth quake together with the vertical load (dead load+live load) is considered for the design of R.C.C. pedestals and the footings. (Drg. No. 6.6, 6.14)

6.7.2 SUPER STRUCTURE

Due to extreme weather conditions & consequently the limited construction time available, the basic frame work of steel columns and steel girder was used to facilitate speedier construction(Plate 6.1). Due to restrictions for transportation, the Girders & columns were precut to a required length and adequate splicings were provided to attain desired length and strength of the structural member, Staircase was designed using M.S. Channel frame work on which wooden planks formed as tread and risers. The structure being multi storey, the steel structure was erected for erected right from ground floor to third floor (Plate 6.2). The junctions of each structural member were properly secured with the help of nuts & bolts (Plate 6.3). After completion of the total basic structure the roof was being laid to carry out the assembly of wall panels in position (Plate 6.4), (Drg. No. 6.5, 6.7, 6.8, 6.9, 6.10, 6.14)

6.7.3 WALLS

Walls consist of light weight sandwich panels (Plate 6.5) as described in chapter IV (4.5.3). Whereas gypsum panels were used for internal partition walls. All the doors and windows are inbuilt in the panels as per the fabrication drawings and they are identified separately as Window panel or Door panel and assembled with the various panel forming the wall. (Drg. No. 6.8, 6.9, 6.10, 6.11, 6.12, 6.15)

6.7.4 FLOORING AND CEILING

Due to the inclement weather condition wooden particle board flooring with sound insulation is provided, also due to its light weight, easy in handling and laying. The formulation of flooring on ground is of precast cement flooring but the flooring on upper floors consists of particle board supported on gridwork of steel girders and channels.

Gypsum panel false ceiling lined with glass wool insulation is provided to take care of sound transmission from upper floors and also the heating pipe & services as the building is designed with central heating system. Powder coated C.G.I. sheet roofing with required slope to adjust against the weather condition is provided on top.

Thus right from the choice of construction, analysis through standardization of prefabricated building components, whose variety had to be reduced to a minimum conceptualisation of design and configuration of analysis to bring down recurring energy requirement overcoming the seemingly unsurmountable difficulties posed by absence of approach road for transportation of materials and acute shortage of water, to giving quake-safe design. We were able to offer perfectly satisfying buildings well within the requirements of cost and time through an array of approaches and design solutions. (Drg. No. 6.13)

LIST OF PLATES

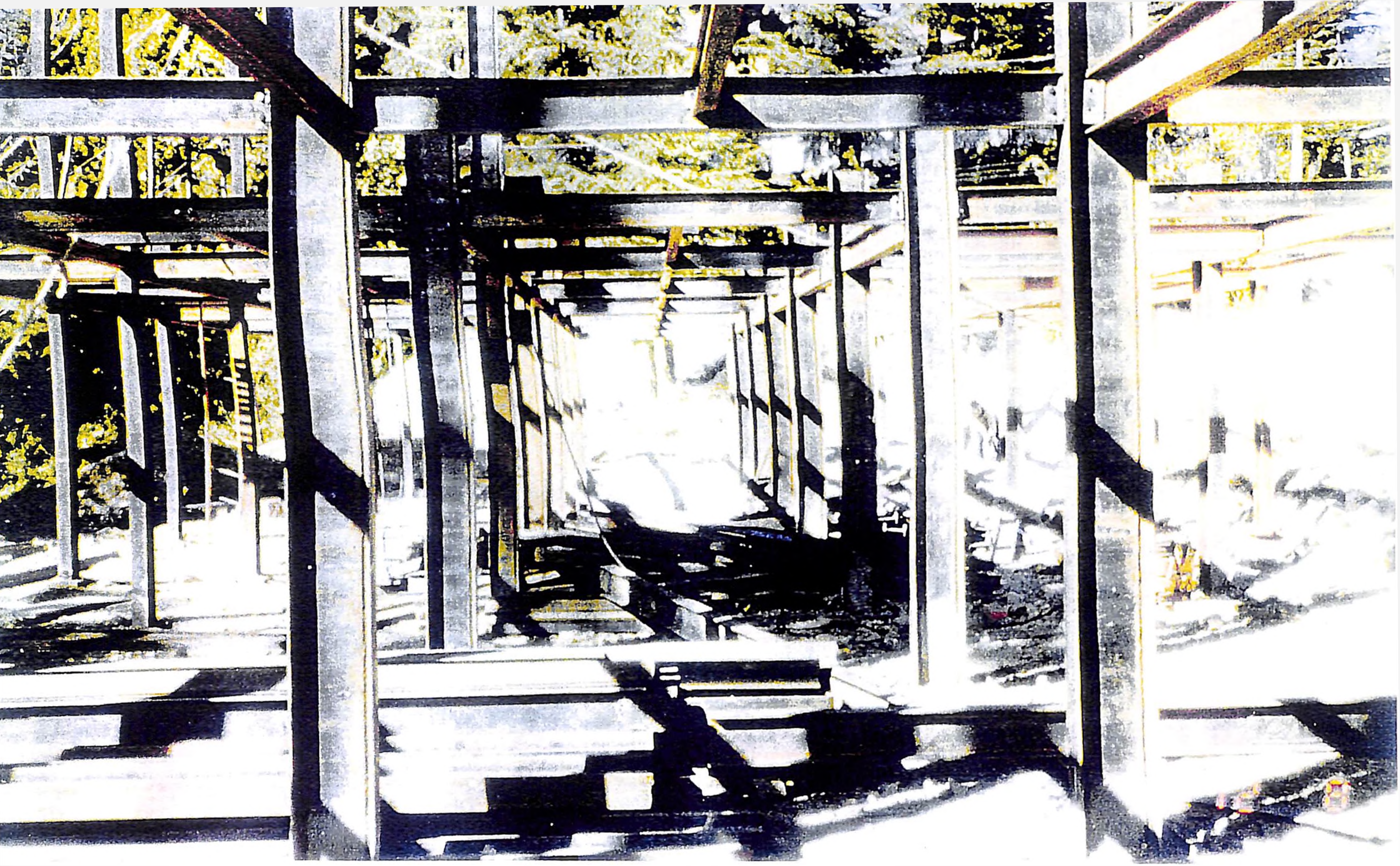
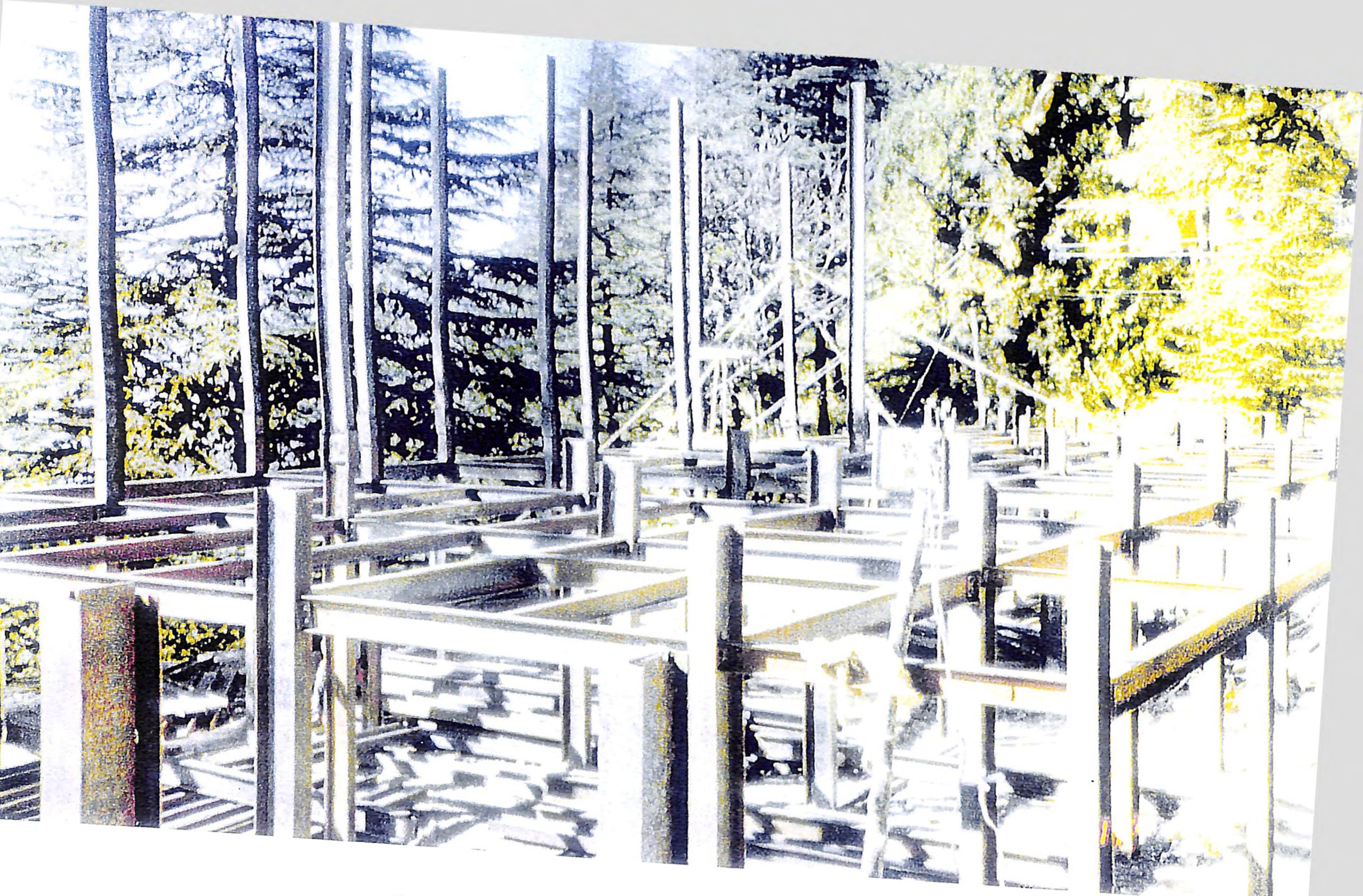
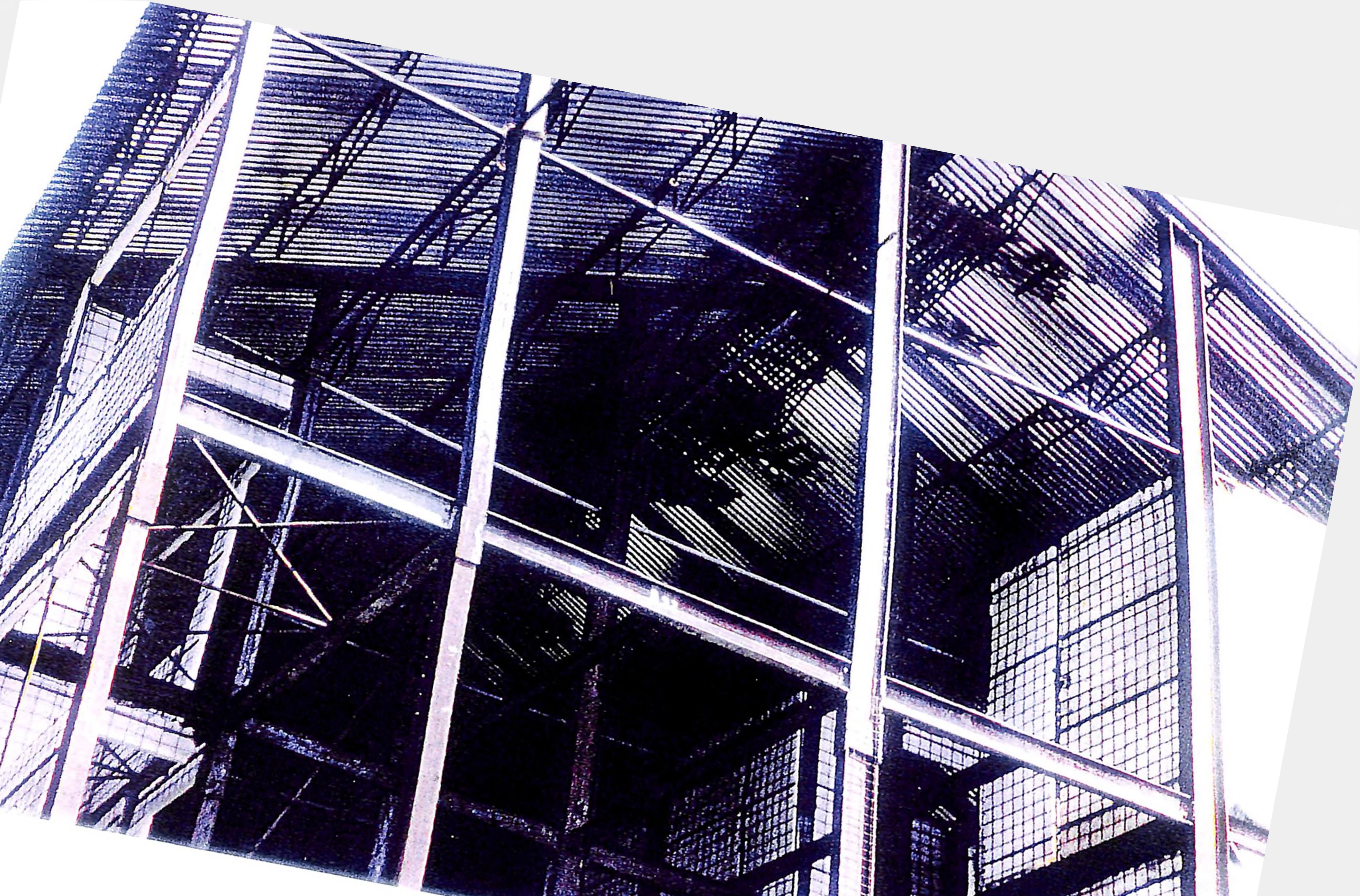


PLATE 6.1   ERECTION OF STEEL STRUCTURE



PLATE

PLATE 6.3 CONSTRUCTION JOINT DETAIL OF STRUCTURE



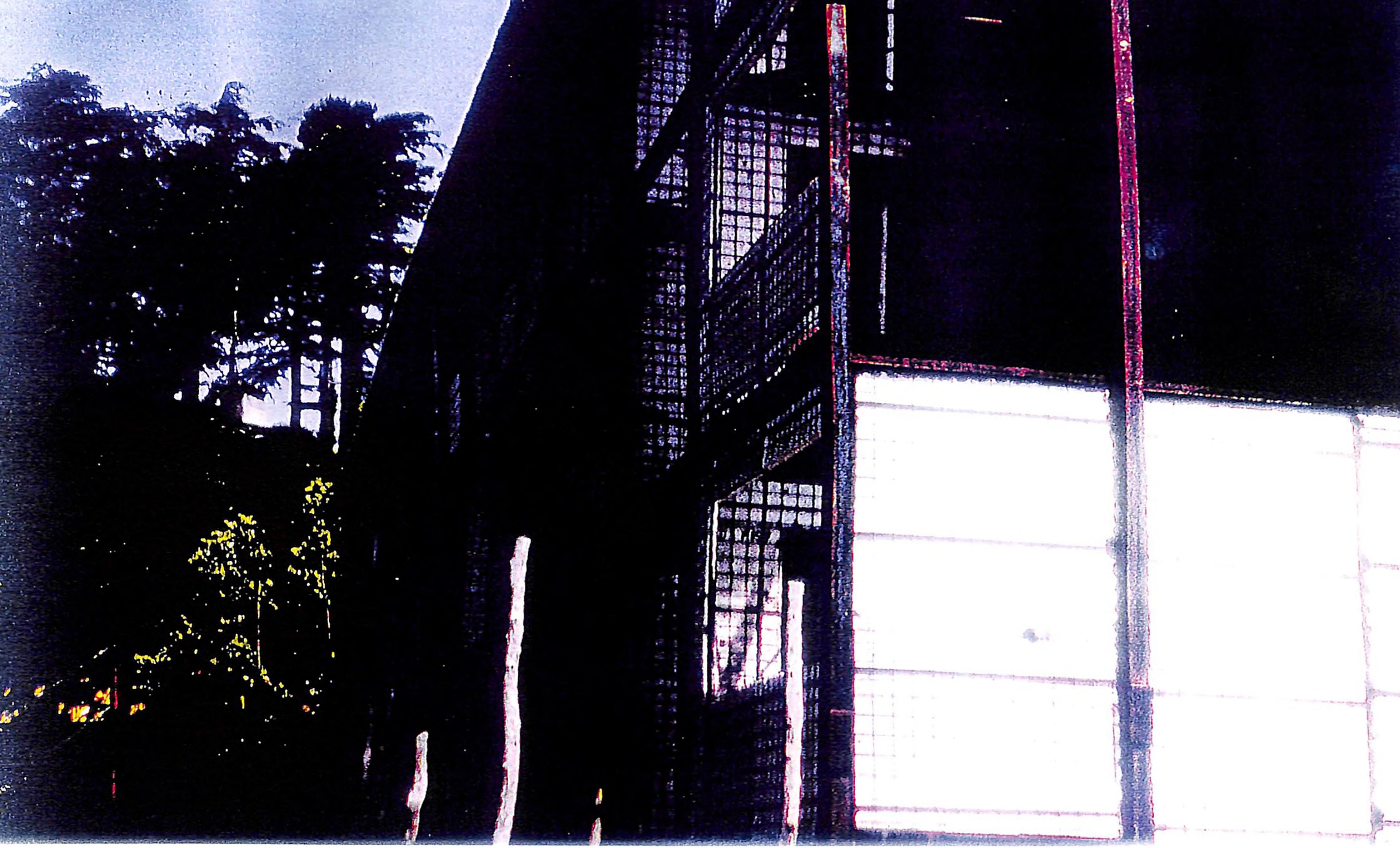


PLATE 6.5 POSITIONING OF SANDWICH PANEL

CHAPTER VII

TECHNICAL ANALYSIS OF EXECUTED PROJECTS

7.1 INTRODUCTION

The Previous chapters explained about the exceptional sites and construction in these area with various constrains.

Author has also cited three examples where he had successfully carried out the construction activity and completed the project in record time in such exceptional sites.

Since the usage of Accommodation constantly changes which results in new style and standard of living and to support to this is the high cost of energy.

In all the three executed projects mentioned in previous chapters gives importance to one aspect in common that is the insulation used in the panel and also the type of construction of such panels as the entire research and the specialized construction work is based on design of the panels.

Author again visited these three sites after more than two years of its execution to study the behaviour of these panels and the related material and the insulation used at different location in relation to its climate and usage, at which was found very satisfying.

Here it may be worth mentioning the various parameters which were considered by the author before selecting the right insulation material for the panel.

7.2 CONDITION GOVERNING INSULATIONS

For hot insulation, the general criteria is to maintain a temperature of around 25 degree C in air - conditioned space and for cold insulation care has to be seen that insulation ensures temperature above dew point. The thickness to be adopted for using Expanded Polyestrylene is annexed and to calculate thickness of PUF normally 60% of Expanded Polyestrylene thickness desirable. This is because PUF has K-value practically half of that of Expanded Polyestrylene.

Whenever calculations are made for thermal insulation, the K-value of insulating material plays a very important part. K-value varies with the rise and fall of temperature and is an anomalous graph. K-value is always calculated at mean temperature which is the average of the worst operating condition and the ambient.

For definition of `K' and `U' value see Annexure - 7.1

7.3 POKHRAN PROJECT

In the Pokhran Project, due to extreme hot conditions prevailing in the region the various method of Heat Insulation were given due consideration e.g.

1. Heat Insulation by Orientation.
2. Heat Insulation by shading.
3. Heat Insulation of Roofs.
4. Heat Insulation of Exposed Walls that is "Panels"

LOCATION	**:**	**POKHRAN**		
Temp	:	Minimum	-	+5
		Maximum	-	49

Description about the site at Pokhran and Description of the Panel used has already been explained in Chapter IV.

THE SYSTEM FOLLOWED

20mm CM Plaster	K - 0.923	- R1
50mm PU Foam	K - 0.021	- R2
Welded Mesh	Negligible	
20mm CM Plaster	K - 0.923	- R3

$$R = \frac{L}{K}$$

$$RT = \frac{1}{fo} + \frac{1}{f1} + R1 + R2 + R3$$

$$= \frac{1}{19.86} + \frac{1}{9.36} + \frac{0.20}{0.923} + \frac{0.050}{0.027} + \frac{0.020}{0.923}$$

$$= 0.0503 + 0.1068 + 0.0216 + 1.851 + 0.0216$$

$$RT = 2.0522 \text{ W/(m2K)}$$

$$U = \frac{1}{RT} = 0.4872 \text{ W/(m2K)}$$

`U' permissible is 2.56 W/(m2k).
Annexure 7.1

7.4 BARALACHLA PROJECT

LOCATION :	**BARALACHLA**		
Temp :	Maximum	-	+5
	Minimum	-	-30

THE SYSTEM FOLLOWED

12mm Cement Based Wood Panel	K - 0.108	- R1
100mm PU Foam	K - 0.021	- R2
12mm Cement Based Wood Pannel	K - 0.108	- R3

$$R = \frac{L}{K}$$

$$RT = \frac{1}{fo} + \frac{1}{f1} + R1 + R2 + R3$$

$$= \frac{1}{19.86} + \frac{1}{9.36} + \frac{0.012}{0.108} + \frac{0.100}{0.021} + \frac{0.012}{0.108}$$

$$= 0.0503 + 0.1068 + 0.1111 + 4.76 + 0.1111$$

$$RT = 5.14$$

$$U = \frac{1}{RT} = 0.1945$$

`U' permissible is 2.56 W/m2K.

Annexure 7.1

7.5 MUSSOORIE PROJECT

Location - **Mussoorie**

Temperature	:	Maximum	-	+32
		Minimum	-	-4

THE SYSTEM FOLLOWED

20 mm Plaster	K	-	0.923	-	R1
50 mm PU Foam	K	-	0.021	-	R2

Welded Mesh

20 mm Plaster	K	-	0.923	-	R3

$$R = \frac{L}{K}$$

$$RT = \frac{1}{fo} + \frac{1}{f1} + R1 + R2 + R3$$

$$= \frac{1}{19.86} + \frac{1}{9.36} + \frac{0.02}{0.923} + \frac{0.05}{0.021} + \frac{0.02}{0.923}$$

$$= 0.0503 + 0.1068 + 0.0216 + 2.38 + 0.0216$$

$$RT = 2.58$$

$$U = \frac{1}{RT} = 0.3875$$

`U' permissible is 2.56 W/m2K.

Annexure 7.1

Note : Since L/K value of Welded mesh is negligible so it is not accounted for.

BIBLIOGRAPHY

1. HUDCO Consultancy, New Delhi

   Low Cost Housing Study, 1983.

2. Govt. of India, Ministry of I & B

   A Reference Annual, 1988-89.

3. Manorama (Anuual issue) 1988.

4. Balwant Singh Saini

   Building in Hot Dry Climate.

   John Willey & Sons, 1980.

5. Nam C.H. & Tatum C.B.

   Towards Understanding of Product

   Innovation Process in Construction

   Journal of Construction, Engineering & Management, 1989.

6. Govt. of India, National Building Organization

   Low Cost Rural Houses, 1987.

7. HUDCO

   MUD Architecture

   A Report by Housing and Urban Development Corporation, 1986.

8. Design with Climate - Bio Climate approach to Architectural Regionalism.
Victor Olgyay, Princeton University Press, Princeton,
New Jersey, 1963.

9. A. K. Lal
Adoption of Partial Prefabrication for Mass Housing
The Indian Concrete Journal (Monthly)
The Associated Cement Companies Limited, July 1990.

10. Tatum C.B., Fellow, ASCE
Process of Innovation in Construction Firm.
Journal of Construction Engineer & Management
Vol. 113, No. - 4, December 1987.

11. Willian I. Sanser, Jr.
Injection Contrast : A key to quality Decisions.
SAM Advanced Management Journal,
(Society for the advancement of Management) Cincinnati, OHIO, AUTUM 1988.

12. Deepak Razdan
Building Houses, The Baker Style.
Hindustan Times, New Delhi, August 20, 1990.

13. Lt. Gen. H. Lal.
NICMAR & PLANNING COMMISSION.
Role of standards in the use of wastes as building National Conference on
Construction in the 8th Five Year Plan, Policies, Perspective Progrramme, N.Delhi.
May 7 & 8 1990.

14. Edward G. Krubasik

Customize Your Product Development.

Harvard Businees Review Nov - Dec 1988.

15. Barbara Golter Heller, AIA.

The Pros and Cons of Prefab Panels

Architectural Technology

(The American Institute of Architects) P.P. 82-87, Fall 1983.

16. S.C. Chakrabarti, G. C. Nayak, D.K. Paul

Structural Behavior of Prefabricated Shear Walls.

Journal of Structural Engineer Vol. 114, No. - 4, P.P. 856 to 868 April 1988.

17. C. Dale Buckner, Vijaya K. A. Gopu.

Design Aspects of Pitched and Tepered Glued Laminated

Beams.

Journal of Structural Engineering Vol. 114, No. 4 April 1988.

18. Micheal Red Clift and Amador Ramigio.

Exploring Technology and Society.

Andover, UK, Routledge. 1988.

19. Kulbushan Jain & Meenakshi Jain

Mud Architecture in India

Design Ideas,Bombay. 1983

* These reference have been utilized for the research purposes & information analysed, however they are not directly reflected in the research works.

20. Bansal N.K. & Sodha M. S.,
An Earth-Air Tunnel System for Cooling Buildings.
Tunnelling and Underground Space Technology. Vol. I, No. 2
P.P. 177 - 182, 1986.

21. Razdan Deepak,
Housing - A Manageable Challenge.
Yojna, Oct 1-15, 1980.

22. Trans Lowrence J. Lafleur
Rene Descartes, Discourse on Medthods and Moditations,
Indian polis : Liberal Arts Press 1960.

23. New Products and Technologies.
Civil Engineering & Constructioin Review. Nov. 1990

24. Recommendations of the National Conference on Construction in the 8th five year Plan. Civil Engineering & Construction Review Nov. 1990.
Civil Engineer & Construction Review.

25. G. Spence,
Predictive Cost Modelling : The power of measurement in new product development, Engineering Digest, Oct 1989.

26. Dr. D. C. Stringer, E.M. Sisa.

The Sky Dome Retractable Roof System.

Engineer Digest, June 1989.

27. Report by ACI Committee 226.

Use of Ash in concrete

American Concrete Institute Material Journal, Sept./Oct. 1987.

28. N. S. Sodhi, Advisor, Punjab State Council for Science and Technology.

Fly Ash - The New Construction Material.

Civil Engineering and Construction Review. Oct. 1989.

29. HUDCO

Abstracts from Building Centre

DDA Slum Wing, New Delhi.

30. UN Global Study of "Green House Effect" Published in

Futures - December 1988.

Source - The Times Higher Education Suppliment

9th September 1988.

31. Analysis of Rice Husk Board.

Test Reports of Indian Plywood Research Institute,

Bangalore & Department of Electrical Communication

Engineering, Indian Institute of Science Bangalore.

32. Encyclopedia Britanica

Thar Desert 1974.

LIST OF ANNEXURES

ANNEXURE 5.1

CONCRETING IN COLD WEATHER

REFERENCE :- ISI HAND BOOK

CONCRETING IN COLD WEATHER

* During cold weather concreting shall be abandoned when the temperaturefalls below 4.5 degree.

If however the work is of urgency or importance that must be continued, it can be carried out with complete success provided certain remedial measures and precautions are taken.

* The most convenient method is to heat the mixing water and for very low temperature to heat the aggregate as well heat the mixing water to 66:C (150 degree F). On no account shall the hot water be added to cement alone. Aggregate may be to 21' C or mixing drum may be warned. Cement must not be heated.

Temperature of fresh concreting exceeding 21'C are undesirable due to the higher water requirement and likelihood of cracking when the concrete contracts on cooling and relatively low strength. Water element ratio should not exceed 6.6 (30 ltrs per 50 kg of cement).

* Fresh concrete must not be allowed to freeze. If concrete is frozen setting and hardening ceases. Avoid the use of frozen aggregate the concrete placed shall be protected against frost action by suitable. Converting concrete damaged by frost shall be removed and work redone.

* Provide layers of straw of other insulating material on freshly laid concretes surface as soon as the concrete is hard enough to sustain it without detriment. An insulating layer for covering concrete may be composed of water proof paper are laid with a layer of straw and finally with second layer of water proof paper.

* An increase of cement content of the mix by about 20-25%, use of rapid hardening cement with admixture of calcium chloride is recommended.

* Accelerators are used in cold weather to increase the rate of hardening and thereby reduce the likelihood of failure. They accelerate the hydration of cement, increase the rate of evaluation of heat. Thus the temperature of the concrete is raised and freezing point of the mixing water is lowered. Enabling concrete to be carried out when the air temperature is near or slightly below the finishing point.

* **RECOMMENDED ACCELERATORS**

- Calcium chloride cannot be used for reinforced concrete.
- Common Salt (Sodium Chloride)

Lower's the freezing point of water for temperature below 0'C dissolve 1 kg of salt in 170 litres of water and which may be slightly more for lower temperatures larger percentage of salt appear to weaken the concrete. Salt over 5% by weight of cement is injurious as it not only affects the strength of the concrete, but may also cause rasting of the reinforcement and afforescense.

* Timber form work is a valuable insulating agent and should used in cold weather the concrete must be kept warm and protected from frost after it has been placed and until it has hardened, suitable methods of protection are wrapping or covering the concrete with dry hessian or backing, straw blankets, old paper cement bags, tarpaulins or dry straw.

* A 15 cm layer of dry straw. If timber work is used it should be left in position as long as possible. Since the rate of concrete will be lower in Cold weather, from work will have to be left in position same what longer.

* **RAPID HARDENING CEMENT**

Is Infact, a highly early strength concrete it sets cement in a much shorter time than the common cement and develops higher strength in the early stages. The advantage of this cement over the common cement are that form work can be removed earlier and structure can be loaded earlier. It has in 4 days the same comprission strength as common in 28 days it is comparatively costlier than common cement. The setting time is about the same as of the ordinary cement. This cement is useful for repair work.

* **HIGH ALUMINA CEMENT**

It is used where it is required to impose leads on the concrete structure even earlier than that possible with Rapid Hardening Cement. It develops strength dry early upto 75% of its ultimate strength being attained during the first 24 hours after mixing. This cements useful for emergency repair works. Its setting time is less. This can be use by adding 1 to 2% by weight of hydrated time.

PRECAUTIONS THAT CAN BE TAKEN

* To heat the mixing water upto 66'C.
* Aggregate may be heated to 21'C or mixing drum can be warmed.
* Providing 15cm layer straw or, tarpaulins over freshly laid concrete.
* Timber shuttering has been done. Shuttering can be kept in position for longer duration say upto 28 days.
* Rapid hardening cement can be used but is very costly.

ANNEXURE 5.2

PHYSICAL PERFORMANCE AT HIGH ALTITUDE

There is a reduced physical performance of an individual who is residing in plans, when he is transferred to a high altitude (above 2700 metres). With acclimatization his performance can be increased though it may remain still low to some extent even after prolonged stay there. It is therefore, important for Commanders to know how much to expect from their men at high altitudes. The performance of local residents is better than that of residents from plains.

ACCLIMATIZATION

* It is important that troops when they are posted above 2700 metres should be systematically acclimatised. It should be on the pattern followed by mountaineers, i.e. the individual works at a higher altitude than one at which he sleeps during the period of acclimatization. When the troops have acclimatised to a certain height they can operate at those heights or even at slightly higher heights without any ill effect. This initial acclimatization is enough as long as the individuals do not go beyond 3600 metres.

* If they are required to be stationed at a height of more than 3600 metres they will require a further period of acclimatization.

* For individuals who return to high altitude after a period of stay in plains for more than 10 days at a time, reacclimatisation is necessary.

ADVERSE EFFECTS AND THEIR PREVENTION

The important symptoms due to hypoxia at High Altitude are :

* Headache
* Mental Irritability
* Impairment of Judgment
* Loss of appetite
* Lack of sleep
* Excessive thirst
* Palpitation
* Breathlessness
* Irritable cough

Usually, there is no symptom below 2700 metres. The Commanders should be aware of the symptoms and educate their troops on the likely ill effects. Any individual who has any of the symptoms mentioned above should be kept under medical supervision.

The following two serious conditions can incapacitate an individual at high altitude within a few days of his induction or on going to higher heights from one where he is stationed. These are preventable with proper acclimatization.

* ACUTE MOUNTAIN SICKNESS

The symptoms usually felt are headache, irritability and impaired judgement. Following measures should be taken for amelioration of symptoms :-

- Thorough acclimatization as mentioned in Acclimatization Procedure below.
- Drink more fluids in the shape of tea, coffee and cocoa at frequent intervals.
- Avoid smoking, alcohol and late dinners.
- Aspirin for relieving headache and mental irritability.
- Men should be encouraged to report sick if they get any abnormal feeling. They should not be left alone.
- In case the symptoms persist, they should be moved to a lower camp for 2-3 days. They can be brought up again when the symptoms clear.

* ACUTE PULMONARY OEDEMA

This is a serious condition. Persons who develop breathlessness, pain in chest, cough and sense of suffocation should report sick immediately to the RMO for treatment. They require administration of Oxygen and Hospitalisation.

FOLLOWING PRECAUTIONS SHOULD BE TAKEN

* Thorough acclimatization.
* No undue physical exertion during the first two days after arrival.
* Persons suffering from Nose and Throat infection should avoid going to high altitude by air.

ACCLIMATIZATION PROCEDURE

* FIRST STAGE ACCLIMATIZATION

This will be applicable to individual posted above 2700 metres and upto a height of 3600 metres. The acclimatization period will be for six days as under :

- First and Second Day

  Rest except for short walk in the unit lines only, not involving any climbs.

- Third and Fourth Day

  Walk at slow pace for 1.5 - 3 km. Avoid steep climbs.

- Fifth and Sixth Day

  Can walk upto 5 km and climb upto 300 metres at a slow pace.

* SECOND STAGE ACCLIMATIZATION

(Above 3600 metres and upto 4500 metres)

This is carried out for 4 days as under :

- First and Second Day

  Slow walk for a distance of 1.5 - 3 km, avoid steep climbs.

- Third Day

  Slow walk and climb upto 300 metres.

- Fourth Day

  Climb 300 metres without equipment.

* THIRD STAGE ACCLIMATIZATION

(Above 4500 metres)

This also lasts for four days and is on the same lines as second stage acclimatization.

RE-ENTRY TO HIGH ALTITUDE

Individuals who have left high altitude area will require acclimatization again if they are away for more than 10 days. Individual who are away for more than 4 weeks will require complete acclimatization as stated in Acclimatization Procedure above while those who have been away for more than 10 days but less than 4 weeks will have acclimatization for 4 days at each stage like fresh inductees as under :

* First and Second Day

  Rest except short walk.

* Third Day

  Walk at slow pace for 1 - 2 km. Avoid steep climbs.

* Fourth Day

  Walk 1 - 2 km with climb upto 300 km.

ANNEXURE 7.1

EXTRACTS FROM I.S. CODE 3792 - 1978

Temperature-cum-Humidity Zones In India

* **HOT AND ARID ZONE** - Regions where mean daily maximum dry bulb temperatures above 38 degree C or higher, and relative humidity 40 percent or less, prevail during the hottest month of the year and where the altitude is not more than 500 m above mean sea level, may be classified as hot and arid zones. Some representative towns falling under this zone are given in Appendix.

* **HOT AND HUMID ZONE** - Regions where mean daily maximum dry bulb temperatures above 32 degree C, and relative humidity above 40 percent, prevail during the hottest month of the year and where the altitude is not more than 500 m above mean sea level, may be classified as hot and humid zones. Some representative towns falling under this zone are given in Appendix.

* **WARM AND HUMID ZONE** - Regions where mean daily maximum dry bulb temperatures of 26 to 32 degree C, and relative humidity of 70 percent or above prevail during the hottest month of the year and where the altitude is not more than 100 m above mean sea level, may be classified as warm and humid zones. Some representative towns falling under this zone are given in Appendix.

* **COLD ZONE** - Regions where mean daily minimum dry bulb temperatures of 6 degree C or less, prevail during the coldest month of the year and where the altitude is more than 1200 m above mean sea level, may be classified as cold zones. Some representative towns falling under this zone are given in Appendix.

APPENDIX

SOME REPRESENTATIVE TOWNS UNDER HOT AND ARID, HOT AND HUMID, WARM AND HUMID, AND COLD ZONES

HOT AND ARID ZONE	HOT AND HUMID ZONE	WARM AND HUMID ZONE	COLD ZONE
Agra	Ahmadabad	Cochin	Darjeeling
Ajmer	Asansol	Dwarka	Dras
Akola	Bhavanagar	Gauhati	Gulmarg
Aligarh	Bhuj	Puri	Leh
Allahabad	Mumbai	Sibsagar	Mussoorie
Ambala	Calcutta	Silichar	Nainital
Bareilly	Calicut	Tezpur	Ootacamund
Bikaner	Cuttack	Trivandrum	Shillong
Gaya	Dohad	Veraval	Simla
Jabalpur	Jamnagar		Skardu
Jaipur	Jamshedpur		Srinagar
Kanpur	Madras		
Khandwa	Madurai		
Kota	Mangalore		
Lucknow	Masulipatam		
Ludhiana	Midnapur		
Nagpur	Nellore		
Neemuch	Patna		
New Delhi	Rajkot		
Roorkee	Ratnagiri		
Sambalpur	Salem		
Sholapur	Surat		
Umaria	Tiruchirapalli		
Varanasi	Vellore		
	Vishakhapatnam		

RECOMMENDED THICKNESS* OF INSULATION (IN MILLIMETRES) PIPE AND PANELS

NOMINAL PIPE SIZES

TEMP C	15mm	20mm	25mm	32mm	40mm	50mm	65mm	80mm	90mm	100mm	125mm	150mm	SURFACES	TEMP F
20	25	25	25	25	25	25	40	40	40	40	50	50	40	68
10	25	25	25	40	40	40	40	40	50	50	50	50	65	50
0	40	40	40	50	50	50	50	50	50	50	50	75	100	32
-10	50	50	50	50	65	65	75	75	75	75	75	75	125	14
-20	50	50	65	75	75	75	75	75	90	100	100	100	150	-4
-30	75	75	75	75	100	100	100	100	100	100	100	125	175	-22
-40	75	75	100	100	100	100	100	100	115	125	125	125	200	-40
-50	100	100	100	100	100	100	125	125	125	125	150	150	200	-58
-60	100	100	125	125	125	125	125	125	140	150	150	150	225	-76
-70	125	125	125	125	125	150	150	150	150	150	175	175	250	-94
	1/2"	3/4"	1"	1-1/4"	1-1/2"	2"	2-1/2"	3"	3-1/2"	4"	5"	6"		

THERMAL PERFORMANCE STANDARDS

S.NO.	BUILDING COMPONENTS	HOT DRY AND HOT HUMID ZONES				WARM HUMID ZONES			
		U, MAX	TPI, MAX	T, MIN	D, MIN	U, MAX	TPI, MAX	T, MIN	D, MIN
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
		W/(m2K)	percent	h	percent	W/(m2K)	percent	h	percent
1	ROOF	2.33	100	20	75	2.33	1.25	20	75
2	EXPOSED WALL	2.56	125	16	60	2.91	175	16	60

THERMAL PROPERTIES OF BUILDING AND INSULATING MATERIALS AT MEAN TEMPERATURE OF 50 DEGREE C

(AS PER I.S. CODE - 3792-1978)

S.NO	TYPE OF MATERIAL	DENSITY kg/m3	THERMAL CONDUCT-IVITY* W/(mK)	SPECIFIC HEAT CAPACITY kJ/(kgK)
a)	Building Materials			
01.	Burnt brick	1820	0.811	0.88
02.	Mud brick	1731	0.750	0.88
03.	Dense concrete	2410	1.74	0.88
04.	RCC	2288	1.58	0.88
05.	Limestone	2420	1.80	0.84
06.	Slate	2750	1.72	0.84
07.	Reinforced brick	1920	1.10	0.84
08.	Brick tile	1892	0.798	0.88
09.	Lime concrete	1646	0.730	0.88
10.	Mud Phuska	1622	0.519	0.88
11.	Cement mortar	1648	0.719	0.92
12.	Cement plaster	1762	0.721	0.84
13.	Cinder concrete	1406	0.686	0.84
14.	Foam slag concrete	1320	0.285	0.88
15.	Gypsum plaster	1120	0.512	0.96
16.	Cellular concrete	704	0.188	1.05
17.	AG sheet	1520	0.245	0.84
18.	GI sheet	7520	61.06	0.50
19.	Timber	480	0.072	1.68
20	Timber	720	0.144	1.68
21.	Plywood	640	0.174	1.76
22.	Glass	2350	0.814	0.88
23.	Alluvial clay (40 percent sands)	1958	1.211	0.84
24.	Sand	2240	1.74	0.84
25.	Black cotton clay (Madras)	1899	0.735	0.88
26.	Black cotton clay (Indore)	1683	0.606	0.88
27.	Tar felt (2-3 kg/m2)	---	0.479	0.88

* The thermal conductivity (k) values have been determined by:

1) Guarded Hot Plate Method, and
2) ASTM Heat Flow Method.

S.NO	TYPE OF MATERIAL	DENSITY kg/m3	THERMAL CONDUCT-IVITY* W/(mK)	SPECIFIC HEAT CAPACITY kJ/(kgK)
b)	Insulating Materials			
01.	Expanded polystyrene	16.0	0.038	1.34
02.	Expanded polystrylene	24.0	0.035	1.34
03.	Expanded polystrylene	34.0	0.035	1.34
04.	Foam glass	127.0	0.056	0.75
05.	Foam glass	160.0	0.055	0.75
06.	Foam concrete	320.0	0.070	0.92
07.	Foam concrete	400.0	0.084	0.92
08.	Foam concrete	704.0	0.149	0.92
09.	Cork slab	164.0	0.043	0.96
10.	Cork slab	192.0	0.044	0.96
11.	Cork slab	304.0	0.055	0.96
12.	Rock wool (unbonded)	92.0	0.047	0.84
13.	Rock wool (unbonded)	150.0	0.043	0.84
14.	Mineral wool (unbounded)	73.5	0.030	0.92
15.	Glass wool (unbounded)	69.0	0.043	0.92
16.	Glass wool (unbounded)	189.0	0.040	0.92
17.	Resin bonded mineral wool	48.0	0.042	1.00
18.	Resin bonded mineral wool	64.0	0.038	1.00
19.	Resin bonded mineral wool	99.0	0.036	1.00
20.	Resin bonded mineral wool	16.0	0.040	1.00
21.	Resin bonded mineral wool	24.0	0.036	1.00
22.	Exfoliated vermiculite (loose)	264.0	0.069	0.88
23.	Asbestos mill-board	1397.0	0.249	0.84
24.	Hard board	979.0	0.279	1.42
25.	Straw board	310.0	0.057	1.30
26.	Soft board	320.0	0.066	1.30
27.	Soft board	249.0	0.047	1.30
28.	Wall board	262.0	0.047	1.26
29.	Chip board	432.0	0.067	1.26
30.	Chip Board (perforated)	352.0	0.066	1.26
31.	Particle board	750.0	0.098	1.30
32.	Coconut pith insulation board	520.0	0.060	1.09
33.	Jute fibre	329.0	0.067	1.09

S.NO	TYPE OF MATERIAL	DENSITY kg/m3	THERMAL CONDUCT-IVITY* W/(mK)	SPECIFIC HEAT CAPACITY kJ/(kgK)
34.	Wood wool board (bonded with cement)	398.0	0.081	1.13
35.	Wood wool board (bonded with cement)	674.0	0.108	1.13
36.	Coir board	97.0	0.038	1.00
37.	Saw dust	188.0	0.051	1.00
38.	Rice husk	120.0	0.051	1.00
39.	Jute felt	291.0	0.042	0.88
40.	Asbestos fibre (loose)	640.0	0.060	0.84

* The thermal conductivity (k) values have been determined by:

1) Guarded Hot Plate Method, and

2) ASTM Heat Flow Method.

DEFINITIONS OF TERMS, SYMBOLS AND UNITS OF QUANTITIES USED IN HEAT INSULATION

* **TERM** : Thermal Conductivity

SYMBOL : k

DEFINITION : The quantity of heat in the `steady state' conditions flowing in unit time through a unit area of a slab of uniform material of infinite extent and of unit thickness, when unit difference of temperature is established between its faces.

UNIT : W/(mK)

EXPLANATION : The thermal conductivity is a characteristic property of a material and its value may vary with a number of factors, including density, porosity, moisture content, fibre diameter, pore size, type of gas in the material, mean temperature and outside temperature range.

* **TERM** : Thermal Transmittance

SYMBOL : U

DEFINITION : Thermal transmittance is thermal transmission through unit area of the given building unit divided by the temperature difference between the air or other fluid on either side of the building unit in `steady state' conditions. It is reciprocal of total thermal resistance.

UNIT : W/(m2K)

EXPLANATION : Thermal transmittance in so far as temperatures are measured on the two surfaces of material or structure in the latter case and in the surrounding air or other fluid in the former. The conductance is a characteristic of the structure whereas the transmittance depends on conductance and surface coefficients of the structure under the conditions of use.

CALCULATION OF THERMAL TRANSMITTANCE U FOR TYPICAL CASES

Procedure

a) Calculate thermal resistance R of each uniform material which constitutes the building unit as follows :

$$R = \frac{L}{K}$$

`R' - Thermal Resistance is reciprocal of thermal Conductance. For a structure having plane parallel faces, thermal resistance is equal to thickness (L) divided by thermal conductivity (K).

L = thickness of material in m, and

K = thermal conductivity in $\frac{W}{mK}$

b) Find the total thermal resistance RT as follows :

$$RT - \frac{1}{fo} + \frac{1}{f1} + R1 + R2 + R3$$

$$U - \frac{1}{RT} \ W/m2K$$

fo = Outside film coefficient at an air velocity of 8.0 Km/hr = 19.86 W/(m2K)

f1 = Inside film coefficient at still air = 9.36 W/(m2K)

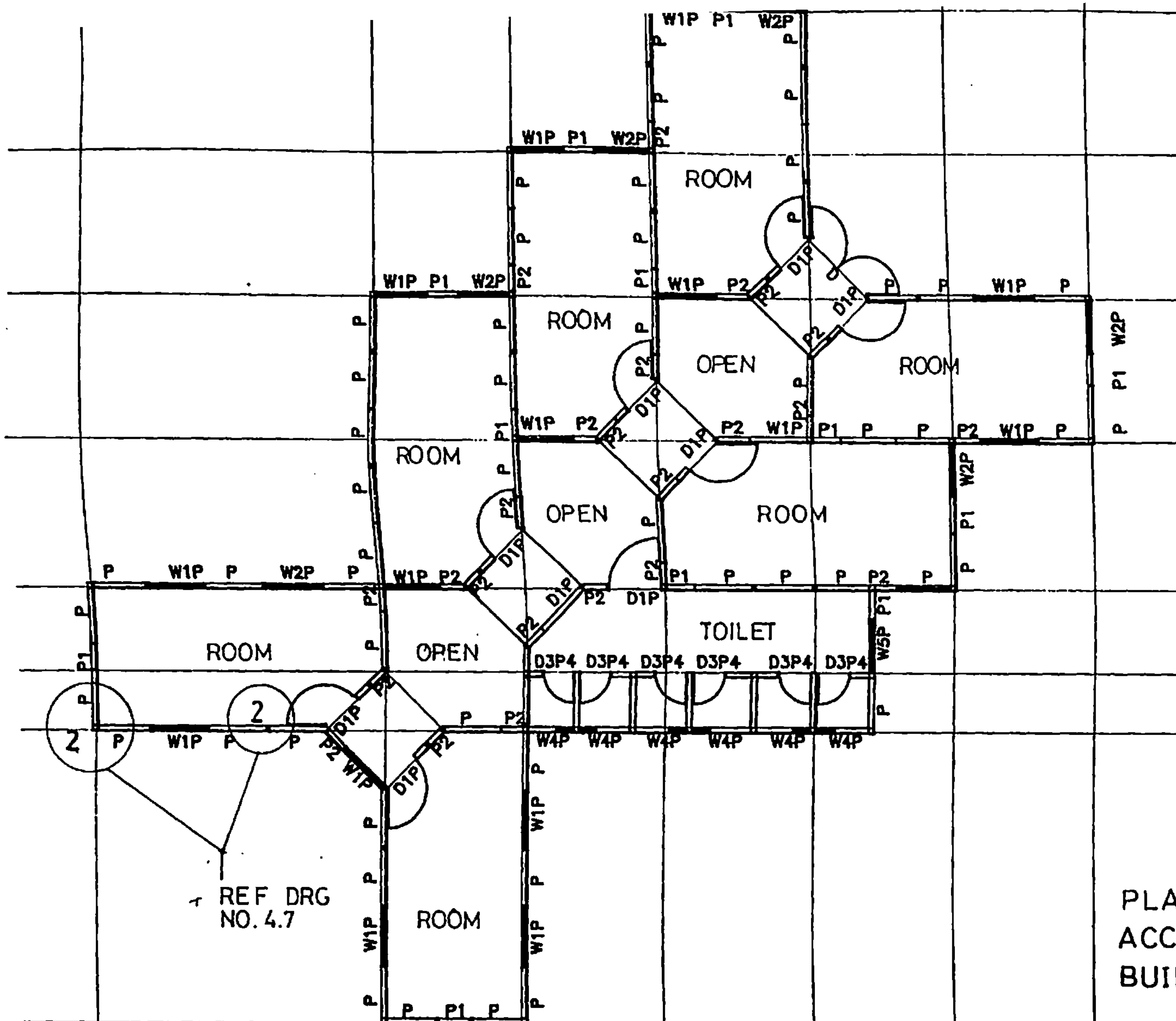
as per IS 3792 - 1978

wmK - Watts/Meter Kelvin

LIST OF DRAWINGS

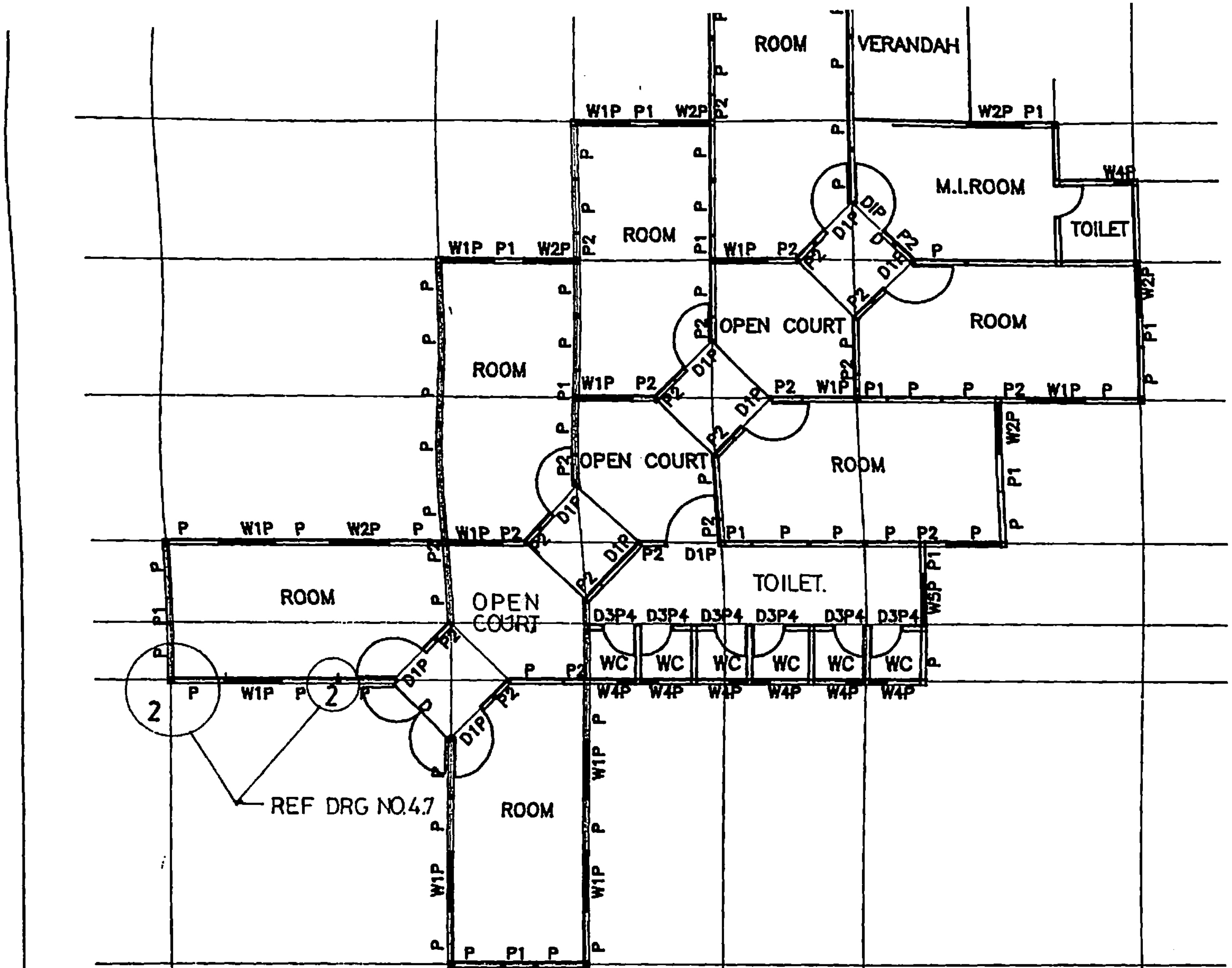
DRG. NO.	DESCRIPTION	PAGE NO.

DEFENCE INSTITUTE OF WORK STUDY - MUSSOORIE : UTTAR PRADESH



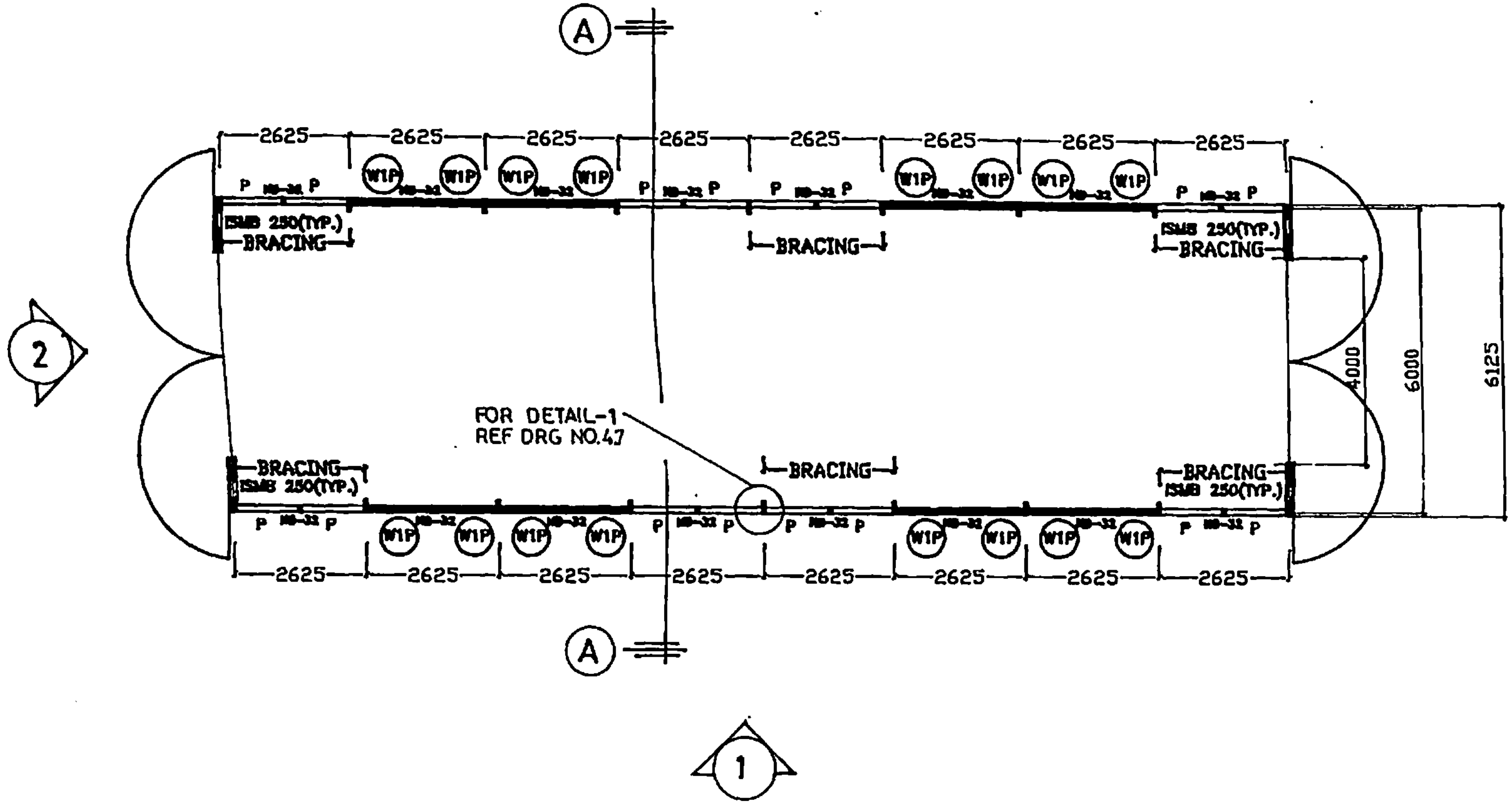
PLAN OF STAFF ACCOMMODATION BUILDING

CONSTRUCTION IN DESERT — THE POKHRAN PROJECT	FOR PENEL DETAILS REF. DRG NO. 4.8 & 4.9	DRG. NO.	4.1
	FLOOR PLAN	SCALE 1:150	



PLAN OF STAFF ACCOMMODATION AND M.I. ROOM

CONSTRUCTION IN DESERT — THE POKHRAN PROJECT	FOR PANEL DETAILS REF. DRG NO. 4.8 & 4.9	DRG. NO.	4.2
	FLOOR PLAN	SCALE 1:150	



PLAN OF STORE BUILDING

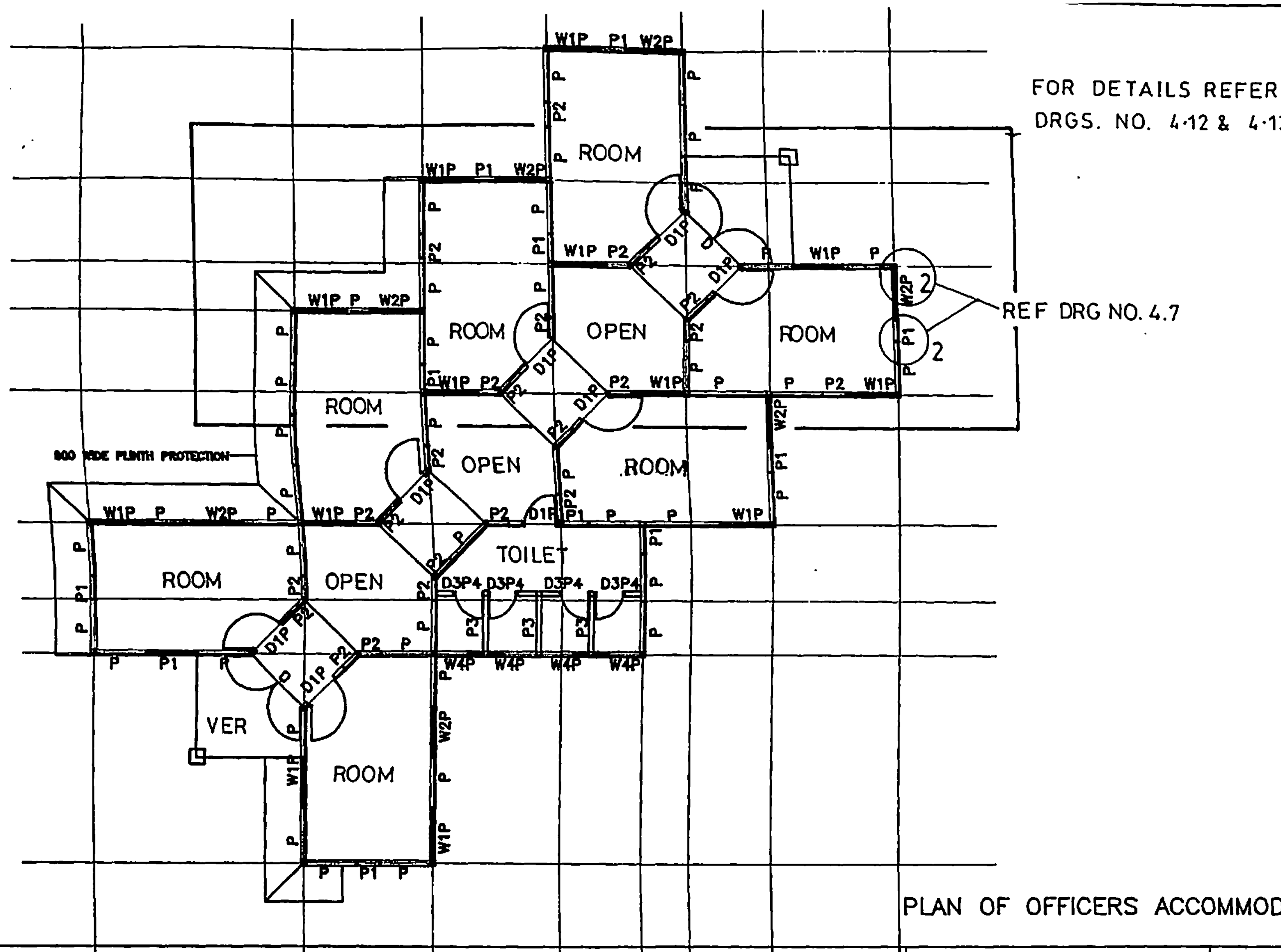
CONSTRUCTION IN DESERT — THE POKHRAN PROJECT

FOR PANEL DETAILS REF. DRG NO. 4.8 & 4.9

FLOOR PLAN

DRG. NO. 4.3

SCALE 1:150



PLAN OF OFFICERS ACCOMMODATION

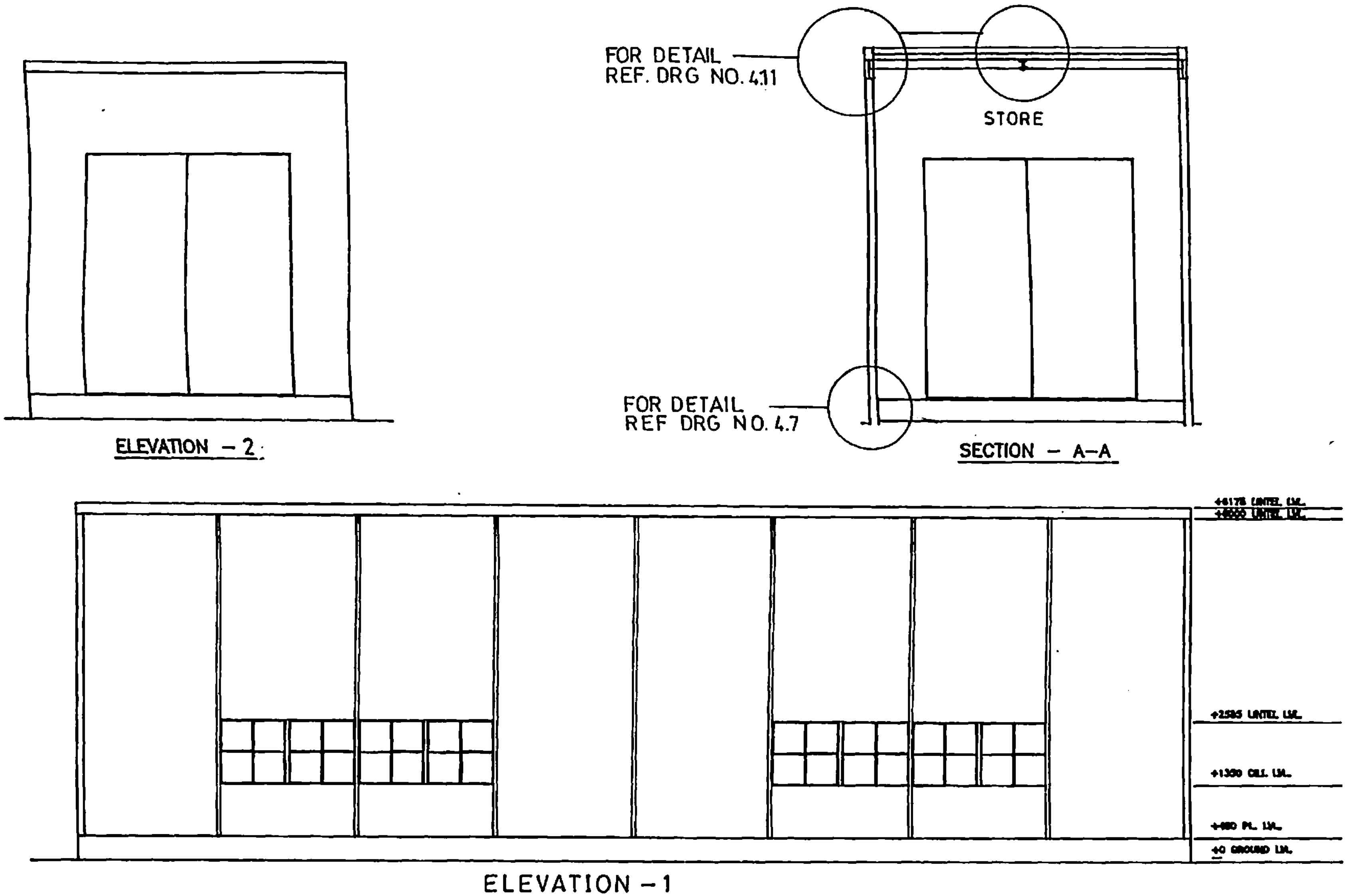
CONSTRUCTION IN DESERT — THE POKHRAN PROJECT

FOR PANEL DETAILS REF. DRG NO. 4.8 & 4.9

DRG. NO. 4.4

SCALE 1:150

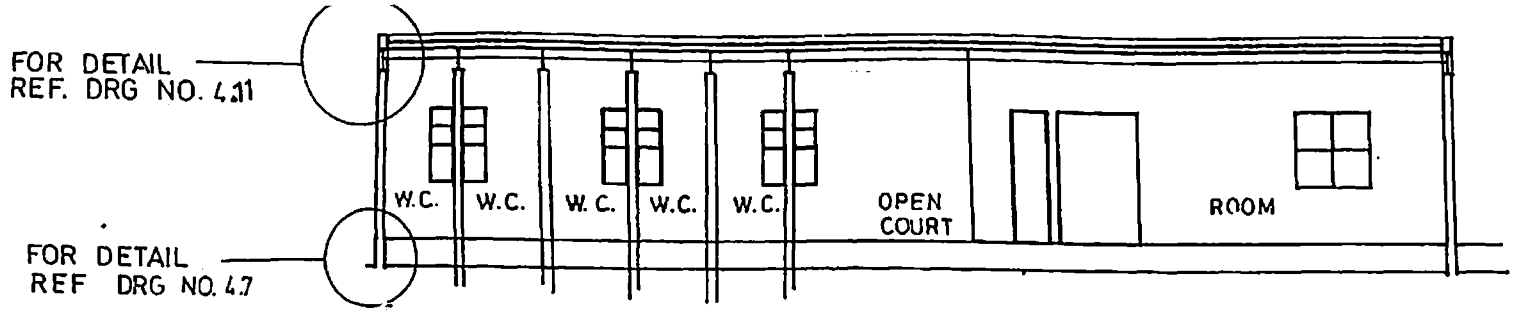
FLOOR PLAN



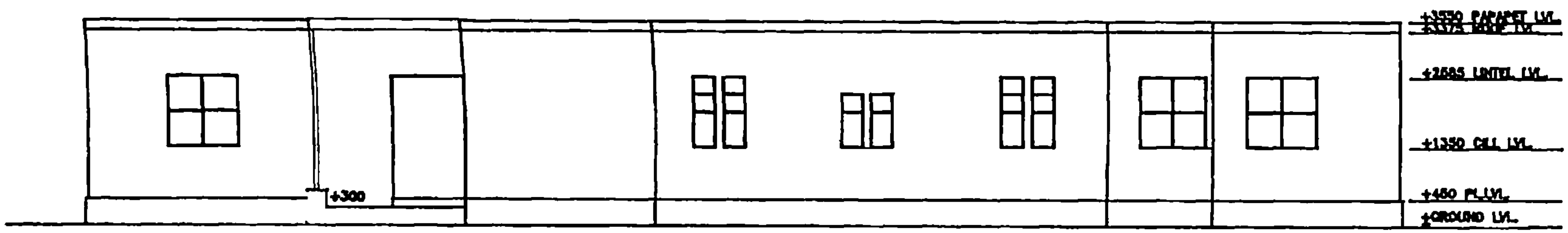
CONSTRUCTION IN DESERT — THE POKHRAN PROJECT

STORE BUILDING
ELEVATION / SECTION

DRG. NO.	4.5
SCALE	



TYPICAL SECTION



TYPICAL ELEVATION

CONSTRUCTION IN DESERT – THE POKHRAN PROJECT	TYPICAL ELEVATION / SECTION	DRG. NO.	4.6
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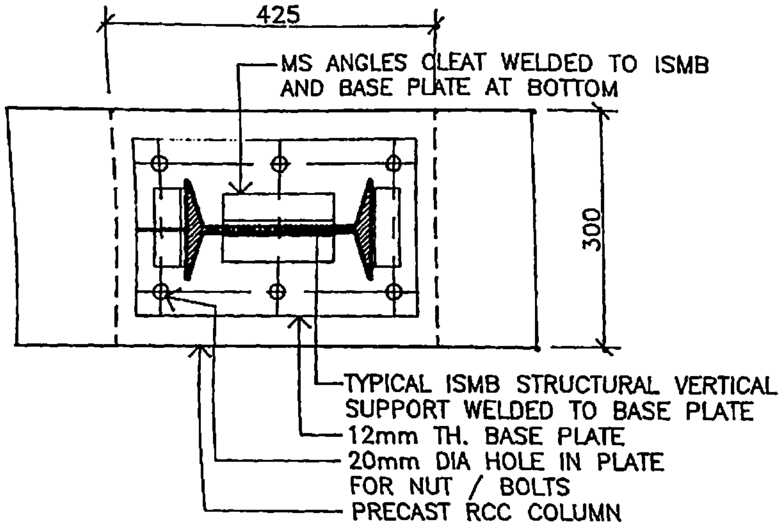

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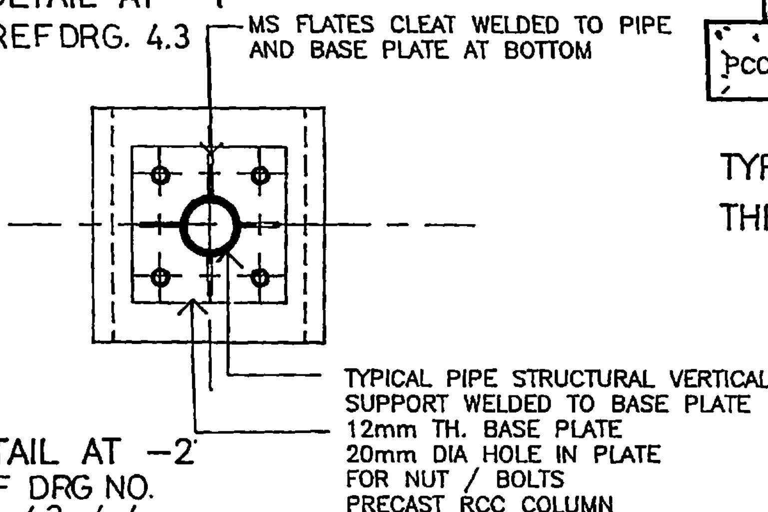
REF DRG. 4.3



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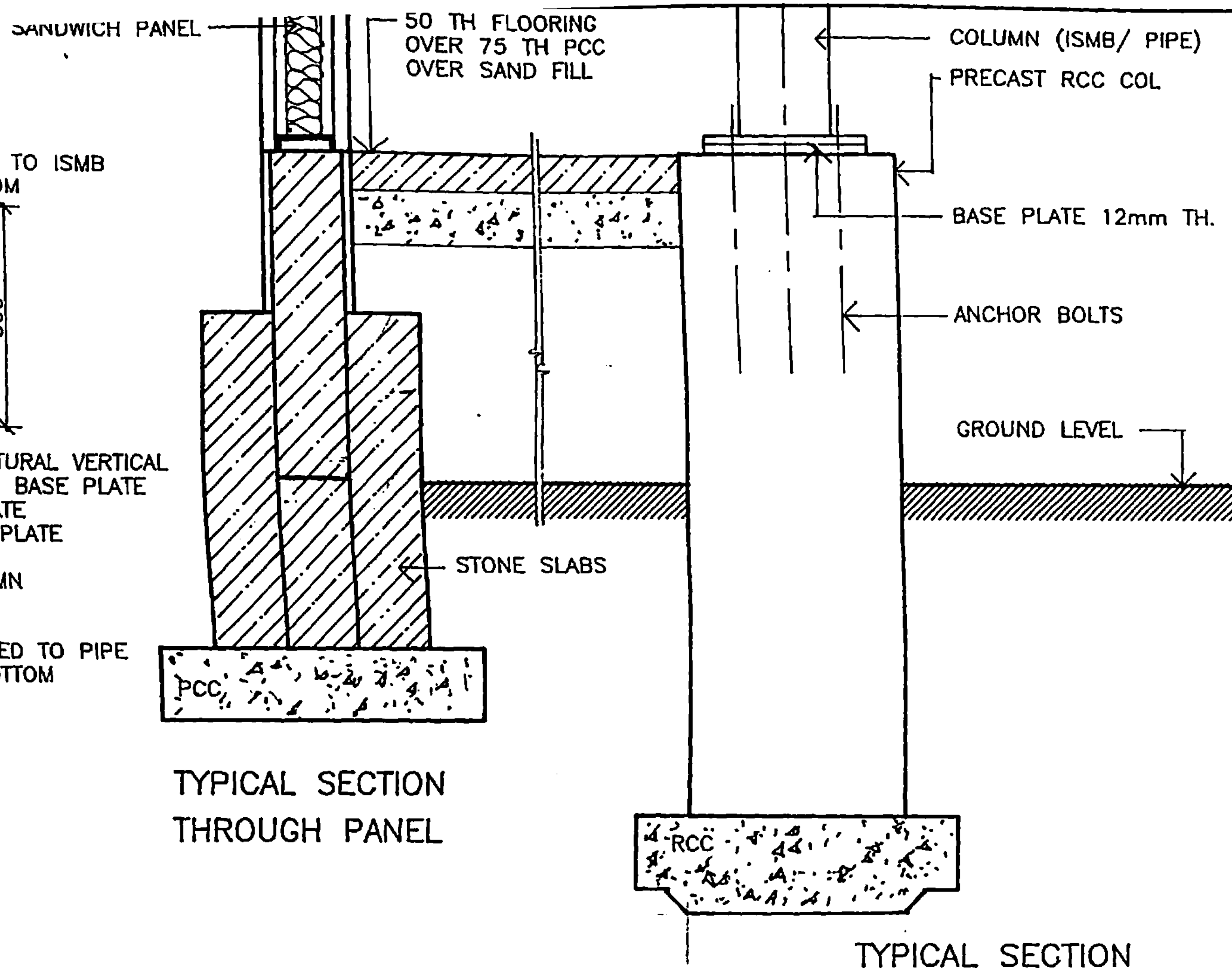

TYPICAL SECTION THROUGH PANEL

TYPICAL SECTION THROUGH COLUMN

CONSTRUCTION DESERT - THE POKHRAN PROJECT	FOUNDATION DETAILS	DRG. NO.	4.7
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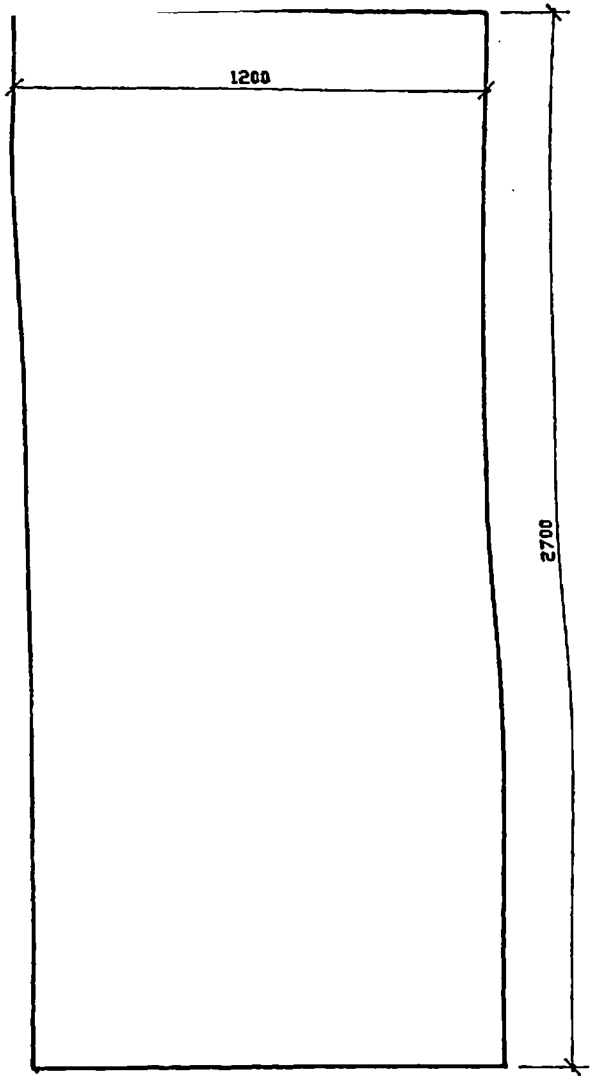
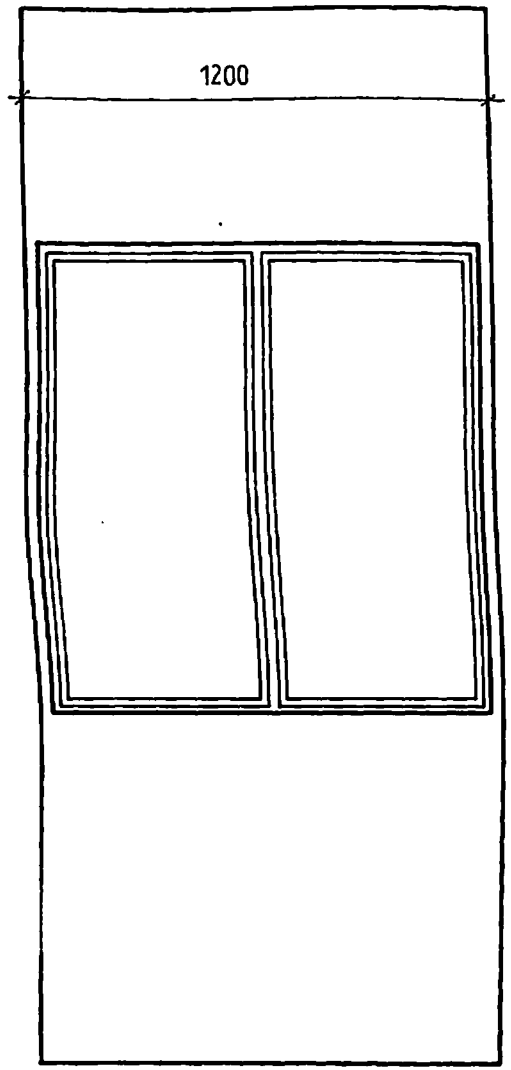
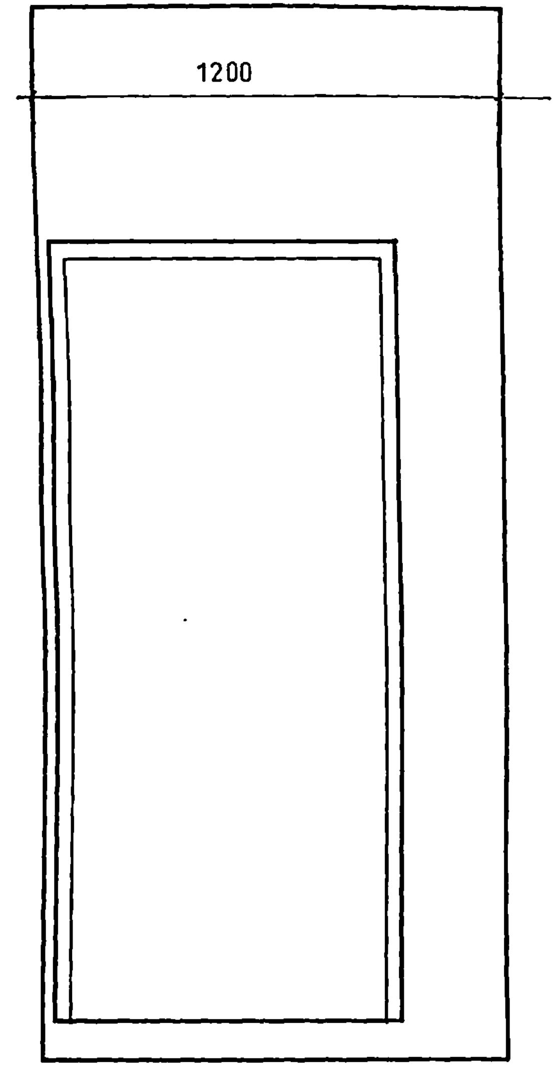


ELEVATION OF A PANEL



ELEVATION OF A PANEL WITH WINDOW OPENING

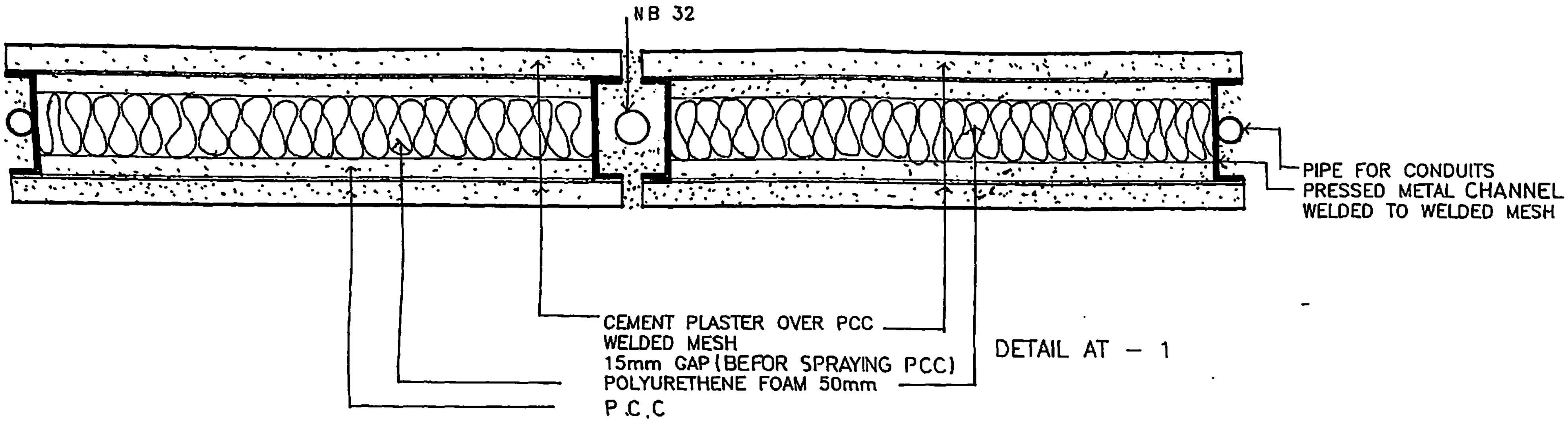


ELEVATION OF A PANEL WITH DOOR OPENING

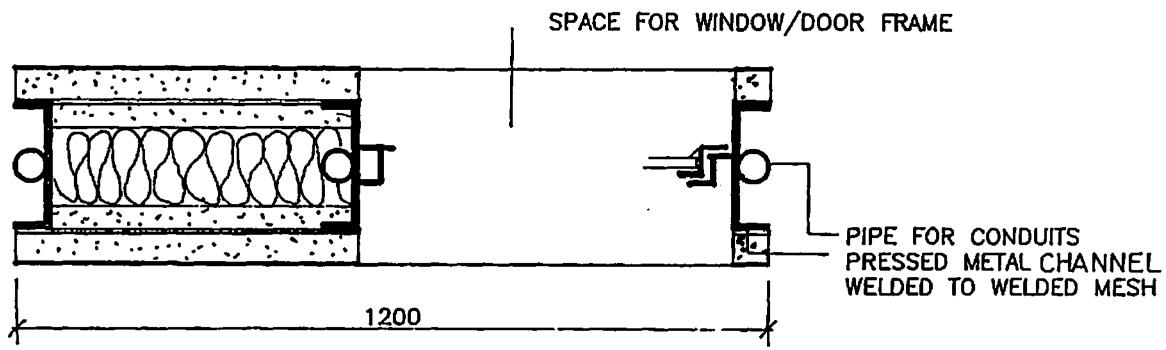
CONSTRUCTION IN DESERT - THE POKHRAN PROJECT

SANDWICH PANEL ELEVATION

DRG. NO.	4.8
SCALE	

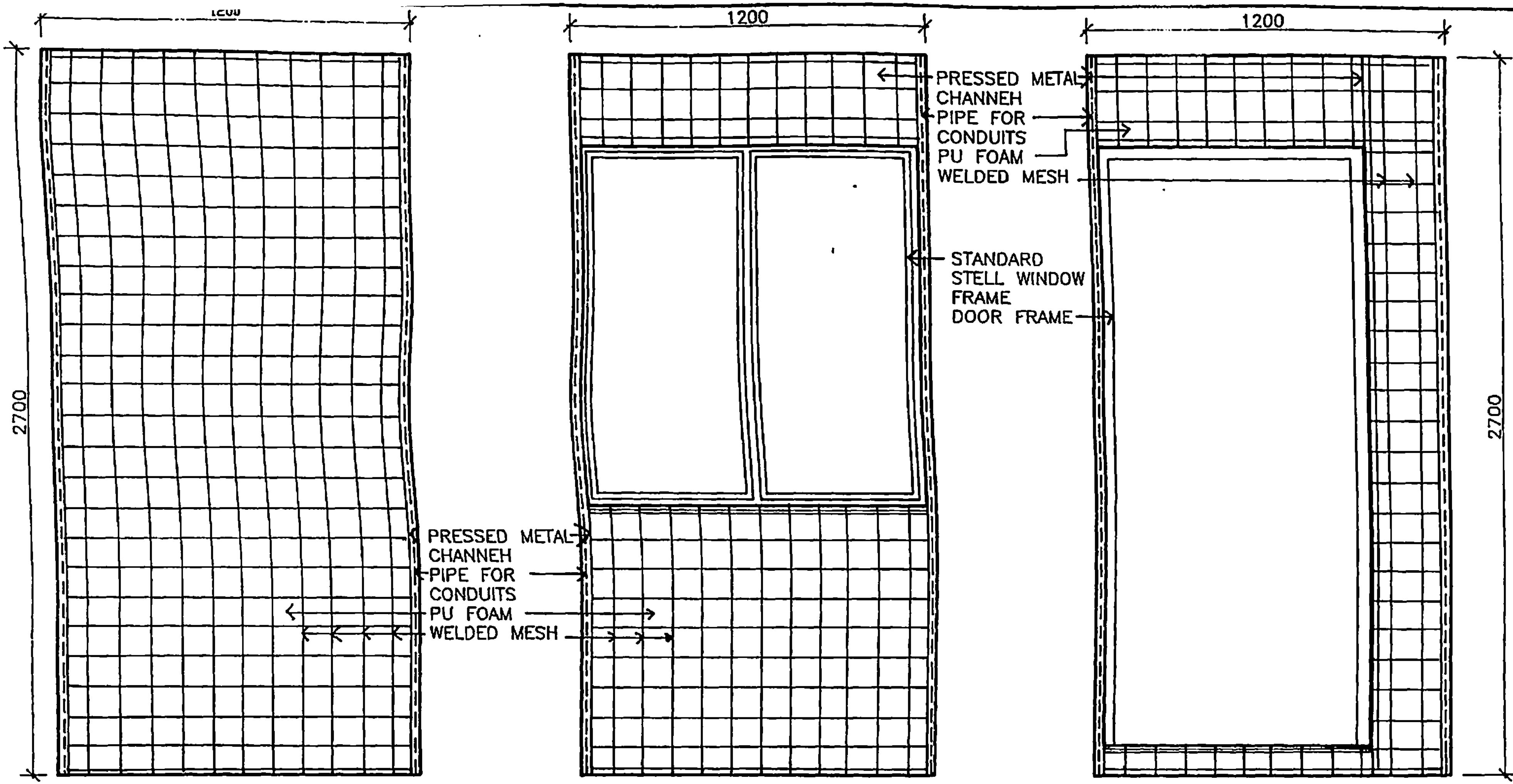


DETAIL AT – 1



DETAIL AT – 2

CONSTRUCTION IN DESERT – THE POKHRAN PROJECT	SANDWICH PANEL DETAIL	DRG. NO.	4.9
		SCALE	



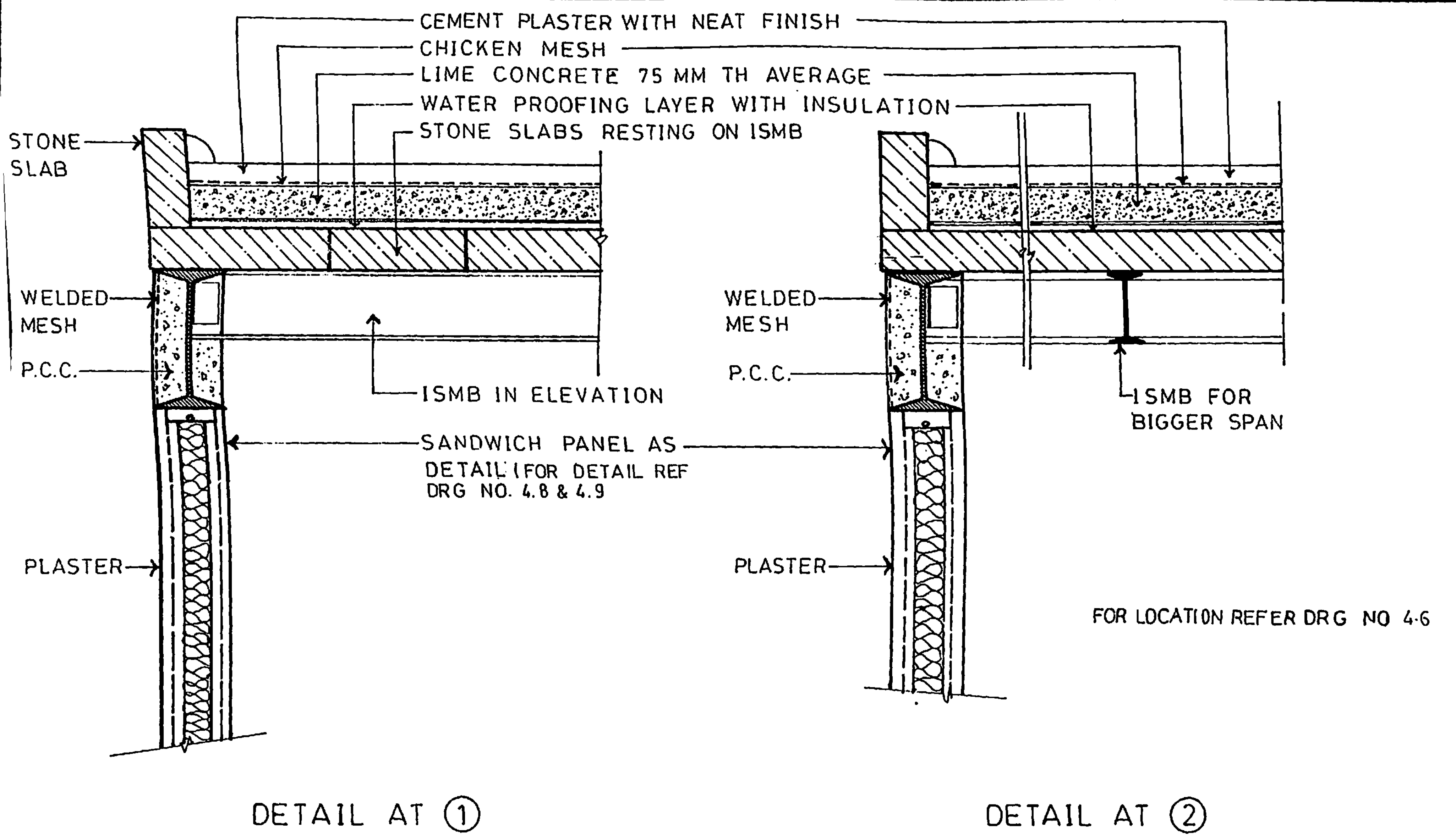
ELEVATION OF A PANEL

ELEVATION OF A PANEL WITH WINDOW OPENING

ELEVATION OF A PANEL WITH DOOR OPENING

FOR DETAILS REFER DRG. NO. 4·9

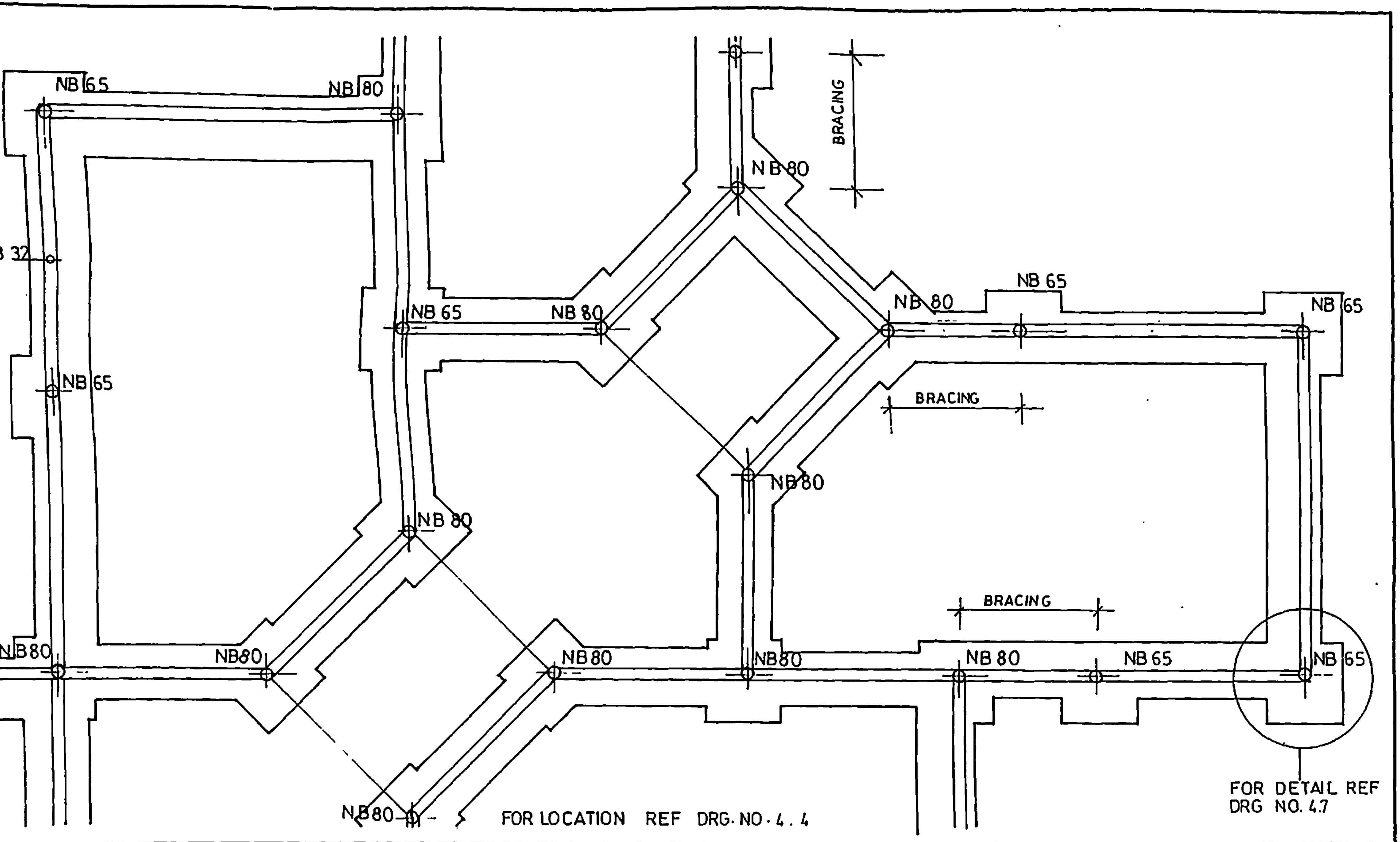
CONSTRUCTION IN DESERT – THE POKHRAN PROJECT	SANDWICH PANEL DETAILS	DRG. NO.	4·10
		SCALE 1:10	



CONSTRUCTION DESERT – THE POKHRAN PROJECT

ROOF DETAILS

DRG. NO.	4.11
SCALE	

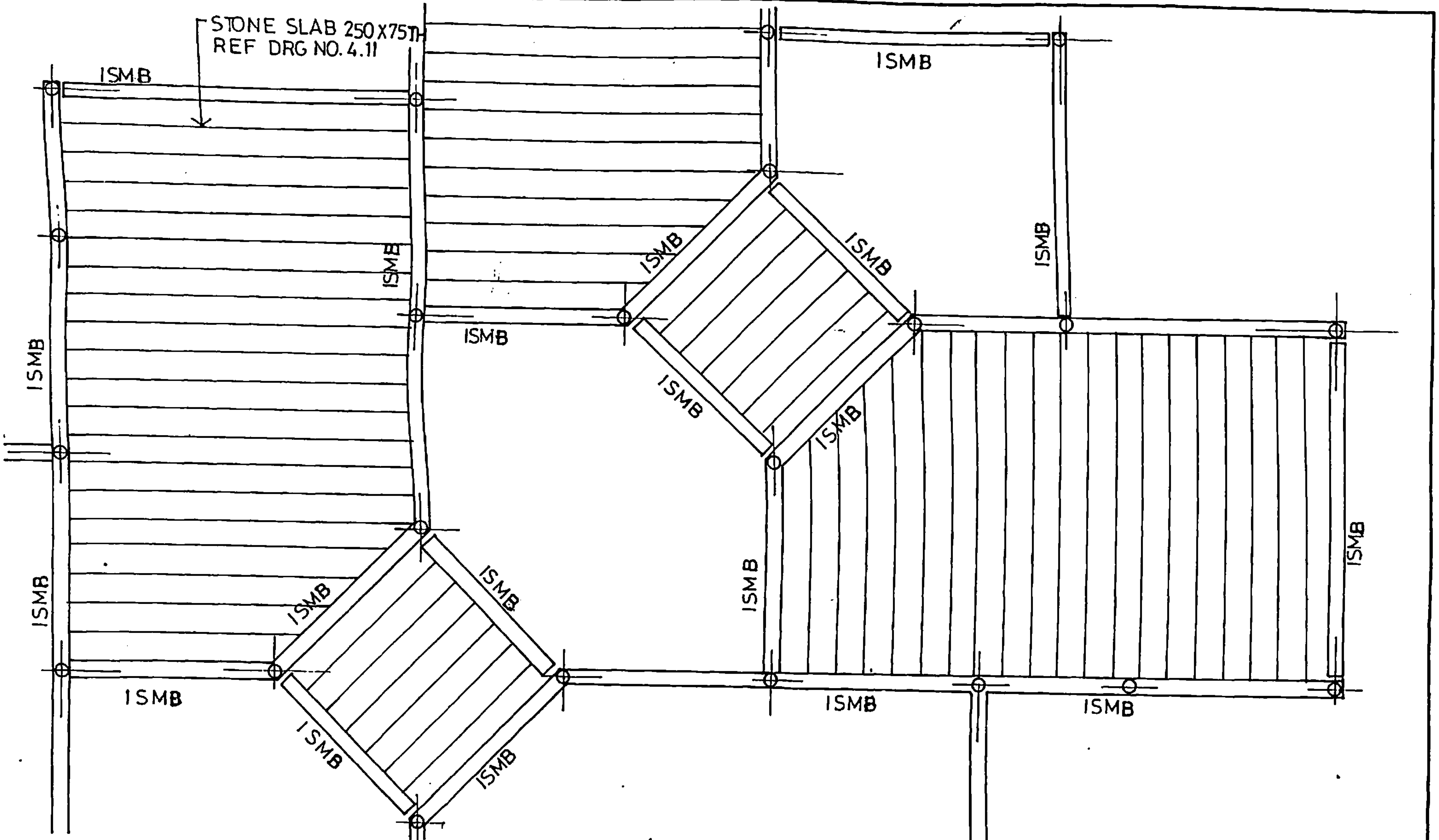


CONSTRUCTION IN DESERT — THE POKHRAN PROJECT

STRUCTURAL ARRANGEMENT

DRG. NO. 4.12

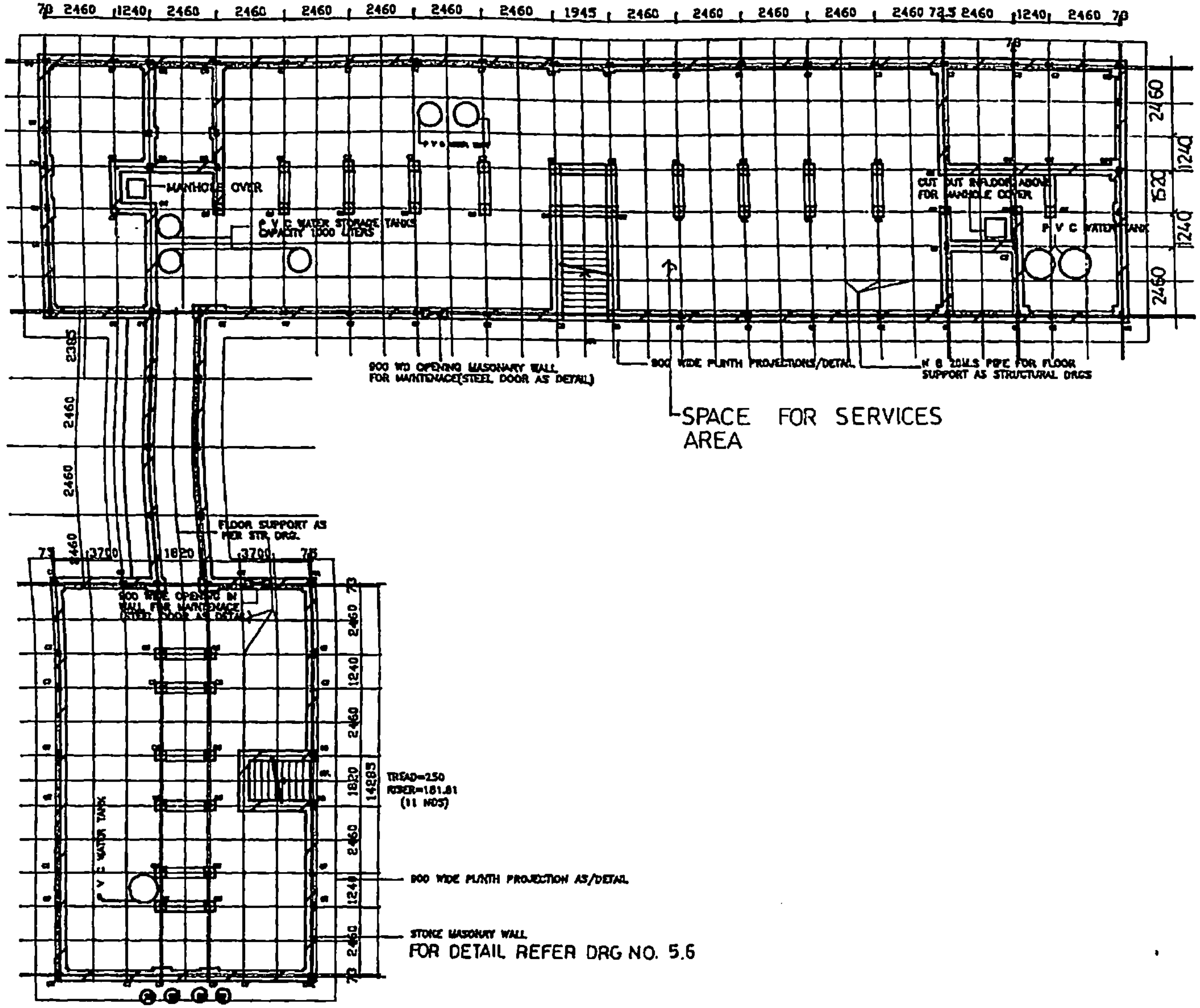
SCALE 1:50



FOR LOCATION REF. DRG. NO. 4.4

CONSTRUCTION IN DESERT - THE POKHRAN PROJECT

STRUCTURAL ARRANGEMENT	DRG. NO.	4.13
	SCALE 1:50	



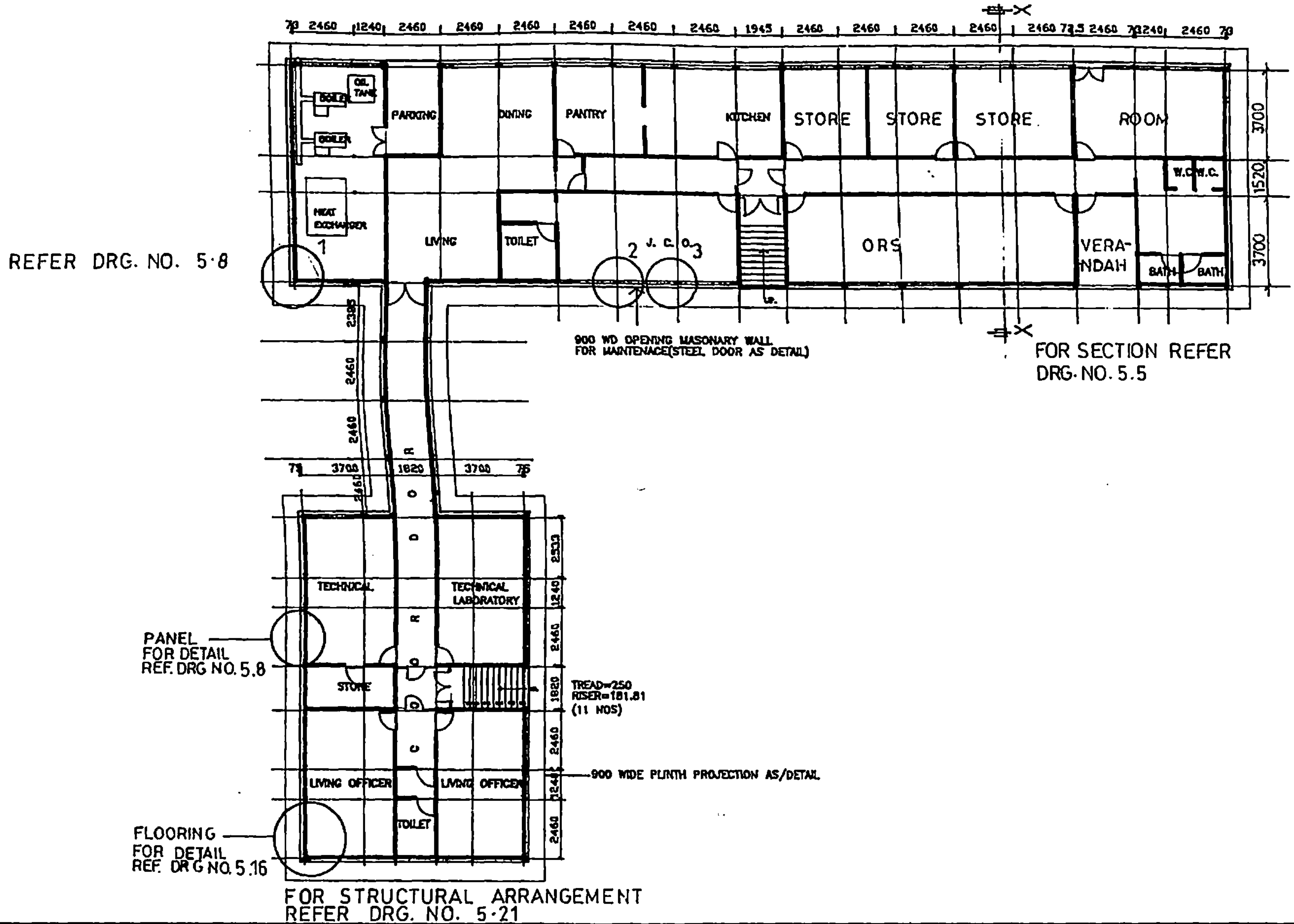
CONSTRUCTION IN HIGH ALTITUDE AREA

SNOW AVALANCHE STUDY ESTABLISHMENT, BARALACHLA, HIMACHAL PRADESH

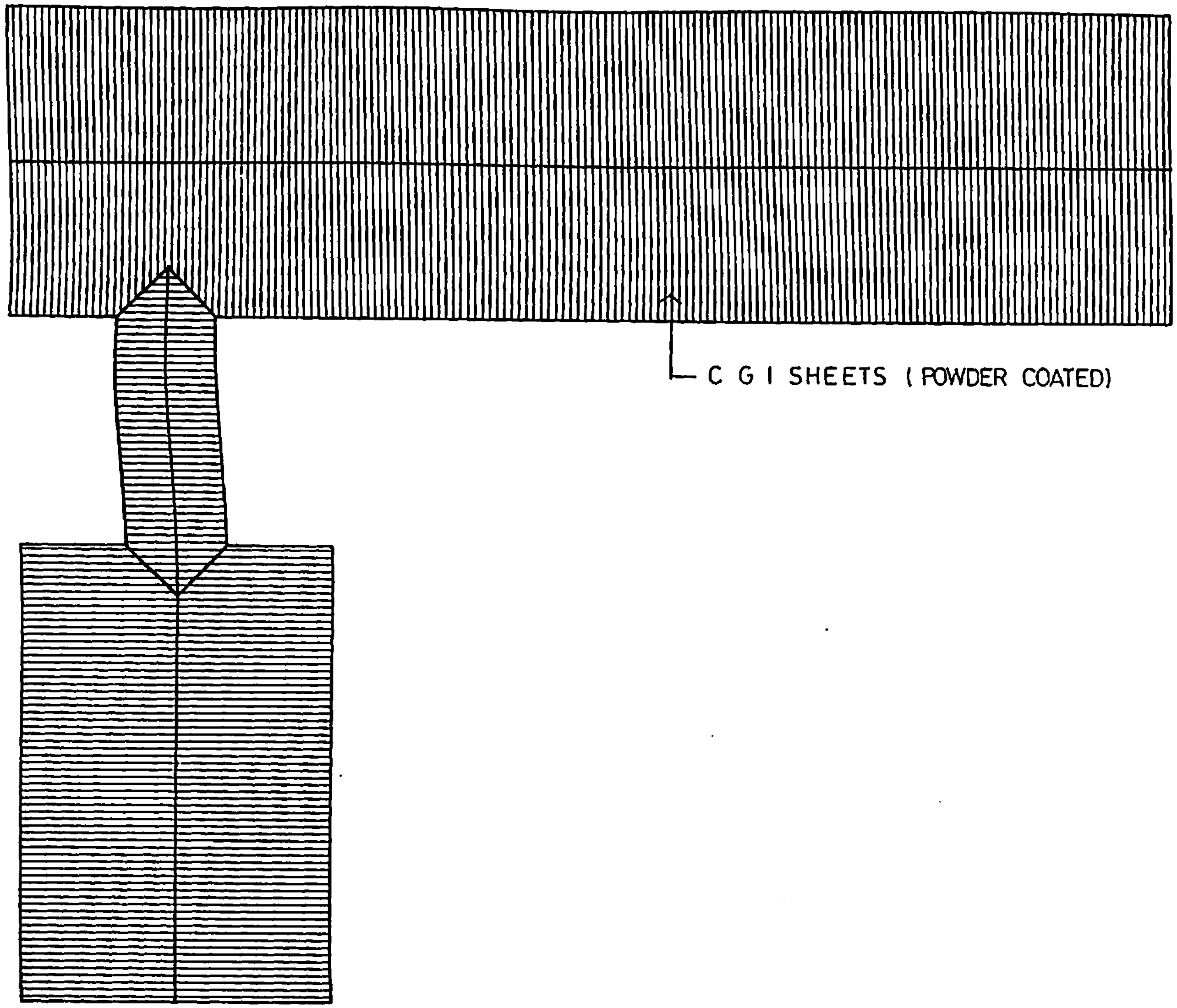
LOWER LEVE PLAN

DRG. NO. 5·1

SCALE 1:250



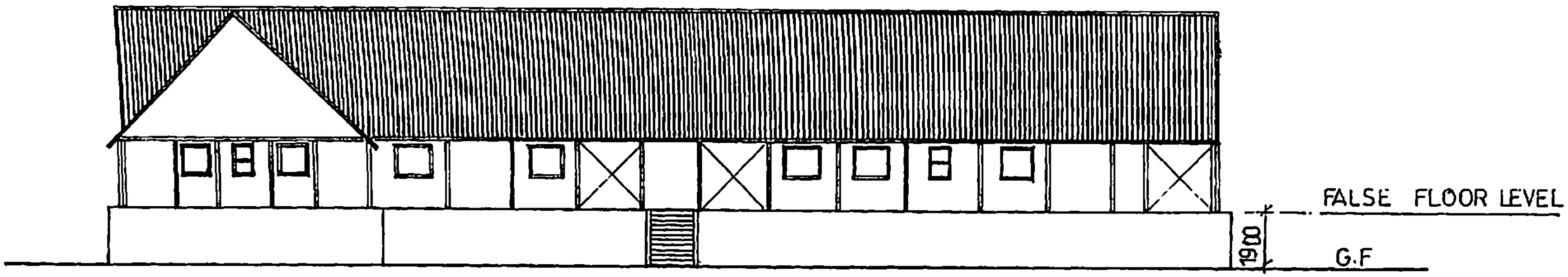
CONSTRUCTION IN HIGH ALTITUDE AREA SNOW AVALANCHE STUDY ESTABLISHMENT, BARALACHLA, HIMACHAL PRADESH	UPPER LEVEL PLAN	DRG. NO. 5·2 SCALE 1:250



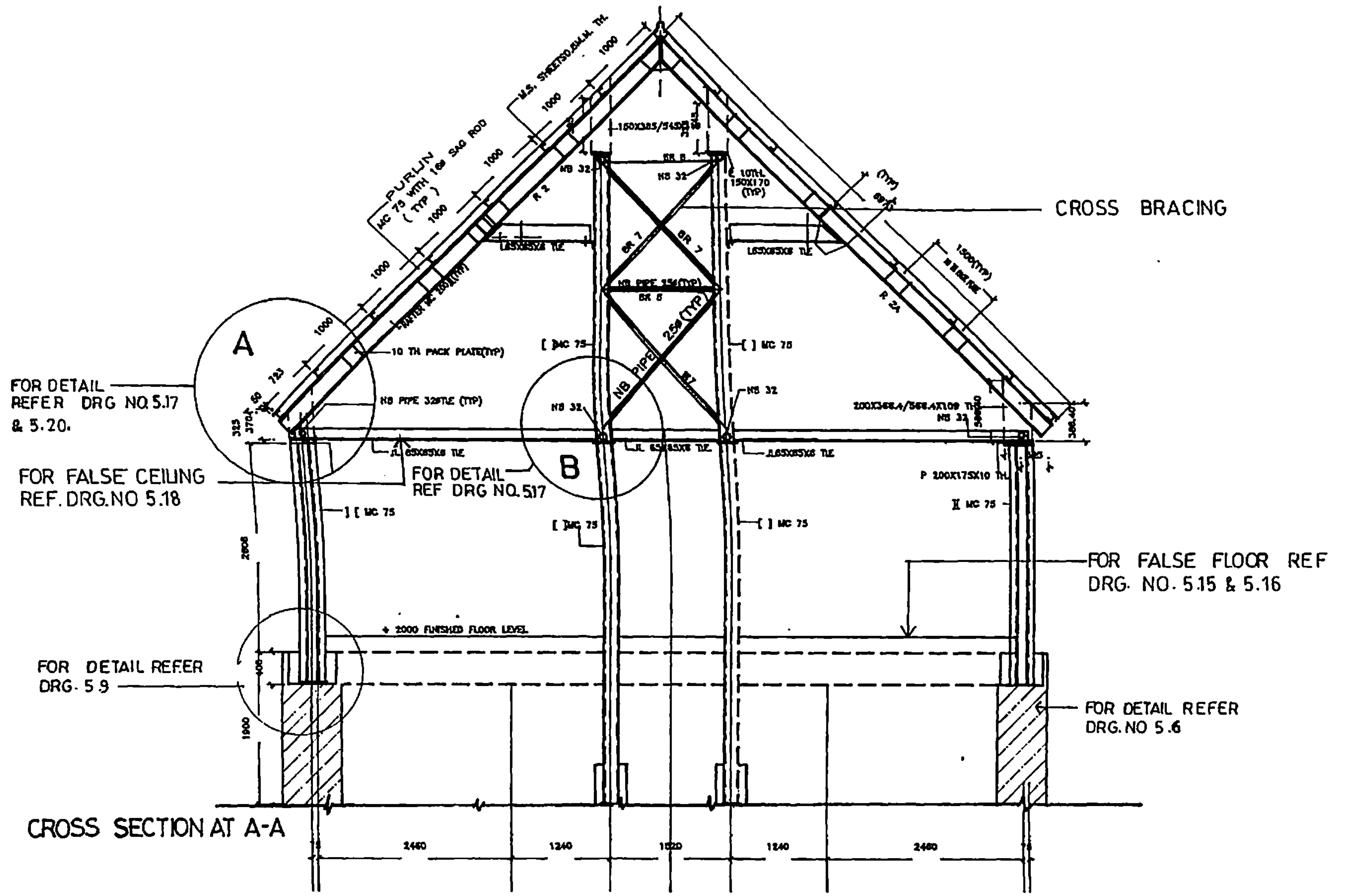
CONSTRUCTION IN HIGH ALTITUDE AREA
SNOW AVALANCHE STUDY ESTABLISHMENT, BARALACHLA, HIMACHAL PRADESH

TERRACE PLAN

DRG. NO.	5·3
SCALE 1:250	

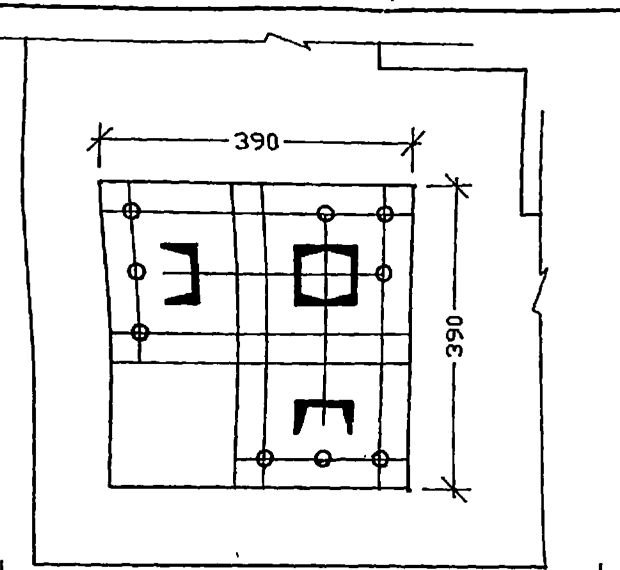


CONSTRUCTION IN HIGH ALTITUDE AREA SNOW AVALANCHE STUDY ESTABLISHMENT, BARALACHLA, HIMACHAL PRADESH	ELEVATION	DRG. NO.	5.4
		SCALE	

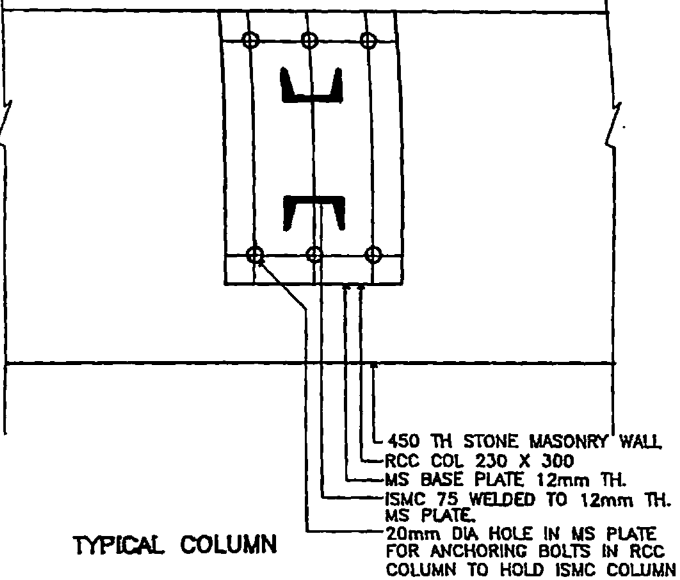


CROSS SECTION AT A-A

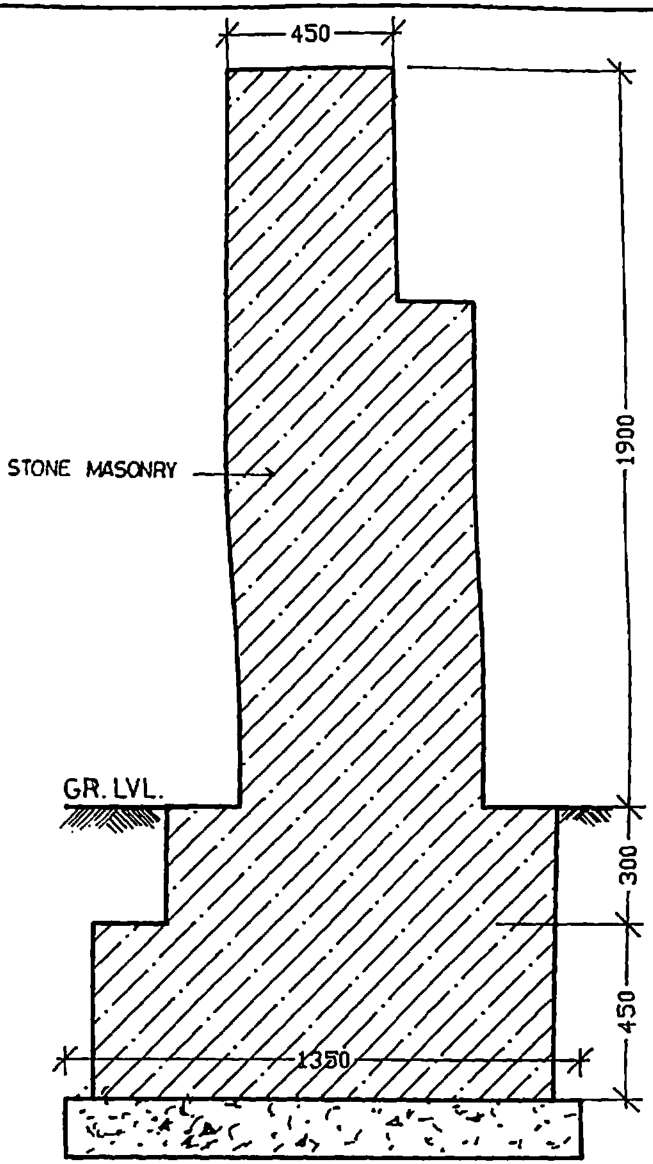
CONSTRUCTION IN HIGH ALTITUDE AREA SNOW AVALANCHE STUDY ESTABLISHMENT,BARALACHLA,HIMACHAL PRADESH	SECTION	DRG. NO. 5·5 SCALE 1:75



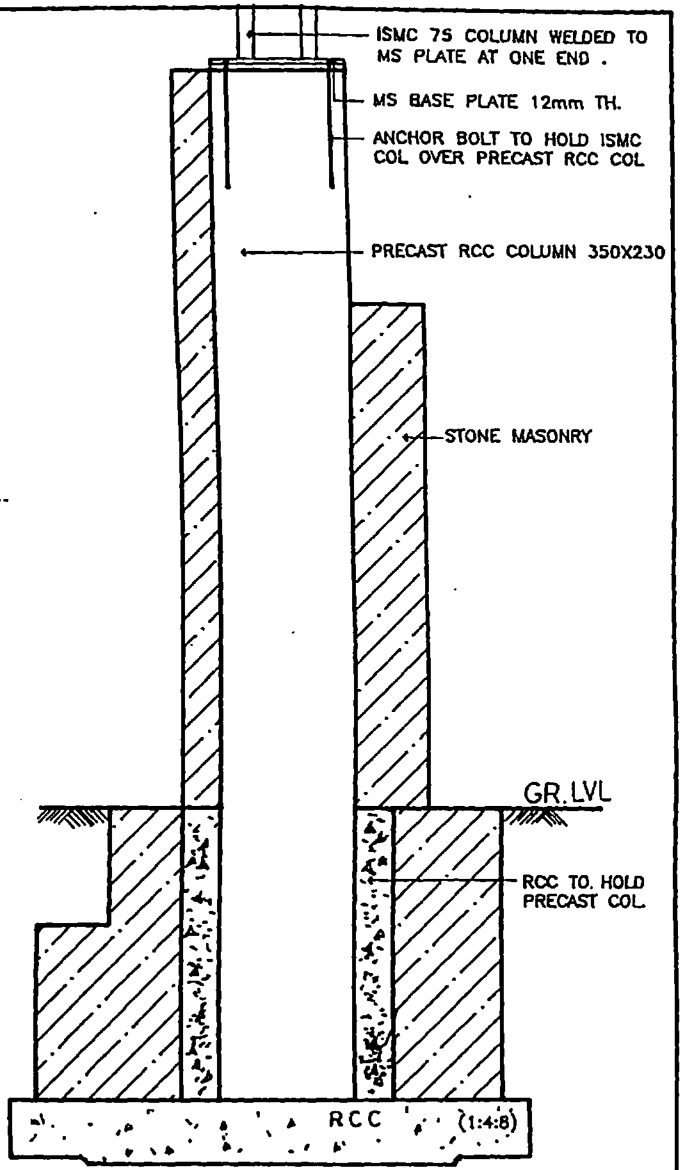
COLUMN AT CORNER



TYPICAL COLUMN

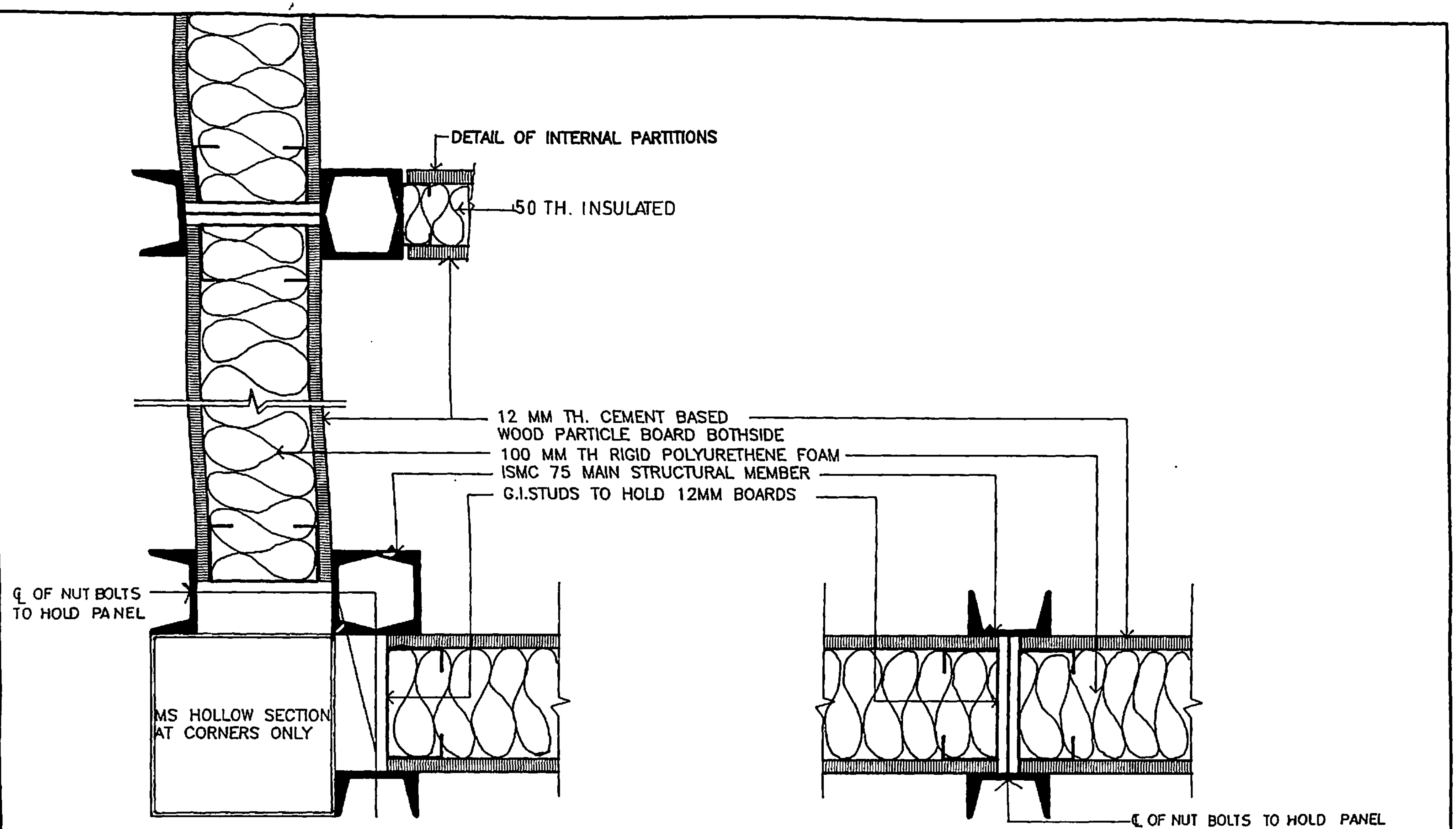


TYPICAL STONE MASONRY RETAINING WALL SECTION



TYPICAL COLUMN PLACING DETAIL

CONSTRUCTION IN HIGH ALTITUDE AREA SNOW AVALANCHE STUDY ESTABLISHMENT, BARALACHLA, HIMACHAL PRADESH	FOUNDATION DETAILS	DRG. NO.	5·6
		SCALE 1:20	

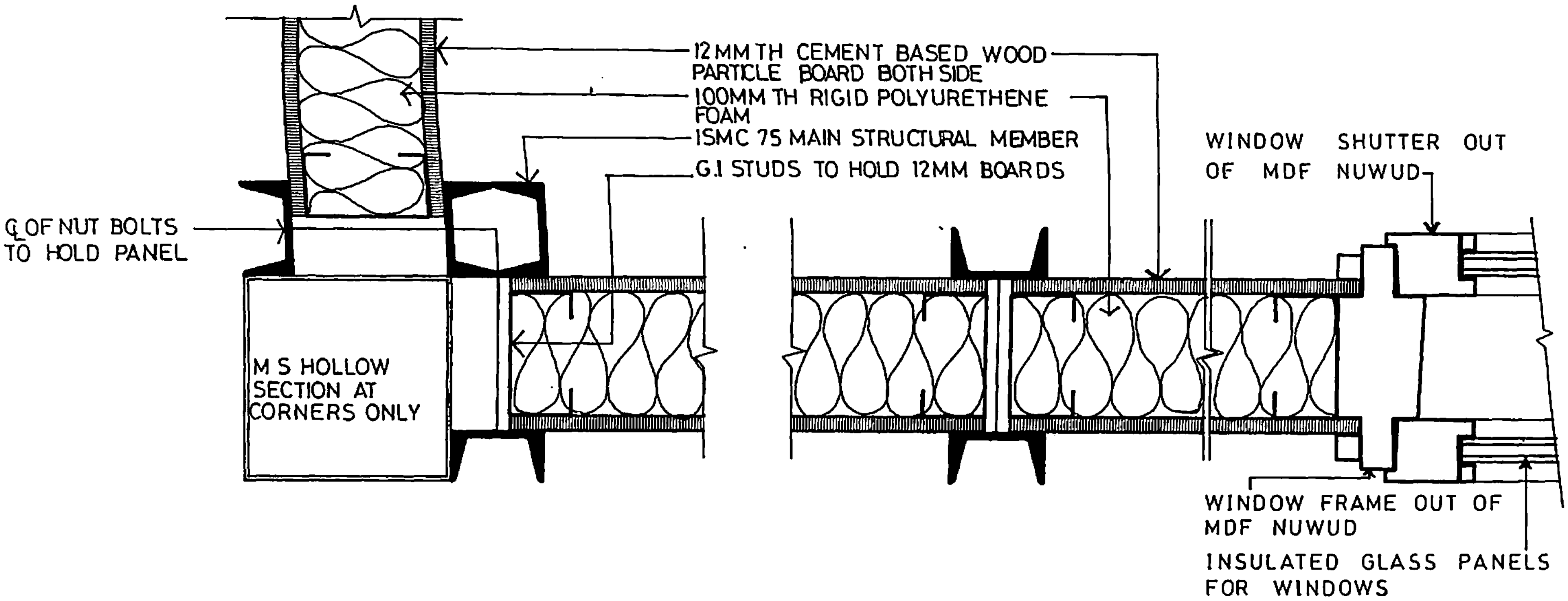


DETAIL OF PANELS PLACEMENT AT CORNER

DETAIL OF PANELS PLACEMENT AT CENTRE

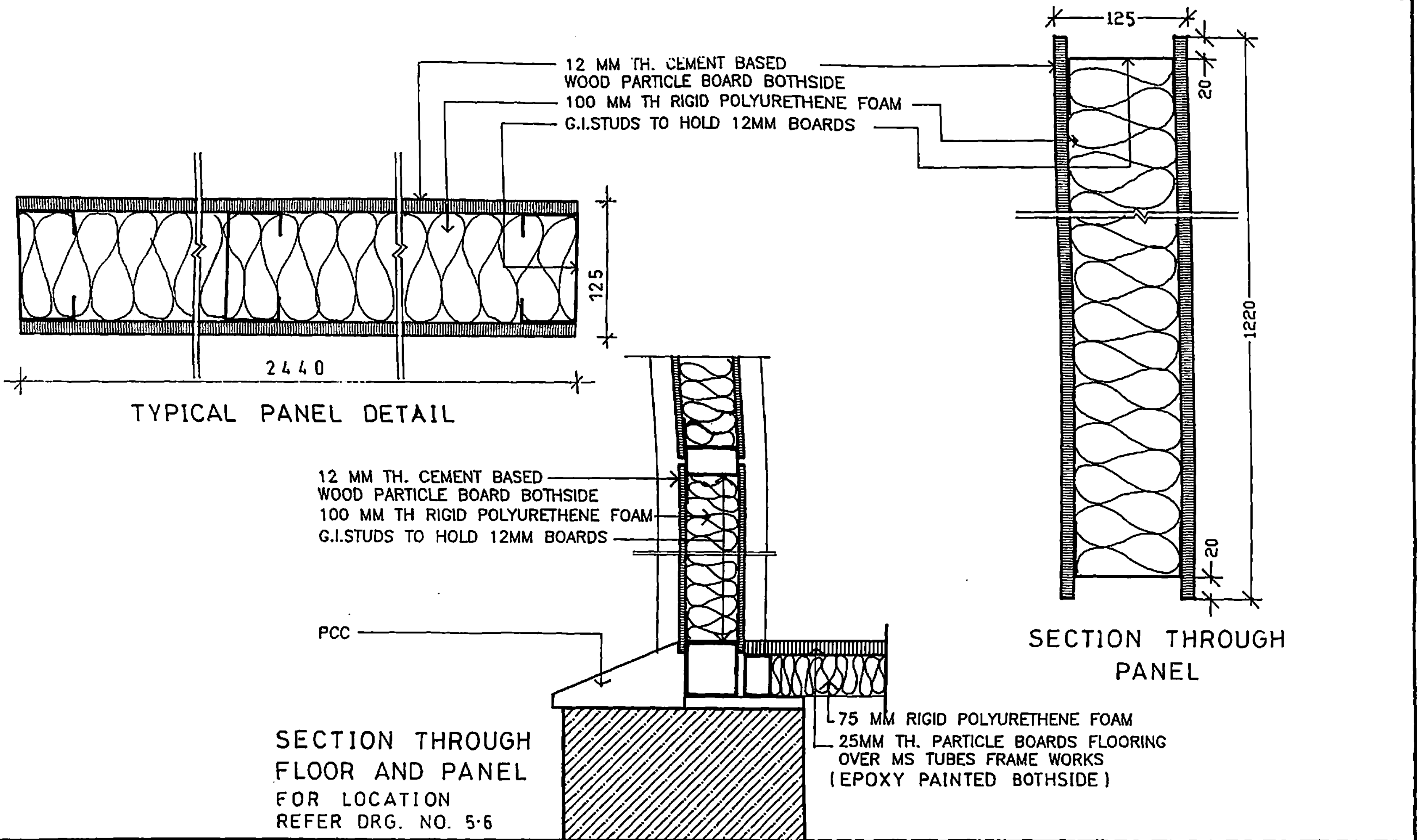
CONSTRUCTION IN HIGH ALTITUDE AREA SNOW AVALANCHE STUDY ESTABLISHMENT,BARALACHLA,HIMACHAL PRADESH	JUNCTION DETAILS	DRG. NO.	5·7
		SCALE 1:5	

FOR LOCATION REFR. DRG. NO. 5.2

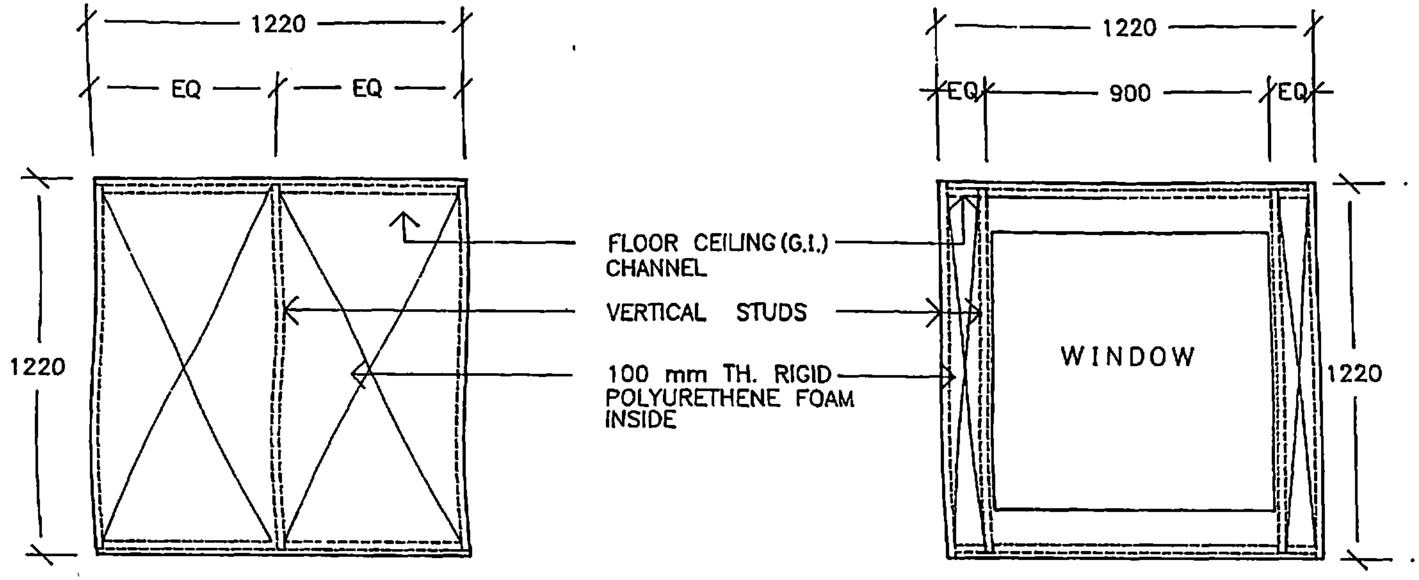


DETAIL AT-(1) DETAIL AT-(2) DETAIL AT-(3)

CONSTRUCTION IN HIGH ALTITUDE AREA SNOW AVALANCHE STUDY ESTABLISHMENT, BARALACHLA, HIMACHAL PRADESH	PANEL FIXING DETAIL	DRG. NO.	5.8
		SCALE 1:5	



CONSTRUCTION IN HIGH ALTITUDE AREA SNOW AVALANCHE STUDY ESTABLISHMENT,BARALACHLA,HIMACHAL PRADESH	TYPICAL PANEL DETAIL	DRG NO.	5·9
		SCALE 1:10, 1:5	



WALL PANEL

SIZE 1220 X 1220 12MM TH.CEMENT BASED

WOOD PARTICLE BOARD BOTHSIDE

WINDOW PANEL

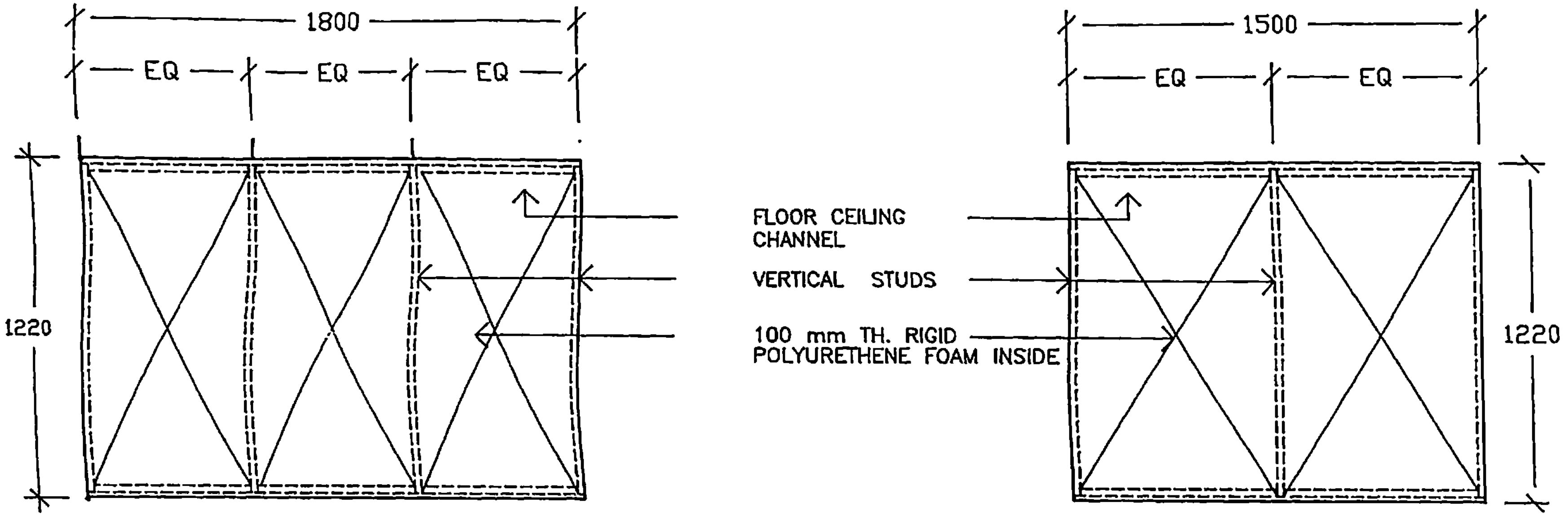
SIZE 1220 X 1220 12MM TH.CEMENT BASED

WOOD PARTICLE BOARD BOTHSIDE

NOTE: FOR SECTIONAL DETAILS REFER

DRG.NO. 5·9

CONSTRUCTION IN HIGH ALTITUDE AREA SNOW AVALANCHE STUDY ESTABLISHMENT,BARALACHLA,HIMACHAL PRADESH	SANDWICH PANEL ELEVATION	DRG. NO.	5·10
		SCALE 1:25	



WALL PANEL

SIZE 1800 X 1220 12MM TH.CEMENT BASED

WOOD PARTICLE BOARD BOTHSIDF

WALL PANEL

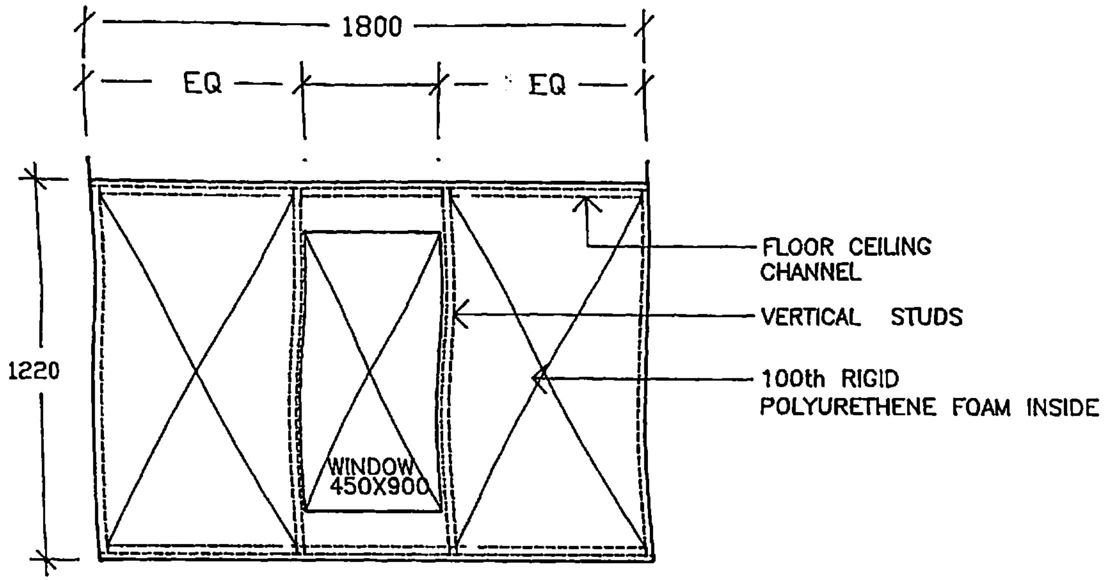
SIZE 1500 X 1220 12TH.CEMENT BASED

WOOD PARTICLE BOARD BOTHSIDE

NOTE : FOR SECTIONAL DETAILS

REFER DRG. NO. 5.8

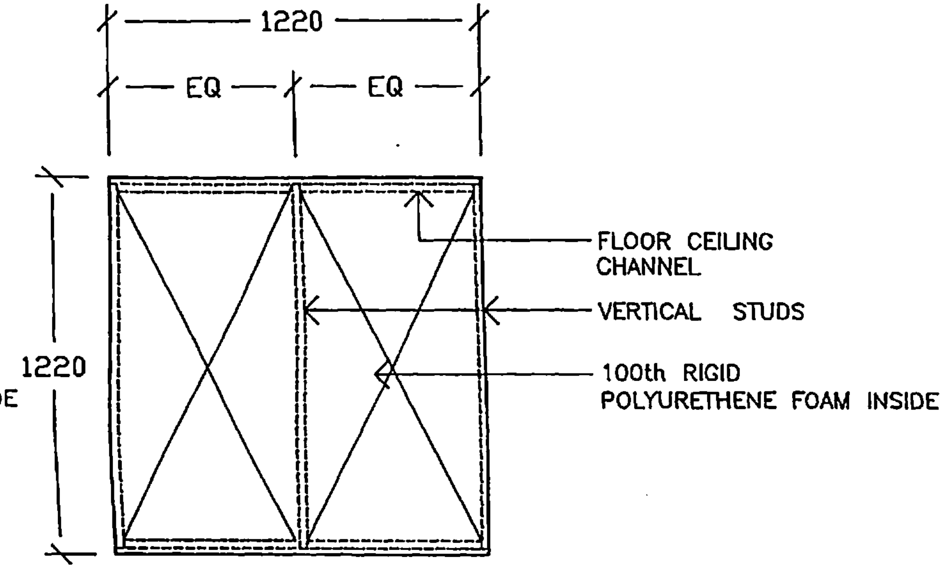
CONSTRUCTION IN HIGH ALTITUDE AREA **SNOW AVALANCHE STUDY ESTABLISHMENT,BARALACHLA,HIMACHAL PRADESH**	SANDWICH PANEL ELEVATION	DRG. NO.	5.11
		SCALE 1:25	



WALL PANEL

SIZE 1800 X 1220 12MM TH.CEMENT BASED

WOOD PARTICLE BOARD BOTHSIDE



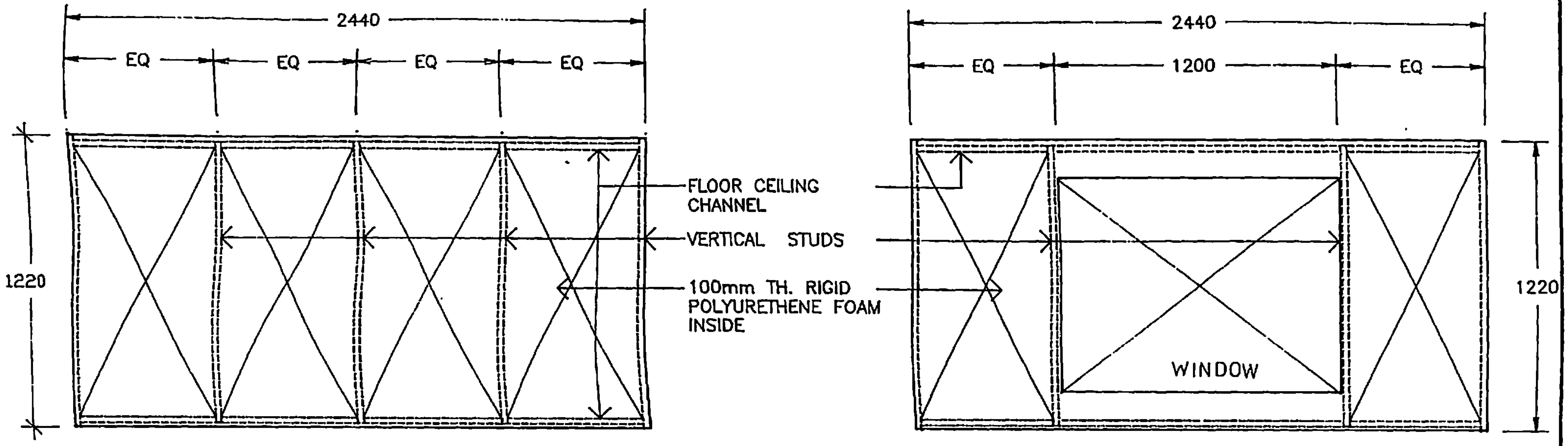
WALL PANEL

SIZE 1220 X 1220 12MM TH.CEMENT BASED

WOOD PARTICLE BOARD BOTHSIDE

NOTE: FOR SECTIONAL DETAILS REFER DRG.NO. 5.8

CONSTRUCTION IN HIGH ALTITUDE AREA **SNOW AVALANCHE STUDY ESTABLISHMENT, BARALACHLA, HIMACHAL PRADESH**	SANDWICH PANEL ELEVATION	DRG. NO.	5.12
		SCALE 1:25	



WALL PANEL

SIZE 2440 X 1220 (12MM TH. CEMENT BASED

WOOD PARTICLE BOARD BOTHSIDE

WINDOW PANEL

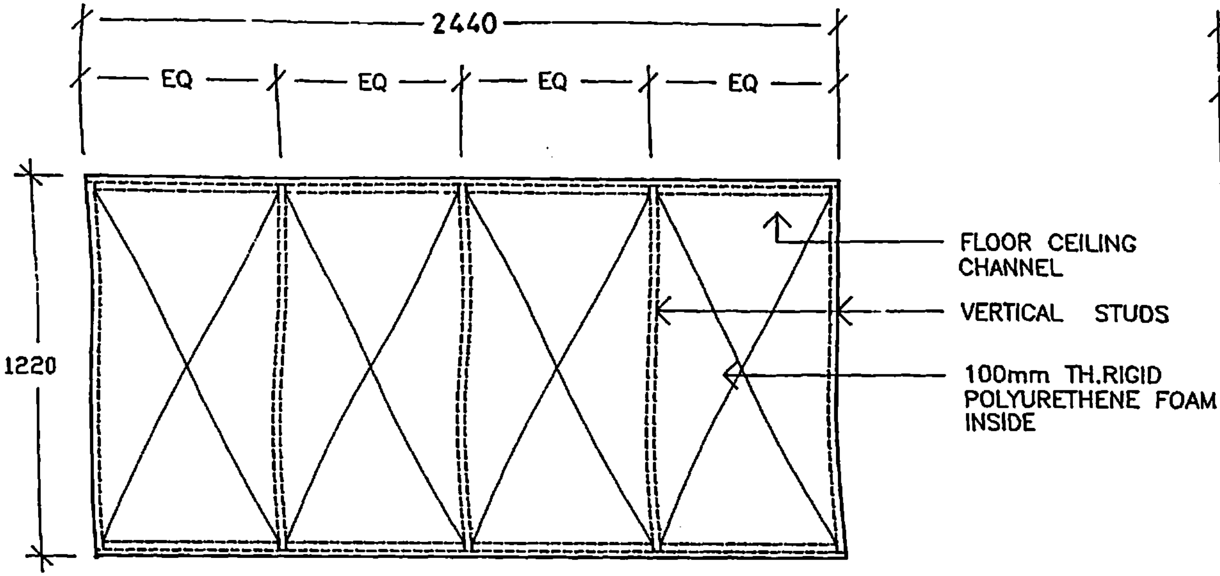
SIZE 2440 X 1220 (12MM TH. CEMENT BASED

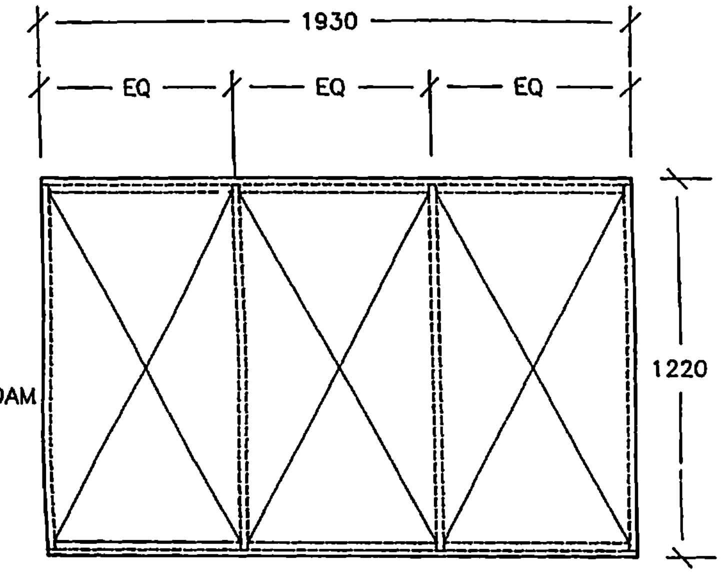
WOOD PARTICLE BOARD BOTHSIDE

NOTE: FOR SECTIONAL DETAILS REFER

DRG.NO. 5.8 & 5.9

CONSTRUCTION IN HIGH ALTITUDE AREA SNOW AVALANCHE STUDY ESTABLISHMENT,BARALACHLA,HIMACHAL PRADESH	SANDWICH PANEL ELEVATION	DRG. NO.	5.13
		SCALE 1:25	





WALL PANEL

SIZE 2440 X 1220 12MM TH.CEMENT BASED

WOOD PARTICLE BOARD BOTHSIDE

WALL PANEL

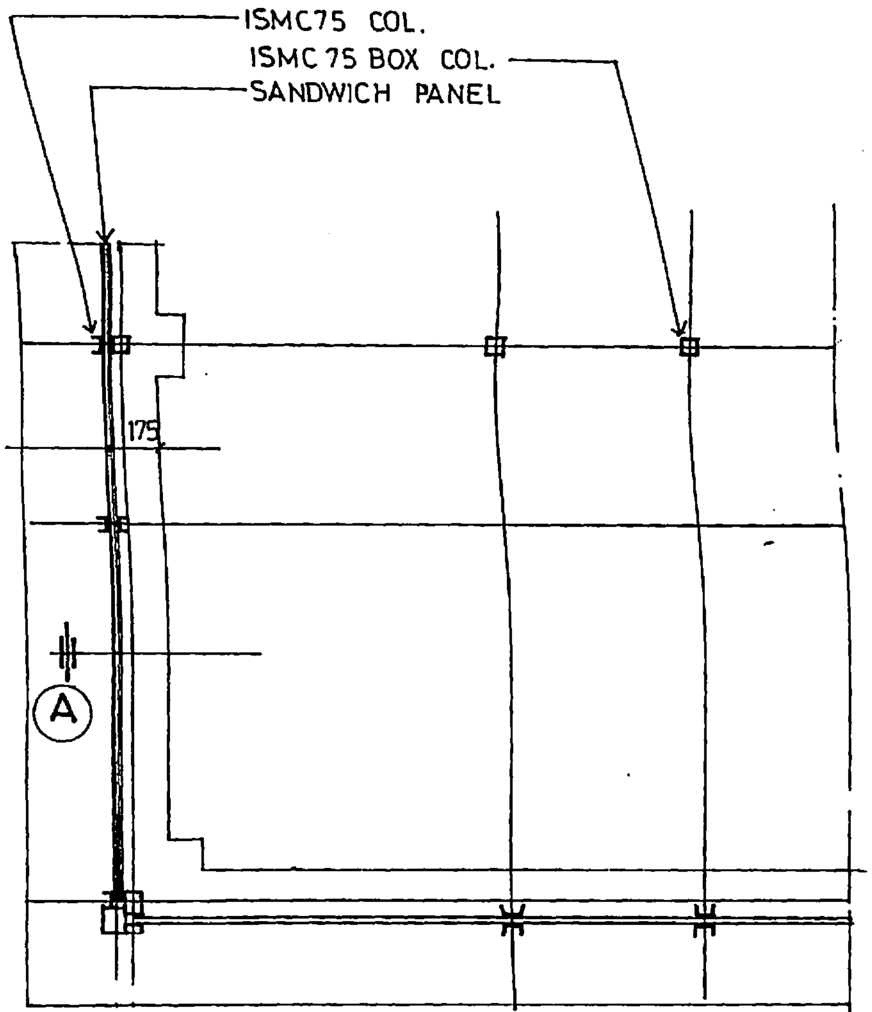
SIZE 1930 X 1220 12MM TH.CEMENT BASED

WOOD PARTICLE BOARD BOTHSIDE

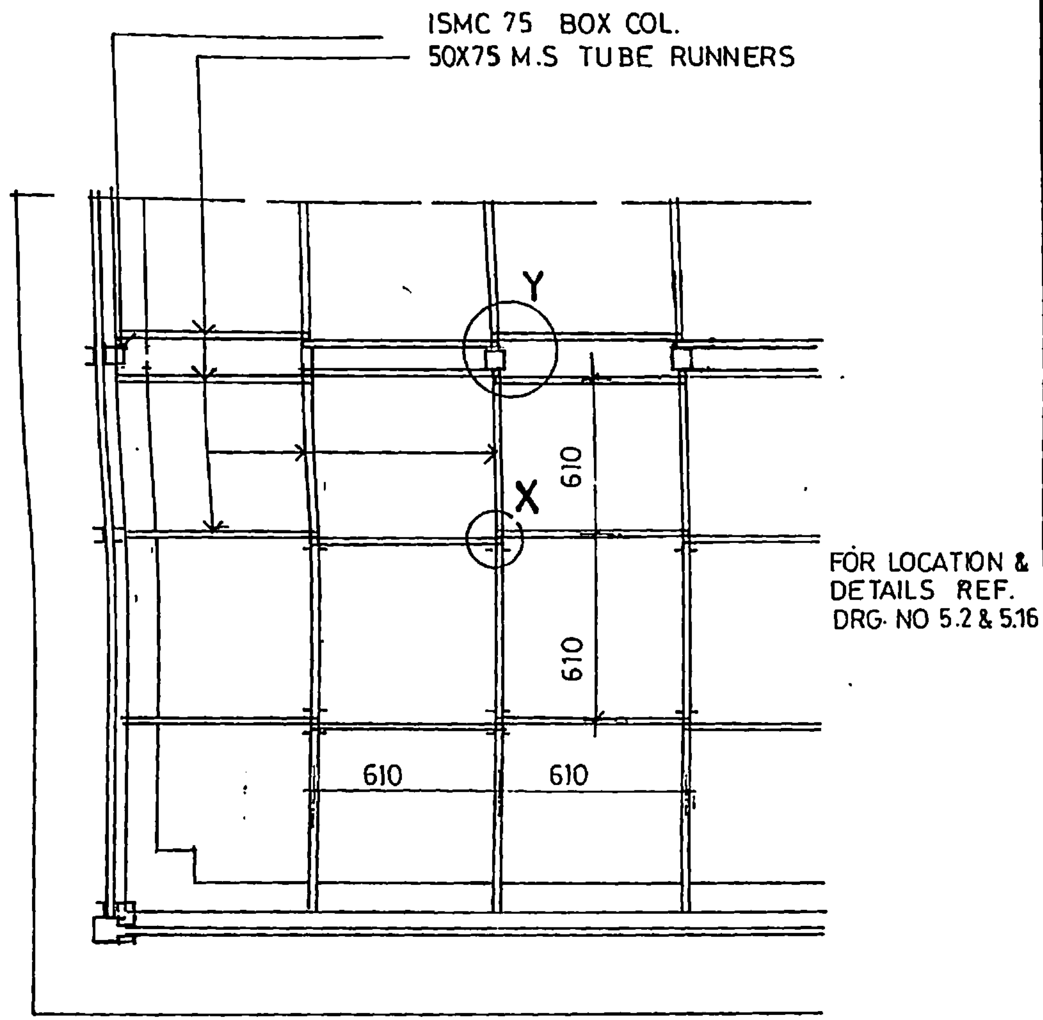
NOTE: FOR SECTIONAL DETAILS REFER

DRG.NO. 5·8 & 5·9

CONSTRUCTION IN HIGH ALTITUDE AREA SNOW AVALANCHE STUDY ESTABLISHMENT,BARALACHLA,HIMACHAL PRADESH	SANDWICH PANELS ELEVATION	DRG. NO.	5·14
		SCALE 1:25	

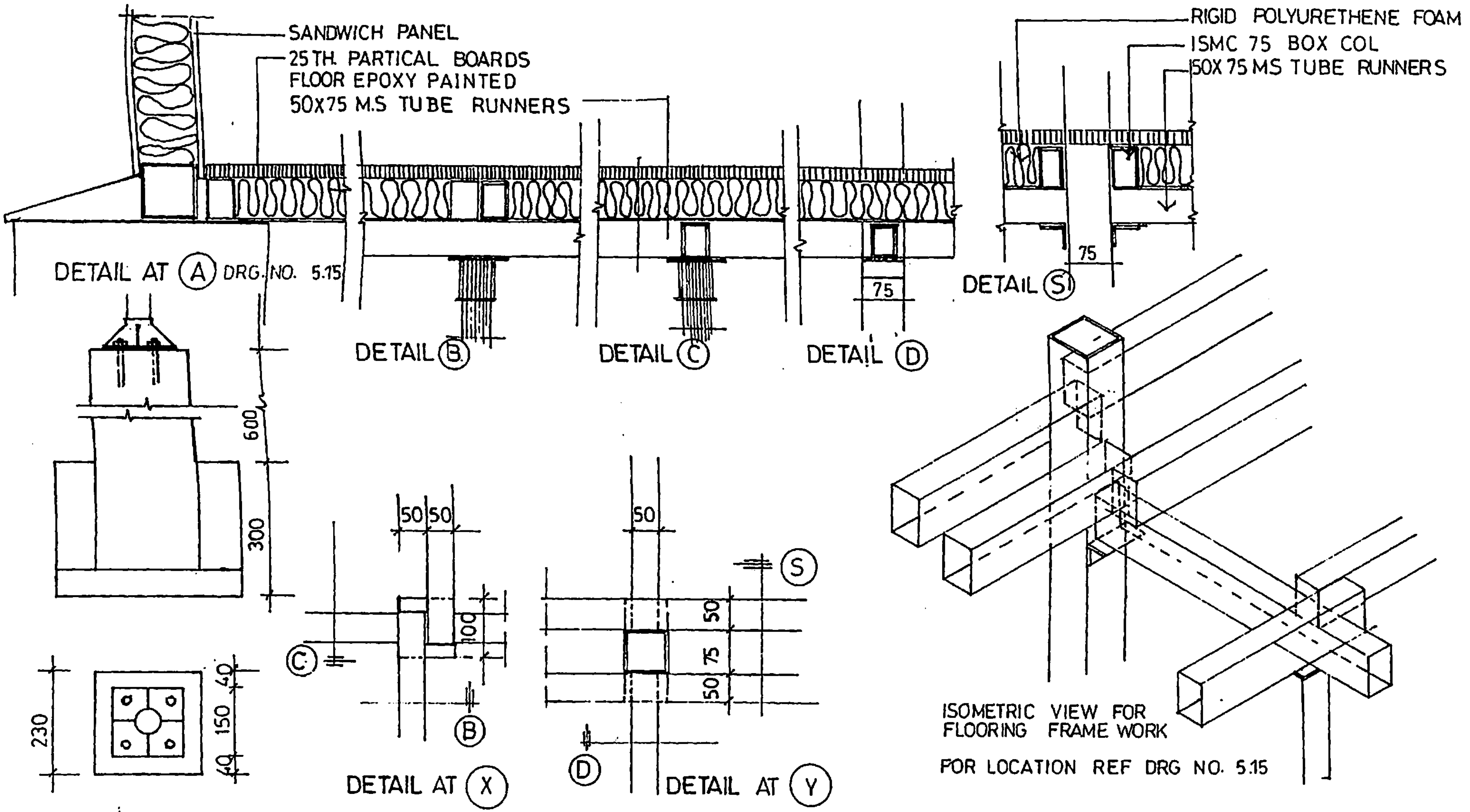


LOWER PLAN



FRAMING LEVEL PLAN FOR FLOORING

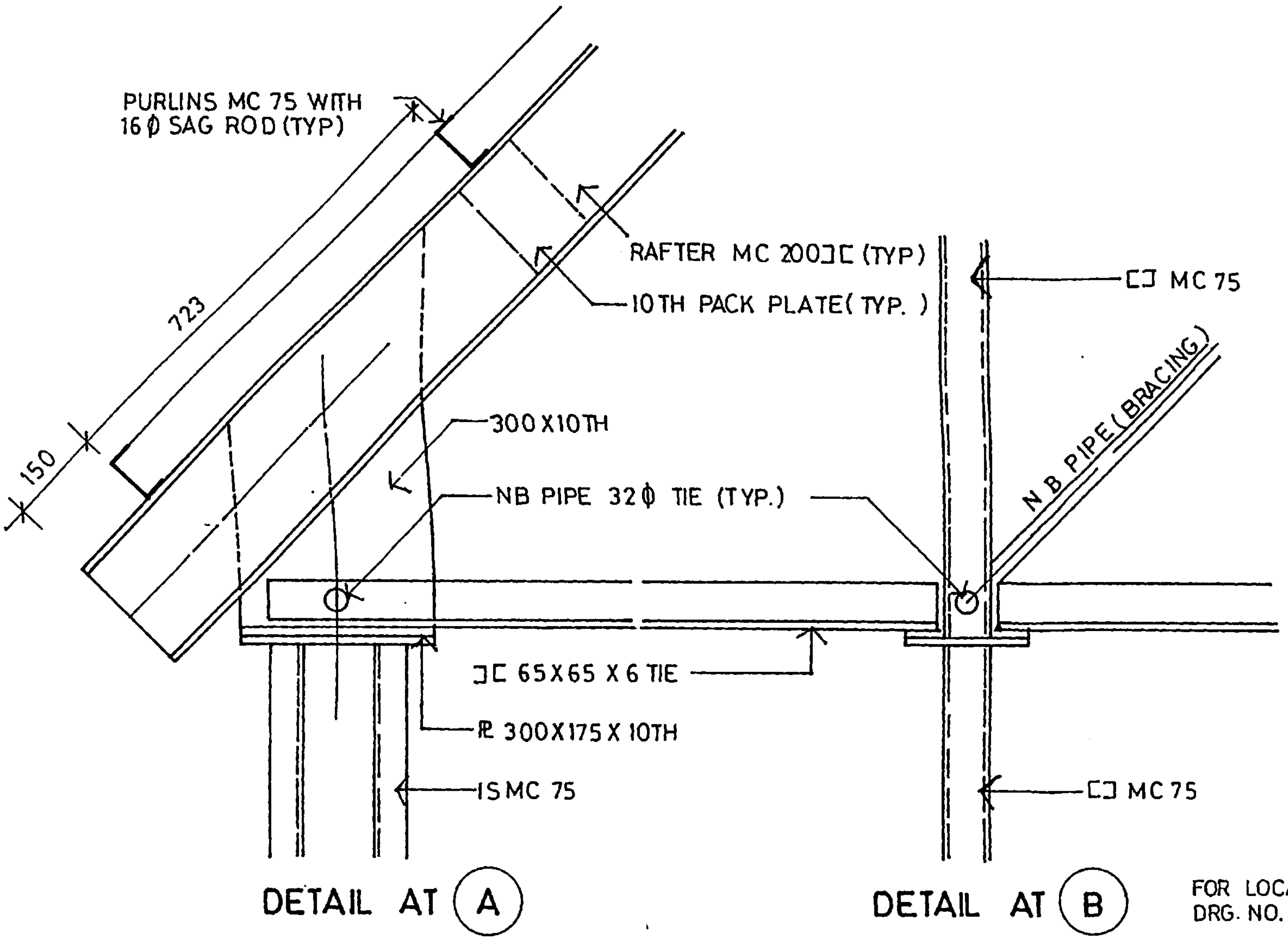
CONSTRUCTION IN HIGH ALTITUDE AREA SNOW AVALANCHE STUDY ESTABLISHMENT, BARALACHLA, HIMACHAL PRADESH	FALSE FLOOR DETAIL	DRG. NO.	5·15
		SCALE 1:25	



CONSTRUCTION IN HIGH ALTITUDE AREA

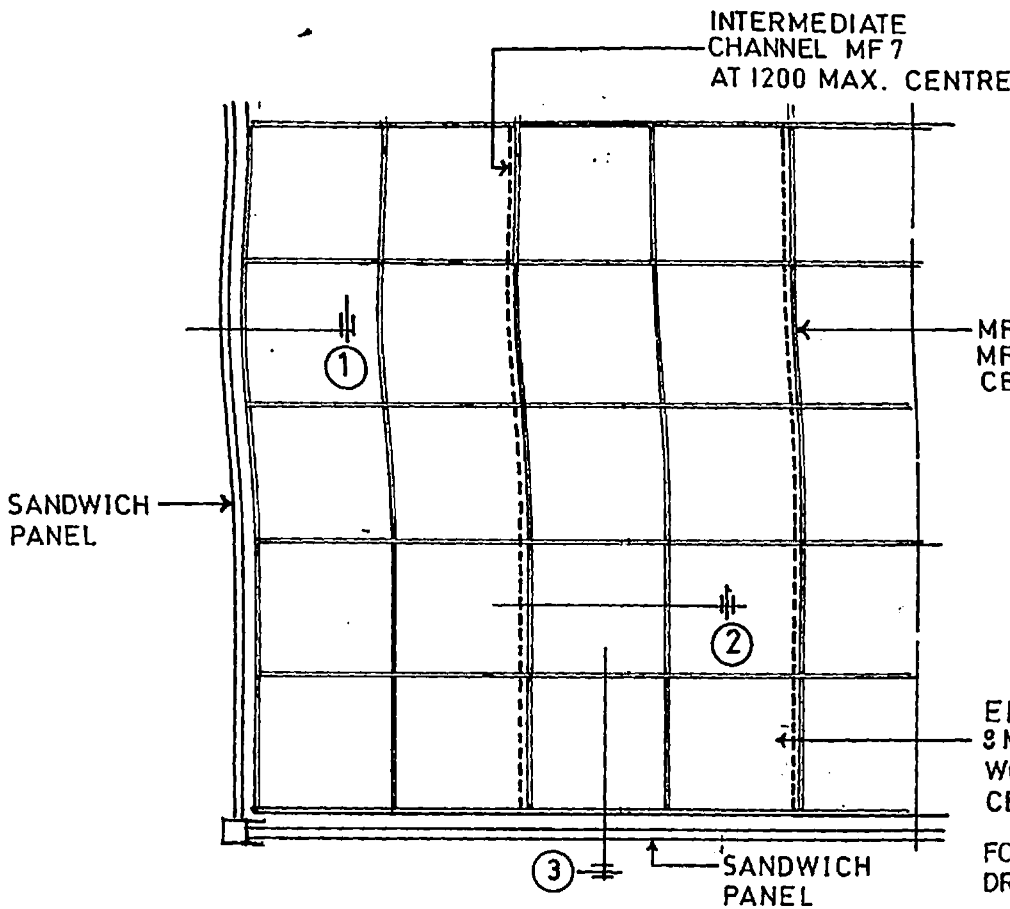
SNOW AVALANCHE STUDY ESTABLISHMENT, BARALACHLA, HIMACHAL PRADESH

FALSE FLOOR DETAIL	DRG. NO.	5·16
	SCALE	1:125. 1:10



FOR LOCATION REF.
DRG. NO. 5.5

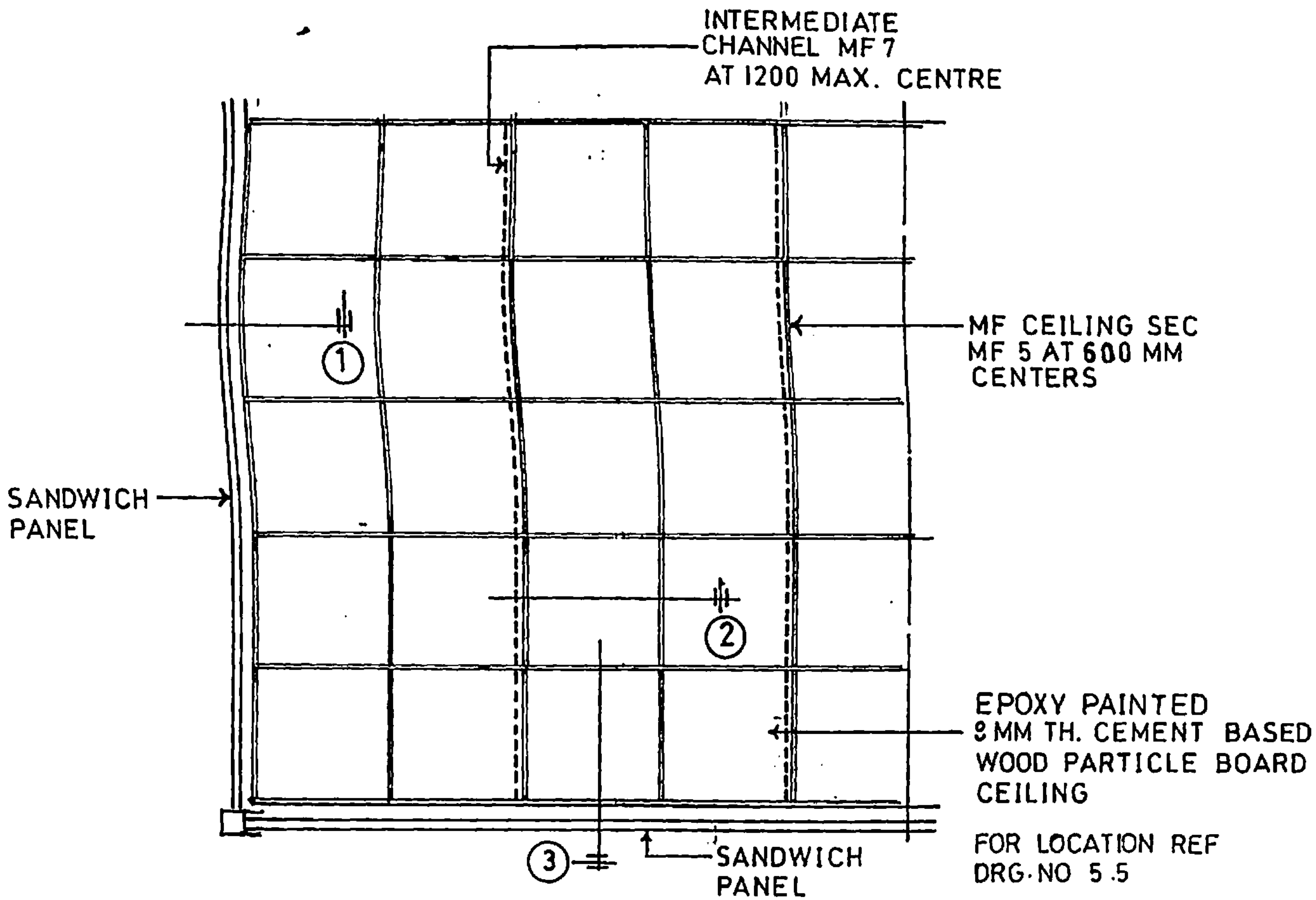
CONSTRUCTION IN HIGH ALTITUDE AREA SNOW AVALANCHE STUDY ESTABLISHMENT, BARALACHLA, HIMACHAL PRADESH	STRUCTURAL DETAILS	DRG. NO.	5·17
		SCALE 1:10	



FOR LOCATION REF
DRG-NO 5.5

REFLECTED CEILING PLAN

CONSTRUCTION IN HIGH ALTITUDE AREA SNOW AVALANCHE STUDY ESTABLISHMENT, BARALACHLA, HIMACHAL PRADESH	FALSE CEILING PLAN	DRG NO. 5.18 SCALE



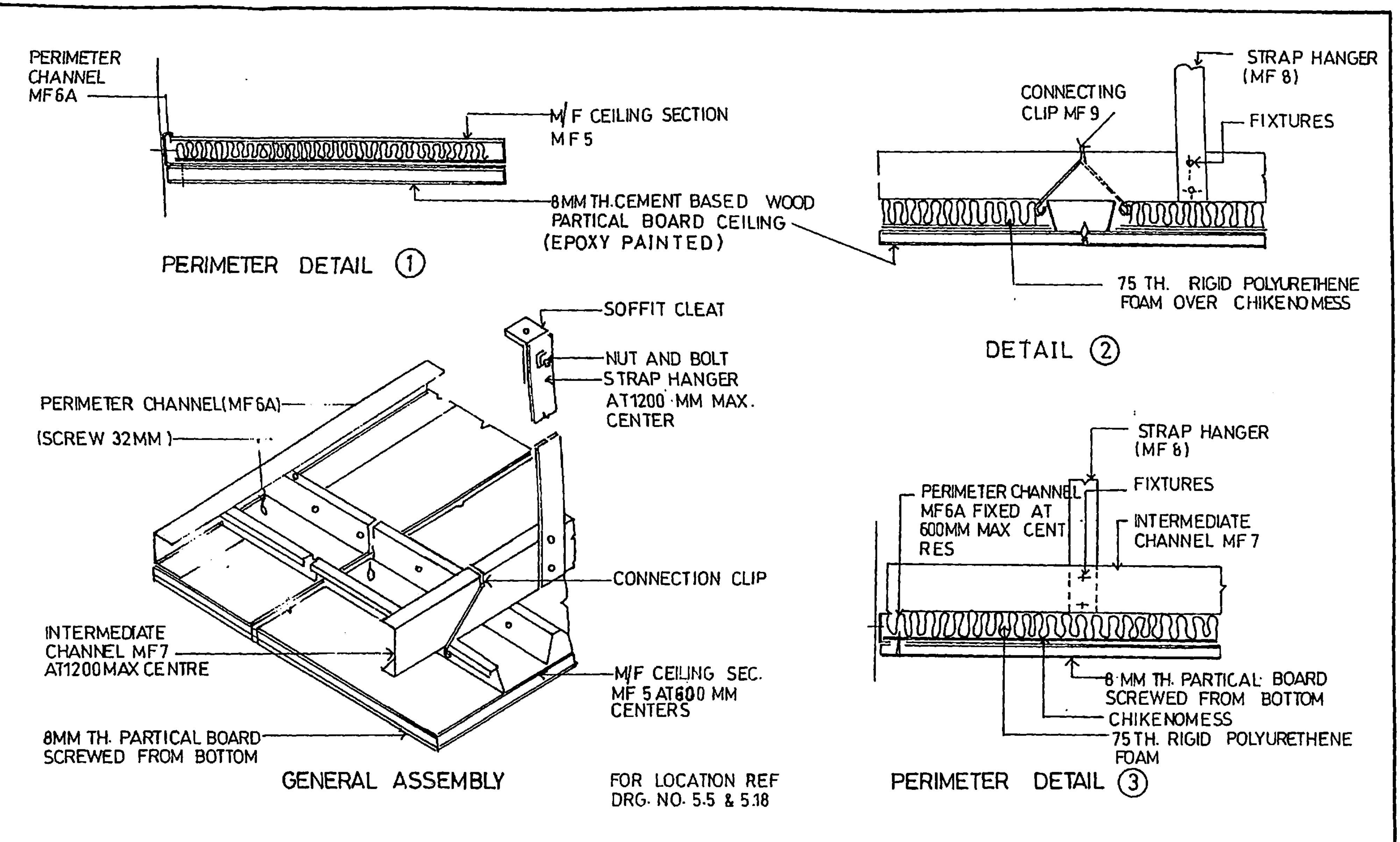
REFLECTED CEILING PLAN

CONSTRUCTION IN HIGH ALTITUDE AREA
SNOW AVALANCHE STUDY ESTABLISHMENT, BARALACHLA, HIMACHAL PRADESH

FALSE CEILING PLAN

DRG NO. 5.18

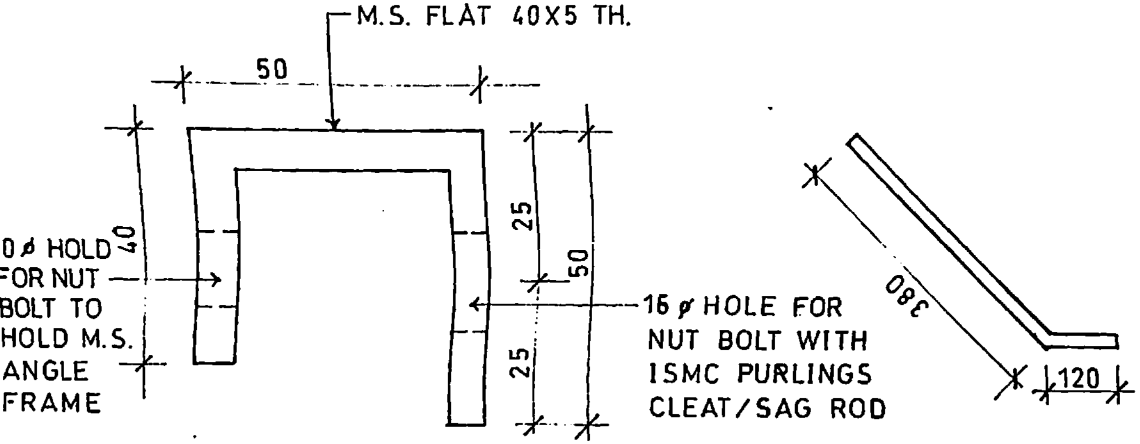
SCALE



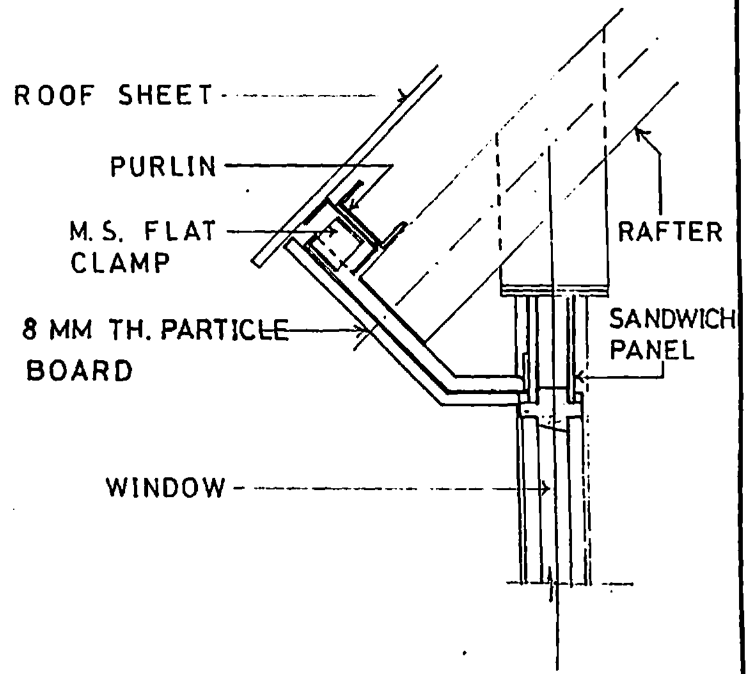
CONSTRUCTION IN HIGH ALTITUDE AREA
SNOW AVALANCHE STUDY ESTABLISHMENT, BARALACHLA, HIMACHAL PRADESH

FALSE CEILING DETAILS

DRG. NO.	5·19
SCALE	NOT TO SCALE

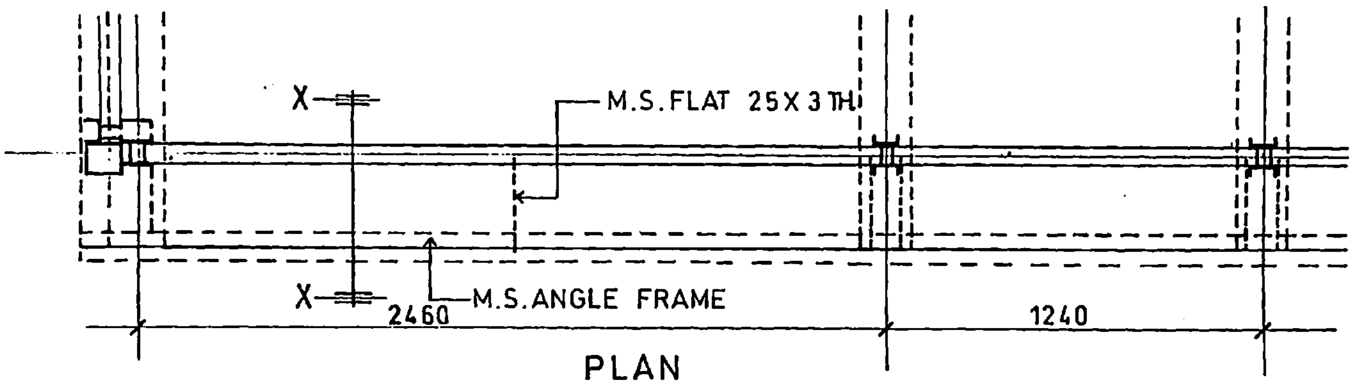


M.S. FLATS CLAMPS TO HOLD M.S. FACIA FRAME



SECTION XX

FOR LOCAD ON
REF DRG. NO. 5.5



PLAN

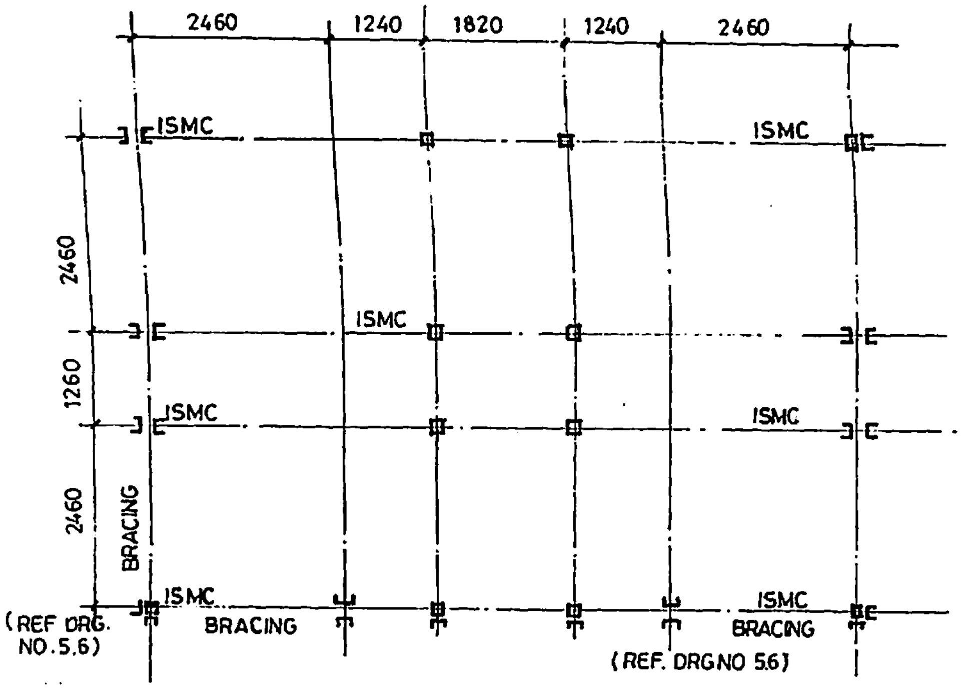
CONSTRUCTION IN HIGH ALTITUDE AREA
SNOW AVALANCHE STUDY ESTABLISHMENT,BARALACHLA,HIMACHAL PRADESH

FACIA DETAILS

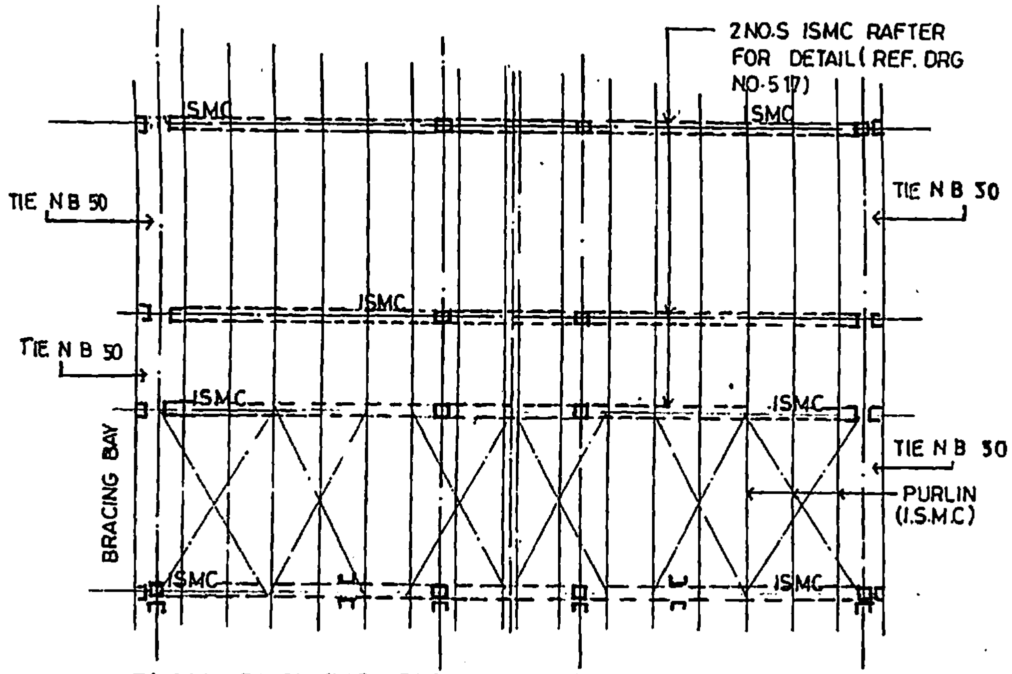
DRG. NO. 5·20

SCALE

FOR LOCATION REFER DRG NO 5·2

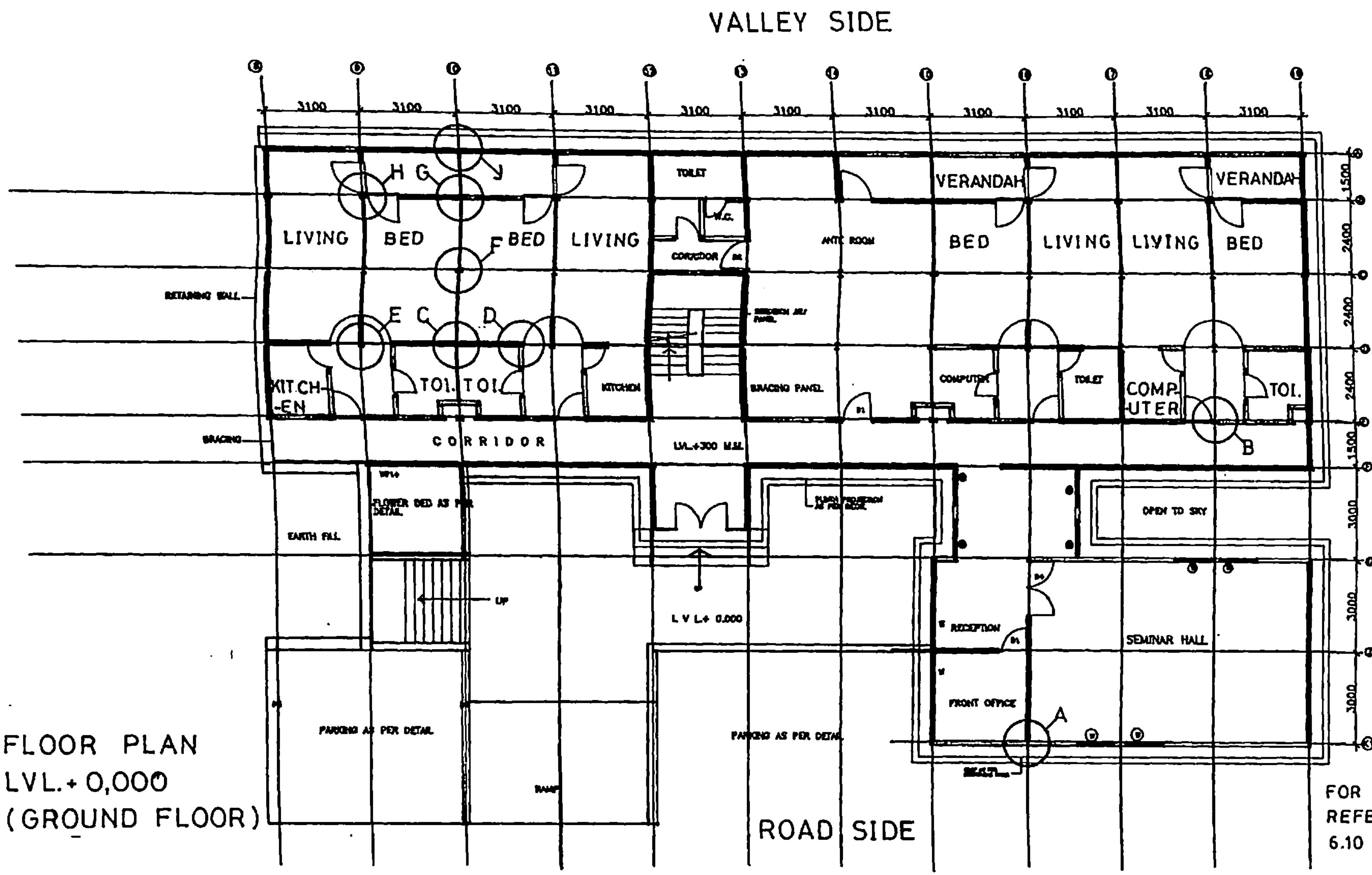


PLAN SHOWING VERTICAL SUPPORTS



PLAN SHOWING STRUCTURAL ARRANGEMENT

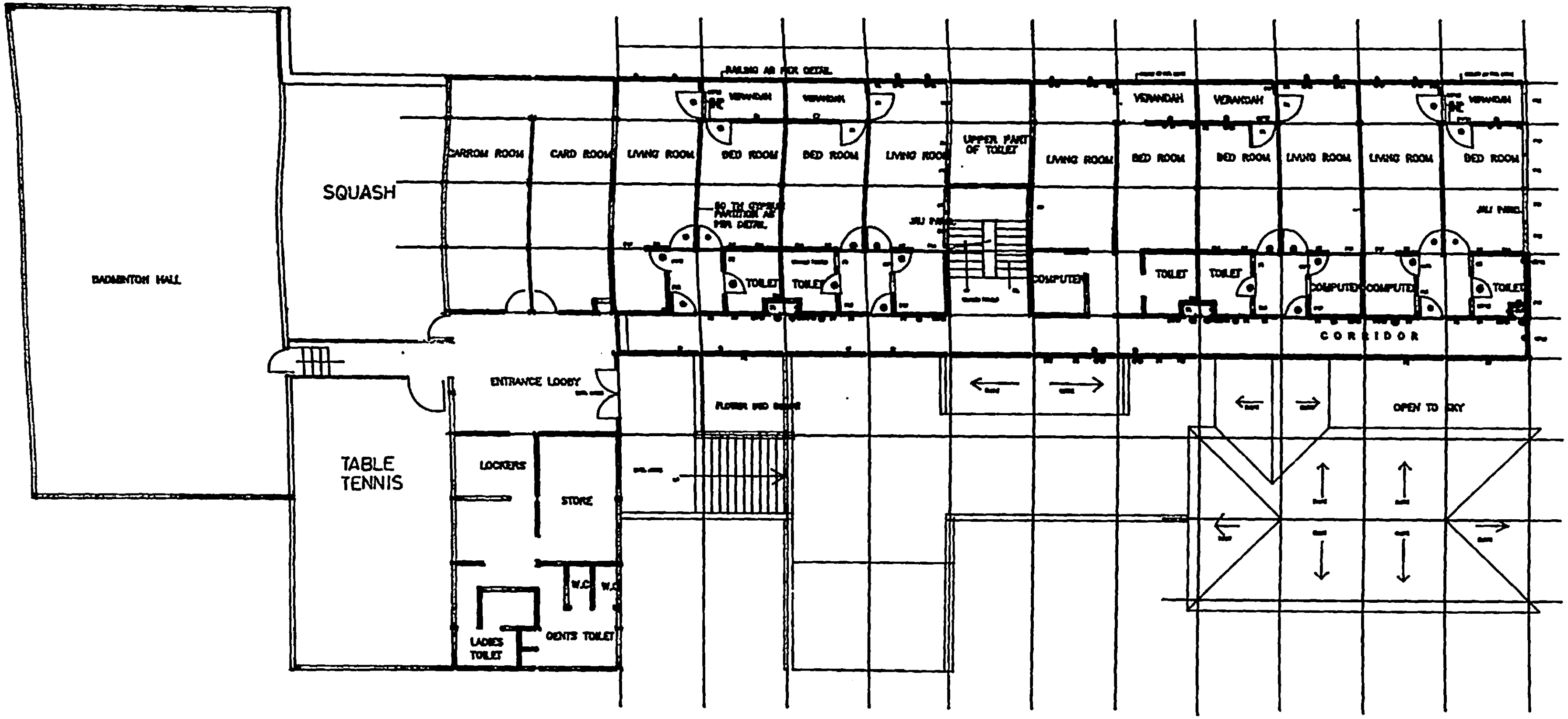
CONSTRUCTION IN HIGH ALTITUDE AREA SNOW AVALANCHE STUDY ESTABLISHMENT, BARALACHLA, HIMACHAL PRADESH	STRUCTURAL ARRANGEMENT	DRG. NO.	5·21
		SCALE 1:10	



FLOOR PLAN
LVL.+ 0,000
(GROUND FLOOR)

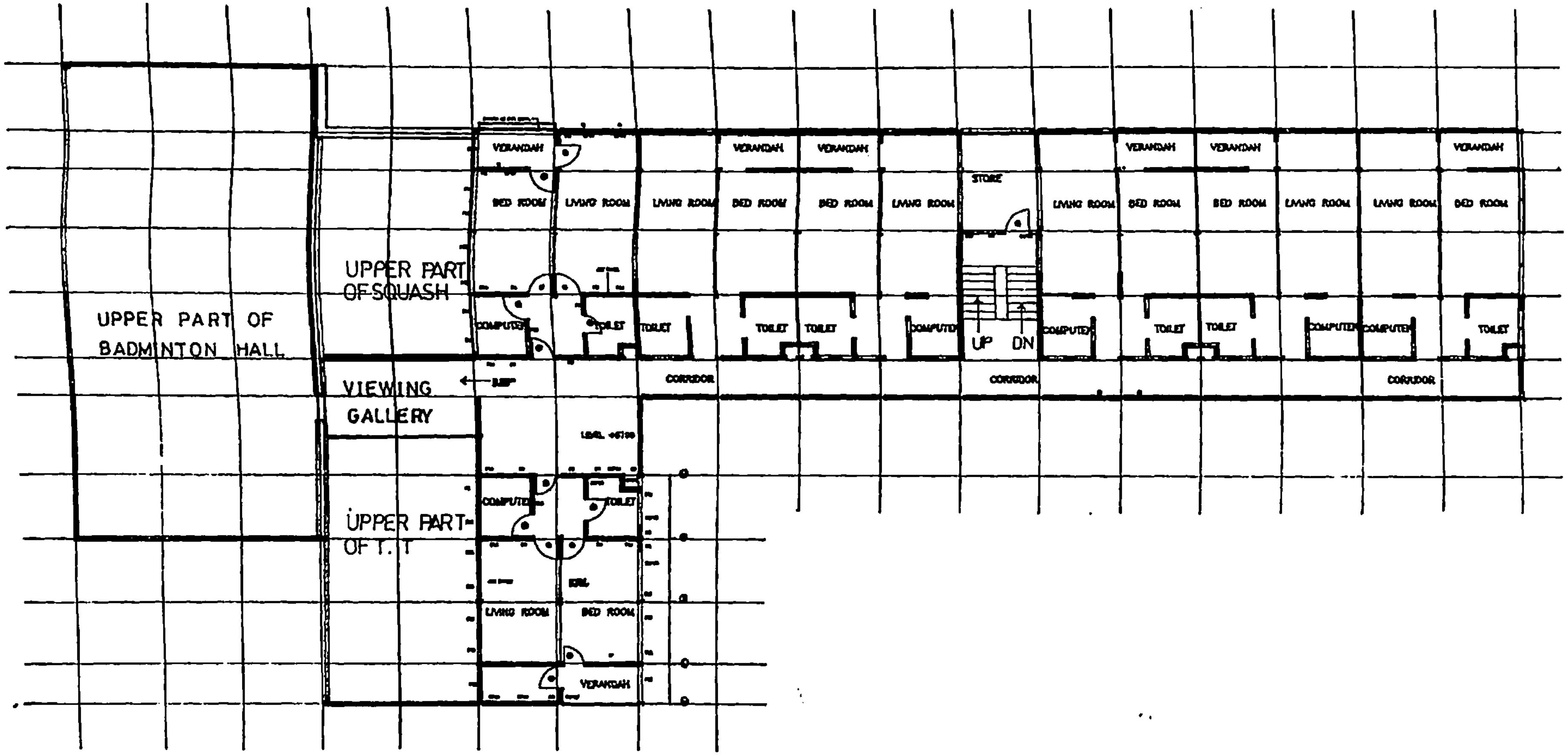
FOR DETAILS DRGS.
REFER DRG. NO. 6.8, 6.9 & 6.10

DEFENCE INSTITUTE OF WORK STUDY, MUSSOORIE, UTTER PRADESH	FLOOR PLAN (GR.FL)	DRG. NO. 6.1
		SCALE 1:175



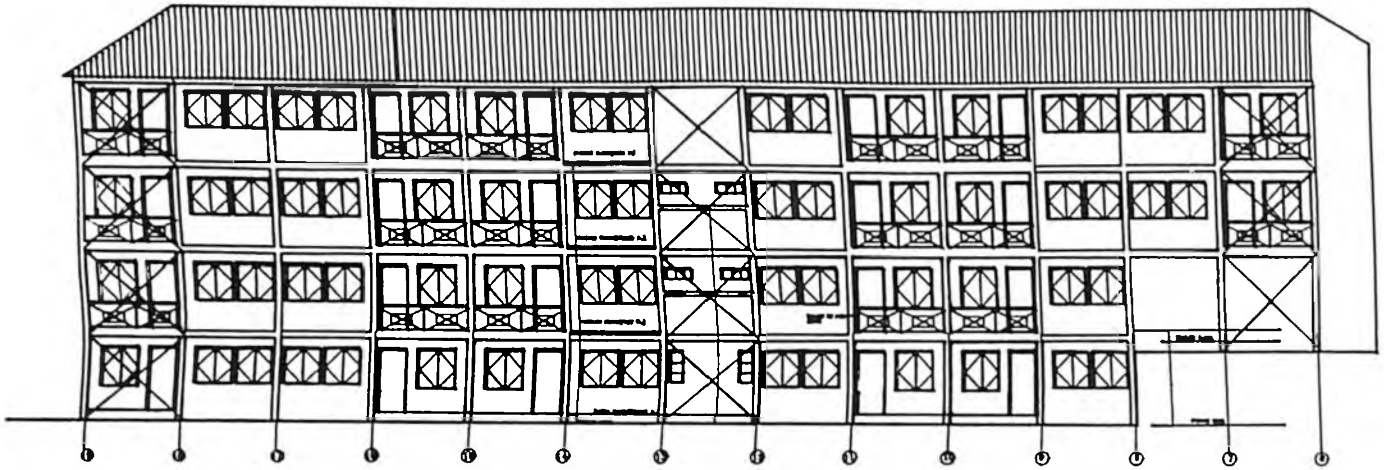
FLOOR PLAN (LEVEL +3000)

DEFENCE INSTITUTE OF WORK STUDY, MUSSOORIE, UTTER PRADESH	FLOOR PLAN (F.FL)	DRG. NO.	6.2
		SCALE 1:250	

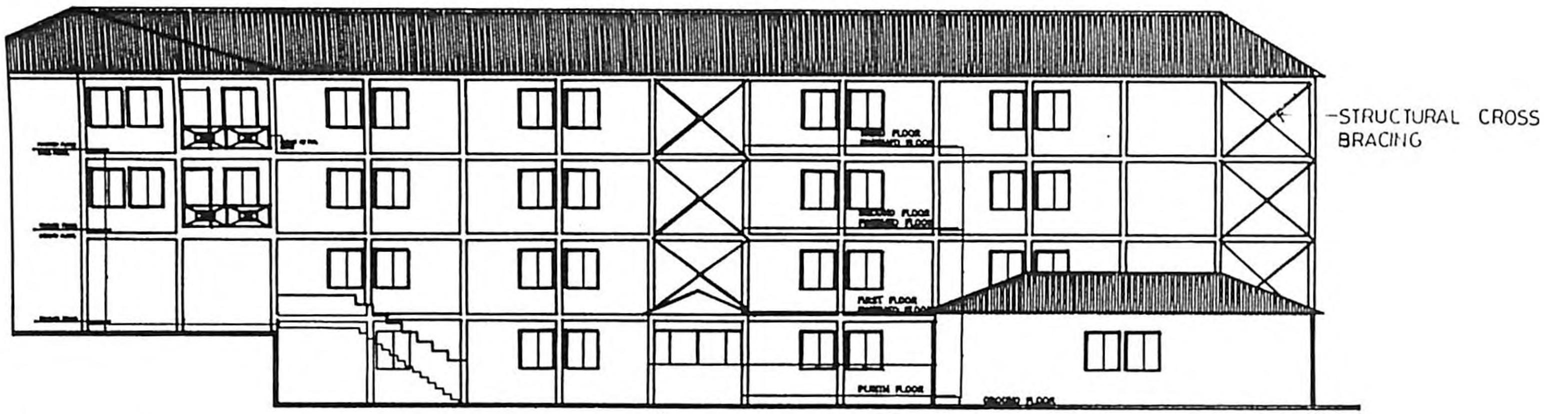


FLOOR PLAN (LEVEL +5700 & +8400)

DEFENCE INSTITUTE OF WORK STUDY, MUSSOORIE, UTTER PRADESH	FLOOR PLAN (S.FL AND T.FL)	DRG. NO.	6.3
		SCALE 1:250	

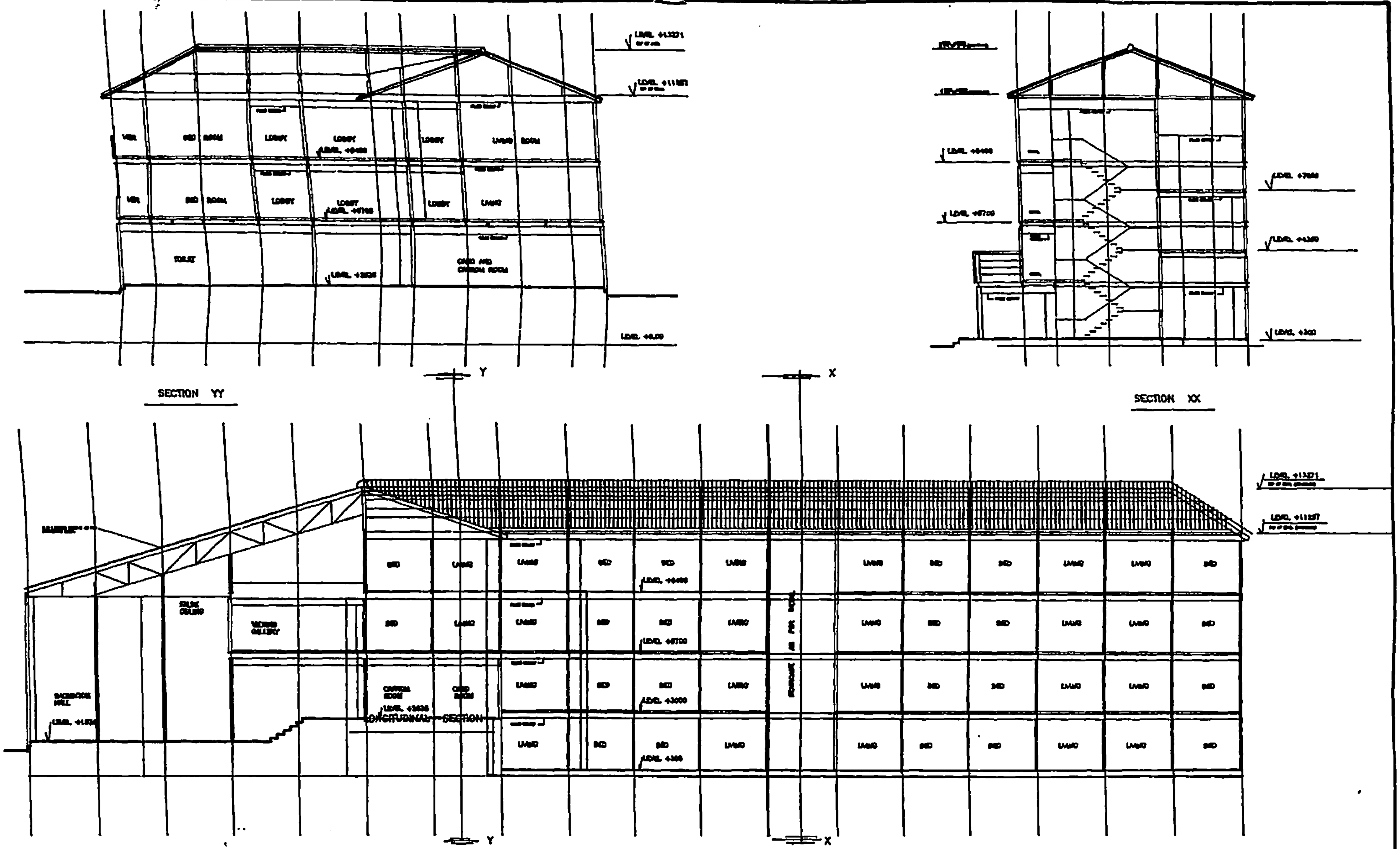


VALLEY SIDE ELEVATION

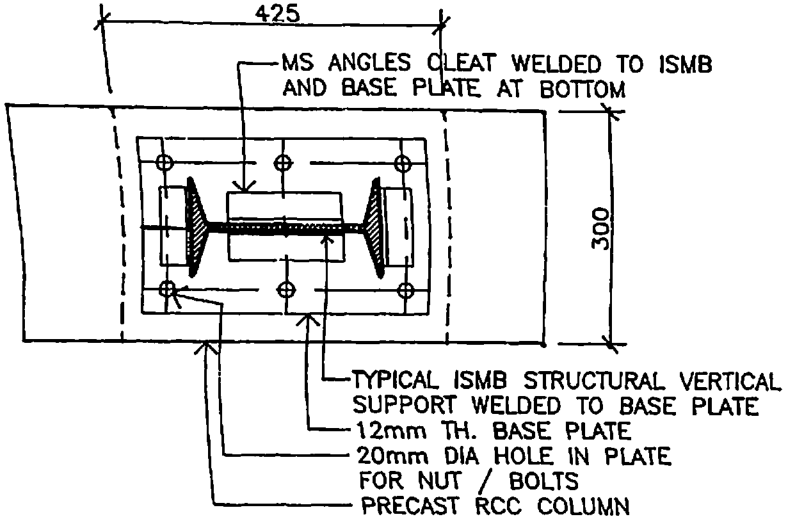


ROAD SIDE ELEVATION

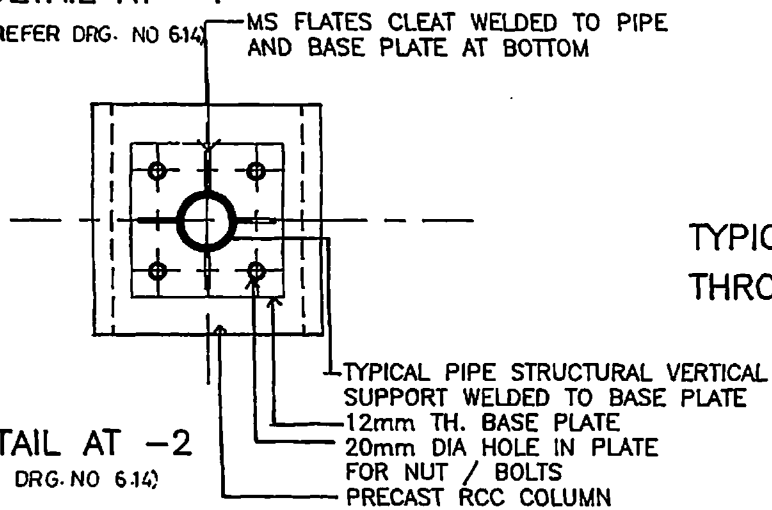
DEFENCE INSTITUTE OF WORK STUDY, MUSSOORIE, UTTER PRADESH	ELEVATIONS	DRG. NO.	6.4
		SCALE 1:250	



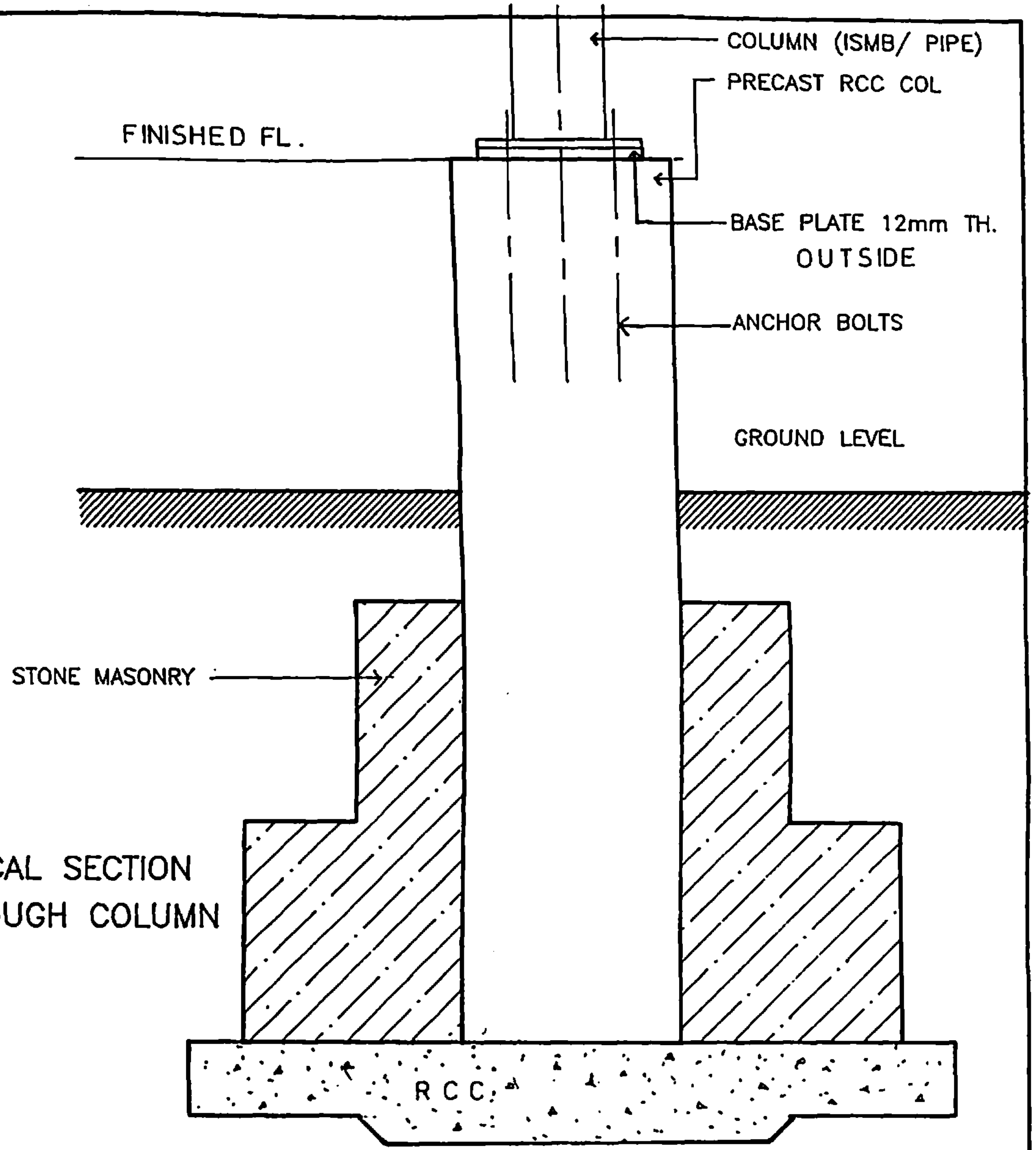
DEFENCE INSTITUTE OF WORK STUDY, MUSSOORIE, UTTER PRADESH	SECTIONS	DRG. NO.	6.5
		SCALE 1:250	



DETAIL AT –1
(REFER DRG. NO 6.14)

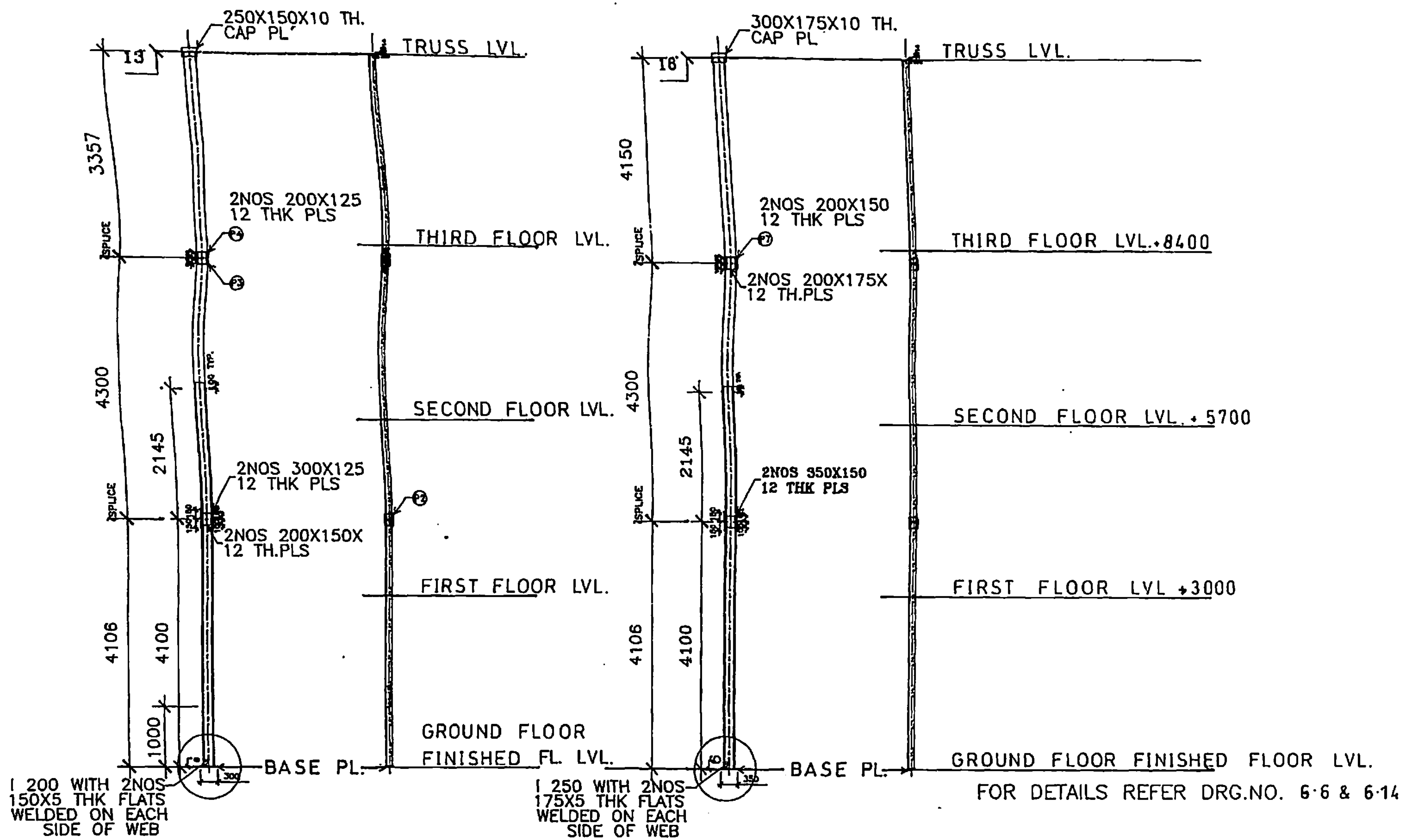


DETAIL AT –2
(REF DRG. NO 6.14)

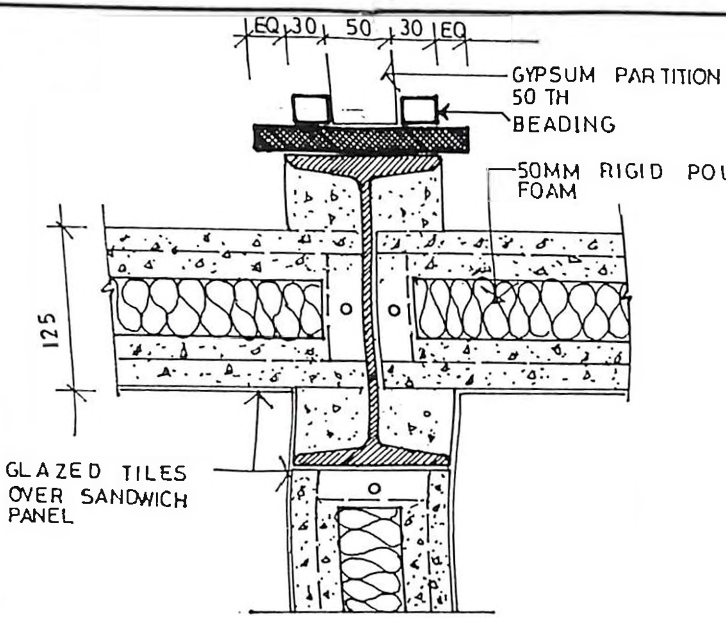


TYPICAL SECTION THROUGH COLUMN

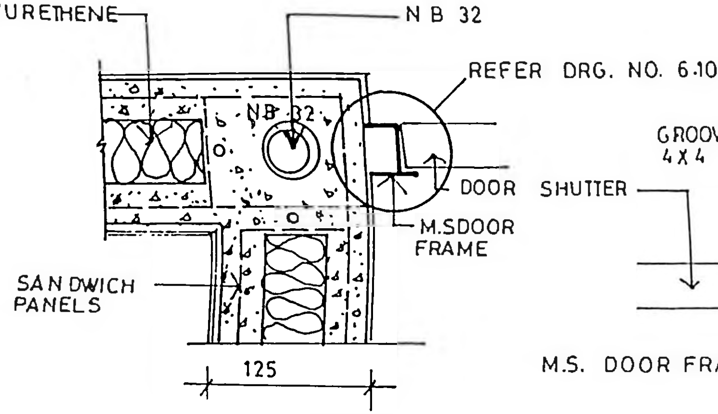
DEFENCE INSTITUTE OF WORK STUDY, MUSSOORIE, UTTER PRADESH	FOUNDATION DETAILS	DRG. NO.	6.6
		SCALE 1:10	



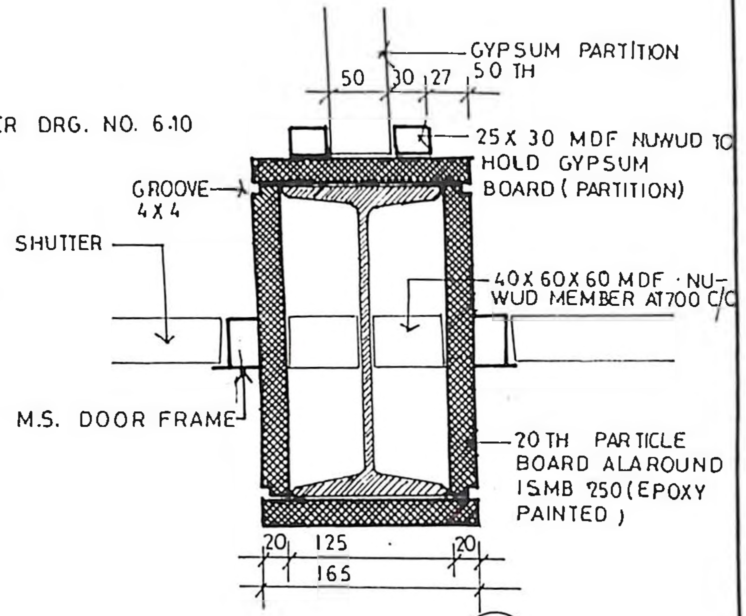
DEFENCE INSTITUTE OF WORK STUDY, MUSSOORIE, UTTER PRADESH	TYPICAL VERTICAL JOINT COLUMN DETAIL	DRG. NO.	6.7
		SCALE	



DETAIL (C)



DETAIL (D)



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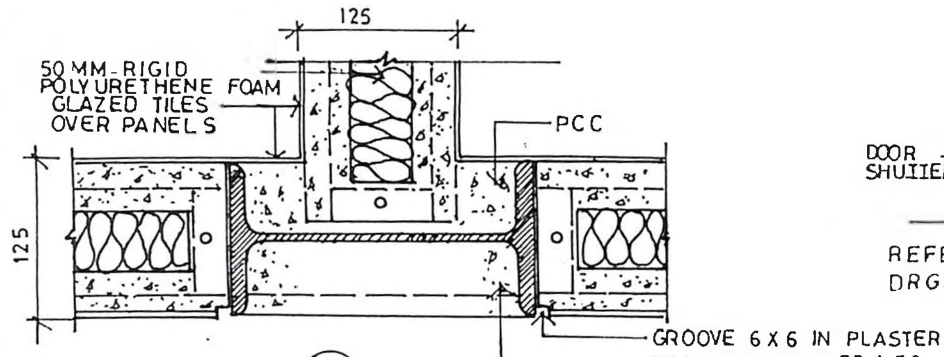

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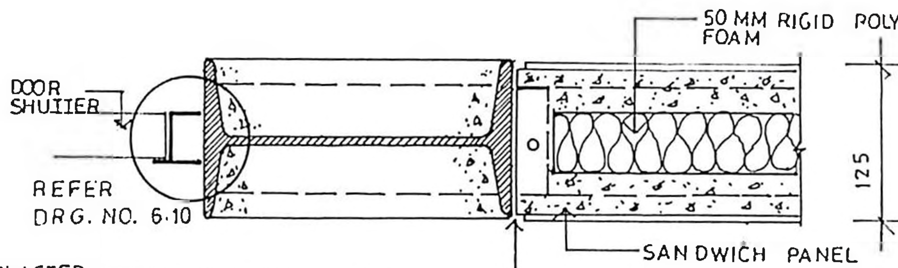

FOR LOCATION OF JUNCTIONS REFER DRG NO. 6.1

DETAIL (B)

DEFENCE INSTITUTE OF WORK STUDY, MUSSOORIE, UTTER PRADESH	JUNCTION DETAILS	DRG. NO.	6.8
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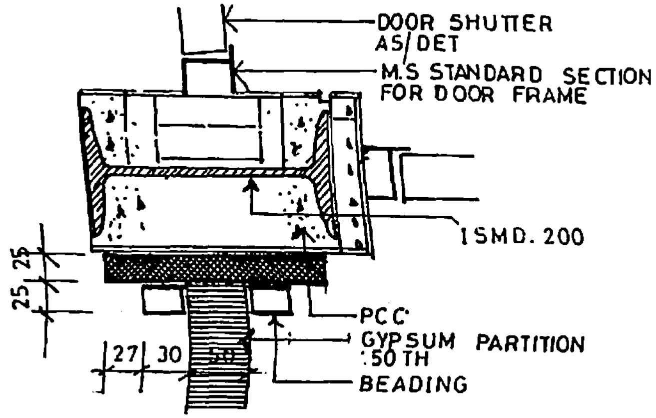

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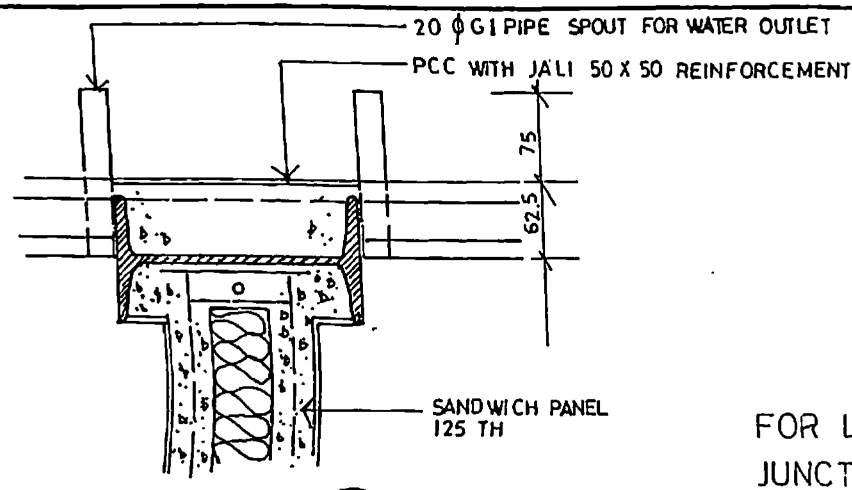
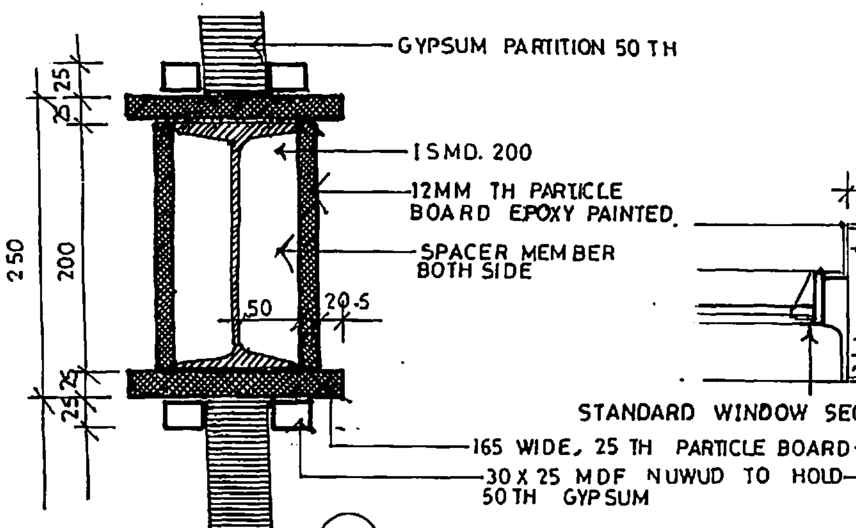


DETAIL (J)

FOR LOCATION OF JUNCTIONS REFER DRG. NO. 6·1



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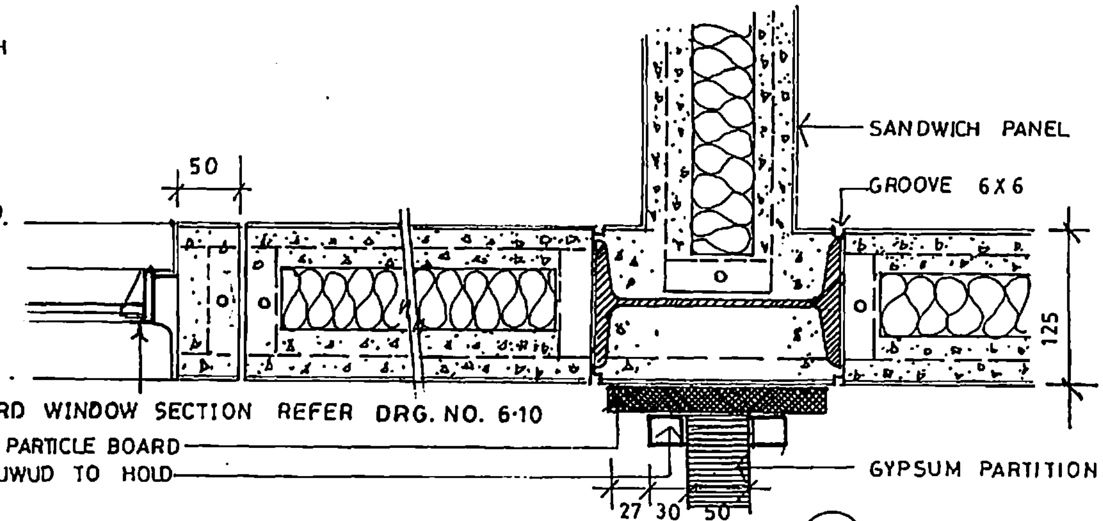

DETAIL (G)

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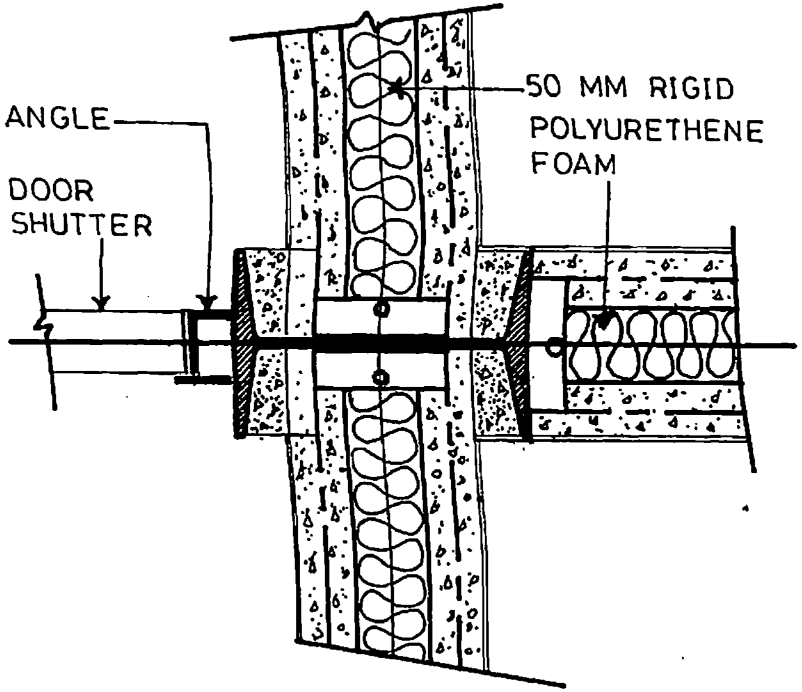
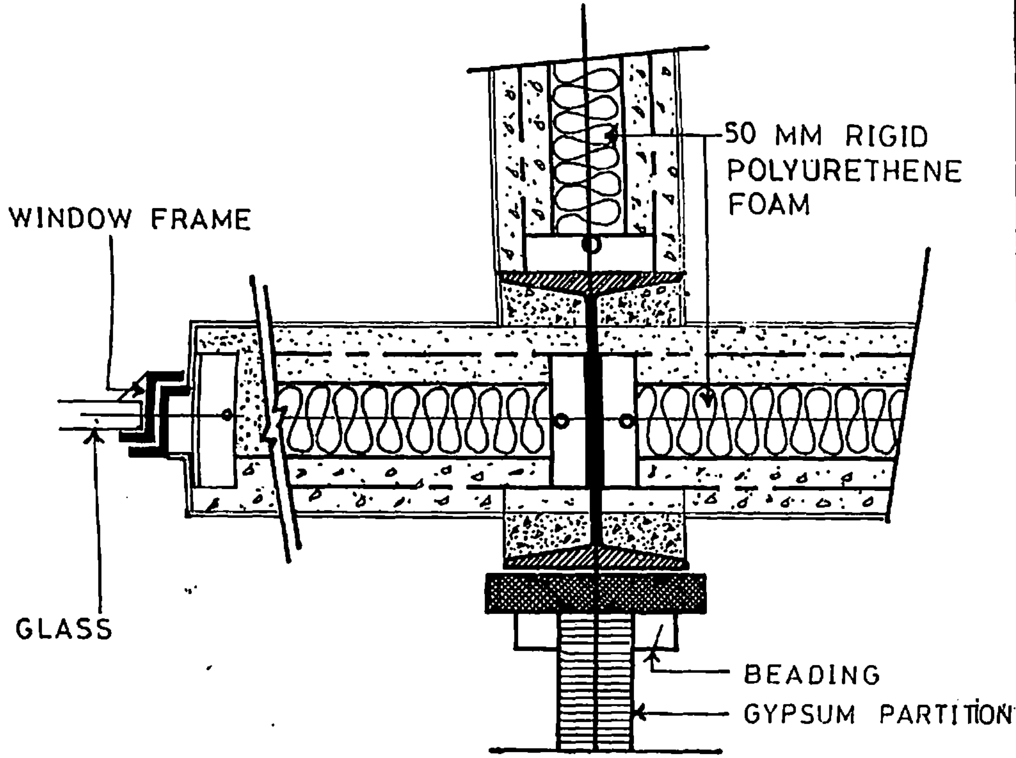


TYPICAL DETAIL OF DOOR FRAME FIXING



TYPICAL DETAIL OF WINDOW FRAME FIXING

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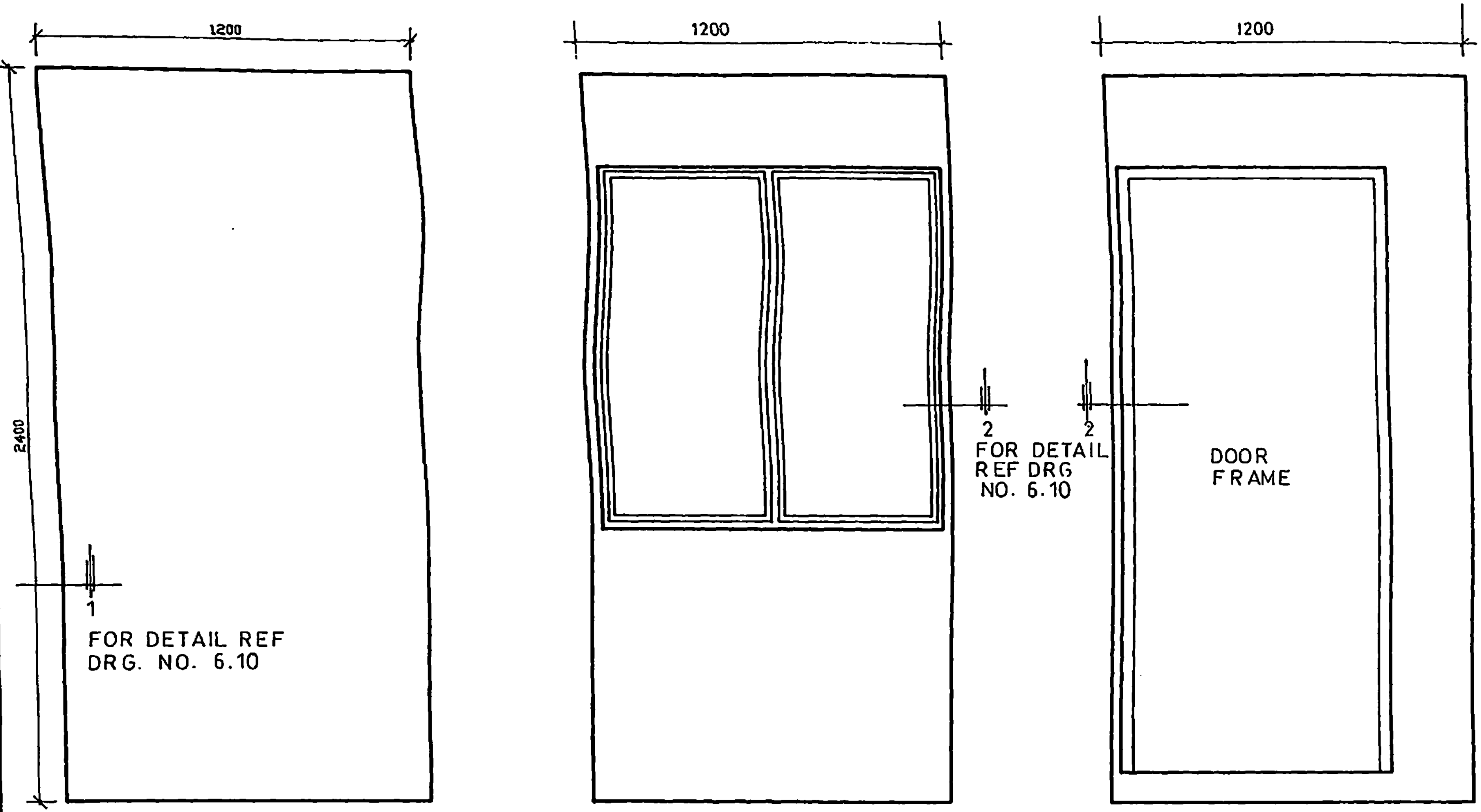

ELEVATION OF A PANEL

ELEVATION OF A PANEL WITH WINDOW OPENING

ELEVATION OF A PANEL WITH DOOR OPENING

DEFENCE INSTITUTE OF WORK STUDY, MUSSOORIE, UTTER PRADESH	SANDWICH PANELS ELEVATION	DRG. NO.	6.11
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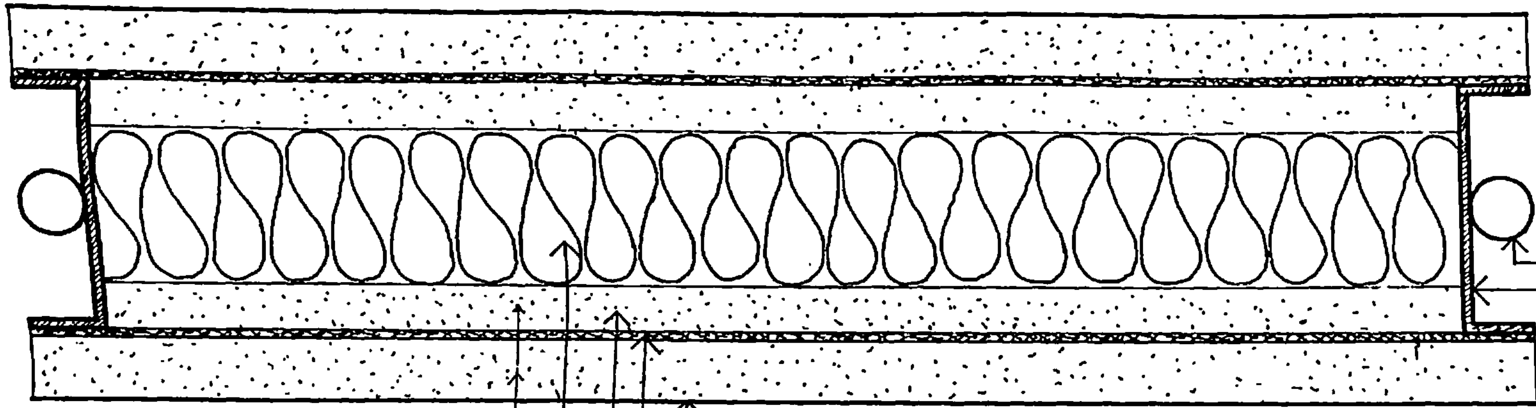
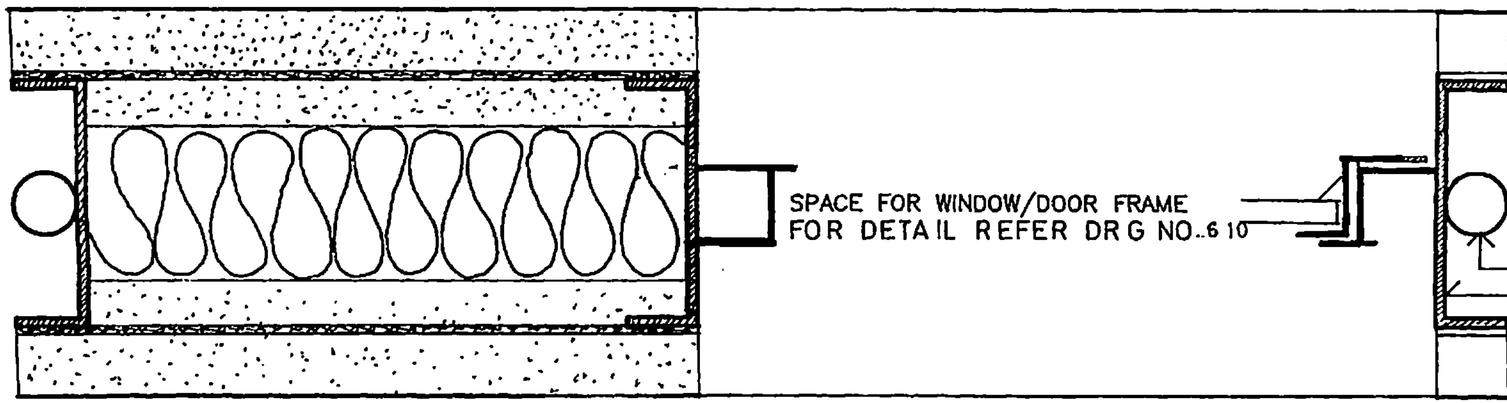


DETAIL AT – 1



DETAIL AT – 2

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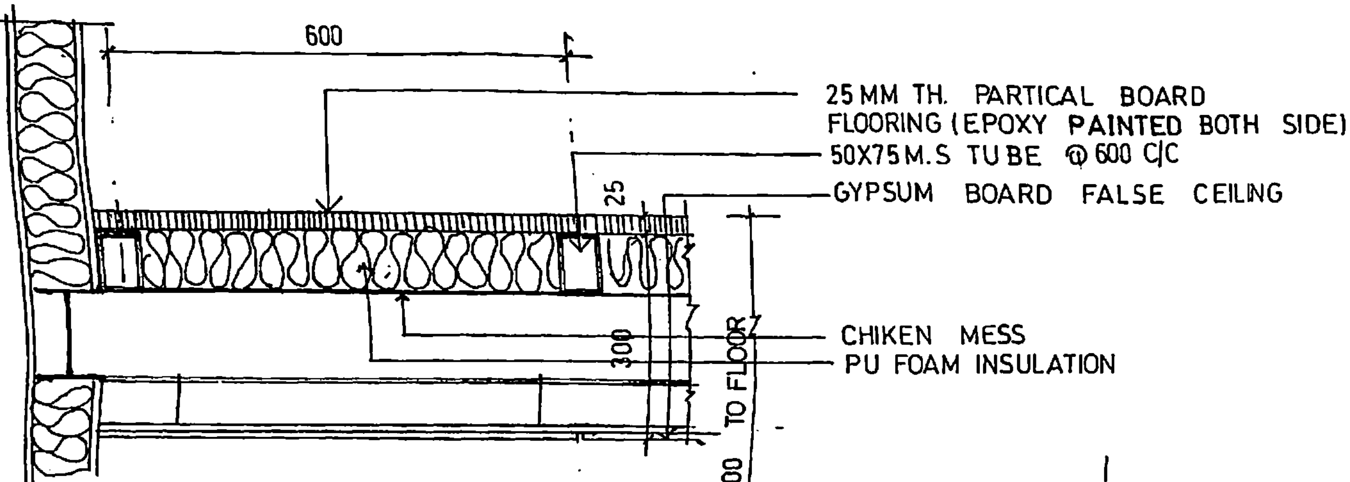
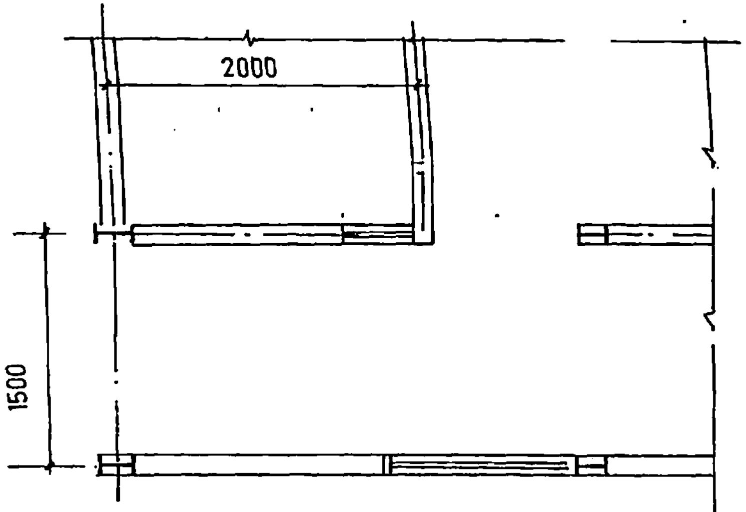
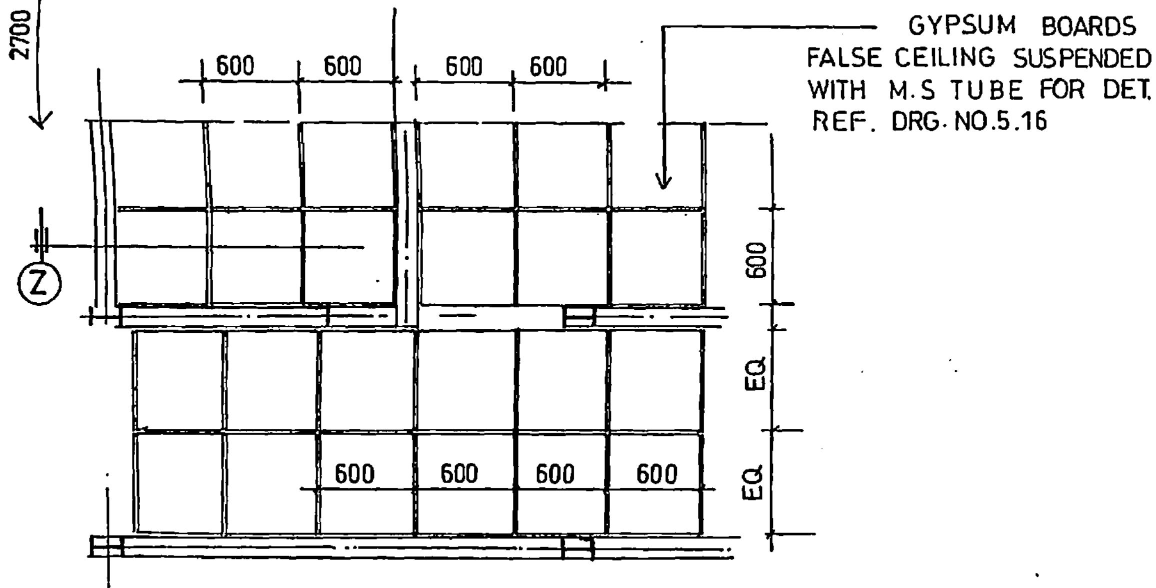


PART DETAIL SECTION AT Z



PART PLAN



REFLECTED CEILING PLAN

DEFENCE INSTITUTE OF WORK STUDY, MUSSOORIE, UTTER PRADESH	FALSE CEILING AND FLOOR DETAILS	DRG. NO.	6. 13
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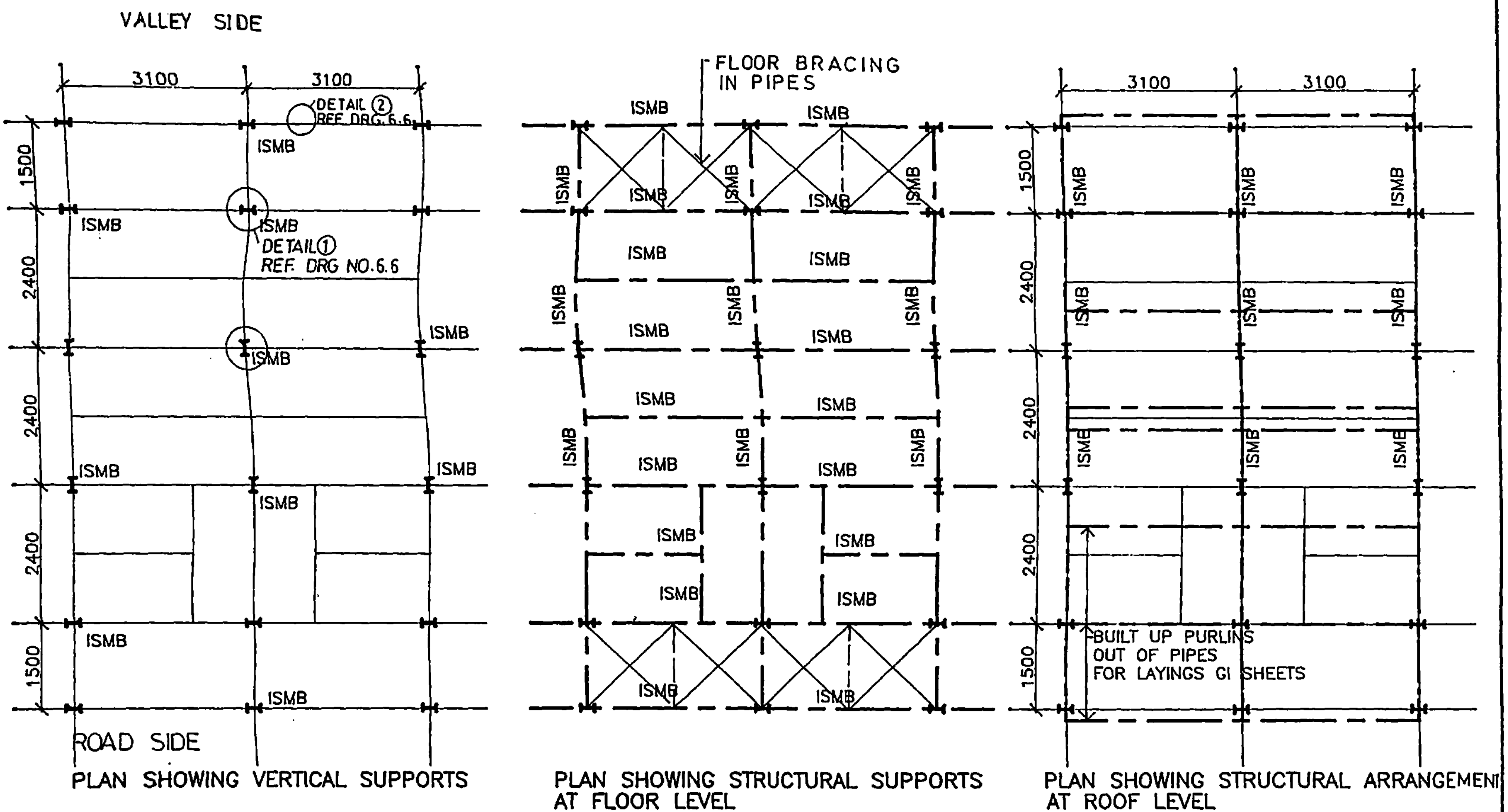

DEFENCE INSTITUTE OF WORK STUDY, MUSSOORIE, UTTER PRADESH	STRUCTURAL ARRANGEMENT	DRG. NO. 6.14
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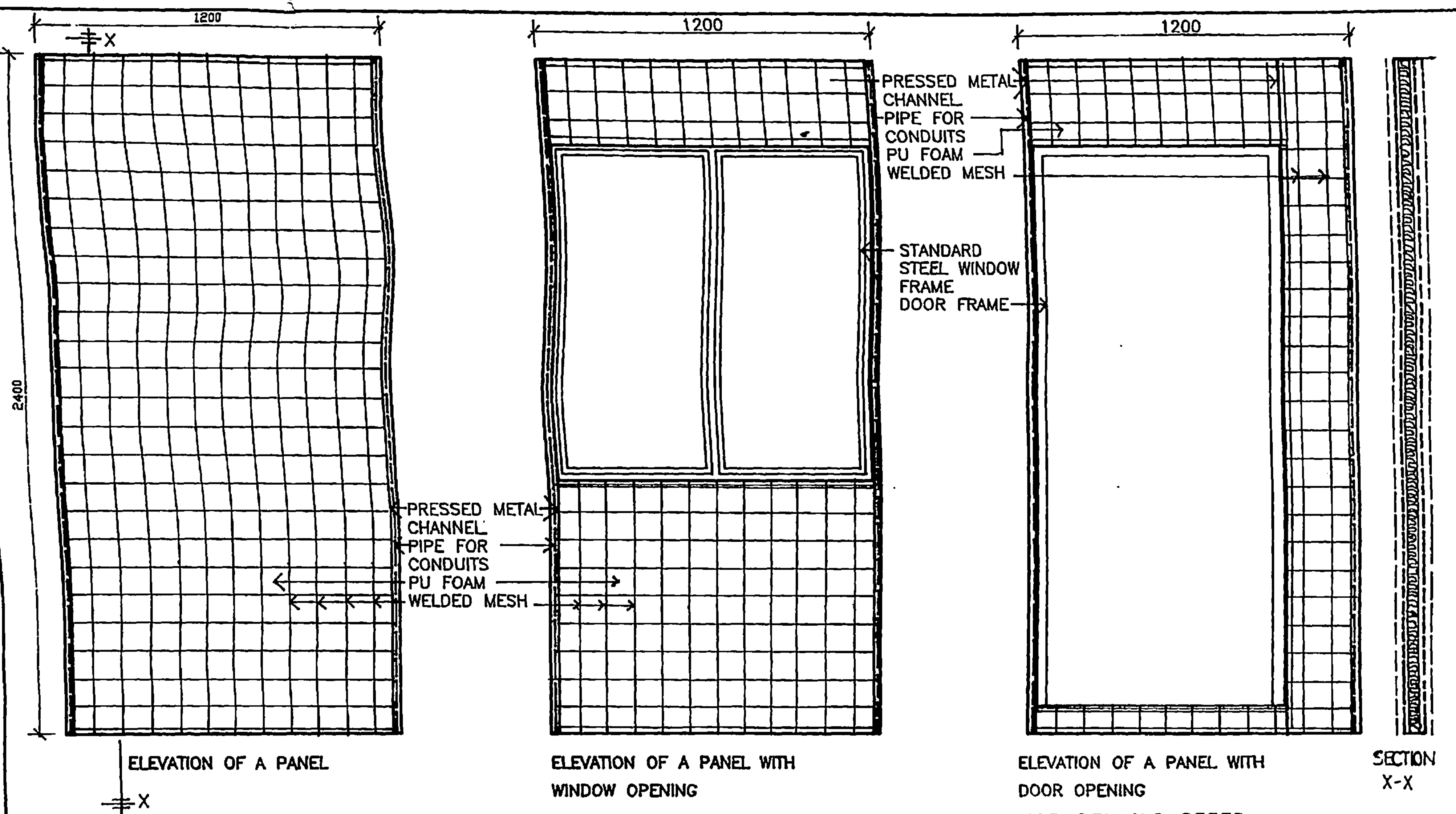

ELEVATION OF A PANEL

ELEVATION OF A PANEL WITH WINDOW OPENING

ELEVATION OF A PANEL WITH DOOR OPENING

FOR DETAILS REFER DRG. NO. 6·12

SECTION X-X

DEFENCE INSTITUTE OF WORK STUDY, MUSSOORIE, UTTER PRADESH	SANDWICH PANEL DETAILS	DRG. NO.	6·15
		SCALE 1:20	

ABBREVIATION

ISMB	:	Indian Standard Medium Beam
ISMC	:	Indian Standard Medium Channel
N.B.	:	Nominal Bore
C.I.	:	Cast Iron
G.I.	:	Galvanised Iron
P.C.C.	:	Precast Cement
R.C.C.	:	Reinforced Cement Concrete
C.M.	:	Cement Mortar
C	:	Celsius
F.L.	:	Floor Level
M.S.	:	Mild Steel
P.U.F.	:	Poly Urethene Foam
TH./THK.	:	Thickness
PLS.	:	Plates
DIA.	:	Diameter
COL.	:	Column
DRG.	:	Drawing
FIG.	:	Figure
D.G. SET	:	Diesel Generator Set
G.F.L.	:	Ground Floor Level
F.F.L.	:	First Floor Level
S.F.L.	:	Second Floor Level
T.F.L.	:	Third Floor Level
NO.	:	Number
M	:	Metre
MM	:	Millimetres
DET.	:	Detail