PROPOSED FRUITS PROCESSING FACTORY
MAKURDI, BENUE STATE

WITH A STUDY OF

THE MAXIM REFABRICATING ARCHITECTURE

BY

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M.TECH/SET/2007/1805

DEPARTMENT OF ARCHITECTURE

FEDERAL UNIVERSITY OF TECHNOLOGY

MINNA, NIGER STATE.

MARCH 2010

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MARCH 2010

DECLARATION

I, hereby declare that this research has been carried out and this thesis written solely by me; PINNE Herbert Teryila (M.Tech/SET/2007/1805). It has not been presented before in any known previous application for a higher degree. All the sources of information are duly acknowledged in the references.

------------------------------ 28-10-2010

PINNE Herbert Teryila Date

(M.Tech/SET/2007/1805)

CERTIFICATION

This thesis entitled, FRUITS PROCESSING FACTORY MAKURDI, BENUE STATE by PINNE Herbert Teryila (M.Tech/SET/2007/1805), meets the regulations governing the award of Master of Technology (M.Tech) degree of the FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

I dedicate this work to;

- God Almighty for his grace and inspiration
- My late mother for her immeasurable love that is felt most now that she is gone
- And to the past generation of Technologist for their efforts in developing the building industry.

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Finally, I must express my gratitude to you my classmates, being your Rep. was an unusually tough and interesting experience.

ABSTRACT

At present, Developers are spending huge amount of money and time investing in housing provision, renovation of buildings takes long period and occupants are often inconvenienced as they have to vacate the buildings for the construction workers. And the rampant cases of building collapse are all challenges professionals in the building industry must rise up to. In view of this, this research examines the situation and proposes that building construction should change from the traditional on-site erection to assembly of factory-made components and that building design should be made to foster prefabrication; what is here referred to as "The Maxim Refabricating Architecture". The study employed the Historical and description survey methods of data collection; where written works from the library and internet, visiting and studying of existing factories and interview of factory workers is employed. The study examines some of the issues hindering the adoption of this maxim, benefits to be derived if adopted and recommendations. In the light of the study, the researcher designed a fruits processsing factory with details of components to be prefabricated. The study made a significant finding that; professionals in the building industry are reluctant in embracing this maxim due to their limited knowledge in this area, and the high initial cost involved. It recommends that more scholars should be encouraged to do more in this area so as to provide the necessary information/knowledge to convince the industry.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

1.0.0 INTRODUCTION

1.1.0 Background

Benue state (The Food Basket of the Nation) is one of the chief producers of fruits in Nigeria. Farmers produce large quantities of oranges and a wide variety of mangoes as cash crop. According to an agro raw materials research institute, 713,000 metric tonnes of different mango species and 1,592,000 metric tonnes of orange species are produced annually. Farmers and traders loss large percentage of these perishable products in trying to preserve, sell or convey these produce to the market and other parts of the country, cost is incurred in transportation and large quantities over-rip and waste in the process. These fruits being seasonal crops are often harvested in excess during the season; else they waste in the farm, and the economics of surplus commodity means a fall in price. Due to lack of proper preservation technique, they become scarce and expensive when the season is over, but the human beings require fruits in her diet all year round. On the other hand the farmer loss large amount annually and some are beginning to be discouraged in the cultivation of these crops. If this trend continues then the cultivation of these crops will stop and the existing ones may be replaced, this will increase the rate of deforestation and by implication global warming, *Ipso facto*, the need to reverse this trend cannot be over emphasized. A system of processing these fruits shall provide a means of preservation thereby eliminating wastage during the harvest season and the cost of transporting concentrates (the processed fruits) will be relatively cheaper. The researcher's investigation shows that no such system exist in the state, hence the need for a fruits processing factory.

The current trend in the construction industry continues away from the conventional method of handcrafting on the building site toward an on-site assembly of components fabricated away from the site. This new trend accounts for greater amount of relatively inexpensive and rapid construction, ease of renovation and expansion which is often associated with industrial buildings. Other related fields like automobile, aerospace and marine architecture are well ahead in this trend. With respect to the above, the segregation of space must be made in modules that conform to existing fabricated elements or elements to be fabricated; the concept of using these elements repeatedly in a design is what Kieran and Timberlake (2004) refers to as **Refabricating Architecture.** The main challenge for this research is "how a fruits processing factory can be design with the maxim refabricating architecture?" This project is a study of refabricating architecture with the possibility of designing a modern (flexible) factory.

1.2.0 AIM AND OBJECTIVES

The aim of the study is to design a factory with the maxim refabricating architecture, that will meets current and future trends in architecture and related fields, and that the following objectives may be met;

i. To carry out a polemic study on the concept of refabricating architecture

ii. To carry out a study of modular design

iii. To carry out a study of common building materials

iv. To determine materials suitable for prefabrication of building components

v. To design the details of custom components

1.3.0 RESEARCH METHODOLOGY

There are basically four (4) methods for sourcing data for research purpose;

1. HISTORICAL METHOD: This method is mostly used by researchers in the humanities (social sciences). It relies on written works since it involves past invents, for instance the historical background of a place can be gotten by written works since the researcher cannot go back to the time past.
2. DESCRIPTIVE SURVEY METHOD: This is mostly used by researchers in environmental sciences; it involves case studies that may require field visit, photographing and interviews.
3. ANALYTICAL METHOD: This involves numerical manipulations, equations and is mostly used for engineering and statistical research works.
4. EXPERIMENTAL METHOD: This involves laboratory activities and used mostly by researchers in the natural sciences.

The methods employed for this research were the Historical and Descriptive Survey methods. Written works (books, journals and newspapers) were consulted in the library and the internet. Case studies were carried out by visiting existing factories, and interview of factory workers to prevent personal bias, taking of photographs for visual documentation and telephone conversations for quick enquiries.

1.4.0 SCOPE AND LIMITATIONS OF STUDY

1.4.1 SCOPE

This study covers a brief history of factory, mass production, prefabrication of building, the maxim of refabricating architecture and the new trends in industrial design. It strives to identify local materials that can be suitable for prefabricating building components.

1.4.2 LIMITATIONS

The limiting factors which were encountered in the course of this project were mainly time, finance, and also the lack of comprehensive and reliable data on fruits species and fruits processing industries in Nigeria. It has been observed that factory officials are reluctant to give or do not want to give out information to researchers during case study visits except for cases where the researcher already has an insider. The study on refabricating architecture and related areas like Systems Design, Industrialized Building System and precast technology have not been exhaustively discussed, as the researcher only used them as points to support the line of argument.

1.5.0 IMPORTANCE OF STUDY

At present, State Governments are spending huge amount of money and time investing in housing provision, renovation of buildings takes long period and occupants often inconvenienced as they have to vacate the buildings for the construction workers. These resources can be reduced by 50% if architects and engineers embrace the **maxim refabricating architecture**. This research shall remain a valuable insight to architects and engineers for the need to adapt these new technologies.

1.6.0 DEFINITION OF TERMS

Fabricate — *to make or construct something from different parts in a factory*

Refabricate — to *construct a component or process again, to make something better than the previous make*

Prefabrication — *the production of building components in a factory or away from place of use, to be assembled at the building site*

Manufacture — *to produce something with a machine and or in the manner of a machine, without creativity*

Architecture — *used interchangeably here as 'building' and as 'design and construction of buildings'.*

CHAPTER TWO

2.0.0 REVIEW OF LITERATURE

2.1.0 Background History of Factory

A factory is an industrial building where goods are fabricated by hand or machine (manufactured). It is believed that the idea of factory first started in ancient China during the Eastern Zhou Dynasty. According to Wikipedia encyclopaedia this is the period between 771-221 BC, while the Encyclopaedia Britannica posits 770–256 BC. Factories started as small mills and workshops and later grew to large Government sponsored industries like the paper-money printing factories established around 960-1279AD during the Song Dynasty *ibid,* each of these factories engaged over a thousand worker per day since they made little use of machine at that time. About the same time, the Chinese iron industry was expanded and a six-fold increase in per capita cast iron by the year 1078AD. In the Islamic world, the first glass and pottery factory was built by Muslim engineers in Ar-Raqqah, Syria in the 8th century. This complex was two kilometres in length. The first large scale flour milling installation in Europe and the first sugar refinery; driven by water mill and later wind mill, were also built by these Muslim engineers.

In the western world, the first factory in the modern sense of the word was sited in Venice, Italy in 1104. It mass-produced ships on assembly line with manufactured parts and apparently produced nearly one ship every day, with 16,000 employees. This was the beginning of modern factory; factories continue to develop as they employed new inventions like the steam engine, power loom and in the 19^{th} century, the new precision machine tools with replaceable parts. This gave rise to increase in efficiency level in the production process and less waste.

Morris T. & William K. H. (2008) revealed that in the early 20th century, Henry Ford further revolutionized the factory concept with the innovation of **mass production,** this required highly specialized workers along a series of rolling ramps with a product such as (in Ford's case) an automobile. This concept dramatically decreased production costs for all factory manufactured goods.

2.2.0 The Factory System

This is a system in which work is organized to utilize both manual labour and power-driven machinery to produce goods on a large scale (mass production), and the social and economic consequences. Formerly, workers had been independent craftsmen who owned their own tools and decide their own working hours, but in the factory system, the employer owned the tools and raw materials and set the hours and other conditions under which the workers laboured. The location of work also changed. Whereas many workers had inhabited rural areas under the domestic system, the factory system concentrated workers in cities and towns, because the new factories had to be located near consumers, power source and means of transportation (alongside waterways, roads, or railways). Many of the new assembly line jobs required little skills and could be easily learned or performed by women and children unlike the former.

Two major advances in the factory system occurred in the early 20th century with the introduction of management science and the **assembly** or **production line** as earlier discussed. Scientific management, such as time-and-motion studies, helped rationalize production processes by reducing or eliminating unnecessary and repetitious tasks performed by individual workers. The old system in which workers carried their parts to a stationary assembly point was replaced by the assembly line, in which the product being assembled would pass on a mechanized conveyor from one stationary worker to the next until it was completely assembled.

By the second half of the 20th century, enormous increases in worker productivity fostered by mechanization and the assembly line system, had yielded unprecedentedly high standards of living in industrialized nations. Ideally, the modern factory was a well-lit, well-ventilated building that was designed to ensure safe and healthy working conditions demanded by workers and mandated by government regulations. The main advance in the factory system in the latter part of the century was the science of **automation**, in which machines were integrated into systems governed by automatic controls, thereby eliminating the need for manual labour while attaining greater consistency and quality in the finished product. Factory production became increasingly globalized, with parts for products originating in different countries and being shipped to their point of assembly. As labour costs in the developed countries continued to rise, many companies in labour-intensive industries relocated their factories to developing nations with high human resources and cheap labour, like China.

2.3.0 Mass Production

Mass production is the principle of specialization, division of labour, and standardization of parts of manufactured goods. Such manufacturing processes attain high rates of output at low unit cost, and expected lower unit costs as quantity increases. Mass production methods are based on two general principles:

- The division and specialization of human labour
- The use of tools, machinery, and other equipment; usually automated, in the production of standard, interchangeable parts and products.

The use of modern methods of mass production has brought such improvements in the cost, quality, quantity, and variety of goods available that the global population is now sustained with high general standard of living. The efficiencies of mass production result from the careful, systematic application of the ideas and concepts outlined above. The following summary lists the basic principles of mass production:

1. The careful division of the total production operation into specialized tasks comprising relatively simple, highly repetitive motion patterns and minimal handling or positioning of the work piece arranged serially, and referred to as the

production line. This permits the development of human motion patterns that are easily learned and rapidly performed with a minimum mental readjustment.

2. The simplification and standardization of component parts to permit large production of parts that are readily fitted to other parts without adjustment. The imposition of other standards (*e.g.,* dimensional tolerances, parts location, material types, stock thickness, common fasteners, and packaging material) on all parts of the product further increases the economies that can be achieved.

3. The development and use of specialized machines, materials, and processes. The selection of materials and development of tools and machines for each operation minimizes the amount of human effort required, maximizes the output per unit of capital investment, reduces the number of off-standard units likely to be produced (by human error), and reduces waste of raw material.

4. The systematic engineering and planning of the total production process permit the best balance between human effort and machinery, the most effective division of labour and specialization of skills, and the total integration of the production system to optimize productivity and minimize costs.

Careful, skilled industrial engineering and management are required to achieve the maximum benefits that application of these principles can provide. Planning begins with the original design of the product; raw materials and component parts must be adaptable to production and handling by mass techniques. The entire production process is planned in detail, including the flows of materials and information throughout the process. Production volume must be carefully estimated because the selection of techniques depends upon the volume to be produced and anticipated short-term changes in demand. Volume must be large enough, first, to permit the task to be divided into its sub-elements and assigned to different individuals; second, to justify the capital investment often required for specialized machines and processes; and third, to permit large production runs so that human effort and capital are efficiently employed.

The need for detailed advance planning extends beyond the production system itself. The large, continuous flow of product from the factory requires equally well-planned **spaces**, distribution and marketing operations to bring the product to the consumer. Advertising, market research, transportation problems, licensing, and tariffs must all be considered in establishing a mass production operation. Thus, mass production planning implies a complete system plan from raw material to the final consumer.

In addition to lowering cost, the application of the principles of mass production has led to major improvements in uniformity and quality. The large volume, standardized design, and standardized materials and processes facilitate statistical control and inspection techniques to monitor production and control quality. This leads to assurance that quality levels are achieved without incurring the large costs that would be necessary for detailed inspection of all products.

A major problem of mass production based on continuous or assembly line processes is that the resulting system is inherently inflexible. Since maximum efficiency is desired, tools, machines, and work positions are often quite precisely adapted to details of the parts produced but not necessarily to the workers involved in the process. Changes in product design may render expensive tooling and machinery obsolete and make it difficult to reorganize the tasks of workers. One answer has been to design machinery with built-in flexibility, for relatively little or no extra cost, machines and tooling can be changed or re-arranged to accommodate process changes. For juice factory instance, the machines can be simply placed on the floor and linked with screw pipes so that when the need for change arises, they can be re-arranged easily by unscrewing the pipes and moving to new position.

At any given stage of technological development, the economies obtained by increasing production volume are largest in the initial stages of growth and level off as volumes are further increased. Indeed, if volumes grow too large, unavoidable breakdowns of facilities, failures of coordination, or other strategic factors may cause costs to rise. Advances in technology or changes in other factors can shift the optimum point to higher levels. For these reasons planners may limit the maximum size of a single production facility and construct an independent facility if greater production is necessary. *Ipso facto,* Speculative planners provide more than one production line.

These mass production principles; **division** and **specialization** of labour and the use of **standardized parts and processes** have been applied to a wide area of productive activity. In agriculture for instance, the development of specialized machines for ploughing, seeding, cultivating, and harvesting are followed by factories for preparing, preserving, and packaging into food products. These have drawn heavily from mass production principles, though there are specialized manual tasks supplementing the specialized machines both in the fields and in the processing plants. Developing countries with high human resources often, and will have to leave a large percentage of their processes to specialized manual labour to create employment, only production stages that require high speed and precision should be reserved for specialized machines. Planners have to consider these social and economic factors because the success of mass production depends on both, for instance the technique above can creates employment on one hand and reduces the huge cost of powering machines on the other, as the provision of power has remained one of the biggest challenges of developing nations.

It is worth stating here that the study of **mass production** has dual purposes in this research. Firstly, it fosters the planning of the proposed factory and secondly, it gives useful clues to the principles behind Industrialized Building System (IBS) that will be discussed in the next chapter.

liquids or gasses and its ability to withstand atmospheric heat. These materials will be used in the construction roof gutters.

E. Roofing

This comprises basically three roofing components.

a. The tubular steel space frame roofing system will make up the roof structure, since it is easy to be prefabricated.

b. Long span aluminium roofing sheets used on the tubular steel space frame which are used to provide the required curvature and slope for roofing sheets so as to provide the required water run and slope respectively. The roof gutter which serve as an additional measure for the drainage of water from the roof, also collects and channels water to the reservoir for purification.

c. The use of translucent roof lantern is used to allow penetration of light to areas that cannot be lit from window openings.

E. Ceiling

The Soffit of the ingenious suspended floor will serve as the ceiling to the floor below while at the first floor, the ceiling is to be will be suspended fire resistant acoustical PVC Ceiling tiles for fire resistance and sound absorption. The ceiling tiles are to be screwed in either a concealed grid or revealed grid system on lightweight stainless steel railings. The PVC Ceiling tiles has the advantage of being water resistant thus even when the fire sprinklers are engaged, the ceiling is preserved after spray.

4.5.3. Vertical Structural Elements

A. Walls

Walls constitute those vertical elements of a structure, which compartmentalize its spaces in the horizontal plane. They may be load bearing or non-load bearing elements. The consideration for the design of walls in the design varied from place to place. Minimal use of concrete walls was made in the exterior. The walls used in the interior for partitioning were most of the non-load-bearing and are made of U-PVC, glass and bricks.

B. Doors

In factory architecture, *double leaf double swing doors* are best used, the frames are factory fitted in the walls; for both the interior and exterior walls. Sealant eliminates any rigid connection between grout-filled frames. Door closers must be strong enough to close the doors against the resistance offered by all types of compression seals. All seals are located in one plane to eliminate leak.

C. Windows

In the design of factories, there is no need for special exterior glazing. Even where such need exists, it should be remembered that an open window for natural ventilation provides zero sound attenuation. The best fire and acoustical improvement that can be made to a window is double glazing, with the provision of the largest possible space between the two panes of glass as much as the wall thickness permits, but not less than 2 or 3 inches. The two Panes must not be rigidly connected to each other. The frame area between the panes should be absorptive. Performance of the two panes is improved if they are of different thicknesses, so that vibrations are not transmitted from one to the other.

D. Column

Basically five types of precast reinforced concrete columns are used in the design. They are analysed and designed purposely for this structure, but are to be precast with dowels at the appropriate points to be grouted insitu with precast beams to form the structural framework of the building. The columns are spaced in a grid at an interval of 5m on one axis. They constitute the load bearing vertical support element of the structure.

E. Glass

Glass cladding constitutes the dominant element in the entrance porch. The glass allows for the lighting the interior of the reception area, and are employed using regular temperature control glass, to reduce the green house effect within the structure as well as trapping the heat along the corridors.

4.5.4. Fitting and Finishes

Floor finishes will be hard wearing, easy to clean, give an impression of quality and aesthetic, finished in bright colours like white, especially for production halls and laboratory areas. All fittings in general shall be mounted as required on walls, columns and ceilings. The fitting would be selected in a manner that will contribute to the interior aesthetic and design of the enclosure

4.6.0 Electricity And Lighting

For proper functioning of the factory, use of electronic or electricity powered machines or appliances will depend basically on the public power supply or the national grid, two stand-by generators and solar panels to compliment power outage. All other forms of electrical appliance such as space lighting, fire alarms, security lighting as well as cables required for wiring will have to satisfy the standard codes of efficiency, safety, durability and reliability. Electrical cables system to be used within this factory is the *surface trunking systems* with socket outlets provided at strategic points in the interior of the building. The solar power will have a parallel cable system specifically for lighting fittings, fire alarms and extractor fans.

4.7.0. Ventilation and Air-Conditioning

Buildings in which people live and work must be ventilated to replenish oxygen, dilute the concentration of carbon dioxide and water vapour, and control olfactory. Natural air movement or ventilation ordinarily is provided by the use of open-able windows in the walls and roof of the building, where the span is about 12m. As the span goes beyond that, mechanical ventilation system has to be employed.

An artificial or mechanical ventilation system will be employed to support the natural ventilation especially at seasons when the weather is dusty. A section of the production hall has to be air-conditioned for proper functioning of the machines therein. The administrative unit and the laboratories can also be conditioned with *split unit* air conditioning system. In recent years, this system has been automated by information technology for the purpose of energy conservation.

The design of an air conditioning system depends on the type of structure in which the system is to be placed, the amount of space to be cooled, the type number of occupants, and the nature of space-use. Air conditioning units are rated in terms of effective cooling capacity, which should be properly expressed in horsepower.

4.8.0 Water Supply

Provision of portable water is made available to the site by the Benue state water board distributed via water mains. The water will be used for fire fighting, sanitation and maintenance of the surrounding landscape, and it will be purified to the test of the quality control officer for juice production and for drinking. A ground reservoir and subsequently transferred to overhead tank of proportional capacity to employ hydraulic pressure system in the distribution.

Plumbing pipes for sanitation is supplied by metal pipes and ducts which are to be specially insulated to inhibit the transfer of sound. Noise generated in the ducts is due to turbulence caused by sudden velocity changes, sharp turns and generally by high air speeds. It tends to be strongest in the middle frequencies. The best solution is to minimize duct noise by careful design. This can be done by promoting smooth airflow at moderate velocities-and by inserting adequate lengths of acoustically-lined duct between points of turbulence (such as volume control boxes).

4.9.0 Drainage and Sewage Disposal

An appropriate network of drainage channels will line the floor of the production halls and road patterns. The slopes of the terrain allow for natural flow and an eventual discharge into the effluent plant at the lowest point on site. The precast concrete drainage tubes or pipes will run underground and pressure pumps shall be fixed at strategic points for sanitation purposes.

The layout of the drainage system will however be simple and direct. The drains should be of sufficient strength and constructed of sufficiently durable material in this case concrete.

4.10. Refuse Disposal

Dust bins, cans, and baskets which are about 450mm in diameter and 620mm in height will be placed at strategic positions for refuse collection. Refuse generated from raw materials, that is fruit piles and nuts will be collected from wash/crush points packaged and sent or sold to the farmers, for manure and seeds respectively.

4.11. Acoustics

Acoustics is a major important design consideration in the factory especially in the production hall, it is important that good and proper acoustic controlled elements are incorporated in the architectural design, to reduce one of the *repetitive stress injury* (**RSI**) caused by continuous noise. The selection and utilization of the site, the horizontal and vertical relationship between spaces within the building, orientation and planning of interior spaces should be carefully designed.

4.12. Solar Control

The control of solar energy is a major consideration essentially in the orientation of buildings. It is a practice in tropical climate to eliminate direct sunrays, glare, and to minimize solar heat gain by orienting the structure such that the longer side of the building is in line with the sun path axis. The sides of the building facing the east and west are being screened from the sun by the use of sunscreens and shades, and window openings are avoided to prevent glare. This is aimed at reducing the cost of cooling

4.13. Design Appraisal

In the design of the **Fruits Processing Factory Makurdi**, careful consideration was made to create a suitable image for the factory that will respond favourably to the desired use and chosen location.

The design is aimed at creating a conducive work environment for factory workers and for proper functioning of the machines. The elevations and the form expresses an absurd beauty to the exactitude of a machine on one part, and celebrates its façade with interesting architectural elements un-like the use-to-be sterile façade of factories. All elements used in the design of this edifice have been carefully considered to achieve an acceptable circulation, communication, and structural stability, initial and running cost, ease of maintenance, sustainability and energy conservation.

4.13.1 Landscape

Planting: soft and hard landscaping elements are used in a manner to harmonize building and immediate environment so as to be user-friendly.

Parking: parking within the site is essential as an industrial building; there are adequate parking spaces for a good number of customers and staffs. Parking for delivery trucks is within the maintenance building.

4.13.2 Accessibility

The site is easily accessible from all cardinal entrance and exits of the Makurdi metropolis, using fully tarred roads within the industrial layout.

4.13.3 Lighting and Ventilation

The factory buildings are adequately lit using windows, clear-storey windows, roof lights and artificial lights where necessary, to adequately light the interiors. It also has adequate open-able glazed windows and extractor fans to allow for air circulation.

CHAPTER FIVE

5.0.0 CONCLUSION

5.1.0 Summary of Findings

As part of measures to abate the ugly trend of building collapse due to poor quality of work, waste of materials and time, and the high cost of construction, the researcher proposes the embrace of **The Maxim Refabricating Architecture**; which posits that the production of architecture should be by the use of new technologies, new materials and prefabrication which is best employed in Industrialized Building System (IBS). That the process of production of architecture should change to embrace manufacturing methodologies similar to those found in automobile, aerospace and ship construction. Refabricating architecture has to embrace systems design which deals with the design aspects, and industrialized building System (IBS) which deals with the construction aspects. **One of the major findings of this study is that professionals are reluctant in adoption of this maxim due to their limited knowledge in these areas.**

5.2.0 Recommendations

As one of the effort to encourage the adoption of systems design and IBS in the Nigerian construction industry, more scholars should be encouraged to do more in these areas so as to provide the needed information to convince the industry.

The study also revealed that factories should be designed to provide a descent work environment, and be sited near consumers, power source and of course where there is easy means of transportation. Modern cities often have industrial layouts with the necessary infrastructures and are best site for factories and as a result, the proposed factory is sited in the Makurdi Industrial layout.

5.3.0 Conclusion

This research study led to a design that specified and produced details of prefabricated components that are used interchangeably in the structure and can be re-used should the building be remodelled in the future. Such components are designed with certain strength values so that the structural design of buildings is simply *serviceability checks*. Having produced a design in line with the concepts of system design and industrialized building system, the aim of this research has been achieved.

It is hoped that; this will be a challenge to professionals in this part of the world and they will rise up to the challenges therein and embrace **the maxim refabricating architecture,** which shall certainly change the face of construction in Nigeria.

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APPENDICES

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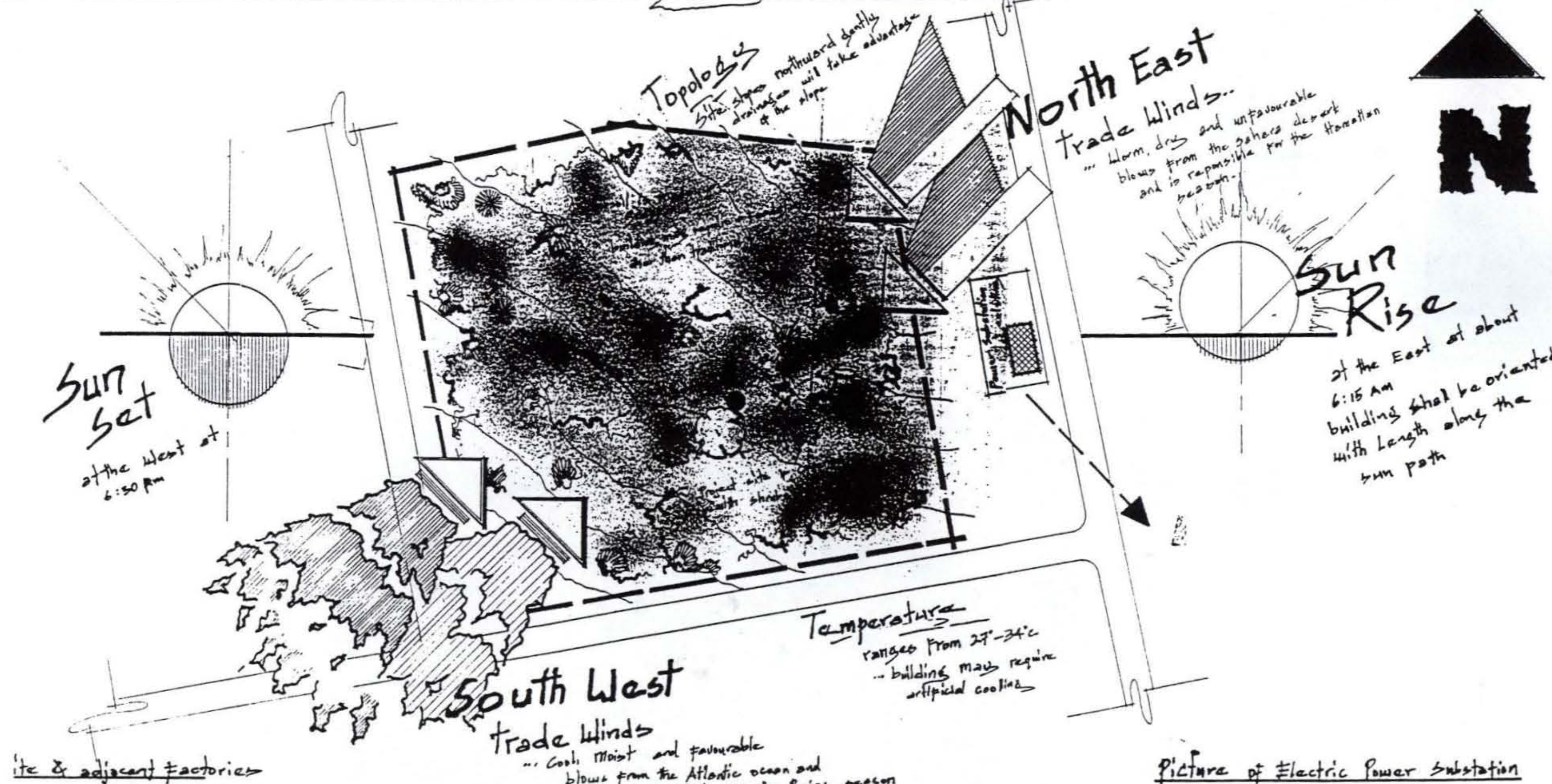

ite & adjacent Factories

Picture of Electric Power Substation

ierbert T. Pinne	
M.Tech/SET/2007/1805	
M.Tech Project - ARC 631	
F00	
ARC C. Y. Makun	

Fruits Processing Factory...

Co-ordinators	
Date	

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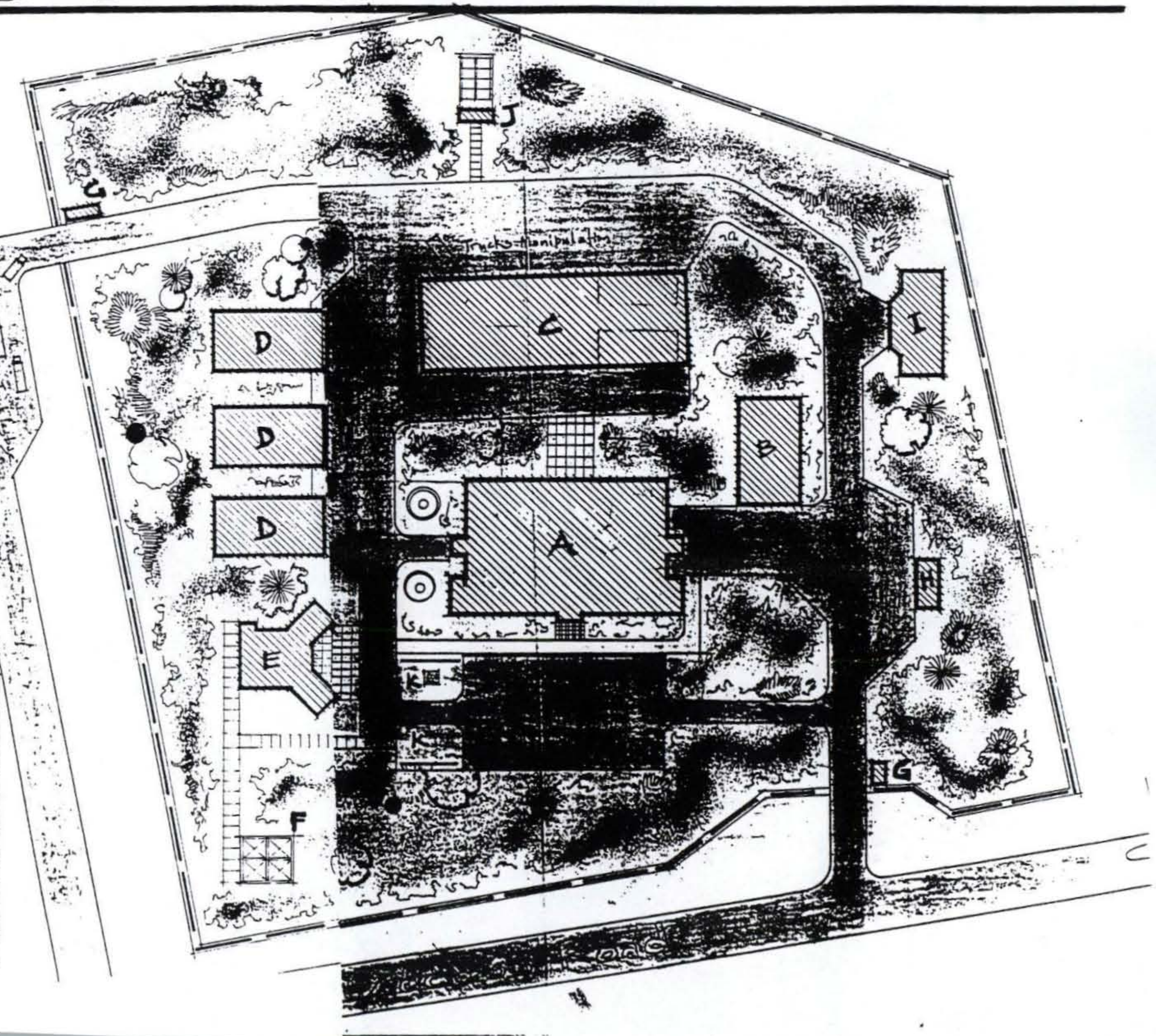
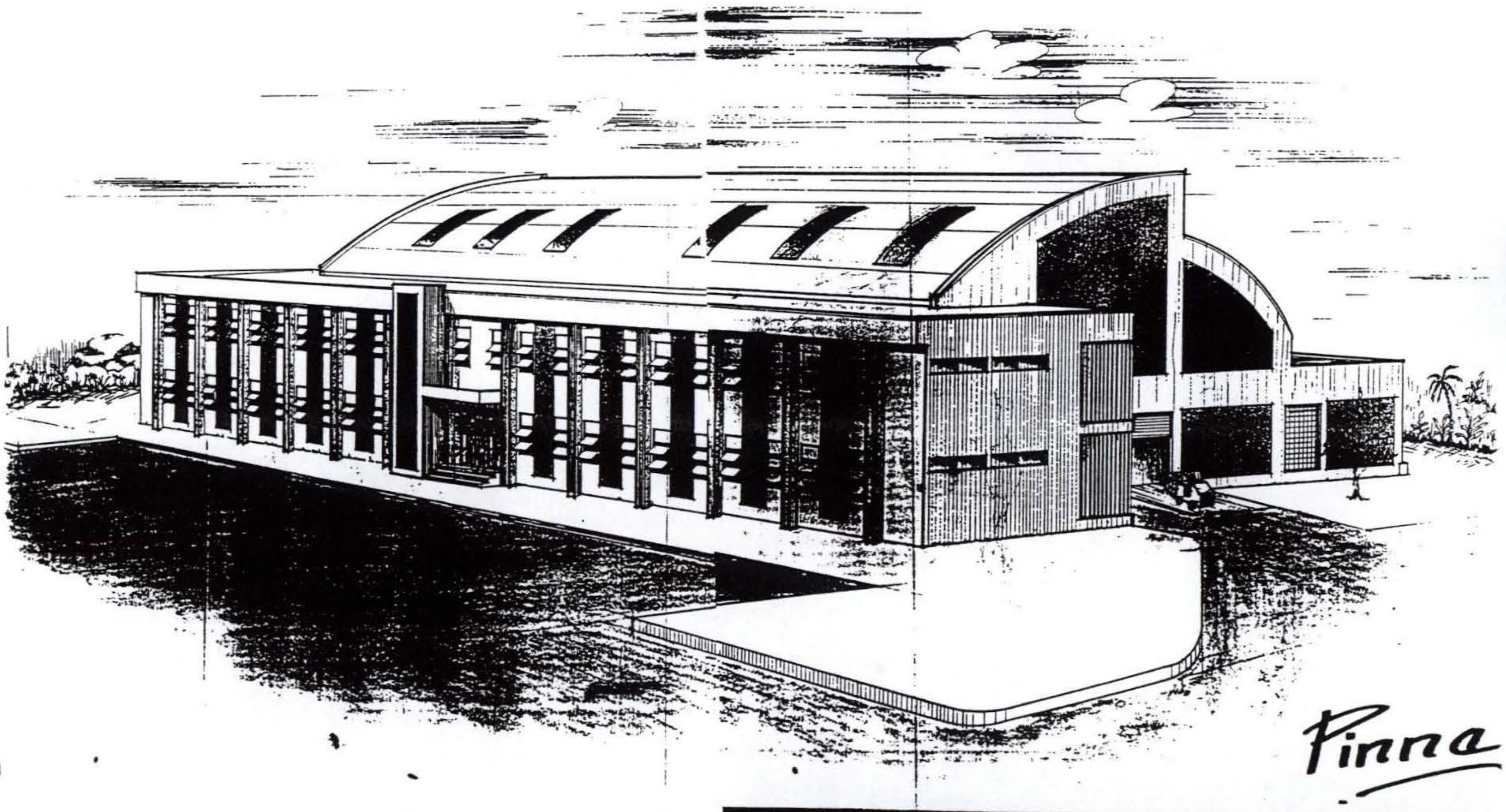
Site Plan...



Legend...

A	Main production hall
B	Raw materials warehouse
C	Engineering section
D	Products warehouse
E	Kitchen/Restaurant
F	Borehole/water tank
G	Gate house
H	Solid waste mgt. plant
I	Clinic/Bay
J	Effluent plant
K	Motor cycle/bicycle
(symbol)	Precast Concrete (PCC) pavements
⊙	Water (cooling) fountain
(symbol)	Tarred area



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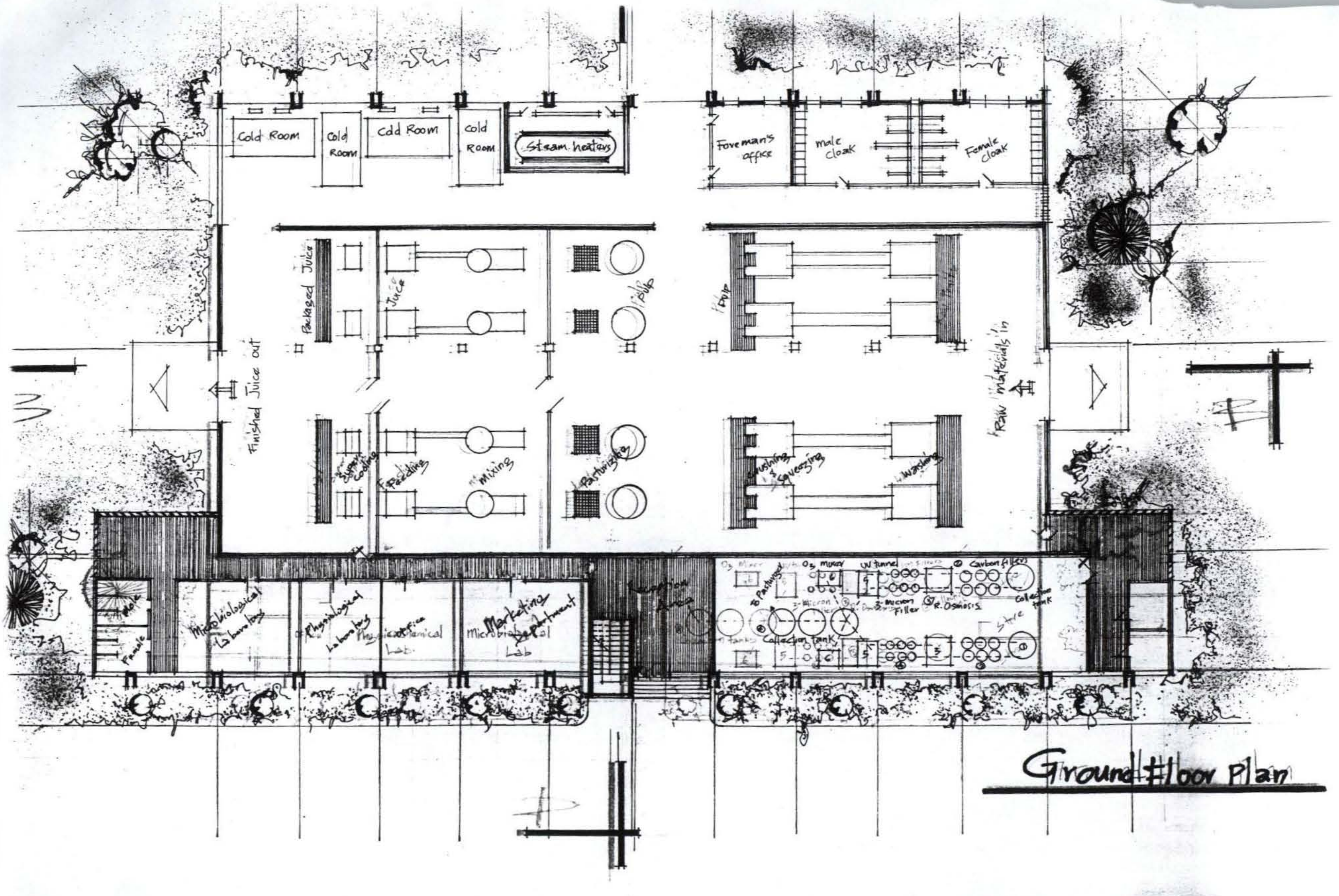
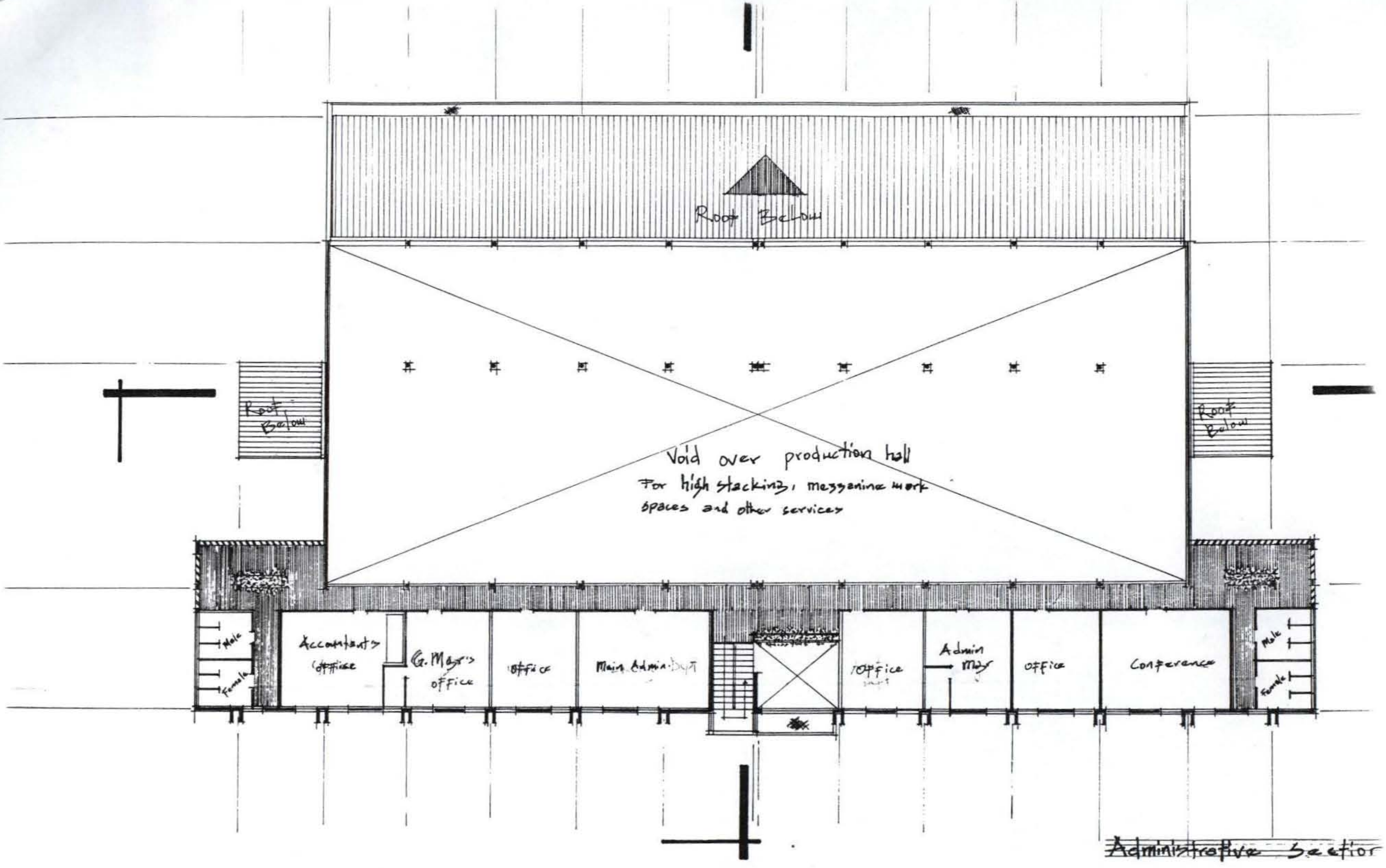
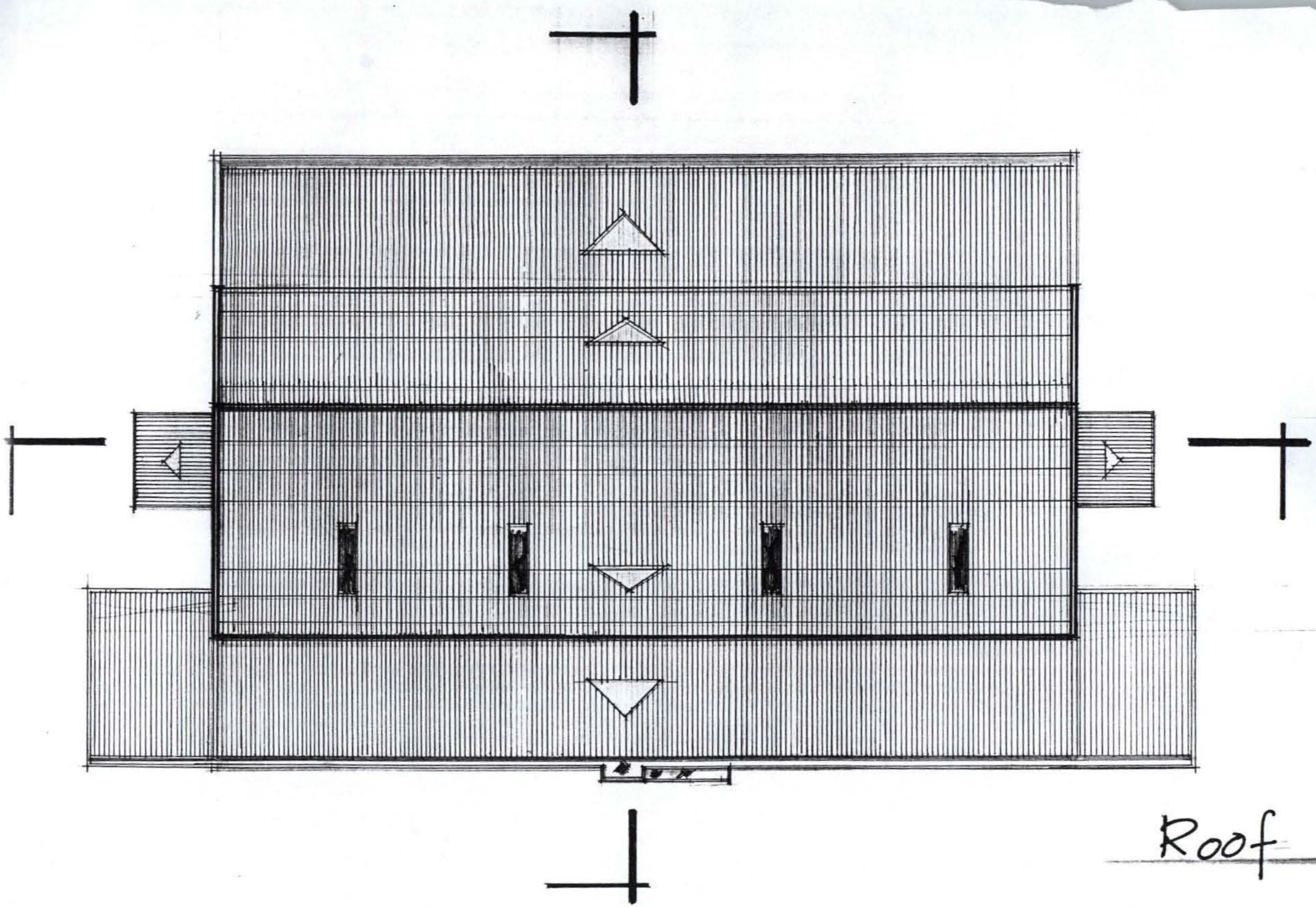


Ground Floor Plan

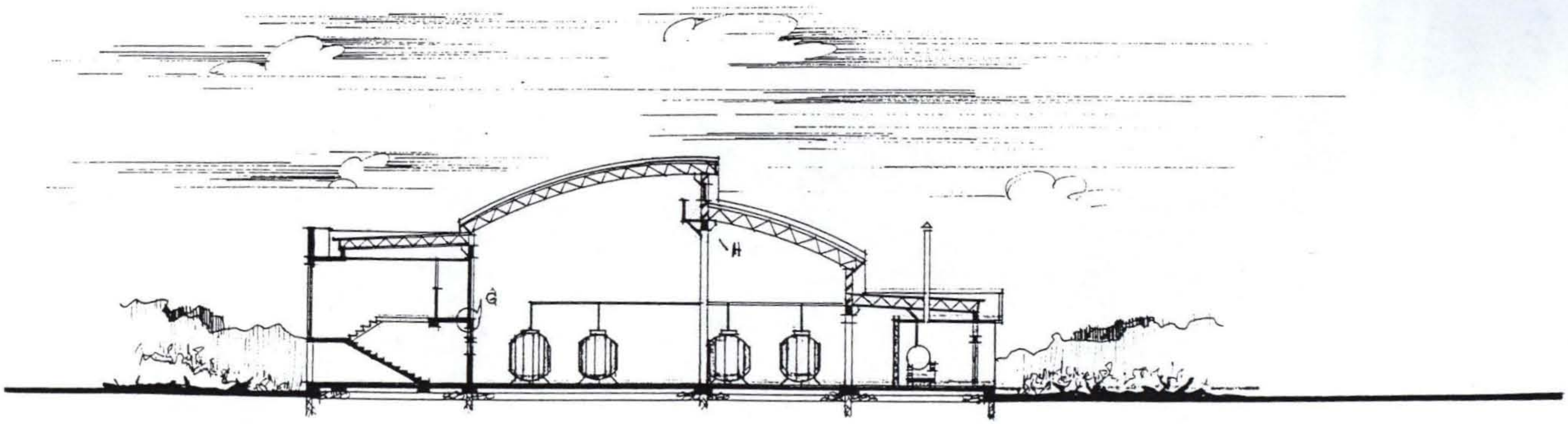


Administrative Section

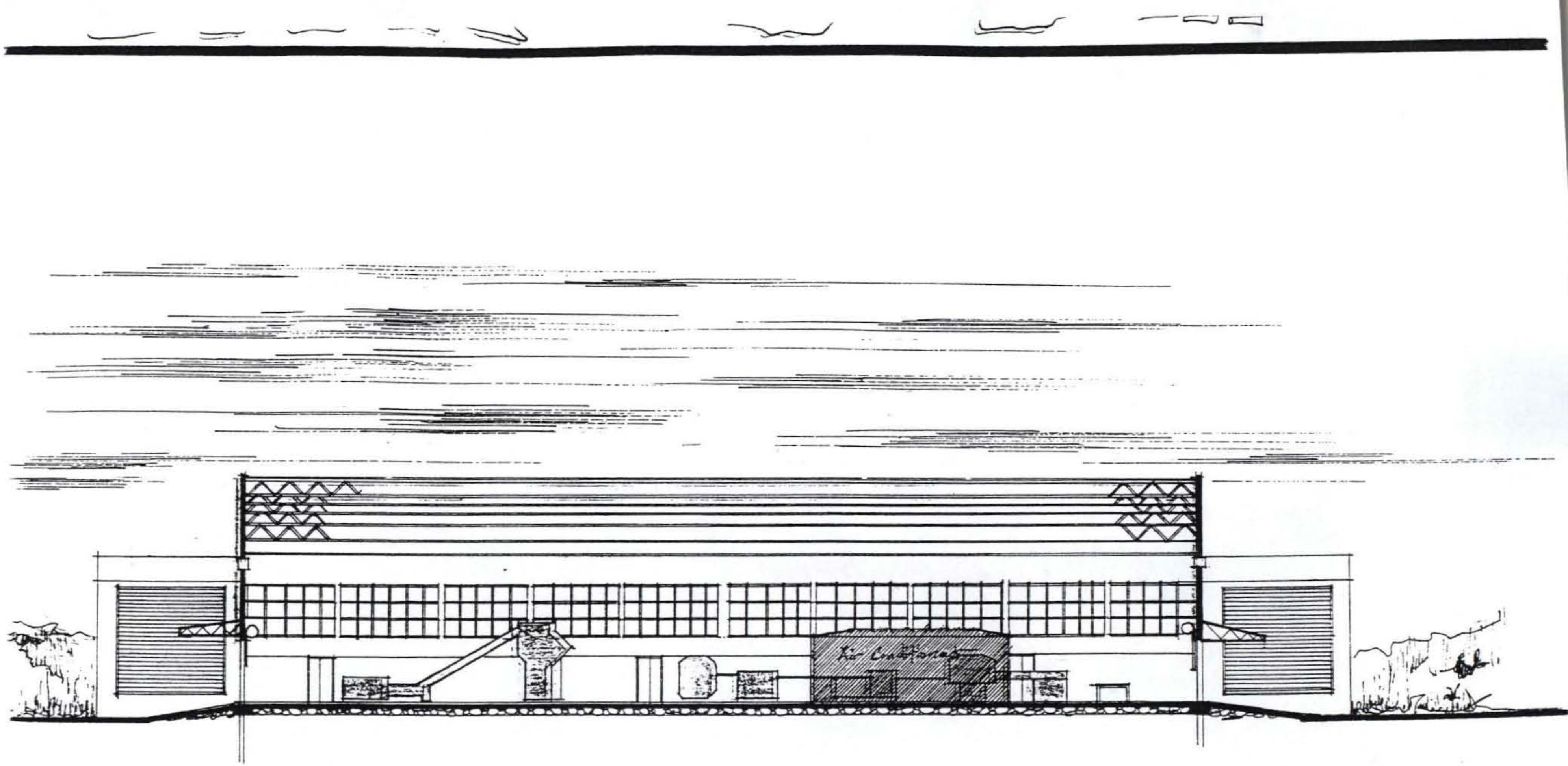


Roof F

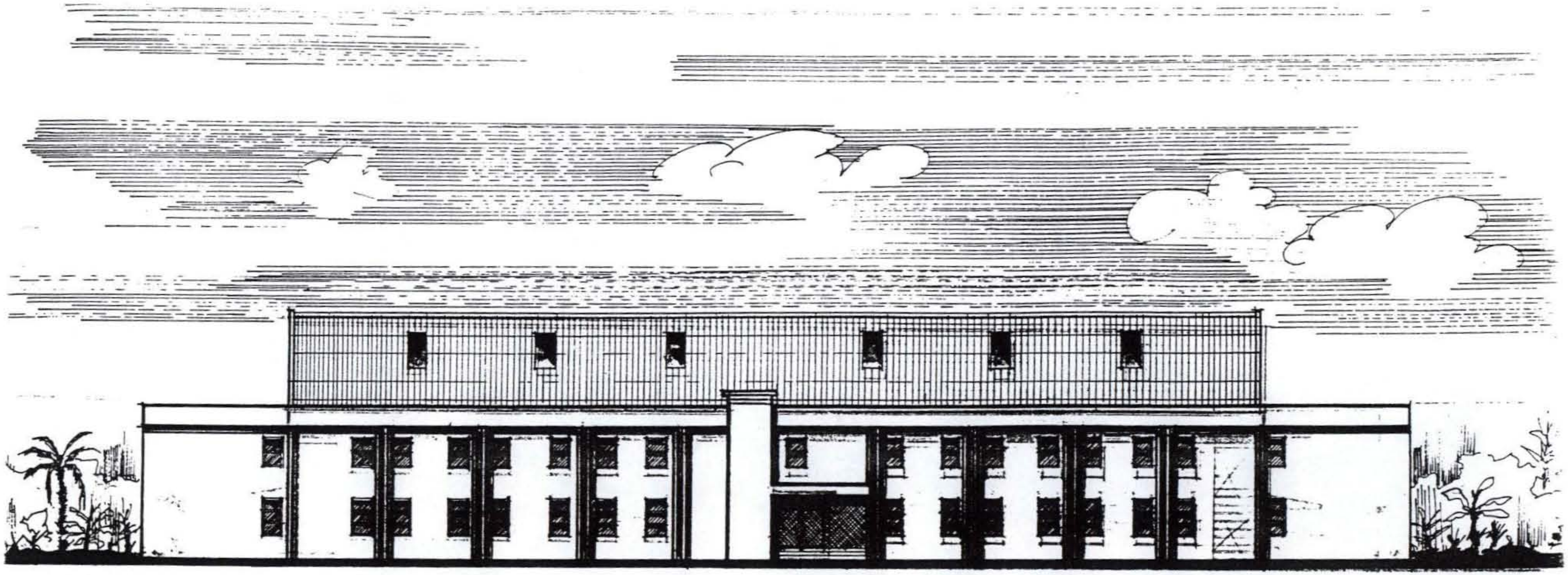
...tion P-P



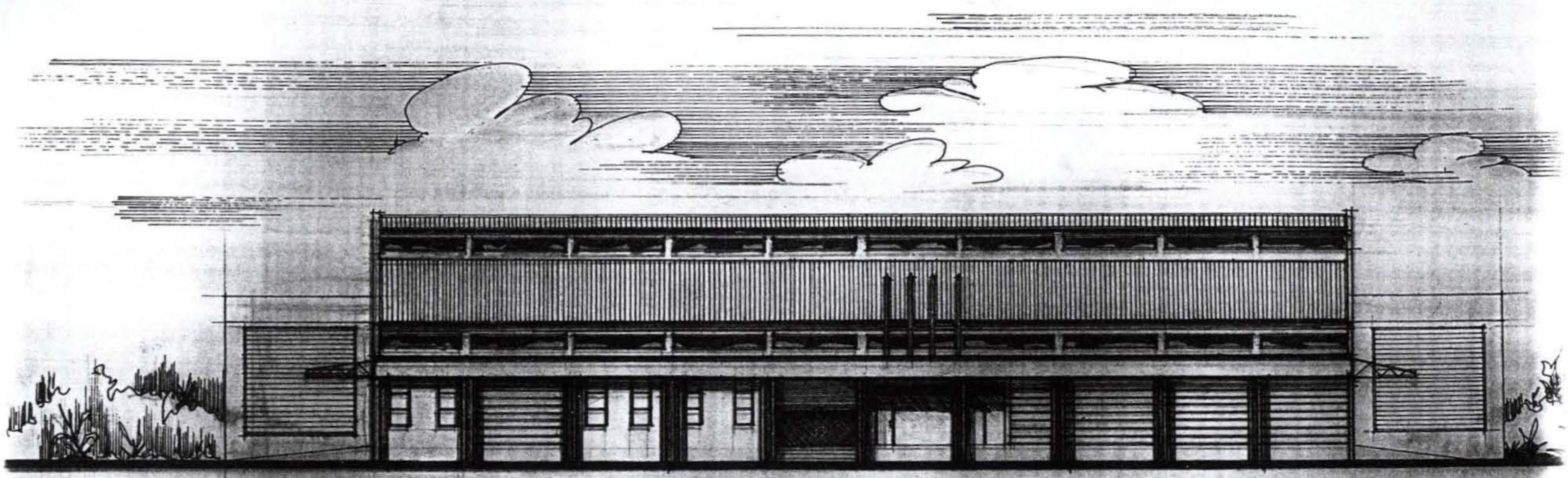
Section P-P



Section

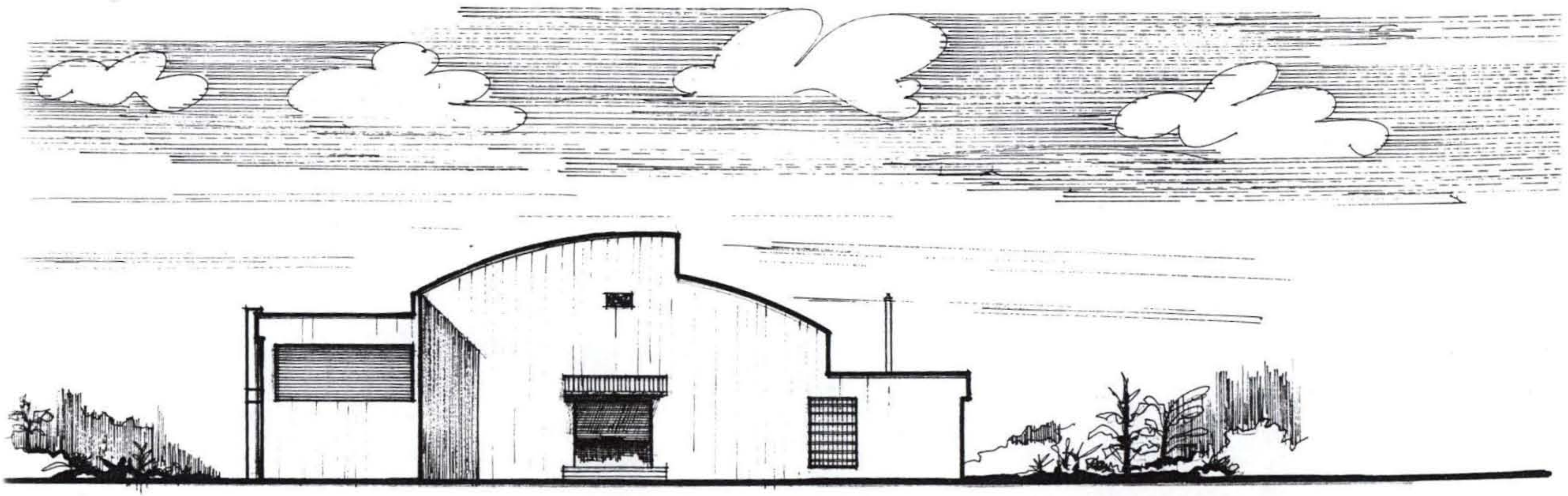


Front Visual - Product

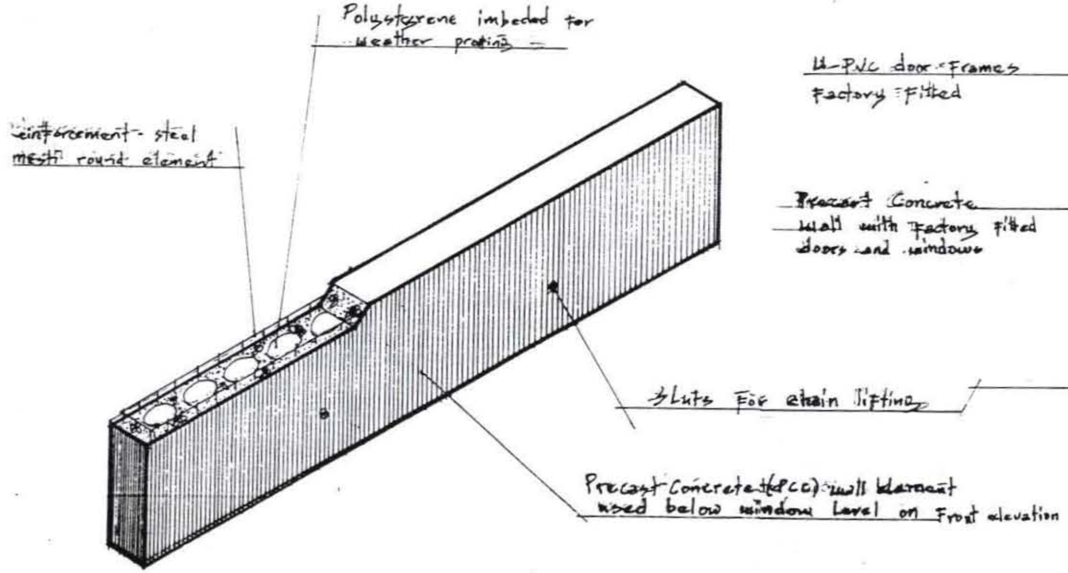


Rear Vi

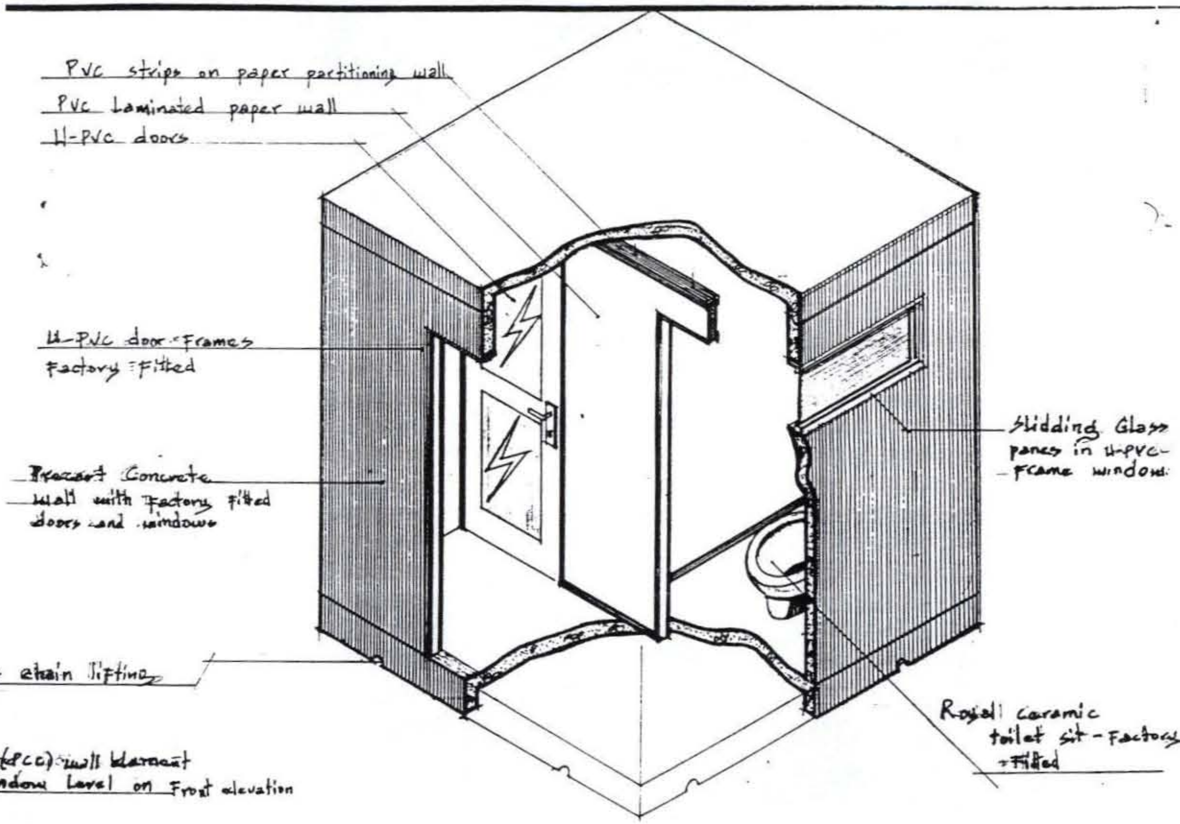
lc		Fruits Processing Factory	Co-ordinators	Arc
B05				Arc



Side View - Typical

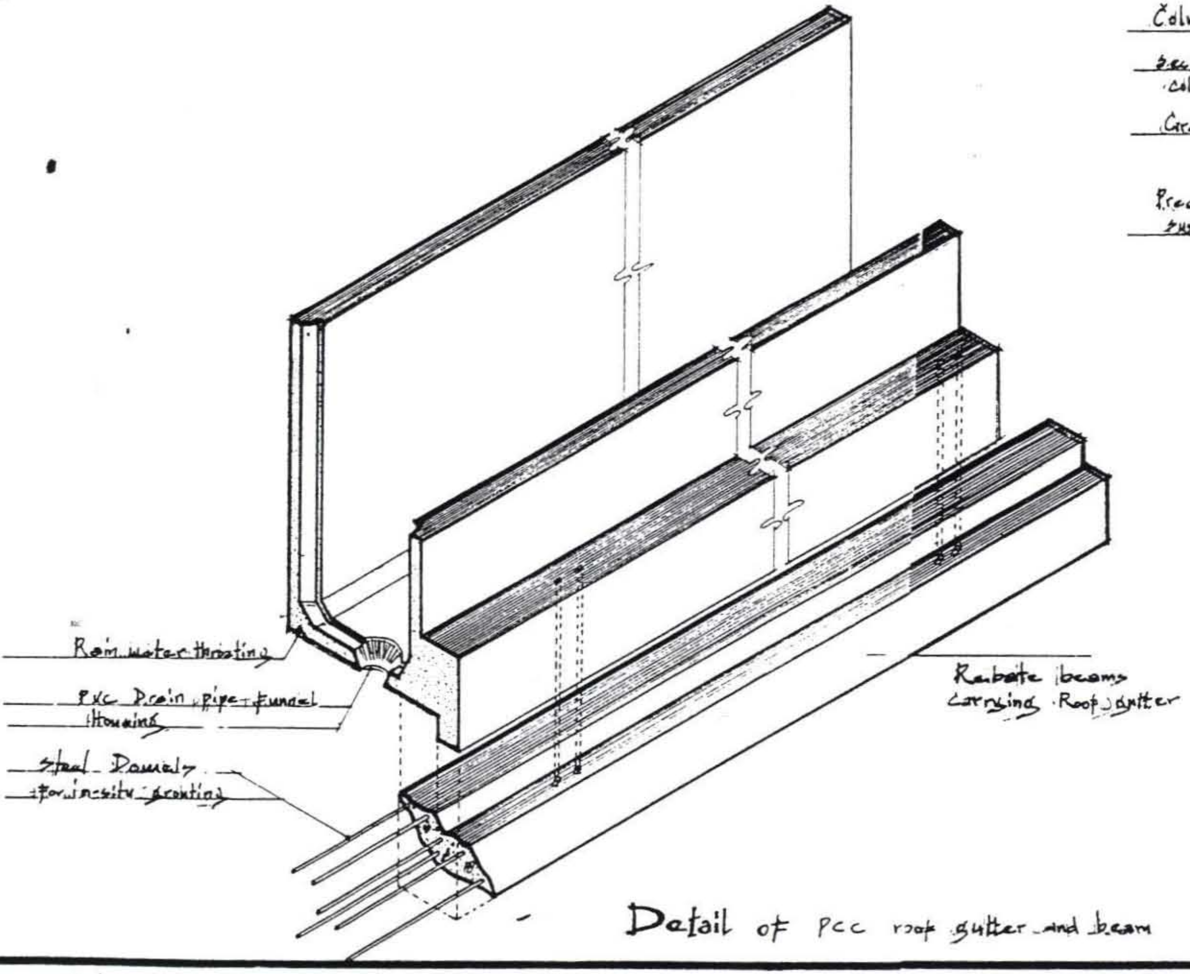


Precast Concrete (PCC) wall section used on the prodection hall perimeter wall between Floor and window still

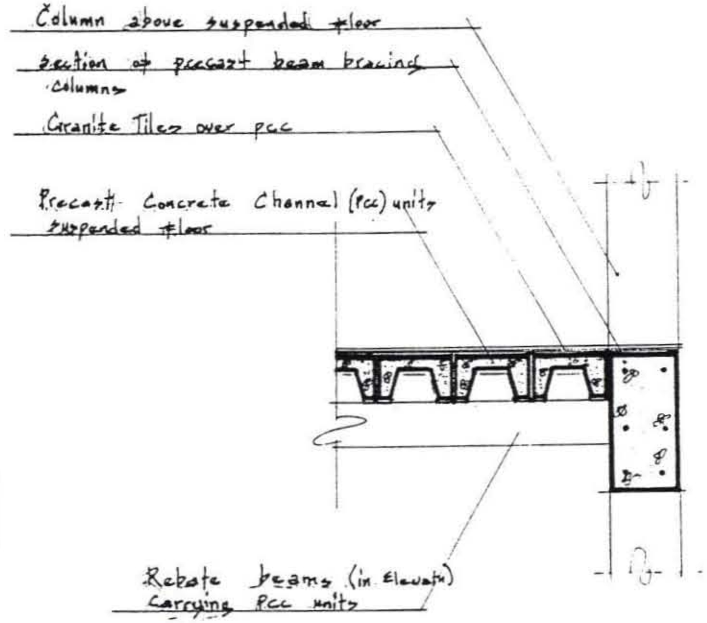


Precast concrete toilet cubicle with Factory fitted partition walls, toilet sits windows and doors.

Details — Precast Elements



Detail of PCC roof gutter and beam



Detail at G

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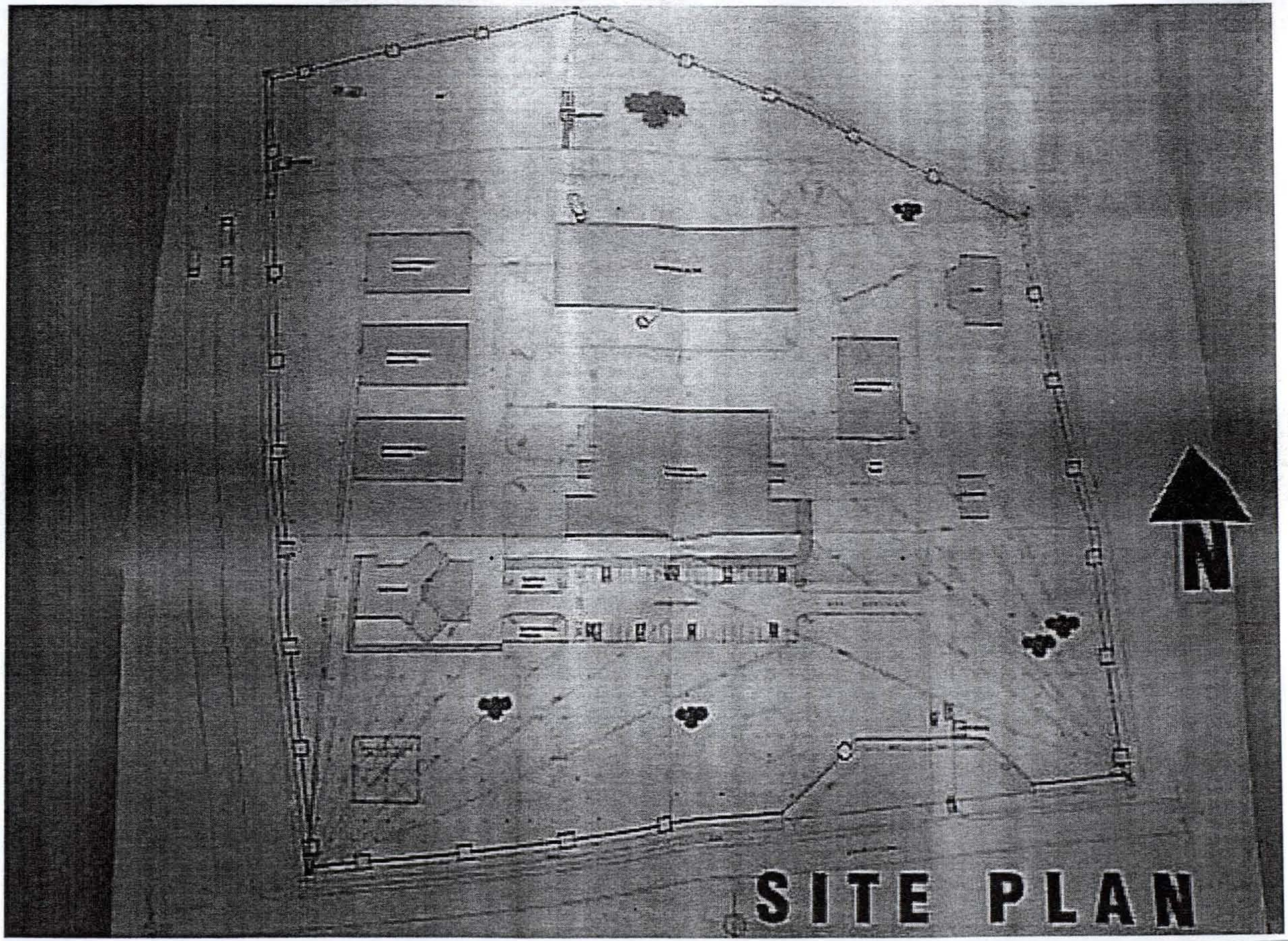
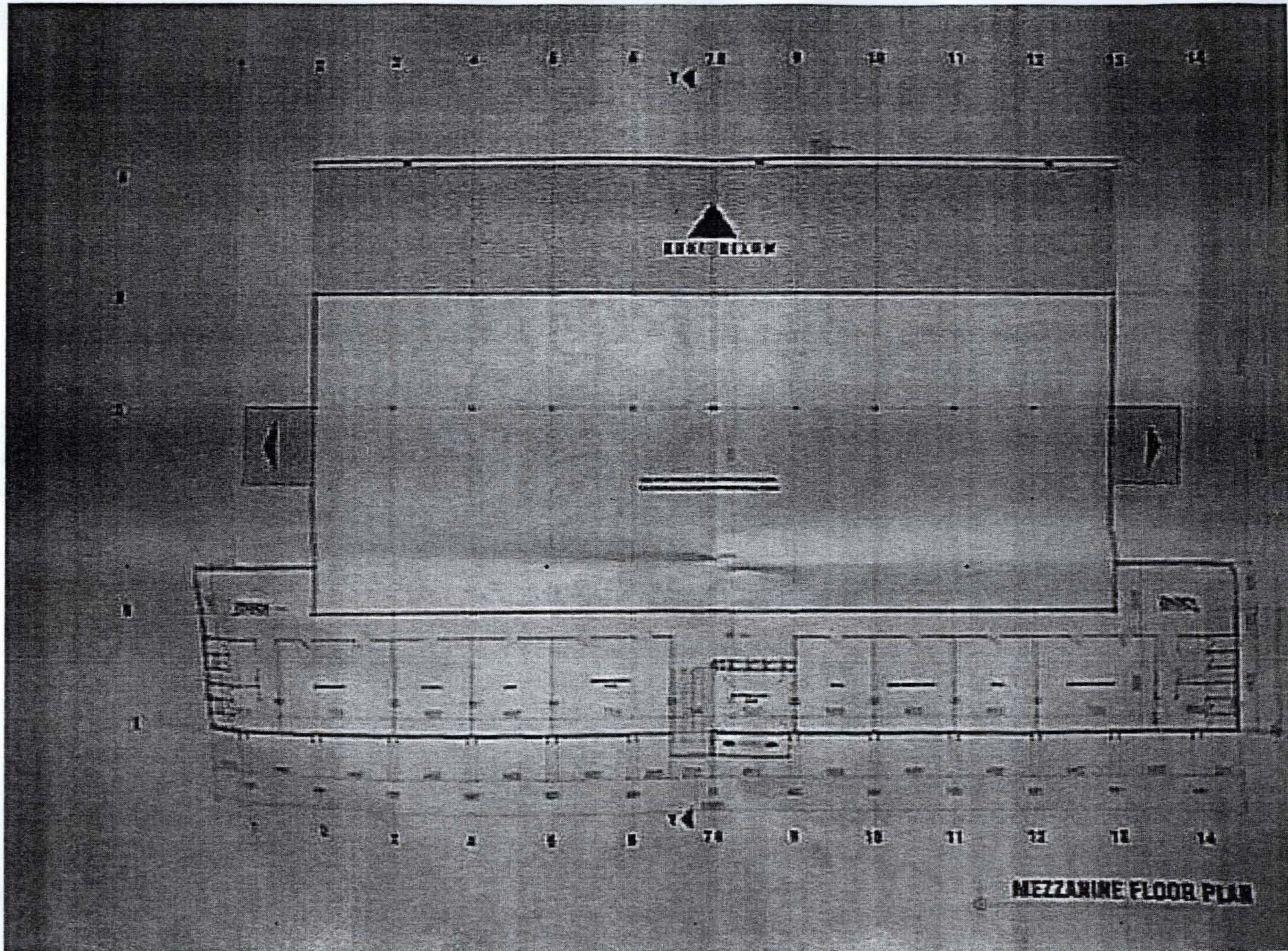
Course	M.Tech Project - ARC 631
Level	700

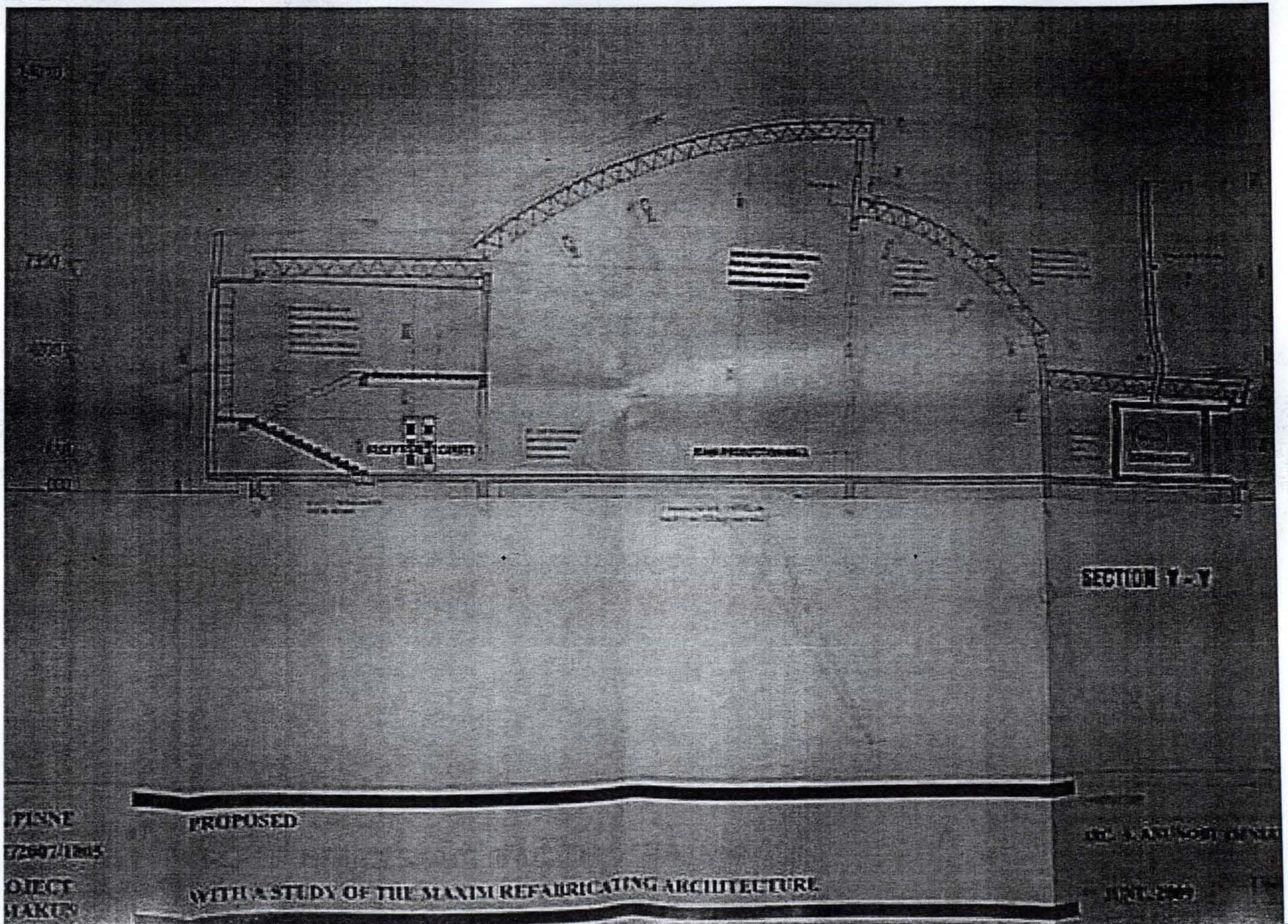
Fruits Processing Factory...

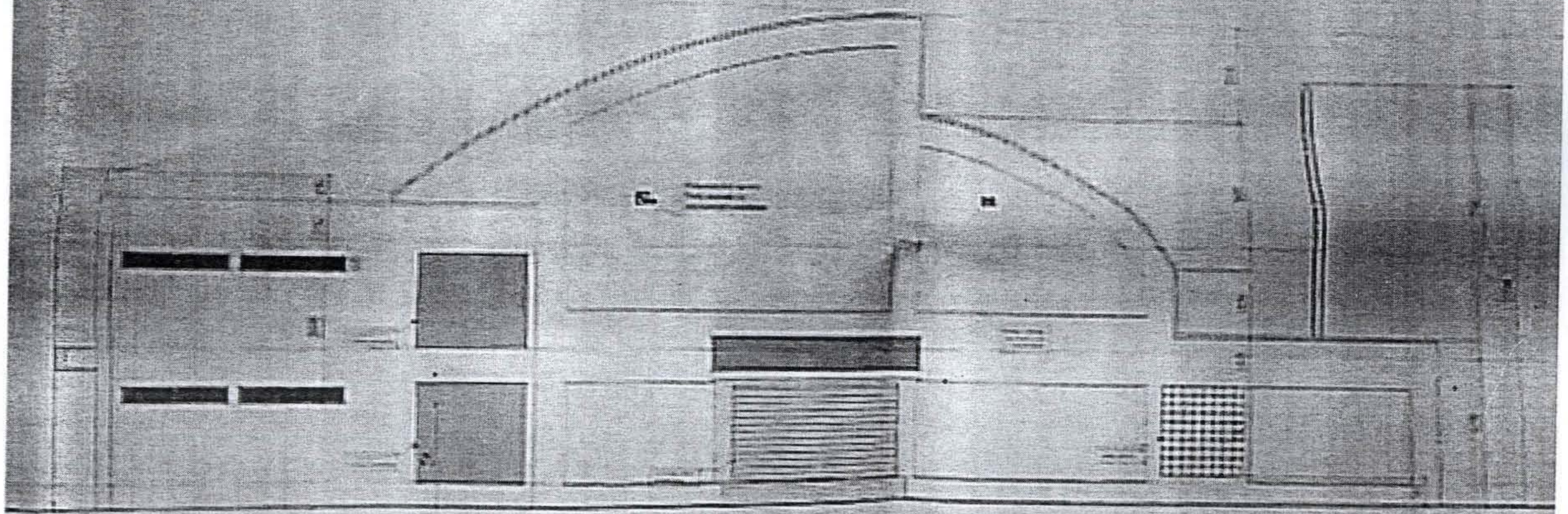
Co-Ordinators	Arc Olagunju
	Arc Anumbi (MNIA) (KSN)
Date	May 2009

WORKING DRAWINGS

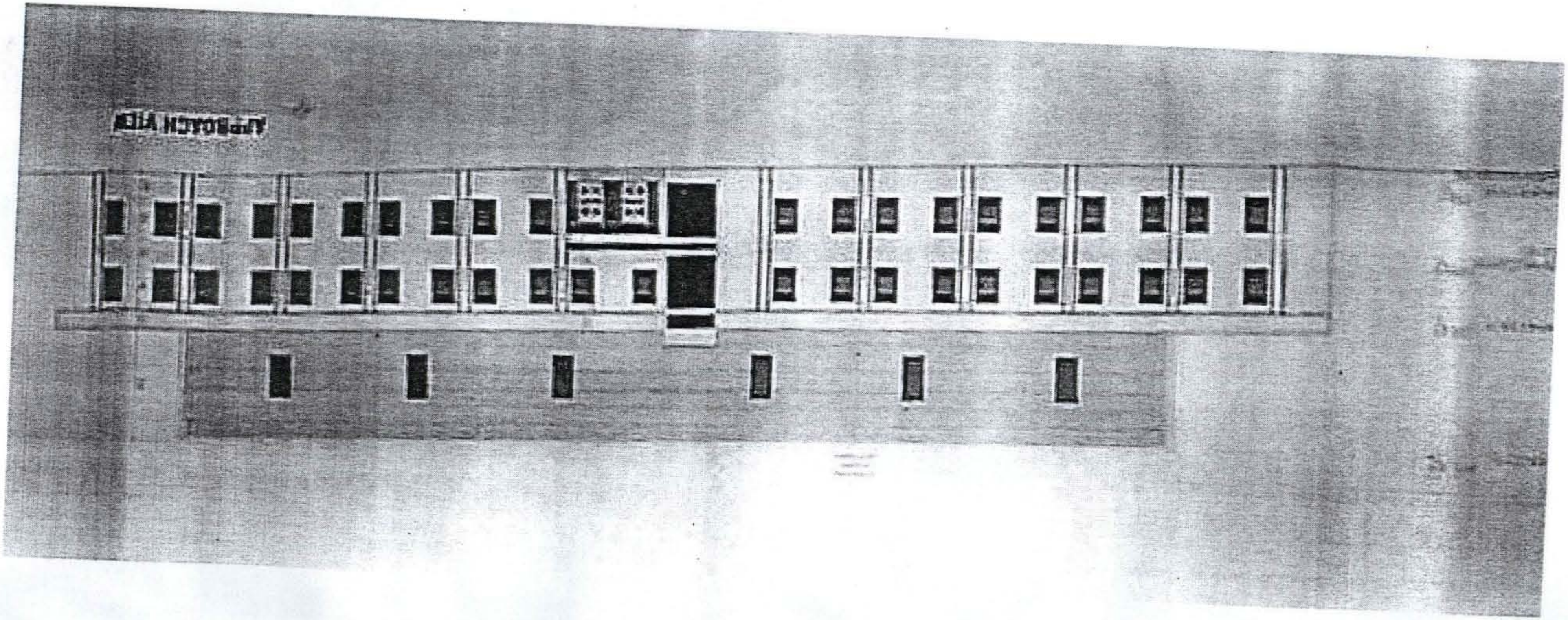

N
SITE PLAN

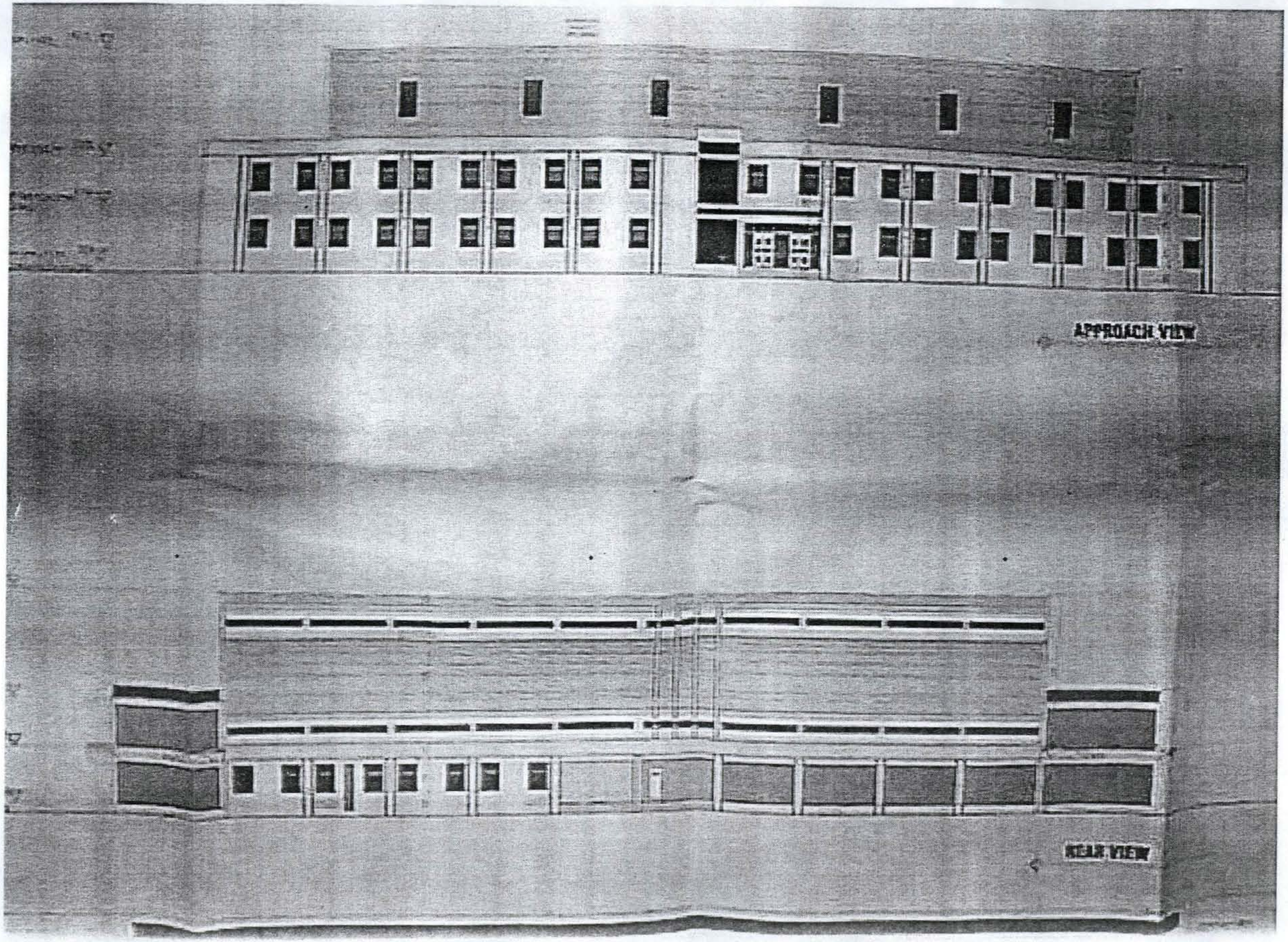

MEZZANINE FLOOR PLAN


SECTION Y-Y
PROPOSED
WITH A STUDY OF THE MAXIM REFABRICATING ARCHITECTURE



RIGHT HANDSIDE VIEW


APPROACH VIEW


APPROACH VIEW
REAR VIEW

2.4.0 Automation

The application of machines to tasks once performed by human beings or, increasingly, to tasks that would otherwise be impossible. Although the term mechanization is often used to refer to the simple replacement of human labour by machines, **automation** generally implies the integration of machines into a self-governing system. **Automation** has revolutionized those areas in which it has been introduced, and there is scarcely an aspect of modern life that has not been affected by it. The term is used widely in a manufacturing context, but it is also applied outside manufacturing in connection with a variety of systems in which there is a significant substitution of mechanical, electrical, or computerized action for human effort and intelligence. A professor of Industrial Engineering, Mikell (2008) defined Automation as;

> *"...a technology concerned with performing a process by means of programmed commands combined with automatic feedback control to ensure proper execution of the instructions. The resulting system is capable of operating without human intervention".*

The development of this technology has become increasingly dependent on the use of computers and computer-related technologies. Consequently, automated systems have become increasingly sophisticated and complex. Advanced systems represent a level of capability and performance that surpass in many ways the abilities of humans to accomplish the same activities. The advantages commonly attributed to automation include higher production rates and increased productivity, more efficient use of materials, better product quality, improved safety, and reduced factory spaces, and the main disadvantage often associated with automation is workers displacement. Others include the high capital expenditure required for the design and installation, and a higher maintenance and running cost; especially cost of power which has remain a faceless challenge to developing economies.

2.5.0 Conclusion

From the above study, factories used to be ordinary places of work for craftsmen until modern times (the 18^{th} century in that sense), when it became a much specialized system. The **production** or **assembly line** then became the core determinant of factory architecture; the building has to enhance the efficiency of the production line and must be flexible enough to sustain a change in product and or process. It has being deduced that the cost of maintaining and powering machines even with partial automation is quite high, therefore factories should be designed to be sustainable, that is they should be design with due consideration of prevailing economy and built with materials that shall require little maintenance, take advantage of passive and active solar design concepts, orientation and day lighting.

The study also revealed that factories should be designed to provide a descent work environment, and be sited near consumers, power source and of course where there is easy means of transportation. Modern cites often have industrial layouts with the necessary infrastructures and are best site for factories and it is best to site this proposed factory in the layout.

CHAPTER THREE

3.0.0 REFABRICATING ARCHITECTURE

3.1.0 Background

In 2001, the college of fellows of the American Institute of Architects (AIA) awarded Kieran Stephen and Timberlake James the inaugural Benjamin Latrobe Research Fellowship for a proposal that later became the book Refabricating Architecture. In a book review by Jordan (2008), the proponents made spirited efforts to convince the audience that the production of architecture (building) is presently insufficient and that one way out is the embrace of the concepts of refabricating Architecture. In their observation, materials, features and processes have remained the same; architecture still takes many years to design and build. In automobile, aerospace and ship construction, new materials and processes abound, fabrication time, cost and waste have reduced greatly and are at variance with quality. Everything has changed in these industries; mass production was the ideal of the early 20th century, mass customization has emerged reality of the 21st century, Kieran and Timberlake (2004). Today's mass customization is a hybrid because it combines the principles of customization and mass production; It proposes new processes to build using automated production, but with the ability to differentiate each artefact from those that are fabricated before and after which is customization. Some of the issues highlighted above; poor quality of work, waste of materials and time, and the high cost of construction are mostly associated with the conventional construction (site-erection) method or what is better termed the Traditional Design System (discussed later).

In the same vein, Merritt F.S. and Ricketts J.T. (2001) also are of the opinion that;

> *"sociological changes, new technology in industry and commerce, new building codes, other new laws and regulations, inflationary economies of nations, and advances in building technology places an ever-increasing burden on building designers constructors... the public continually demands more complex buildings than in the past. They most serve more purposes, last longer and require less maintenance and repair".*

To successfully meet these challenges, there has to be improvements in the production of architecture. Building Professionals must be more pragmatic in adoption of new technologies and learn how to apply them skilfully. One of such advances worthy of note is the adoption of operations research, also termed systems design to building design.

The **maxim refabricating architecture** posits that one way to improve the production of architecture; that is the process of designing and building, is to embrace the use of new technologies, new materials and prefabrication which are best employed in Industrialized Building System (IBS). That the process of production of architecture should change to embrace manufacturing methodologies similar to those found in automobile, aerospace and ship construction. A brief study of these fields shows that there is a high integration of information technology (**IT**) in their design and construction, parts are prefabricated in a section of the factory or in separate factories, and assembled on assembly line process. Mass production principles are fully utilized without hindering customization; mass customization therefore is a hybrid of mass production and customization principles.

In the previous chapter, mass production and ICT integrated production processes (automation) were studied. This chapter presents a theoretical argument for factory production of building components otherwise known as **Industrialized Building System (IBS)**, and the adoption of **System Design**. The research takes the Nigerian building industry as case study and it concentrates more on the most common building materials, concrete.

3.2.0 THE DESIGN SYSTEMS

Building design is a process of providing all information need for construction of buildings that meets client's requirement without compromising public health, welfare and safety requirements. This research identifies and discusses two (2) design systems, the basic traditional design system and systems design.

3.2.1 The Basic Traditional Design System

The system will be understood best, if itemized as follows;

- Client recognizes the need for a building, due to a dream, need or economic feasibility report.
- Engages a professional Architect and discuss the needs.

- The architect conceives a scheme (sometimes several schemes) that will meet the client needs, considering Economic and Statutory regulations. He presents what is called presentation drawings to the client to make a choice. If the client is not satisfied then he modifies the scheme(s) or conceives another until the client is satisfied. This marks the end of **stage 1** of architectural consultancy and design process.
- **Stage 2** begins with further development of the chosen design scheme, production of detail scaled drawings for (planning authorities) approval purposes, and specification for tendering purposes.
- At this stage the client either through the architect engages other professionals and the architect hands a copy of the design to these professional for their inputs. They make their inputs and produce drawings and bill of quantity (BOQ) in case of Quantity Surveyor. The detail Architectural drawings and all the drawings of the other professionals and the BOQ form part of the contract document in preparation for the tendering process. This marks the end of **stage 2** of the design process.
- The Tendering process, this involves the selection of a suitable contractor whose primary duty is to bring the design to reality using the information in the contract document.
- After selection of suitable contractor, who having fully mobilized to site, **stage 3** begins; The consultants supervises the construction by regular visits to site to

ensure that the contractor is complying with instructions and information in the contract document.

- Problems and or variations often arise on site that require these professionals to modify their designs, make more inputs and produce more details as construction progresses. This means the consultants continue to design until construction is completed to client's satisfaction. **Stage 3** finally rounds up with the handing-over ceremony or commissioning of the project.
- The entire system ends with the Architect issuing the final certificate of practical completion of work after making good defects, after the defects liability period.

This system recognises the following persons and professionals:

1. The Client
2. Consultants
    - ✓ Architect
    - ✓ Structural Engineer
    - ✓ Mechanical Engineer
    - ✓ Electrical Engineer
    - ✓ Builder
    - ✓ Quantity Surveyor
    - ✓ Other (specialist) consultants (Acoustic, Landscape, Golf, Tourism)
3. Contractors and Suppliers

It is obvious at this stage to note that the system does not recognise a design team. Often decision to prefabricate major components of the design is taken by the contractor or his project manager either for necessity or to save time; if such a design have complex forms, it becomes difficult since the designer never considered this possibility. This leads to variation, redesign and change in contract sum. Under normal supervision, the consultants are obliged to visit the site only once a month giving the contractor, who is so profit conscious, the opportunity reduce the design mix thereby compromising design standard. Also, it is difficult for building inspectors to go to all corners of the street where construction work may be taking place, to check standards. This result to poor standard of construction and is responsible for the rampant cases of building collapse in Nigeria. This is the main short coming of the basic traditional design system over systems design.

3.2.2 Systems Design

In the past, design of building was mainly an imitation of the design of an existing building and little innovative additions. It was not until the advent of modern architecture that this trend changed, and has continued to change. Though it can be argued that modern architecture was at cross-purpose with creativity, since it rejected ornamentation, over emphasised rationality of materials and simplicity of form. This may have being as a result of extreme adherence to the traditional design system. Systems Design on the other hand, encourages creativity and gives room for Radical Architecture. It was developed around the mid-twentieth century, initially applied to design of machines and electronic equipments. Towards the end of the century, some post modernist began to incorporate some aspect of it in their design.

The term systems design is used to define a method of design in which the main goal is to achieve an integrated planning of structural, mechanical, electrical and architectural systems. A full application of the system also includes programming, manufacturing, scheduling, financing and management of methods of a mechanized production of building.

According to Aguilar (2001);

> *System Design is the application of scientific method to selection and assembly of components or subsystems to form the optimum system to attain specified goals and objectives while subject to constraints and restrictions.*

The scientific method here refers to operational research which shall be discussed in terms of goal, objectives, analysis, synthesis (modelling), appraisal and feedback.

1. **Goals:** goals in this respect are answers to this questions,

   What does the client actually want to accomplish?

2. **Objectives:** these are the conditions that exist or will exist during construction that are beyond the designer's control, but must be considered.

What requirements for the building or conditions affecting system performance does design control (constraints, code & standards)?

What performance requirements, time and cost criteria can the client and designers use to appraise system performance?

Like any other research, data collection and analysis are vital part of operational research. Data collection starts at the inception of the design and is continuous throughout the design, while analysis is simply critiquing for the next stage of the system design process. As a result, these are not listed amongst the basic steps.

3. **Synthesis:** the designers must conceive at least one system that satisfies both the objectives and constraints, and an alternative that has the potential of achieving optimum result. For this, they rely on their past experience, knowledge, intuition, and creative skills and on advice from consultants, including value engineers, construction experts, and experienced operators of the type of facilities to be designed.

4. **Models**: the design team should represent the system(s) or design by a model that will simulate it or part of it, to enable them study the system and evaluate its performance. The model should be simple, consistent with the role for which it is selected, for practical reasons. The cost of formulating and using the model should be negligible compared with the cost of assembling and testing the actual system. Cost model for instance, is done by the value engineer's study the initial cost and running cost of a system, say use of solar energy, over a period of time.

Models can be classified into;

Iconic – physical replica of the actual design or system

Symbolic – these include flowcharts whose input and output enables mathematical analysis e.g. cost models.

Analogue – these are real systems but with physical properties different from those of the actual system. Examples include dial watches for measuring time, thermometers for measuring heat changes.

5. **Appraisal:** at his stage of systems design, the designers should evaluate the results obtained in step 4 above, modelling the system and applying the model. The designers should verify that construction and life-cycle costs will be acceptable to the client and that the proposed system satisfies all objectives and constraints, otherwise the next step Feedback apply.
6. **Feedback:** During the preceding steps, value analysis (prospects of a system) may have been applied to parts of the design. In step 6 of the *fig 3.1 below*, however, value analysis should be applied to the whole building system. This process may result in changes only to parts of the system, producing a new system, or several alternatives to the original design may be proposed. In steps 7 and 8, therefore, the new systems, or at least those with good prospects, should be modelled and evaluated. During and after this process, completely different alternatives may be conceived. As a result, steps 4 through 8 may be repeated for the new concepts. Finally, in step 9, the best of the systems studied should emerge as the design.

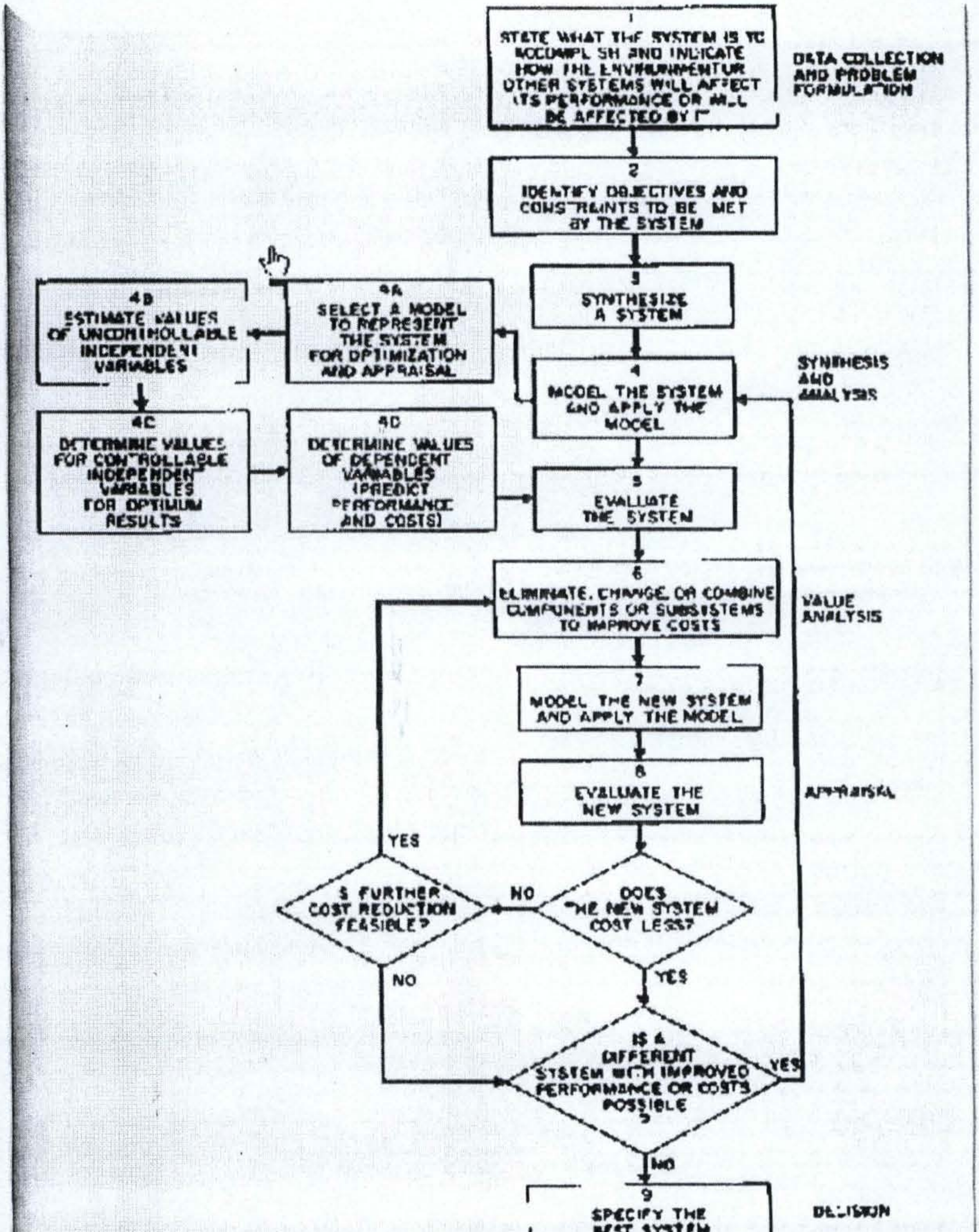


Figure 3.1: Basic steps in systems design in addition to collection of necessary information.

Source: Excerpt from Building Design and Construction Handbook (6^{th} ed.), p 1.31.

3.3.0 Industrialized Building System (IBS)

A polemic study of systems design above shows that, a full application of it includes selection and management of a mechanized process of production of building; these mechanized processes are best achieved under factory conditions. Factory production of building systems or components is otherwise term Industrialized Building System (IBS).

Industrialized Building Systems (IBS) has been identified as a potential solution to improve overall performance of construction industry like quality, cost effectiveness, safety, waste reduction and productivity. Whereas the advantages are very plausible, the idealism of industrialised construction is far from being practical. In reality, the majority of contractors and builders are not keen to IBS due to cost and risk issues, negative perception, legislation and regulation, lack of personnel to perform specialised skill and limited IT adoption. In fact, the use of IBS requires tremendous efforts in changing existing construction practices and in training the personnel to acquire specialized skills in **IBS** enhancing design, production, assembly and coordination of components. It leaves the buildings professionals with noticeable difficulties and often fails to reinvent their current roles to suit IBS project.

3.3.1. Background

The construction industry and particularly construction companies, is typified by the fact that its business mainly run through projects. One of the claims is that construction is inherited differently from other industries in that its factory moves around and hardly ever develops the same product twice. IBS is defined as a construction technique in which components are manufactured in a controlled environment (on or off site), transported, positioned and assembled into a structure with minimal additional site works *(fig.3.2)*. It is classified as a project that use one or a combination of the following systems; pre-cast concrete frame building, pre-cast wall system, reinforce concrete building with pre-cast concrete slab, steel formwork system and steel frame building and roof trusses system.

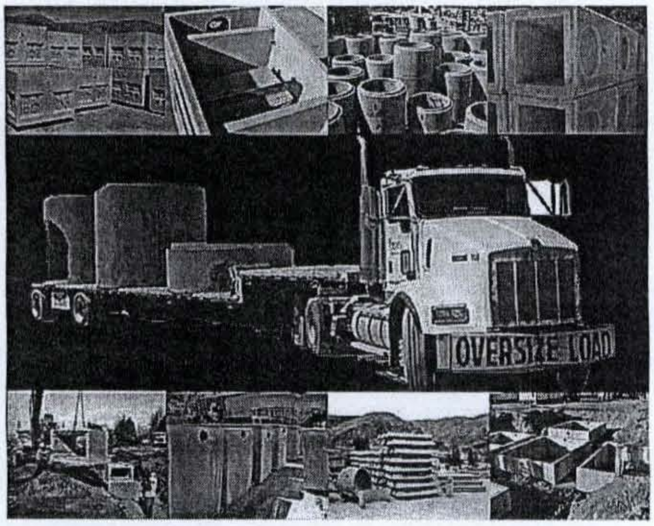


Fig 3.2: Industrial manufacture, transportation and assembly of components.
Source: Author's graphic archive.

The construction industry constitutes an important element of Nigerian economy. The industry is critical to the national wealth creation as it acts as a catalyst for and has multiplier effects to the economy as it engages other industries namely manufacturing, professional services, financial services, education and others. The construction industry also provides job opportunities for a large percentage of the urban population. Nevertheless, the state of the local construction industry is not in line with the concepts of sustainability, because the construction industry in Nigeria has always been associated with insufficient level of quality, pollution and excessive reliance on skilled and unskilled foreign workers. The embrace of Industrialized Building System (IBS) components as a part of construction process shall bring about three major achievements;

1. to promote systematic construction process that put quality, safety and environment issues into account
2. to reduce the dependency on foreign workers and
3. to reduce the overall cost of construction project and improve value for money.

For constructors, proper planning, procurement and co-ordination throughout IBS project cycle will give positive outcome in term of reducing construction time and labour cost. Despite all the plausible advantages and the availability of skilled personnel, the industry is still reluctant in the use of IBS. This problem is due to lack of confidence, lack of detailed information to convince the construction sector. Low standard, simple taste and over-emphasis on cost-reduction are perceived cause of the problem. Although the members of the industry are open to the idea, a major portion of the industry's stakeholders have been made; by foreign contractors and multi-nationals, to believe that IBS is more expensive than the conventional method, perhaps this is just a marketing strategy. In the same vein, Alshawi M. and Zuhairi A.H. (2003) observed that the barriers to IBS adoption in construction industries are as follows;

- Mindset problem towards achieving acceptance by the construction community,
- The cost of using IBS exceed the conventional method of construction given the ease of securing cheap available labour,
- IBS design concept is not being taken into consideration at the onset of the project,
- Designers will not design using components as they not find the components in the market,
- whilst producers will not produce components as they do not see design using components,
- Lukewarm acceptance of IBS among designers and developers especially from private sectors.
- Lack of best practice sharing and showcasing is a main reason the practitioners are reluctant to change their mindset.

As one of the effort to encourage the adoption of IBS in Nigeria construction industry, more scholars should be encouraged to do more into this area so as to provide the needed information to convince the industry.

3.3.2. IBS Classification

The types of Industrialized Building System (IBS) according to Construction Industry Development Board Malaysia, (CIDB, 2003) as reported by Alshawi M. and Zuhairi A.H. (2003):

1) Pre-cast concrete framed building

The pre-cast concrete framed is one of the most popular forms of industrialized building system. The framed building consists of slab, beam and column component that are fabricated or manufactured off-site using machine and formwork. The advantage of the system is high degree of flexibility in term of larger clear distance between columns, as a result longer span give bigger open space and greater freedom of designing floor areas.

2) Pre-cast concrete wall system

This system consist a structural framework of the building composed of pre-cast slab and load bearing wall. The load–bearing walls and slabs are manufactured off-site and transferred at site to be erected. The system is preferred in simple and uncomplicated with a lesser degree of flexibility whereas the removal of load bearing wall are restricted during the service life. With careful design and good coordination between **erectors and designers**, the erection process can be very fast with the number of wet trade on site can be reduced significantly.

3) Reinforced concrete Building with Pre-cast concrete slab

This system is also known as **hybrid construction** as it integrates pre-cast concrete and cast in-situ concrete. It consist a combination of cast in-situ frames with pre-cast concrete hollow core slab or pre-cast planks. It become so popular by the builders because of the benefit of speed and high quality of pre-cast concrete slabs are combined with the benefit of economy, flexibility, monolithic property and structural stability of cast-in situ concrete frame eventually gives a practical and efficient buildings.

4) Steel Formwork System

This system categorized as an IBS because the process of construction is carried out using a systematic and mechanized method that is by using reusable steel formwork panels. The system allows the rapid on-site placement of cast in-situ concrete to form beams, columns, slabs and walls. The system is better preferred for the construction of walls instead of column and beam due to many repetitive of similar wall components in wall frame buildings. Steel formwork components are normally available in standard panel sizes and stiffened using built in stiffeners or tie rods to resist lateral concrete pressure during concreting. It offers faster speed of erection, comparatively lower cost and simplicity in equipment. It also provides good accuracy and smooth internal finishing that eliminate the need of plastering.

5) Steel-framed building and Roof Trusses

Steel, a strong and stiff material is suitable for the construction and for preparing frame building with architectural detailing with high flexibility in providing long-spanning structure. It normally used in multi story frames for tall and slander building and also for roof construction. The advantages of using steel frame system are build-ability and simplicity of construction as well as greater construction speed.

3.3.3. Benefit of IBS to the construction industry

Adopting Industrialized Building System and other pre-fabricated technique has the following benefits to the practitioner when compared to the conventional construction method as outlined by Thanoon, (2003) as reported by Alshawi M. and Zuhairi A.H. (2003):

a) The repetitive use of system formwork made up steel, aluminium, etc and scaffolding provides considerable cost savings

b) Construction operation is not affected by adverse weather condition, because prefabricated components is done in a factory controlled environment

c) Prefabrication takes place at centralized factory, thus reducing labour requirement at site. This is true especially when high degree of mechanization involved

d) An industrialized building system allows for faster construction time because casting of pre-cast element at factory and foundation work at site can occur simultaneously. This provides earlier occupation of the building, thus reducing payment or capital outlays

e) An industrialized building system allows flexibility in architectural design in order to minimize the monotony of repetitive facades

f) An industrialized building system provides flexibility in the design of pre-cast element as well as in construction se that different system may produce their own unique prefabrication construction methods

g) An industrialized building system components produces higher quality components attainable through careful selection of material, use of advanced technology and strict quality assurance control

3.3.4. Open System and the Closed System

A closed system is mainly, production based on specific client's design while production based on pre-caster's design, is referred to the open system. The first category is designed to meet a spatial requirement of the client's that is the spaces required for various functions in the building as well as the specific architectural design. In this instance, the client's needs are paramount and the pre-caster is always forced to produce a specific component for a building based on design specification. On the other hand, the production based on pre-caster's design includes designing and producing common assortments of component for uniform type of buildings, this fosters mass production especially if there is sufficient demand for a typical type of building such as school. Nevertheless this type of building arrangement can be justified economically only when the architectural design observes large repetitive element and standardization. In respect to this, an ingenious prefabrication system can overcome the requirement of many standardized elements by automating the design and production process, as shown in *fig. 3.3*

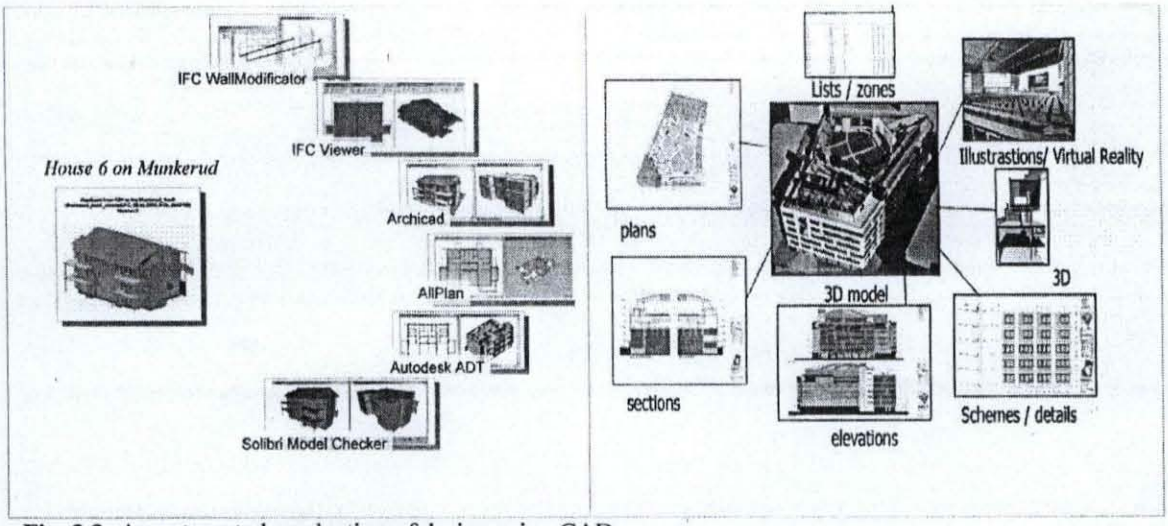


Fig. 3.3: An automated production of design using CAD

Source: Author's graphic archive.

The beauty of the system is to allow openness in its structure or component suppliers where everybody can bid to produce at lower price. In addition, the pre-caster and erectors will look for cooperation models that will create benefit for both. The open system also provides a high degree of design flexibility but required a maximum coordination between the designer and pre-caster (*ibid*). And it also allows the pre-caster to produce a limited number of elements with pre-determined range of product and at the same time maintaining architectural aesthetic value.

3.4.0. CASE STUDIES

Having studied the maxim refabricating architecture and with the aim of this research in mind, the paragraphs below present deductions from case studies, and feasibility report of site which gradually lead to the design.

Case study as a research activity falls under the descriptive survey method as described in *section 1.3.0.* on page 3. In Architecture, it involves the physical observation of existing similar structure. Case study is aimed at giving the researcher a chance to come to terms with the shortcomings of existing structure, and to appreciate where necessary. This vital activity provides information that enhances future proposals.

Despite its importance and usefulness in research, case study has its limitation. The major limitation experienced by the researcher using this method of research bothers on security, cost and administrative/bureaucratic hindrances. This tends to limit the amount of data obtained and its authenticity. For this study, the following existing factories were visited for the purpose of carrying out studies on them:-

1. Sambest Juice Factory, Zaria road Kaduna, Kaduna State.
2. Belphins Nig. Ltd, Mandakiya road kafanchan, Kaduna State.
3. Mai Dabino Juice and Products Industries, Usman Nagogo road Katsina, Katsina State.

These case studies shall be discussed on the bases of their relevance to the researcher area of emphasis discussed in chapter three.

3.4.1 Case Study One: Sambest Juice Factory Zaria road Kaduna, Kaduna State.

Sambest Juice Factory is a division of Sambawa farms owned by Alhaji (Dr) I.I. Sambawa, one time Minister of Agriculture. The farm is located along Kaduna-Zaria road, 30km from Kaduna. Preparation for the Juice processing section started in 2000AD. Before the end of that year, machines were imported from India at the cost of N350 million and production started in 2006 with a capacity of 12000 Cartons per day. Seven (7) flavours are produced from the following fruits: orange, mango, banana, passion, guava, pineapple, and cashew. These are gotten mostly from (Sambawa) feeder farm.

3.4.2 Facilities Available.

- 1no. Production hall
- One Ware house
- Cold room
- Administrative Building
- Generator house
- Steam heater
- Water fountain
- Water source (borehole)

3.4.3. Relevance to Study Area.

The production hall was built purposely for juice processing with;

- Long span aluminium roofing sheets (insulated on the inside), for both roof and wall cladding.
- And prefabricated steel sections as structural member.
- The floor is finished with white colour ceramic tiles.

Basically the structure is made of light weight material prefabricated (*fig.3.5, fig. 3.6 & fig.3.7*) and assembled on site. Structural details show that the structure can easily be demounted and re-assemble when necessary, which is one of the many advantages of prefab architecture.

3.4.4. The Layout.

The layout planning is quite loose but functional, as you enter through gate you are ushered into an open space (forecourt), on you left is the administrative building and the warehouse. The production hall is directly opposite the warehouse and between is the cold room. *Figure 3.4* below shows that the layout generally takes a horse-shoe formation.

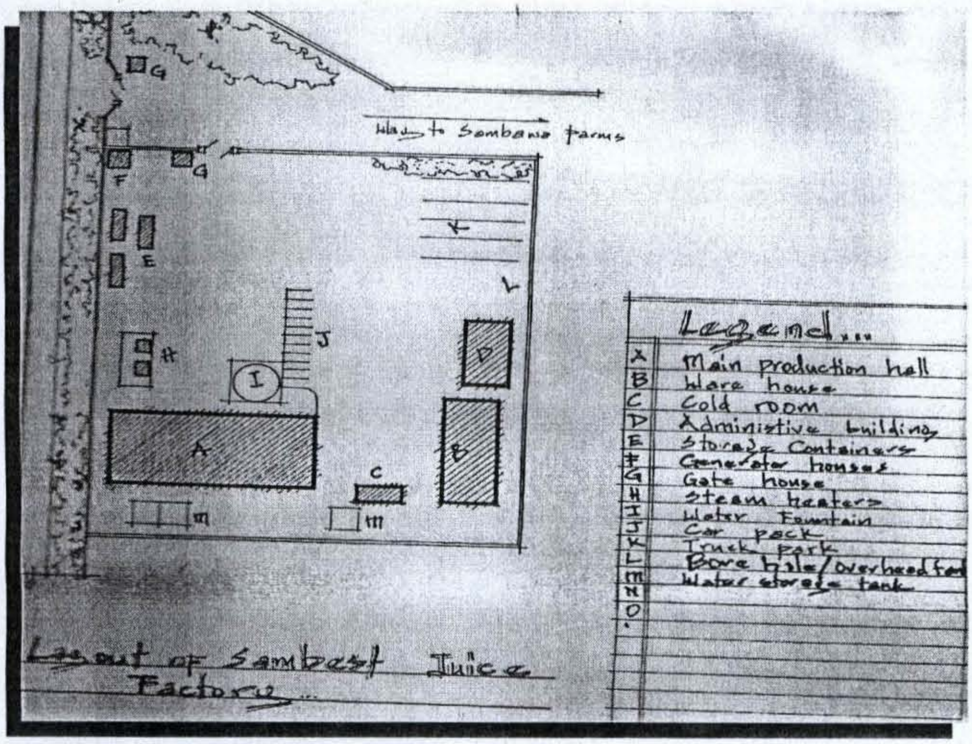


Figure 3.4; Sketch of the Layout

Source; Author's Fieldwork, 2008

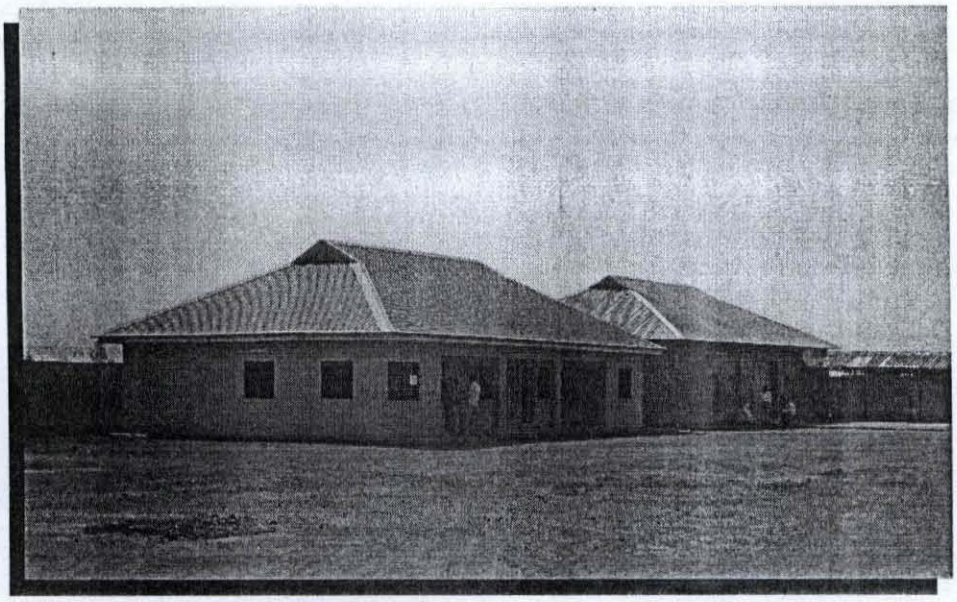


Figure 3.5; Picture showing the Administrative building Ware house

Source; Author's Fieldwork, 2008

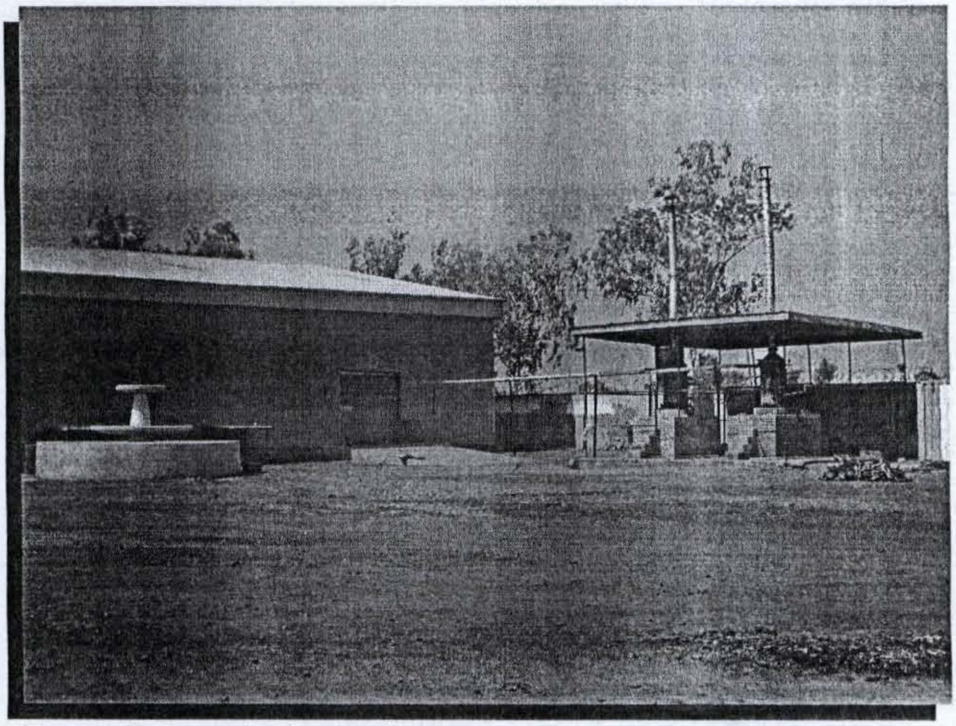


Figure 3.6; Picture showing the Production hall, Steam heater and fountain

Source; Author's Fieldwork, 2008

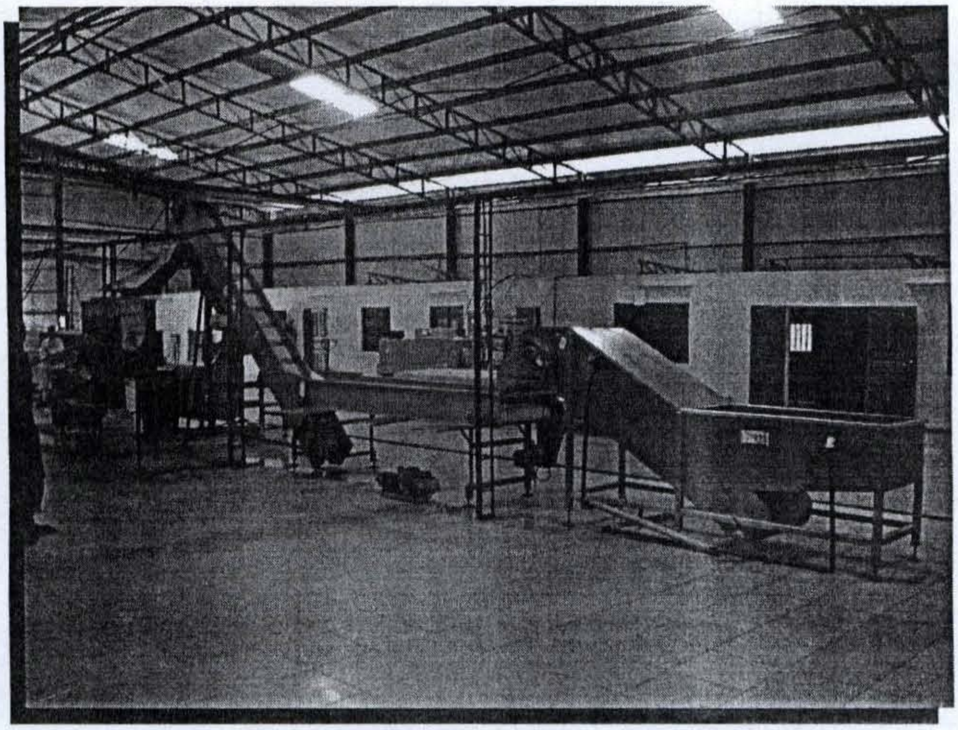


Figure 3.7; Picture showing structural materials in the production hall
Source; Author's Fieldwork, 2008

3.4.5. Case Study Two: Mai Dabino Juice and Products Industry Katsina, Katsina State. The factory is owned by Alhaji Mai Dabino, a Katsina based businessman. The factory had been into ice cream, yoghurt and table water production since inception, juice production only started in 2001. The factory do not have a feeder farm, they buy concentrates from other factories. The buildings are rigid and are built from the conventional construction method making it very difficult for expansion; therefore for every new product, a new and separate building has to be erected. The main building materials used includes sandcrete block walls, concrete, steel and glass (*fig.3.9 & fig.3.10*). Their products include Juice, Yoghurt, Ice cream and Table water.

3.4.6. Facilities Available.

- Production hall for Juice and Yoghurt
- Production hall for Ice cream
- Production hall for Table water
- Administrative Building
- Quality Control Unit
- Cold room
- Generator/Workshop

3.4.7. Relevance to Study Area.

The factory has three production halls because the initial one became obsolete when new products (Ice cream & Table water) were introduced. The main production hall where juice and yoghurt is produced was not designed and constructed with room for future expansion. Even the steel roof was welded in-situ to the steel columns *(fig. 3.9)*. This is one example of the many demerits of conventional construction method.

3.4.8. The Layout.

The layout planning is quite loose but functional. *Figure 3.8* below is a sketch of the site layout.

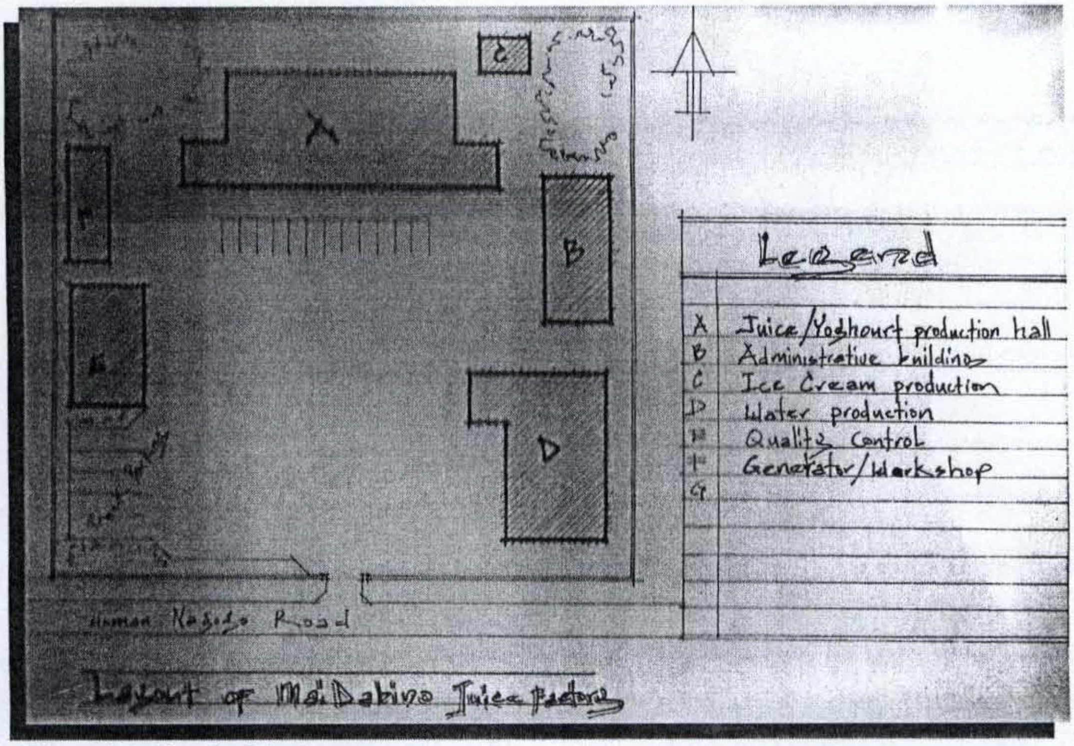


Figure 3.8; Sketch of the Layout

Source; Author's Fieldwork, 2008

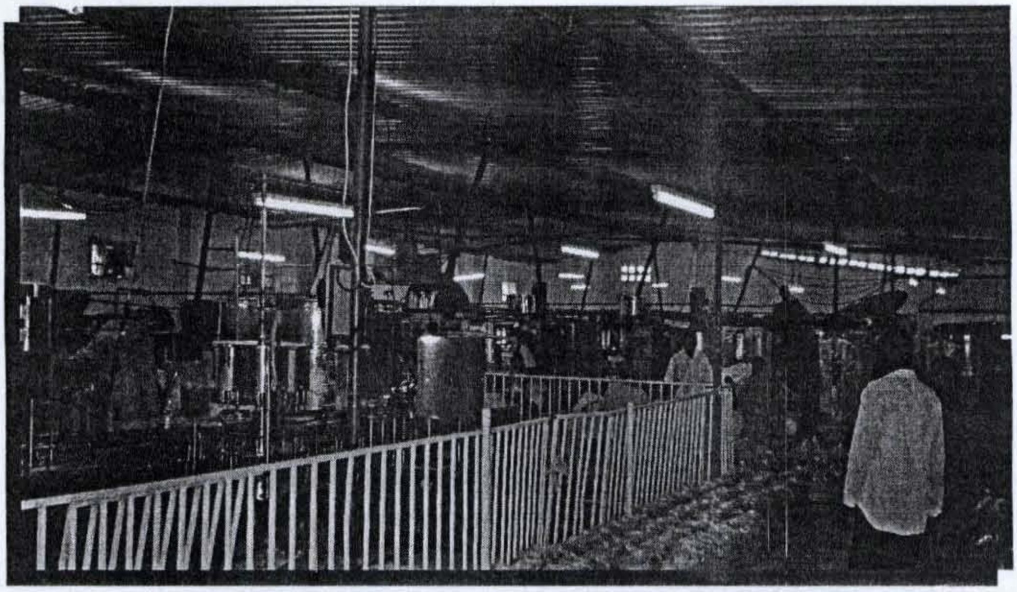


Figure 3.9; Picture showing interior view of Table water production hall

Source; Author's Fieldwork, 2008

Figure 3.10; Picture showing the Table water production hall

Source; Author's Fieldwork, 2008

3.4.9. Case Study Three: Belphins Nig. Ltd., Mandakiya road Kafanchan, Kaduna State. The factory is built with sandcrete block walls with the conventional construction method.

3.4.10. Facilities Available.

- Production hall
- Administrative Building
- Staff rest room
- Mechanical unit/Ware house
- Under-ground reservoir
- Ethanol tank
- Gate house

3.4.11. Relevance to Study Area.

The factory buildings are built with the conventional construction method.

3.4.12. The Layout.

The layout planning is quite loose but functional. *Figure3.11 below* is a sketch of the site layout.

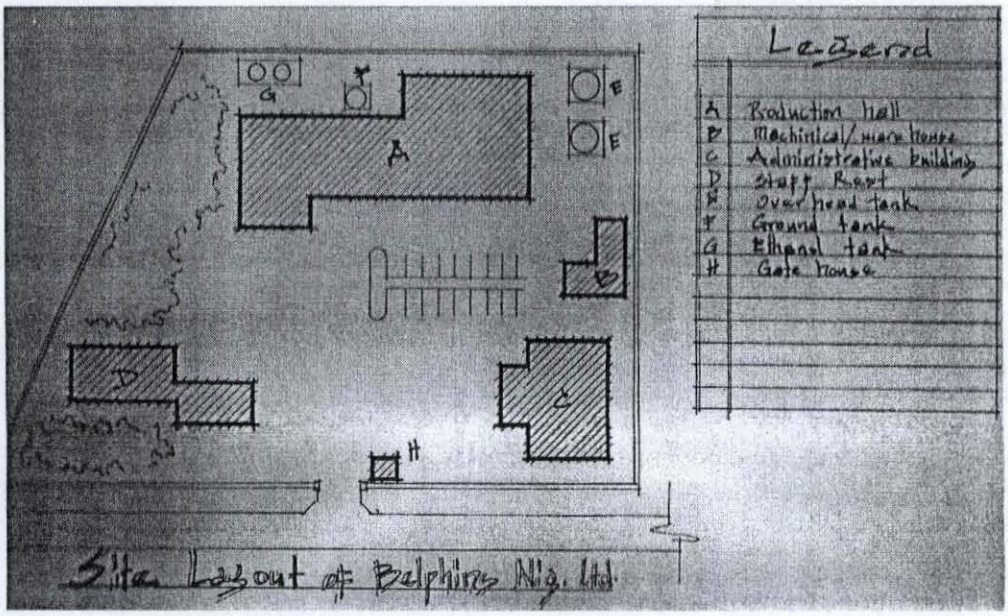


Figure3.11; Sketch of the Layout

Source; Author's Fieldwork, 2008

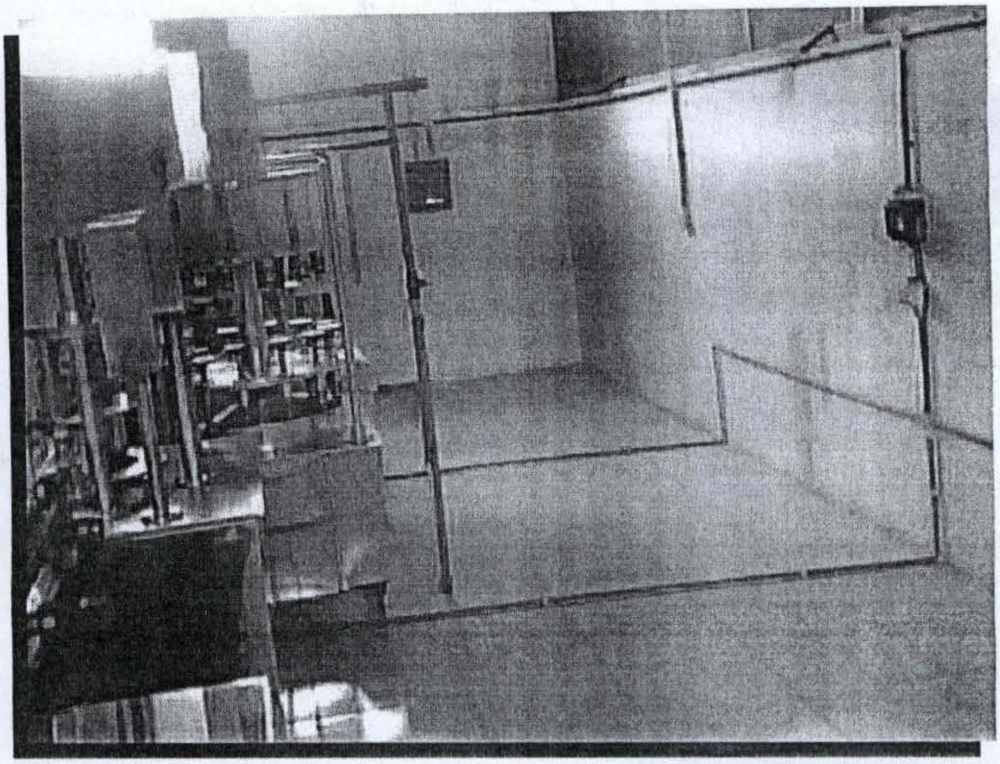


Figure 3.12; Picture showing placement of services pipes and cables in the production hall.

Source; Author's Fieldwork, 2008

Figure 3.13; Picture showing exterior view of production hall

Source; Author's Fieldwork, 2008

3.5.0 DATA COLLECTION

The project is proposed to be located in Makurdi, the Benue State Capital. Benue state was created on February 3, 1976. It derived its name from the River Benue, which is the most prominent geographical feature in the state. The state lies in the middle of the country, in the region referred to as the Middle Belt or North Central geographical zone. It shares boundary with five states; Nassarawa to the north, Taraba to the East, Kogi to the west, Cross River and Enugu to the south. It also shares a short international boundary with the Republic of Cameroon along its south eastern boundary.

Makurdi the state capital doubles as also the local Government Headquarters of Makurdi Local Government Area. It is located within the ethnic territory of the Tiv people. Situated by the Banks of the River Benue, a major part of the city is on the south bank of the River. It was founded in 1927. The city has developed into an important commercial and transport centre after the construction of the railway bridge in 1932 and later a road bridge.

3.5.1. Climatic Conditions

The state lies between latitude $6^0 25^1$ and $8^0 81^1$N and longitude $7^0 47^1$ and $10^0 00^1$E it has a sub-humid climate with two distinct seasons. The wet season which lasts for seven months starts from April to October and the dry season begins from November to March. The annual rainfall range is between 150–180mm.Temperature fluctuates between 23^0C and 31 ^{0}C within the year. The day time temperatures are high.

3.5.2. Soil

The soil is mainly tropical ferruginous soils with hydromorphic soils along the flood plains. Deep seated laterite crust occurs over extensive areas on the plains. The soil generally has good bearing capacity that can accommodate any building.

3.5.3. Relief and Drainage

River Benue is the dominant geographical feature of the state and major drainage especially for Makurdi which is located by its banks. Other drainages are the River Katsina-ala which is its largest tributary while smaller Rivers include Loko, Itobi, Aya, Amile, Dura. Konshisha, Ogede and Ombi. The surface drainage is good except at the flood plains which are characterized by extensive swamps.

3.5.4. Vegetation

The area lies within the southern Guinea Savannah which consists mainly of tall grasslands with scattered trees, mostly economic trees such as Mangoes, Oranges, Locust bean, Shea Butter.

In the southern part of the state, the vegetation is mainly oil palm bush. Dense forests are few, and typical rain forest trees such as mahogany, *obeche, iroko* occur and are used as timber.

3.5.5. Socio-Cultural Life

Benue state has three major ethnic groups; the Tivs, the Idomas and the Igedes; the Tivs form the majority in the state. These ethnic groups posses a rich and diverse cultural heritage which finds expression in the colour of clothes, exotic masquerades, sophisticated music and dance. Traditional dances from the state have won recognition at national and international cultural festivals.

Makurdi to a largely multicultural city, apart from state indigenes who make up the majority, other ethnic groups such as the Hausas, Igbos, Jukuns have settled there, these form the majority among settlers though other ethnic nationality are also present.

3.5.6. Economy and Commerce

Agriculture forms the backbone of the state's economy, engaging 70% of the working population, so much so that it is acclaimed **"The Food Basket of the Nigeria"**. Agricultural products produced in large quantities include sesame seeds, yams, rice, cassava, millet, maize, millet, sorghum, groundnuts, soya beans, goats, pigs, and also fruits such as oranges, mangoes, cashews, bananas pineapples, pawpaw and pears. And this is the reason for the proposed establishment of a fruits processing factory.

The state accounts for 70% of Nigeria's soya beans production and the largest producer of Cassava. The state has large deposits of limestone which has lead to the establishment of Benue Cement Factory in the early 1980s and construction is presently on for two more Cement factories in the state. Other minerals available in commercial quantities are gypsum, clay, coal, calcite gemstone, and salt.

Makurdi is an important trade and transport centre because of the two bridges that link the northern and eastern parts of the country. It is also an important educational centre with the presence of a federal university of agriculture, the state university and school of nursing. It is the most important commercial centre in the state with most banks and companies having offices there. It also has a 2,500 shop ultra modern market. Its political status as capital makes it home for all state ministries and, and some federal parastatals too.

The city is in the process of becoming an important industrial centre with the provision of necessary infrastructure to aid production and consequently high rate of development of its industrial layout, in addition to the long existing industries; the Benue brewery and an Agro-milling industry.

3.5.7. Demographic Data

Though Benue state lies in the middle region which is generally regarded as a low population area, it has more than the national average population density.

3.5.8. Transportation

The state is accessible by land, air and water. Makurdi is a major transportation centre with an airport and railway station and during the rainy season a river port, which makes distribution of finished products easy, thus the best location for a factory of the nature.

3.6.0. DATA ANALYSIS

The data above is analysed in brevity by interpreting and relating it to the proposed project site. Site analysis is usually conducted by designer, engineers and the other relevant specialists so as to ascertain existing natural conditions above, on and below the natural ground level of the site. Site analysis will consider in detail climatic conditions such as temperature, humidity, winds, rainfall and accessibility, sunlight, topography, vegetation, sources of noise soil and geology, slope and drainage.

3.6.1. Criteria for Site Selection

The proposed factory will be sited in the industrial layout because relevant facilities like developed road network, water supply and an electric power substation already exist in the layout, and it is the area approved for such projects by the planning authorities.

3.6.2. Location of Site

The industrial layout is located on the south part of Makurdi town which is on the south bank of the River Benue, along Naka Road. The site is located behind the electric power substation.

3.6.3. Site Inventory

The site is 50,826m^2 and is a swamp covered basically with shrubs, wild bushes without any man-made features and it used to be a rice farmland.

3.6.4. Site Topography and Vegetation

The site slopes towards the north from the major road. There is a 0.0167 drop in gradient after every 1m moved inward from southern boundary. The site does not have any serious vegetative cover, but for the shrubs and wild bushes.

3.6.5. Utilities and Access

There is water mean round the layout, electricity and communication facilities on site. There is an electric power substation to step-up power for the heavy plant used in factories. The layout has a network of well developed roads and the proposed site can be accessed from two adjoining roads.

CHAPTER FOUR

4.0.0 DESIGN REPORT

4.1.0 Introduction

The proposed Fruits Processing Factory Makurdi was born out of the socio-economic factors discussed in chapter one.

4.2.0 The Brief

The proposal does not have a particular client but is intended to convince any prospective investor, the Government of Benue State and or the Federal Ministry of Agriculture. The brief therefore is based on these **needs** and **wants** (*Table 4.1*) of the factory operators and an average cost of existing medium scale factories.

Table 4.1 Client's Needs and Wants

NEEDS (Requirements)	WANTS (Desired)
1. Production hall	1. Sick bay/Clinic
2. Raw materials warehouse	2. Water treatment plant
3. Finished product warehouse	3. Power plant
4. Administrative section	4. Waste management plant
5. Engineering/Maintenance workshop	
6. Security section	
7. Checking & weighing unit	

4.2.1. Goals and Objectives

Goals and Objectives with respect to system design have been discussed in *section 3.2.2* of chapter three. The Goal of this design is;

To design a contemporary factory that can be constructed quickly using commonly available materials and techniques that enhances high standard, so as to reduce maintenance cost to the bearable minimum. The change must be capable of accommodating a change in work-flow and production plants.

Objectives;

- The factory must be sited in the Industrial layout in Makurdi, Benue State.
- The design should be easy to build, flexible for future expansion and should be capable of accommodating a change in product.
- Well planed circulation pattern for both product and pedestrian traffic with parking.
- The building must be oriented such that the sun path runs across the width to achieve minimum solar heating.
- Keep total cost of project within One Billion naira limit
- The design should be such that its components can be prefabricated for speedy construction and for an improved standard of

construction, which shall consequently lower the building's maintenance cost.

- The design must provide all the **needs** and possibly all the **wants** outlined in *table 4.1* above.

4.2.2 User Space Analysis

The table below describes space elements in terms of size and relationship with other areas.

Table 4.2 User Space Analysis

Space Element	User	Size	Relationship
Production hall	Factory worker	1806 m^2	Access from both warehouses
Admin Section	Admin. Staffs	555 m^2	Visible from entrance, Access from car park
Laboratories	Quality-control staffs	104 m^2	Accessible from the production hall
Raw material ware house	Statisticians, Loaders	540 m^2	
Fin. Product warehouse	Statisticians, Loaders	1620 m^2	
maintenance section	Engineers, Technicians	1750 m^2	Accessible
Parking for car	Staffs, Guest	52 car cap.	Visible from the main gate, and close to the Admin. section

4.3.0. Design Concept

Traditionally, Architectural concepts have been the designer's way of responding to the design situation in any project. It has been the means for translating the nonphysical problem statement into the physical building product. Every project has within it what might be described as prime organizers, central themes, critical issues or problem essences. All these exist within the project situation or within the designer's perception; creating concepts for dealing with them architecturally, and this is the designer's primary duty.

The designers concepts are sometimes called "the big idea", "basic framework", or "primary organizer". When the concept or *"the big idea"* is a physical object, the creative process of converting this object form to building form is called **conceptualization**. This analogical object could be from natural forms, plant, life, animals, or inanimate objects. It could also be taken from man-made objects or even some of the basic shapes of geometry. The big idea could sometimes be a theoretical principle that guides the designer in the evolution of the building, which is also a very creative process.

In view of the aforementioned, the concept was evolved as a way of responding to the unique situation which the project tends to portray. The design was conceived from the theoretical concept **"Form follow Function"** and the idea of **"Machine Aesthetics"** which is the doctrine that that postulates that the form of a building should be determined by practical considerations such as use, material, and structure, as distinct from the attitude that plan and structure must conform to a preconceived picture in the designer's mind, and that the aesthetic of the structure should be based on how well it satisfies its functional requirement. This concept,

Form follow Function was the popular dictum of Luis Sullivan one of the pioneers of modern architecture, but it was later interpreted as the open plan system where spaces can be free to accommodate multiple interior arrangements.

Considering the limited site area, the designer thought it wise to bring the drama of production to the administrative staffs by attaching the administrative section to the production hall. This also eliminate the old **"Slave-and-master"** system where the administrative staffs are isolated and are completely ignorant of what of what goes on in the production section, and consequently take highly un-informed decisions on issues concerning production and the production workers.

Considering the goal and objectives of this design, the production hall and the other buildings are designed with open plans for the flexibility of different workflow patterns. Most horizontal elements are made of rectilinear forms, while the roof structure will be a barrel vault of tubular steel space frame, for ease of construction (which is one of our design objectives). The columns and beams shall be analyzed and designed for the worst case scenario. The Administrative section provides for an estimated 74 staffs on a suspended floor over the laboratories and water treatment unit.

4.4.0. Design Considerations

Certain criteria are outlined within the context of physical Architecture so as to enhance the buildings functional qualities. Physical architecture has been mostly related to the form, which the architect incorporates into his design. The choice of a particular form is arbitrary after due consideration of certain facts often called the determinants of forms, these determinants are as follows:

A. Function

The functional aspects of a factory are defined by how best its spaces and space arrangement foster production. A 21st century factory's functional requirement must include *flexibility of spaces,* which is a phrase describing the open-plan system or the clear (un-interrupted) floor that will accommodate a change assembly line and or a change in production machines. This requirement has been discussed in detail in chapter two.

B. Circulation

The circulation pattern in factory architecture is usually two-fold. Firstly, the movement of factory products from raw materials storage point to finish products storage. Secondly, the circulation of factory workers and guests round the factory. From the polemic analysis of data collated from the case studies discussed in *section 3.4.0* chapter three, *fig. 4.1* below presents a functional flow chart.

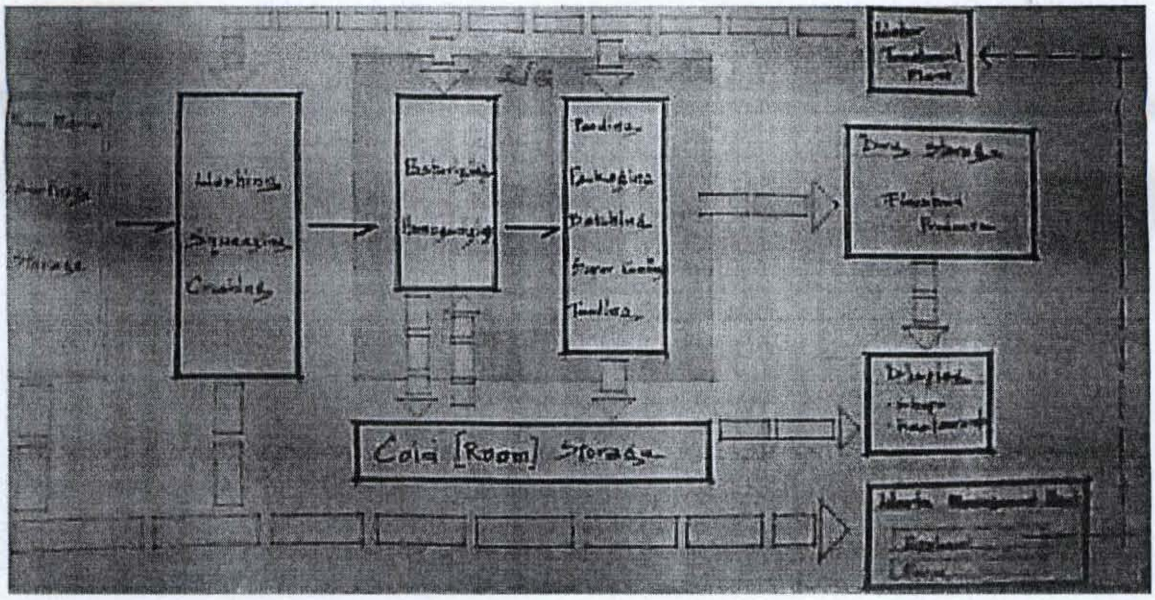


Figure 4.1; Production functional flow chart

Source; Deduced from researcher's case studies & research findings

C. Structure

The structural framework of the building follows an arrangement of four non-similar cuboids for plans and two sections of asymmetric cylinders for the roof. The cuboids are arranged with node in a modular system to enhance space planning and ease location structural components as well as the entire structural design.

D. Landscaping

The most appropriate approach to landscaping would be the use greens wherever possible to prevent heat-gain into the building and enhance heat-loss, and to cool the entire environment (ground) by planting climbers over all the un-used grounds.

E. Aesthetics

The designer employed the concept of "*machine aesthetics*" as discussed earlier; with the aesthetics of the structure based on how well it satisfies the functional requirement above. In view of this and considering our goals and objectives, the design provided for a linear assembly line process and an open plan which is one of the rudiments of sustainable architecture.

F. Fire Hazards

The extent of automation determines the kind of fire safety device to be used. For a moderately automated process recommended for this factory, the structure is designed with openings for both day lighting and ventilation. This is to increase the rate of air-change, so that as the functioning machines dissipate heat, it is quickly lost to air-change. This reduces over heating in machines and prevents electric cables from melting, short-circuiting and igniting of fire. The wall material (precast concrete with polystyrene infill) reduces heat gain from the harsh tropical climate. Fire preventing and fighting systems shall be installed to specialist consultant's specifications

4.5.0. Materials and Construction

In line with our goal, concrete which is the most common building material in Nigeria was employed for most of the vertical and horizontal structural element, except for the roof where the steel and aluminium were specified. Glass and U-PVC frames are specified for doors and windows. The design is an array of components to be prefabricated in **IBS** factory and grouted or fixed on site in the case of precast concrete and steel respectively, therefore their sizes are such that can be carried by available transportation plants locally available.

4.5.1. Modular Components

To enhance standardization, modular planning was employed so that prefab components and materials can be produced as interchangeable parts. Modular components are designed as part or sections to be constructed away from site, this eliminates much on-the-job construction work. This means that components that will make up the superstructure can be constructed even before work is completed on the foundation. The components include;

1. 230mm thick precast concrete hollow wall filled with polystyrene material, and fitted with and windows
2. Precast reinforced concrete columns with dowels for grouting
3. Precast reinforced concrete beams with dowels for grouting
4. Precast reinforced concrete troughs for partial self centring suspended floor
5. Precast reinforced concrete straight flight stairs with dowels for grouting
6. Precast reinforced concrete roof gutter with dowels for grouting
7. Prefabricated tubular steel space frame units to Structural Engineer's specification
8. Prefabricated glass/U-PVC interior partitioning wall

These different varieties of component have been used repeatedly in the production hall and the engineering/maintenance unit.

4.5.2. Horizontal Structural Elements

A. Foundation

The foundation of a building constitutes its substructure and acts anchors the building to the ground on which it is built and also transfers vertical load from superstructure to the ground.

A careful analysis of soil type and bearing capacity usually influences the choice of foundation type. After visiting the site, the designer recommends an insitu-reinforced concrete raft on short friction piles as an adequate foundation for the proposed project. Due to the nature of the soil and the expected load the foundation is expected to carry, the top layer of the site will be stabilized by mixing sharp sand with the muddy site soil.

B. Floors

The function which floors must satisfy/provide includes;

a. To withstand load imposed on it.
b. To prevent dampness penetrating the building.
c. To prevent the growth of vegetation inside the building.
d. To provide an adequate surface which meets the needs of user with respect to looks, comfort, safety and maintenance.

e. And in the case of juice factory, it most also carry crates and drainage pipes that will remove waste water from cleaning processes.

An advance flooring system was adopted for the suspended floor carrying the administrative unit, the use of partial self centring floor system comprising of precast concrete floor troughs to be placed on rebated precast concrete beams. While the ground floor is basically cast insitu, the suspended floor has the capacity of spanning large areas without support and the soffit provides a good aesthetic effect in the interior below.

C. Aluminium sheets

Aluminium roofing sheets are to be used for external roof covering in the proposed project. Long span aluminium sheet comes in varying colours. The pure aluminium sheet containing at least 99% aluminium and a gauge of 0.75millimetres is to be used. This is because these sheets have moderate mechanical strength and can be readily bent and beaten into quite complicated shapes without damage.

D. Bituminous felt /asphalt

Bituminous felt is a black, sticky mixture of hydrocarbon completely soluble in carbon-disulphide, while asphalt is a mixture of black mineral hydrocarbon containing bituminous substances. The most useful properties of these materials is their impermeable nature (to water), resistance to acids and other corrosive