A STUDY ON FERTILIZER GODOWNS IN BANGLADESH

BY

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DECLARATION

The undersigned do hereby declare that the project work reported herein has been performed by him and this work has not been submitted to this or any other institution for any other degree.

P.L. Podder
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DEDICATED TO MY PARENTS

ABSTRACT

This project report is based on an extensive survey of warehouses built by the Bangladesh Agricultural Development Corporation (BADC) throughout the country. Details of construction and loading faults and subsequent deterioration impairing serviceability, are recorded and remedial measures are suggested. These include depression of floor, deterioration of surfaces due to chemical reaction of urea, loading pattern, ventilation problem, cracks in roofs and shear walls, leakage of rainwater through roof, faulty expansion joints and plastering and depression of platform etc. From structural point of view the warehouses were found to be heterogeneous in construction. The study revealed that a considerable amount of saving, both in the time and cost of construction could be achieved if a standardized design could be adopted in the construction of superstructure and substructure. An attempt has been made in this study to arrive at a standardized design for such warehouses which will provide structurally sound and most cost effective solution to this problem. The result of analysis revealed that a warehouse with a roof span of 22.5 ft by 32 ft would provide an optimum solution from technical and cost point of view.

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ABBREVIATIONS

AASHTO	- American Association of State Highway and Transportation Officials
ACI	- American Concrete Institute
ADB	- Asian Development Bank
BADC	- Bangladesh Agricultural Development Corporation
CIDA	- Canadian International Development Agency
DL	- Dead Load
EEC	- European Economic Community
FFYP	- First Five Year Plan
FRG	- Federal Republic of Germany
GDP	- Gross Domestic Product
HYV	- High Yielding Varity
IFAD	- International Fund for Agricultural Development
LC	- Lime Concrete
LL	- Live Load
MP	- Murate of Potash
PDP	- Primary Distribution Point
RCC	- Reinforced Cement Concrete
SFYP	- Second Five Year Plan
SPT	- Standard Penetration Test
USAID	- United States Agency for International Development

NOTATIONS

A_s	Tensile steel area
A_s'	Compressive steel area
b	Width of beam
b'	Width of web
d	Effective depth
d'	Distance from compression face to compression steel
f_c'	28 day-cylinder compressive strength
f_c	Allowable stress in concrete
f_s	Allowable stress in tensile steel
f_s'	Stress in compressive steel
j	Ratio of distance from centre of compression to centre of tension with effective depth
k	Ratio of depth of compression zone to effective depth
M	Moment
n	Modular ratio
p	Reinforcement ratio
R	$\frac{1}{2} f_c kj$
t	Slab thickness

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CHAPTER 1

INTRODUCTION

1.1 General Introduction

Agriculture is the core sector of Bangladesh economy. This accounts for 55% of the GDP, provides employment opportunities for 75% of the active population and contributes to about 90% of the national export. The total area of Bangladesh is 35.5 million acres of which 23.2 million acres are cultivable, 1.8 million acres remain fallow, 0.25 million acres are cultivable waste and the rest are occupied by dwellings, forests, rivers, lakes, etc.

The present population of the country is about 100 millions with an annual growth rate of approximately 2.4%. To meet the growing demand of food grains in the country, it is estimated that 18-20 million tons of food grain shall have to be produced in current year. One way of achieving this objective is to bring more land under cultivation. But evidently, there is not much scope for large scale increase of acreage for arable land. Besides, increase of acreage account of new land is lower compared to population growth rate. As a matter of fact, Bangladesh has little or no potentiality in land area increase and at present, is regarded as one of the densely populated countries.

In the absence of any significant possibilities for increasing food production by reclamation of additional cultivable land to feed the increased population it has become imperative to emphasize vertical expansion of agriculture by adopting the modern seed based technology.

1.2 Seed Based Technology and Fertilizer

Japan produces about 6 metric tons of rice per hectare compared with 2 metric tons per hectare in the India-Pakistan-Bangladesh subcontinent. Bangladesh could produce as much as four times the present output if it could achieve the Japanese standard of productivity. The increased yield in Japan and other developed countries is mainly due to application of improved varities of inputs such as seeds, fertilizers, pesticides, etc, effective soil and water management and better extension services. In this respect Sangar(1) commented that, "one of the most promising large areas of high production potential is the rich alluvial plain of the Indo-Ganges-Brahmaputra river system, an area of some 100 million acres. This area if farmed with present multiple cropping technology is capable of producing as much as 10 tons of grain per hectare per year, a total of more than 1 billion tons - an amount almost equal to the present world production and 10 times India's present level of output".

Among the agricultural inputs mentioned above, fertilizer is regarded as the most crucial for achieving higher productivity. Borlaug[1] in his speech made during accepting the Noble award remarked, "If the high yielding dwarf wheat and rice varities are the catalysis that have ignited the Green Revolution, then the chemical fertilizer is the fuel that has powered its forward thrust". Some years ago,Food and Agricultural Organization (FAO) of the United Nations has made a comparative study of the relationship between grain yields and the amount offertilizer used in a number of countries. The result of the study indicates that the countries using little or no fertilizer have an average yield of grain, ranging from 800 kgs to 1,400 kgs per hectare, while the countries using fertilizer at the rate of 60 kgs per hectare have achieved an average yield of 2000 kg or more per hectare.

Like many other developing countries, Bangladesh has also been making serious efforts to increase food production by increased use of fertilizer, improved varities of seeds and irrigation. Fortunately, Bangladesh is also endowed with abundant supply of natural gas which has formed the basis of setting up of gas based urea fertilizer factories in the country. This has gone a long way in meeting the country's requirement of chemical fertilizer.

1.3 Objectives of the Present Study

Efficient distribution of fertilizer which is one of the crucial factors for high productivity, largely depends on the availability of suitable godowns at different sales centres. In this regards the BADC has drawn up a nation wide storage plan. A lot of godowns have already been constructed. A lot more will be constructed within their hardcore programme or with the assistance of different aid giving agencies. But it is noticeable thatstorage godowns are not alike from structural point of view. The most common type used are concrete folded plate roof structures, reinforced concrete beam and two way slab structures with defferent grids etc. Some construction problems have been reported in many cases. The modern trend of designing cost effective structures by optimum utilisation of materials are not being followed in these cases. Besides, the mode of financing in construction by the foreign agencies restrict the use of local design concepts in some cases.

In light of the foregoing discussions the objective of the present study are fixed as follows:

i) Field studies of the construction problems facing the existing fertilizer godowns.

ii) Suggest remedial measures for the problems that affected the existing godowns for fault free future constructions.

iii) Evaluation of the nature of construction, utility and performances of the existing as well as newly constructed warehouses.

iv) Arriving at a standardized design for typical superstructure and substructure of godowns, which would provide a sound cost effective godown structure with scopes for modifications.

CHAPTER 2

FERTILIZER USAGE IN BANGLADESH

2.1 Background

Farmers are using organic manure such as cow-dung or farm yard manure from time immemorial. A large amount of cow-dung is used as fuel and a small portion is available for application in crop. The nutrient contents of the cow-dung or farm yard manure is very small and it cannot meet the full requirement of crop. The bulk requirement of nutrient for raising crops is therefore to be channelized through chemical fertilizer and at a cheaper rate than that of organic manure.

The use of chemical fertilizer was introduced in Bangladesh as early as 1951-52 in the form of ammonium sulphate. The sale of chemical fertilizers increased from 2598 tons in 1951-52 to 28,300 tons in 1961-62. Most of these fertilizers were, however, used in the tea gardens of Sylhet and Chittagong. Urea fertilizer was introduced in the country during 1957-58 but it's scale reached only 24300 tons by 1961-62. During the same year Triple Super Phosphate (TSP) was introduced and its sale was only 6055 tons. The Directorate of Agriculture of the Government was responsible for procurement and distribution of fertilizers throughout the country upto June 1961. Thereafter the responsibility of procurement and distribution of fertilizer was entrusted on the then EPADC (Now BADC) following recommendation of the Food and Agricultural Commission set up by the Government. After taking over this responsibility BADC changed the prevailing distribution system and appointed retail dealers throughout the country for selling fertilizer to the farmers instead of selling from Thana (Now Upazila) and Union level seed stores. With the introduction of retail dealers fertilizer was made available within easy access of the farmers and the sale increased to 73,226 tons during 1962-63 from 58,753 tons in the previous year, which is equal to an increase of greater than 24%. This increasing trend steadily continued upto 1966-67.

During 1967-68 High Yielding Variety of rice was introduced which resulted in even further consumption of fertilizers 211, 141 tons as against 162,096 tons in the previous year. Upto 1970-71 consumption offertilizers increased at an average of 17% per annum.

2.2 Performance During the First Five Year Plan

In the first plan period fertilizer sale increased from 380,000 tons in 1973-74 to 719,000 tons in 1977-78. The sales volume steadily increased during the plan period except in 1974-75 when the Ghorasal Urea Fertilizer factory had to be closed down and there was delay in lining up import from abroad due to resource constraints. The sales volume however improved in the following year.

During the entire first plan period a cummulative quantity of 2.34 million tons fertilizer was sold against a target of 2.356 million tons. In otherwards nearly 100% target was achieved. Yearwise sales figures indicated that in 1977-78 sales volume was 19% above the target.

2.3 Constraints Against Fertilizer Usage

In the past it was observed that a number of constraints limited the increased use of fertilizer. The major constraints are listed below:

a) Irregular supply from local factories.

b) Inadequate allocation of funds for import.

c) Inadequate credit support to farmers for purchase of fertilizer.

d) Lack of adequate transportation facilities within the country for movement of fertilizer.

e) Inadequate extension services for imparting improved farm techniques.

f) Absence of proper training programme for dealers for motivating farmers in the use of fertilizer.

g) Inadequate irrigation facilities.

h) Vagaries of nature.

i) Use of unbalanced fertilizer.

j) Lack of proper feed back from the farmers to the extension workers.

k) Inadequate storage facilities for fertilizer.

The present study looks at the particular aspect of storage facilities for fertilizers in Bangladesh.

CHAPTER 3

STORAGE PLAN : CRITERIA USED BY BADC FOR STORAGE SPACE : SITE SELECTION AND MODE OF FINANCING IN CONSTRUCTION OF FERTILIZER GODOWNS

3.1 General Introduction

During early sixties the then EPADC (Now BADC) constructed some large capacity (2000 tons) and intermediate capacity (500 to 1000 tons) godowns for transit purposes and small capacity (100 to 500 tons) godowns at primary distribution points for storage of fertilizer. With the introduction of HYV rice during the late sixties (1967-68) the demand for fertilizer increased sharply requiring further storage space. To meet the situation BADC constructed godowns from time to time under their hard core programme. Besides BADC also hired or requisitioned godowns to meet the emergency requirements. A list showing the capacity of existing godowns by the terminal year (ending June 1979) of first five year plan is shown in Table 3.1.

3.2 BADC's Storage Plan

To achieve the national objective of attaining self sufficiency in food grain production, BADC took up a program for distribution of 1.9 million tons of fertilizer by the terminal year of SFYP. To execute the programme of distributing 1.9 million tons of fertilizer, BADC required to handle 2.5

Table 3.1 Capacity of existing godowns by the terminal year of FFYP

Types of godowns	BADC's own godown		Hired & requisioned godowns	
	Nos.	Capacity in tons	Nos.	Capacity in tons
Transit	6	33,500	11	35,115
Big and Intermediate	62*	56,500	235	1,01,613
	*Capacity 2000T 10 Capacity 1000T 21 Capacity 500T 31			
Upazilla	246*	66,000	679	1,04,203
	*Capacity 500T 4 Capacity 400T 78 Capacity 200T 164	2,000 31,200 32,800		
Sub-total	314	1,56,000	925	2,40,931
Grand total			1239	3,96,931

million tons of fertilizer during 1984-85 including a buffer stock.

BADC has introduced a new marketing system by which fertilizer is distributed to the farmers through its appointed retail and wholesale dealers. The dealers buy fertilizer from Upazila godowns/PDP on commission basis and sell to the farmers at prices fixed by the Government. The dealers are required to lift a minimum quantity of 1(one) ton from PDP. A network of dealers has been established throughout the country for easy access of the farmers.

Efficient distribution of fertilizer largely depends on the availability of suitable godowns at fertilizer sales centres. Hired godowns even if available are not generally suitable for fertilizer storage and there is more wastage and shortage in these godowns due to their prevailing unsuitable condition. To overcome these difficulties BADC has drawn up a national storage plan throughout the country. To implement this scheme, BADC required 524,000 tons of storage capacity at transit and PDP levels by the terminal year of SFYP. In this regard BADC took up a programme[11] for constructing 2,94,500 tons of storage capacity with the assistance of international aid giving agencies. The details of godowns already constructed and are being constructed under this programme are given in Table 3.2. and 3.3.

Table 3.2 Source of funds

Source of funds	Proposed storage capacity (in tons)
Hard core (BADC's own sources)	12,000
USAID Phase II	1,62,000
IFAD	13,000
IDA	29,500
ADB-CHT	3,000
ADB-CHIP I	10,000
ADB-CIP II	10,000
Dutch Phase I & II	22,000
USAID Phase	33,000
Dutch & EEC(Phase I and II)	22,000

Total: 2,94,500 tons

Table 3.3 Position of BADC's fertilizer storage capacity by the year 1984-85

Storage capacity	Tons
Total requirement of storage capacity by 1984-85	5,24,000
Existing storage capacity available at transit and PDP level	-1,33,600
	3,90,400
Additional storage capacity developed/under development	2,94,500
Shortfall in storage capacity	95,900

3.3 Storage Space Requirement

Several factors determine requirement of storage space for fertilizer. The total consumption of fertilizer in the course of a year has a direct bearing on the storage requirement. But a fraction of annual consumption is required to be stored at any given time. Fertilizer usage fluctuates seasonally. Analysis of BADC's monthly fertilizer sales statistics reveals a preponderance in fertilizer sales during the dry season period from October to March which amounts for 60% of the annual sales. Therefore, stocks dwindle during peak demand periods and accumulates during slack demand periods. Places where transportation facilities are not available round the year, a higher stock is maintained close to the end user to avoid shortage during peak periods. Similarly due to difficulties in matching domestic and foreign procurement of fertilizer with period of demand, a buffer or reserve stock is maintained for which additional storage space is required.

A sound policy for procurement and storage of fertilizer is essential for proper inventory management. During 1976 when the stock of fertilizer was unusually high, many godowns carried stocks twice their normal capacity. Such a situation is not desirable. Considering ventilation and easy movement for handling upto 70-80% of the total volume of a godown could be utilized for storing fertilizer. For inventory management, a 'first in first out' principle should be followed.

Storage capacity of warehouses is worked out by BADC on the basis of highest three months sales for a particular area which is adjusted for some areas to account for transportation difficulties to replenish stocks. The capacity of transit godowns depend on the schedule of ship arrivals bringing in imported TSP and MP fertilizer. To overcome periodic shortages of these products, BADC is embarking on a programme to build up 5 months buffer stock at transit godowns.

3.4 Site Selection

The selection of site for construction of warehouse is dependent on communication facilities available and proximity of the site to the end user. The river communication is a very convenient and cheap mode for movement of fertilizer. But many rivers are not navigable throughout the year. Although movement by railway is expensive, it is regarded as more reliable. Over the year road transportation in Bangladesh is gradually replacing both river and rail communications as more and more roads are constructed to open up the countryside. Therefore, accessibility to highways and roads now determine the location of a BADC warehouse rather than rail or river links. Other technological factors relating to particular site are given due weightage before site is finally selected.

3.5 Mode of Financing in Construction of Godowns

BADC has built and will build godowns from its own resources or with the assistance of foreign aid giving agencies such as USAID, IDA, ADB, IFAD, CIDA, FRG, JAPAN, SAUDI, EEC etc. Local consultants were employed for design and supervision of construction of those warehouses which will be built from its own resources. In case of warehouses built with foreign assistance there are contracts between BADC and the donar agencies. USAID has employed consultants as well as contractor for construction of godowns under Phase II and III of their aid programmes. The fee for consultancy is paid directly by the USAID. The agency engaged an American consulting company 'International Engineering Company Inc.' (IECO) for the design work and Korean contractor, Korean Development Corporation (KDC) to construct the warehouses on the basis of the consultant's design. Most of the BADC's fertilizer godowns have been built and more are expected to be built under this aid programme. In case of Dutch & EEC assistance, the donar agencies employed local consultants, only to supervise the project works.

CHAPTER 4

FIELD OBSERVATIONS OF WAREHOUSES AND DISCUSSION

4.1 General Introduction

The warehouses so far built or proposed to be built by BADC are spread all over the country. Although some of these warehouses are similar,most of them are different from structural point of view. The present study presents an investigation into the causes of structural failure as well as functional faults in these warehouses and suggests possible remedial measures. The relevant observations made by the author during field survey in this regard are also presented here.

4.2 Field Observations

Field observations recorded during survey are presented in the following subsections.

4.2.1 Depression of floor

Depression of floor slab is a common problem in fertilizer godowns. Owing to continuous heavy floor loading the subsoil in some godowns has been consolidated. Also due to existance of local soft pockets in the subgrade on which the concrete floor is placed, localized settlement of the floor has occured due to self weight and heavy live loading placed on them.

4.2.2 Chemical reaction of urea

It was observed in some of the warehouses containing urea that the aggregate particles of the floors have disintegrated. In many cases the walls and columns in contact with urea, TSP and patassium chloride suffered chemical reaction on the surface (Fig. 4.1 and 4.2).Urea is highly hygroscopic, absorbs moisture from air. This is a weak base, the pH of a 10% solution in water being 7.2 to 9. Urea undergoes hydrolysis in acidic as well as alkaline solutions. The hydrolytic products of urea are highly corrosive. They would damage concrete structures unless properly protected.

4.2.3 Wastage of loading space

In many of the warehouses a 20 ft by 20 ft column grid has been used. The fertilizer bags are not allowed to be stored in contact with the face of the column because the columns are not designed to withstand the lateral load and it is also not desirable that the live load from the floor slab is transferred to the column. Therefore, no load is placed on an area of 3 ft by 3 ft around the columns thereby decreasing the effective storing space.

4.2.4 Loading error

It was observed in some godowns that bags are stored in close contact with the columns and on spaces very near the edge of the outer walls of the warehouses (Fig. 4.3) As already explained this causes lateral thrust on the columns. Such lateral thrust and heavy floor slab live load may not have been considered in the design of foundation in some cases. As a result there is settlement of the columns which has disrupted the whole or part of the structure.

4.2.5 Ventilation problem

It was observed in some recently constructed godowns that there was no louvre openings in the lower part. As a result the interior of the godown has become warm and unconfortable. Some old godowns have concrete louvre openings but these were not constructed properly and pilferage through these openings have been reported. Some godowns were found with glass window and concrete louvre openings alternately in the upper grid of ventilation (Fig. 4.4). Such openings are again easily accessible to the pigeon and other birds to make nest within the warehouse. During heavy shower rain-water also enters through the opening rendering the space near the wall completely unusable for storing.

4.2.6 Cracks in shear wall

It was observed in some godowns that the concept of shear wall has been utilized to transmit the horizontal shear directly to the foundation without significant flexure.

But in all most all cases the shear wall has cracked horizontally at the mid heights.

4.2.7 Depression of platform

It has been observed in some places (e.g. at Jangalia, Comilla) that the platform is depressed. The settlement of newly filled subsoil (not properly compacted) is responsible for the depression.

4.2.8 Cracks in roof and girder

It was observed in some godowns (Sandwip, Feni, Comilla, Fig. 4.5 and 4.6)that cracks have developed throughout the roof and also in some cases in the girder (e.g. at Comilla, Chittagong port).

4.2.9 Expansion joint problem

In one godown (at Feni) the expansion joint of roof was large enough to make the sky visible and allow penetration of rain water rendering a large part of storage space unusuable.

4.2.10 Error in site selection

The warehouses at Feni are located far from the railway station and fertilizer is transported by truck to Feni PDP. This is expensive and would increase the handling loss.

At Daudkandi, because of insufficient river draft in dry season, movement of burges near the PDP location is affected. Small boats are used to transfer fertilizer from the burges to the river bank. This also causes secondary hazards and increases the handling cost.

4.2.11 Leakage of rainwater through roof

In some godowns, leaking of rainwater through the roof slab was reported. During heavy monsoon rainfall, most flat roofs tend to leak, regardless of its construction methods.

4.2.12 Faulty plastering

A network of fine shallow hair cracks known as crazing were observed in the plastering of walls in several godowns. Efflorescence and persistent dampness were observed in some godowns of coastal regions (e.g. at Shiromoni, Khulna Fig. 4.7).

4.2.13 Faulty door system

In some godowns narrow gaps were observed between the floor level and the bottom of the door system. As a result during monsoon rain water penetrate the warehouses. Mechanical problems of jamming and corrosion of moving parts presented by the iron roller doors was reported in many godowns.

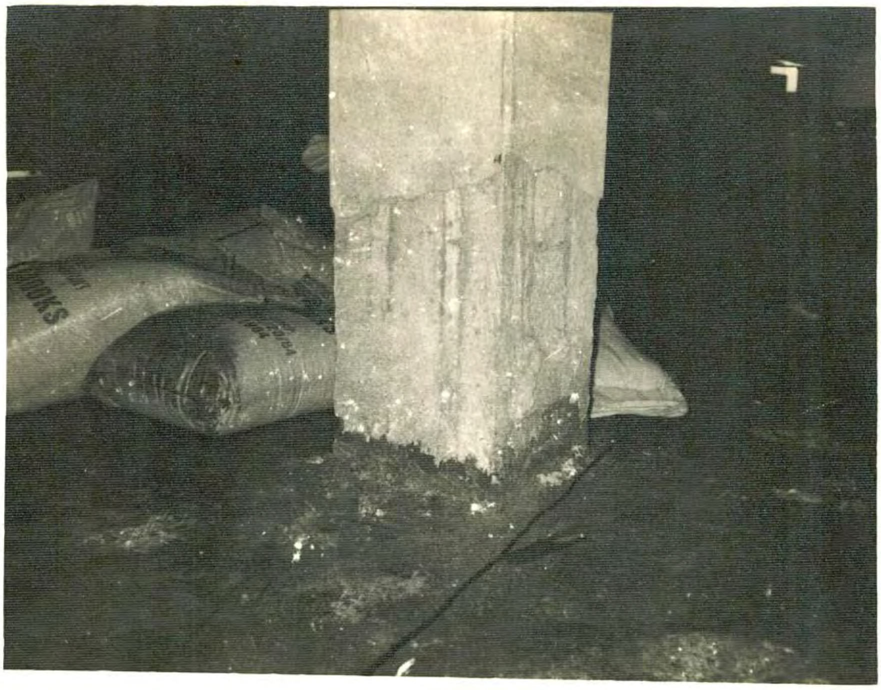

Fig. 4.1 Effect of urea on column (Shiromoni, Khulna).

Fig. 4.2 Effect of urea on floor slab.

Fig. 4.3 Loading of fertilizer bags closely near to the column.

Fig. 4.4 Ventilation system at Daudkandi which permit entry of rain water into the godown.

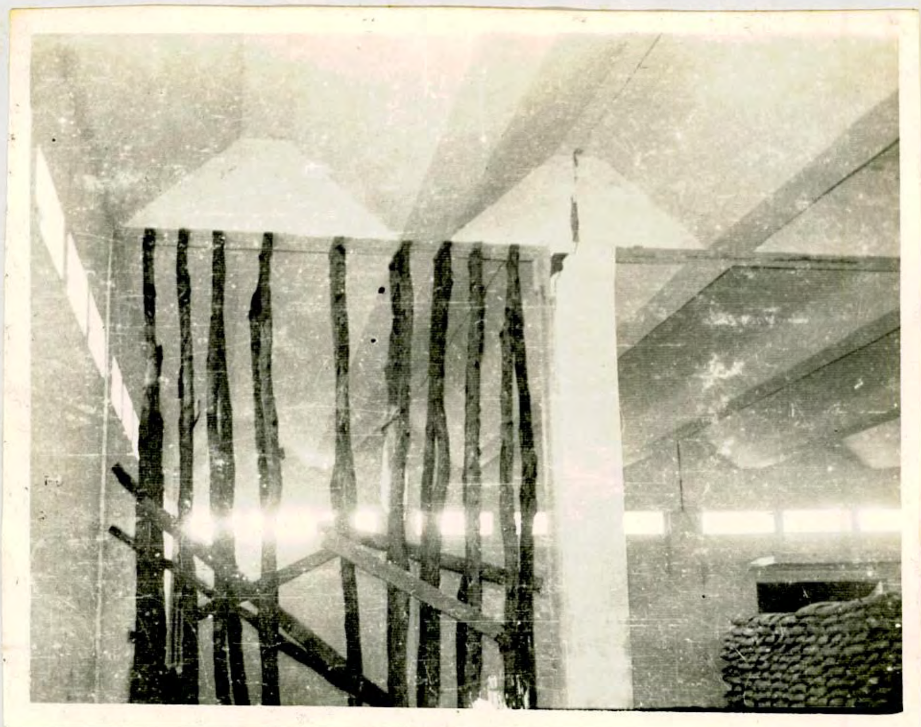

Fig. 4.5 Cracks in beam in a folded plate roof structure in Comilla.

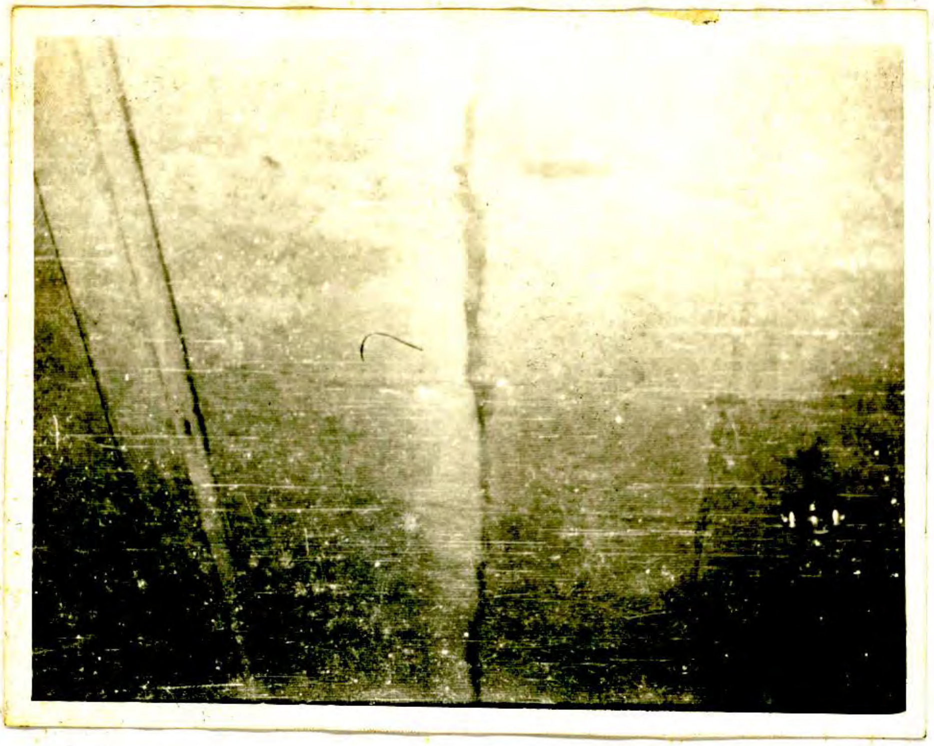

Fig. 4.6 Cracks in roof slab in Feni godown.

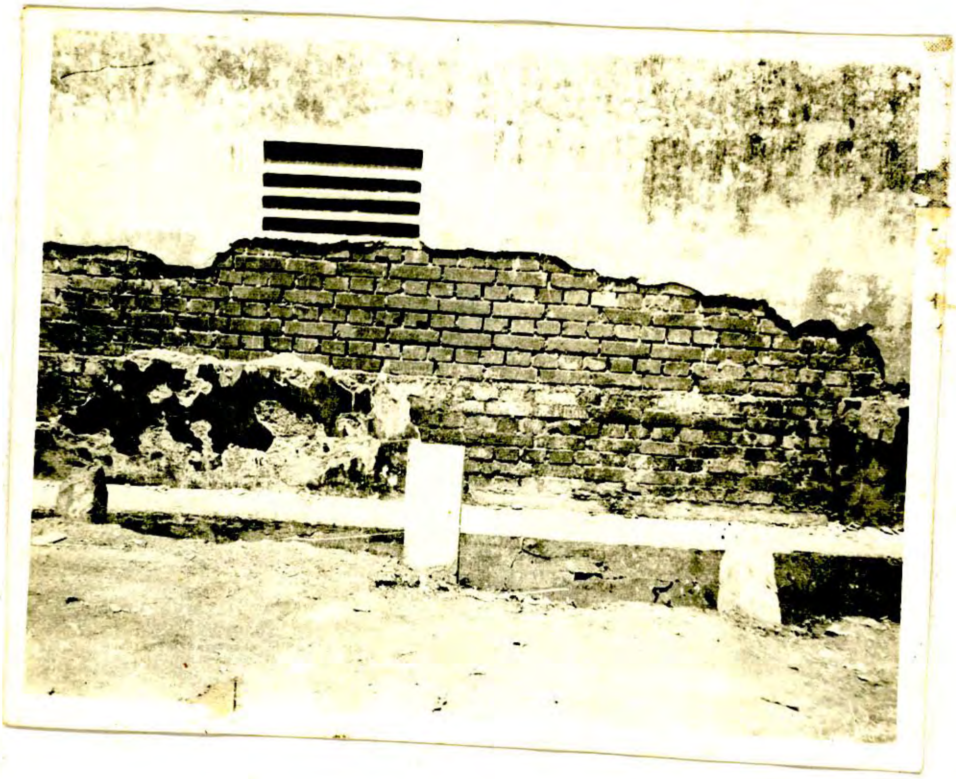

Fig. 4.7 Spalling of plastering on wall in coastal regions.

4.2.14 Over-designed structure

The warehouses designed by some consultants used shear wall concept to resist the lateral (earthquake) forces resulting in a ground acceleration of 0.1g and considered storage load of 850 psf. Plinth area calculated by the consultants for these cases were 7 sq.ft per ton of loading. Both the seismic intensity and plinth area required for loading per ton assumed are considered to be on the high side.

4.3 Suggested Remedial Measures for the Faults

4.3.1 Depression of floor

To overcome this difficulty the subgrade should be well prepared. Sand filling in plinth should be done with coarse sand compacted to 90% standard AASHTO specification which would require use of mechanical devices. The floor slab should be separated from the main frame structures to minimise differential settlement. The casting and finishing of concrete floor would be done after loading the unfinished floor upto a minimum of one year. This is done to reduce residual settlement.

4.3.2 Chemical reaction of urea

Concrete is not totally impervious. Urea finds its way into the concrete as urea solution or as urea wash-water. The penetration is progressive. The urea that penetrates into the concrete, during the process of crystallisation exerts enormous pressure disrupting the concrete and separating the aggregate particles.

Concrete used in structures in chemical plants should be given protective treatment before it is allowed to come in contact with chemicals. Swaminathon,[13,14] suggested that initial penetration of urea solution into concrete should be restricted by way described in the following.

a) Reducing porosity of concrete by use of denser concrete i.e lower water cement ratio (low slump) and aggregate gradation for least void ratio.

b) Reducing number of construction joints i.e by casting columns from foundation to the bottom of the beam in one stretch and casting of slabs and beams monolithically.

c) Increasing more than normal clear cover to prevent or at least delay the process of corrosion of reinforcement. To protect the columns from attach by the fertilizer, suitable sealant or other protective materials such as linseed oil should be used.

4.3.3 Wastage of loading space

It is often said that one pays a premium for column free floor space. But a grid of 30 ft by 30 ft in some warehouses have been used to provide more storing space and better functional arrangement. This type of grid many also be adopted in other warehouses subject to specific structural considerations and cost benefit analysis.

4.3.4 Loading error

The labourers engaged in loading-unloading of fertilizer are not always aware of the restriction of loading at the face of the wall and column. This causes lateral thrust on the columns which has already been explained (Art. 4.2.2). Either this should be communicated to them by the wading supervisory staff or the area should be clearly demarkated.

4.3.5 Ventilation problem

As urea releases ammonia which creates an acrid atmosphere within the warehouse, ventilation is necessary. Usual practice is to provide louvre openings at two levels. The lower grid should be located at sufficient height to prevent ingress of flood water and the other grid at about 16 ft above the floor. Concrete louvres are used at near floor level while hinged glass windows are provided below the roof slab. Fresh air intake must be kept to a minimum as air exchange carries moisture to the bags. To control ventilation during the monsoon, the lower opening should be provided with a horizontal sliding cover. The whole openings should be covered with iron net to restrict the entrance of birds into the warehouses. The projection of roof slab beyond the wall should be enough and the louvred opening should be designed in a manner to prevent entry of rain water.

4.3.6 Depression of platform

Use of trains require fast and uniform rate of loading/ unloading. The warehouses therefore, should be provided with continuous platform running the whole length of the warehouse. As per requirement of Bangladesh Railway the height of platform should be kept at 3 ft. 6 in from the top of the rail. Continuous platform should be provided also on the ruck way side of the warehouse. Therefore, no ramps or steps will be required for loading or unloading from train or truck. Platforms on the railway side is usually used for temporary stacking of bags and its width should be at least 10 ft. The width of the platform in the truck way side should be 6 ft which is minimum requirement for efficient movement of two head-loaded labours crossing at a point.

In designing platform and floor slab, careful investigation of subsoil and consideration of liveload is essential. Generally storage load of 300 psf is considered in a designing platform.

4.3.7 Cracks in roof and girder

The cracks in concrete is an inherent feature which can not be completely prevented but can only be controlled and minimised. Cracks generally occur due to overstress from loads not considered in the design, error in design assumptions and methods of analysis and incorrect placing of reinforcement. Moreover, all concrete structures are designed on the basis of an assumed concrete strength dependent mainly on the quality and proportion of the constituent materials, the method and control of production such as batching, mixing, placing, finishing and curing. The use of sub-standard constituent materials and/or higher water-cement ratio may lead to production low strength concrete. Similarly lack of adequate supervision during batching, mixing etc. may also produce low grade concrete. All these factors might have caused cracking of concrete in these godowns. Foundation movements mainly due to differential settlement might also have caused overstressing and cracking of these structures.

4.3.8 Expansion joint problem

Functional joints are required to render a structure safe against expansion, shrinkage, sliding and warping of concrete. Such joints are made through continuous breaks in the structure at suitable distance apart. These breaks permit the concrete to expand (or contract) freely without disturbing the structure. The joints or breaks may be 1/4 in. to 1½ in.wide. The design and spacing of the joints depend on the nature of structure, soil condition and environmental situation.

The expansion joint in roof slabs must be water-tight as well as should allow free movement. So that the joint may not be visible on the ceiling, it is always located over a wall or beam. A bituminous paint is very necessary between the slab and the wall or beam under it so as to ensure free movement. The joint can either be vertical or made in the form of a step to eliminate further possibility of water leaking through it. The joint is filled with asphalt. To prevent cracking of asphalt in the joint, a piece of hessian is laid over the joint and covered with more asphalt. This reinforces the asphalt and keeps it separate from the slab, thereby increasing its flexibility.

4.3.9 Error in site selection

A PDP should be so located as to enjoy all possible means of economic transportation facilities. Road transport is mainly in the hands of private sector and its availability for specific movement depends on the attractive rate for the operators. Locating warehouses near railway (as in case of Jangalia Comilla) may avoid unnecessary truck transport for short distances which was not observed in case of warehouse at Feni. Although it is difficult to select a site free from river erosion or silting with certainity, more careful consideration should be given to ensure that the river channel near the warehouses is navigable for barges for most part of the year.

4.3.10 Leakage of rain water through roof

A proper drainage of the roof requires that the water should not fall on the platform and cause splashing of the walls. The roof should be sloped such that water falls away from the platform. To stop penetration of water light waterproofing of the roof may be affected by using bituminized paper and with a roof slope of 1 in.in 35 ft.

4.3.11 Faulty plastering

A network of fine shallow hair cracks is due to drying shrinkage, carbonation or differential shrinkage between the surface and the main wall. It is not possible to prevent craziness but its occurance could be minimized. The surface to be plastered should not be dry enough to absorb water from the mortar. The rich mixes (about 1:3) should be avoided as it is likely to expand and contract more with temperature variation. Fresh plastered surface should be protected from superfluous quantity of water such as rain and also from excessive heat from direct sun rays.

The presence of chlorides causes efflorescence on the surface of wall as the salts are brought out along with the moisture. Therefore, the use of saline water in coastal regions (e.g. at Shiromoni, Khulna) is not advisable for plastering purpose which is subsequently going to be painted. In mixing mortar for plastering and also for curing purposes the stagnant water of pond which may contain permissible amount of chlorides should be used in coastal zones.

4.3.12 Faulty Door system

All godowns should be fitted with two doors on opposite or adjacent walls. Top hinged two parts sliding gates are suitable which are economical, effective and not prone to jamming due to corrosion of moving parts as observed in case of iron roller doors in current use. If the interior floor level is higher than the bottom part of the door system or a rubber channel is fitted at the bottom of the door to fill the gap, water penetration could be stopped into the warehouses.

4.3.13 Overdesigned structure

Bangladesh is divided in three zones in respect of seismic consideration(6). Zone 1, the most active seismic zone of the country with a design ground acceleration of 0.08g comprises only the north eastern part including the town of Sylhet*, Mymensingh and Rangpur. Zone II covers Dinajpur, Bogra, Tangail, Dhaka, Comilla and Chittagong with a design ground acceleration of 0.05g. The town of Rajshahi,

* Former districts.

Pabna, Kushtia, Jessore, Faridpur, Khulna, Barisal, Patuakhali and Noakhali falls in Zone III with a design ground acceleration of 0.04g. Since most of our land is in the region having design ground acceleration of 0.05g, the shear wall concept which is expensive and require more skill in construction could be avoided. Conventional framed structure comprising beam and column would be suitable to resist the lateral forces.

For normal loading of 14 ft. stack height the weight of urea per square foot is 840 lbs. Loading calculation on this basis would result in a over designed structure as the entire space is not loaded and not at all time. Spaces, enmarked for labour movement, kept for segregation of various types of fertilizer and kept restricted for loading near column, wall and door also considered in carrying part of live load. Therefore warehouses could be designed with a live load of 450 to 500 psf assuming it to be distributed all over the floor area, which has been practiced efficiently in some of the warehouses designed by local consultants. The plinth area requirement at the rate of 7 square feet per ton is also on the higher side and area of 5.4 square feet per ton could be considered.

CHAPTER 5

DESIGN AND COST ANALYSIS OF TYPICAL FERTILIZER GODOWN WITH DIFFERENT GRIDS

5.1 General Introduction

The various structural defects observed in the warehouses in the course of field survey and remedial measures suggested thereof are discussed in previous chapter 4. A warehouse should be free from such faults to ensure efficient storage condition for fertilizer and longer economic life of the warehouse. A fertilizer warehouse is generally a single stored building approximately 18 feet in height and designed to withstand heavy imposed load. Consideration should also be given to minimise effect of corrosive action of urea. Therefore, all warehouses to be used in storing fertilizer may have a infrastructure in respect of superstructure. The size of godowns will depend on the storage space requirement but the basic framework in all cases will be similar. In regards to substructure subsoil investigation is required for warehouses that may directly applicable or applicable with modifications for various locations.

5.2 Design of a Godown of Capacity 2000 Ton

An attempt is made to design and analyse a godown having 2000 ton capacity by considering various panel configurations.

Total area required for 2000 tons capacity godown is 10,800 sq.ft. This was calculated by considering the required rate of 5.4 sq. ft per ton. Two grids of the existing godowns such as 20 ft. x 20 ft. and 30 ft. x 30 ft. and the proposed grid of 22.5 ft x 32 ft have been analysed and designed for the purpose of comparison. The floor plans for the three type of godowns mentioned above are shown in Figs. 5.1, 5.2 and 5.3.

The criteria and specifications for the design of the godowns are summerized as follows:

a) f'_c = 3000 psi

b) f_s = 18,000 psi

c) n = 9

d) Lime terracing average 3 in.

e) Live load on roof 20 psf

f) Code used ACI 318-1977

g) Floor loading 500 psf

h) Allowable soil pressure = 2 ksf

The results on design of these three types of godowns are presented in Table 5.1. The detailed designs are presented in Appendices A_1, B_1 and C_1.

5.3 Comparison of the Different Godowns with Respect to Different Items of Works

The comparison of the godowns are based on the estimated quantities of major items such as (a) earthwork, (b) Brick work,

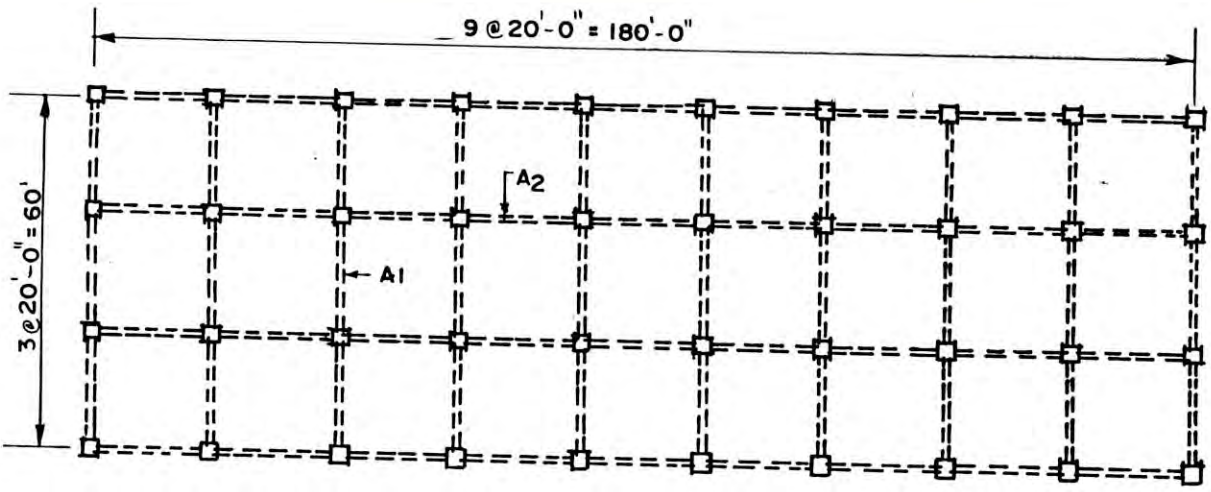

FIG. 5.1

20' x 20' GRID WITH TOTAL AREA 10,800 SQ. FT.

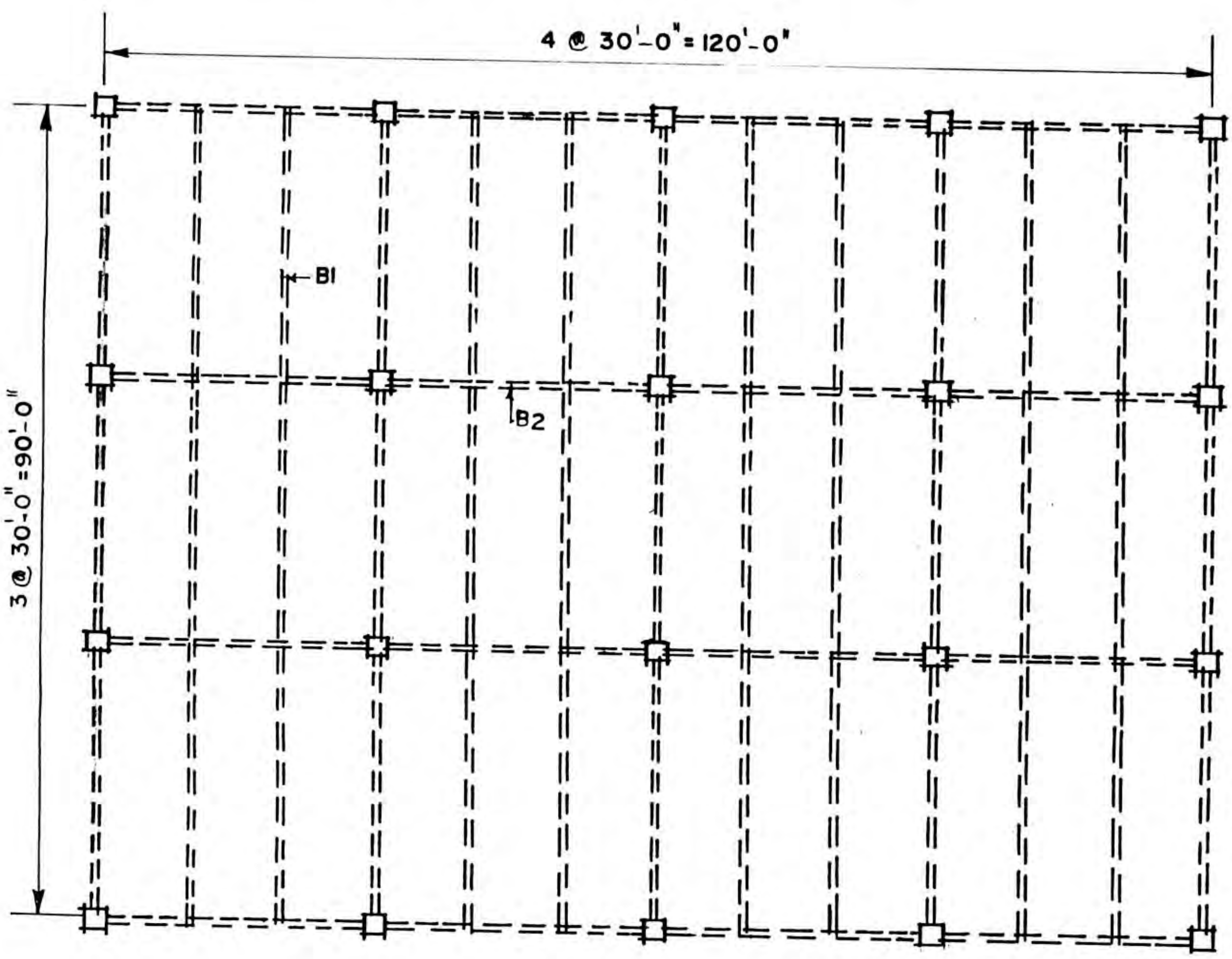

FIG. 5.2

30' x 30' GRID WITH TOTAL AREA 10,800 SQ. FT.

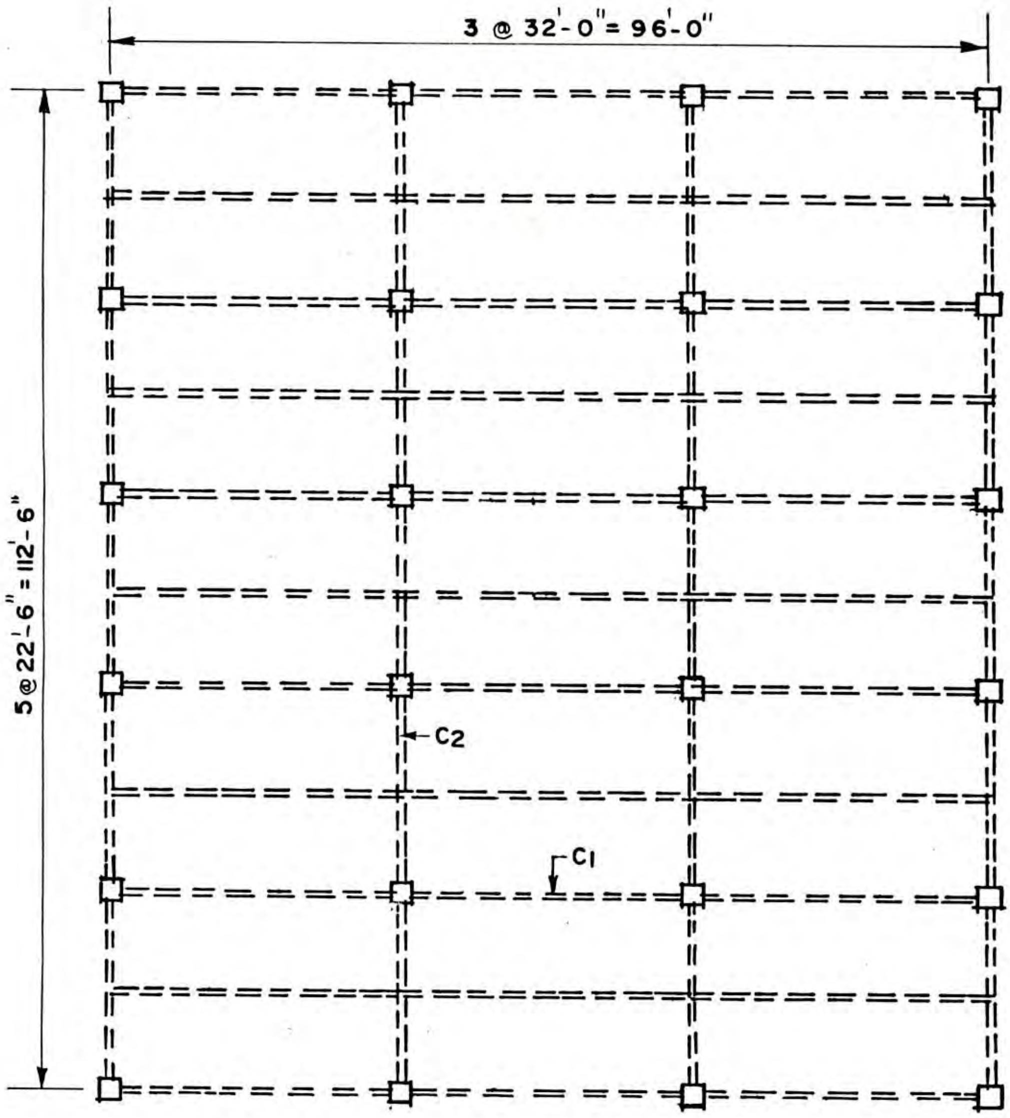

FIG. 5.3

22.5' x 32' GRID WITH TOTAL AREA 10,800 SQ. FT.

Table 5.1 Results on design of godowns with different grids.

Grid size (ftxft)	Roof slab thickness in inch	Beam size (including slab thickness)		Column		Footing size (in inch)
		Transverse direction in inch	Longi-tudinal direction	Size in inch	Nos.	
20x20	5.5	10x21.5	10x21.5	14x14	40	7x7
30x30	4	12x24	14x33	16x16	20	10x10
22.5x32	4	12x24	12x28	15x15	24	9x9

(c) Plain concrete work, (d) Reinforced concrete work and (e) Reinforcements. Other items such as plastering, lime terracing, doors, windows,sand filling etc. are assumed to be same for all the types considered. For the foundations the footings have been considered on the basis of assumed allowable soil pressure of 2 ksf. However if the allowable soil pressure is less than 2 ksf, which is likely in some areas in this country, the cost of the footing will increase. This is further considered and discussed later in Art. 5.5.

For comparison, the quantity of works involved in different item of works for different grids are shown in Table 5.2. From Table 5.2 it is evident that a fertilizer godown built with 22.5 ft. x 32 ft grid has the minimum quantity of works in almost all items considered compared with other two grids except cost for reinforcement. This is approximately 11% higher than that for 20 ft x 20 ft grid godown but lower than that for 30 ft. x 30 ft godown. However, it will be shown later in Art. 5.5 that the cost of piling for foundation on poor soils in 22.5 ft x 32 ft grid is quite low from that for 20 ft x 20 ft grid.

5.4 Floor Space Utilization

Since fertilizer bags are not allowed to be stored in contact with the face of columns or walls, near doors, the whole space within a warehouse cannot be utilised for storing purpose. A space of 3 ft. x 3 ft. around columns

Table 5.2 Comparison of different grids with respect to quantity of work in different items of a 2000 ton capacity fertilizer godown.

Type of grid ftxft / Items	20x20	30x30	22.5x32
a. Earthwork in cft	9,730	10,250	9,483
b. Brickwork in cft	7,720	6,856	6,799
c. Plain concrete in cft	556	542	531
d. Reinforced concrete in cft.	10,657	11,632	10,367
e. Reinforcement in cwt.	674	826	757

and at least 3 ft from outer walls is restricted for loading in a warehouse. Besides, for the movement of the workers and for piling up of the bags one over another upto a height of 14 feet approximately, the available floor cannot be utilised in full. Considering this to be same for all the other godowns the space utilization in this article is based only on the restricted areas around columns and exterior walls.

The available floor space to be utilized for storing in case of different grids are shown in Table 5.3.

Table 5.3 Floor space utilisation in case of different grids

Grid size (ftxft)	Floor space available in percent of total plinth area
20x20	79.40
30x30	85.67
22.5x32	84.85

From the Table 5.3 it appears that godown with grids 20 ft x 20 ft. has the minimum efficiency in floor space utilisation due to the largest number of required columns. The other two grids have nearly equal efficiency. It indicates, from this consideration, that both types are equally efficient in construction of a godown but the better one depends on other factors such as cost consideration etc.

5.5 Foundation for Godowns

In previous articles, the foundation is designed by assuming an allowable soil pressure of 2 ksf. But most of the soils upon which fertilizer godowns are built or to be built are of low bearing value. The footing area required for different grids with different allowable soil pressure are given in Table 5.4. It is seen that the footing area required for supporting column loads increases sharply with the decrease of allowable bearing pressure. When the size of footings are increased, these are subjected to pressure transmitted from floor loading. Therefore, in soils of low bearing value open foundation is not feasible because of settlement problems. This in turn may cause cracks in floor as well as in beams, columns and slab. The subsoil conditions along with the recommended foundation type for a few sites, where godowns are presently being constructed, are described in the following.

1. Baghabari site: At this site, the soil from the top 10 ft to 15 ft. is comprised of loose fine sand with trace silt. This soil, having low SPT value, appears to be recently filled. Open foundation within this depth is not feasible. The consultant suggested pile foundation using 16 in dia., 50 ft long piles bearing a design load of 30 tons with a factor of safety of 3.

Table 5.4 Area of footing required depending on different allowable soil pressure for 2000 ton capacity godown.

Grid size (ftxft)	Allowable soil pressure (ksf)	Footing area required ft^2	Required footing size (ftxft)
20x20	2.0	49	7x7
	1.5	72	8.5x8.5
	1.0	169	13x13
30x30	2.0	100	10x10
	1.5	169	13x13
	1.0	343	18.5x18.5
22.5x32	2.0	81	9x9
	1.5	121	11x11
	1.0	256	16x16

2. Natore site: At this site, the soil from the top 20 ft is comprised of clayed materials with low SPT values. The allowable bearing pressure at 8-10 ft below ground level is about 0.8-0.9 ton/sq.ft. Considering a surcharge load from 10 feet filling, which is required for the site, and high compressibility of the upper layers, open foundation is not feasible. The consultant suggested pile foundation using 16 in. dia., 55 ft. long piles to carry a design load of 35 tons per pile with a factor of safety of 3.

3) Shiromoni site: At this sites the soil from the top 10 ft. is comprised of loose fine sand and appears to be of recent origin. The layer below (upto 25 feet) is silty clay having very low SPT values. The allowable bearing pressure at a depth of 12 ft is about 0.25 ton/sq.ft. Open foundation is, therefore, not feasible. The consultant suggested to provide pile foundation using 16 in. dia., 50 ft. long piles to carry a design load of about 30 ton with factor of safety 3.

It is obvious, from the above discussion, that all the soils need pile foundation and the number, size and length of pile depends on the load to be assigned to each pile and prevailing soil condition.

5.5.1 Pile foundation for different grids

Piles can never be driven perfectly straight and at the exact locations. A certain amount of variation does occur.

Even if piles are located accurately in position, there is some bending moment transmitted to the pile cap by the column. Therefore, building codes do not permit the use of less than three piles to support a major column unless the substructure is so framed as to bring the load concentrically to the centroid of piles. When the columns are supported on two piles the caps must be connected by grade beams in either direction with the adjacent column.

When piles are used it is better to concentrate more load under one column so that at least threee piles can be used under one column for better and efficient functioning. The exact number of piles required for different grids considered is calculated from the actual load of the columns, taking 12 inch x 12 inch precast piles 40 ft in length carrying a design load 25 ton with factor of safety 3, are shown in Table 5.5 for the purpose of comparison. For 3 piles the required area of pile cap is about 29 sq.ft (Appendix-E-1) and there has no significant effect for heavy floor loading.

Table 5.5 Number of piles required for different grids.

Grid size (ftxft)	No. of piles required
20x20	120
30x30	80
22.5x32	72

It appears from Table 5.5 that the number of piles required in 22.5 ft x 32 ft grid is minimum thus reducing the foundation cost to a large extent than that in case of the other two grids. Design details of pile foundation are given in Appendix E-2.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

On the basis of the field observations and analyses of fertilizer godowns and considering three different grid patterns for a typical godown, the following conclusions may be made.

a) A warehouse can be designed with standardised superstructure and foundation with scope of modification to take into account the varying soil condition.

b) The roof span of 22.5 ft. x 32 ft. may conveniently be adopted in a fertilizer godown from technical as well as economic points of view.

c) The fertilizer warehouses may be erected on pile foundations using three piles under one column for efficient functioning.

d) The casting and finishing of concrete floor slab for a fertilizer godown may be done after loading the subsoil (bare floor) so that the major settlement of the subgrade is already taken place, thereby reducing residual settlement.

e) The column section of a fertilizer godown should have more than normal clear cover to prevent or at least delay the process of corrosion of reinforcements.

The column may also have larger section than the structural requirement due to possible weakening of concrete.

6.2 Recommendations for Future Study

From the analysis and discussion of the present study the following further investigations on fertilizer godowns are recommended.

a) Investigation into other possible economic panels than the proposed 22.5 ft x 32 ft taking consideration to cost-benefit ratio and technical soundness.

b) Investigation for finding simple solutions for the adverse effect of urea on floor and column of a ertilizer godown.

c) Investigation into analysis and cost comparison of a two way beam-column roof system with a flat slab system for a economic panel and to suggest the better type.

d) Extensive investigations regarding the remedial measure for constructional and structural faults in the existing godowns.

These findings will probably pave the way to establish the most economic design for a warehouse.

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APPENDICES

APPENDIX-A-1

Design Details of 20 ft. x 20 ft Grid Godowns

(Ref. Fig. A-1.1)

Slab: Perimeter/180 = $\frac{4x20x12}{180}$ = 5.5"

Beam: D.L (from slab) = $\frac{5.5x150}{12}$ = 70

L.C = 30

L.S = 20

120 psf

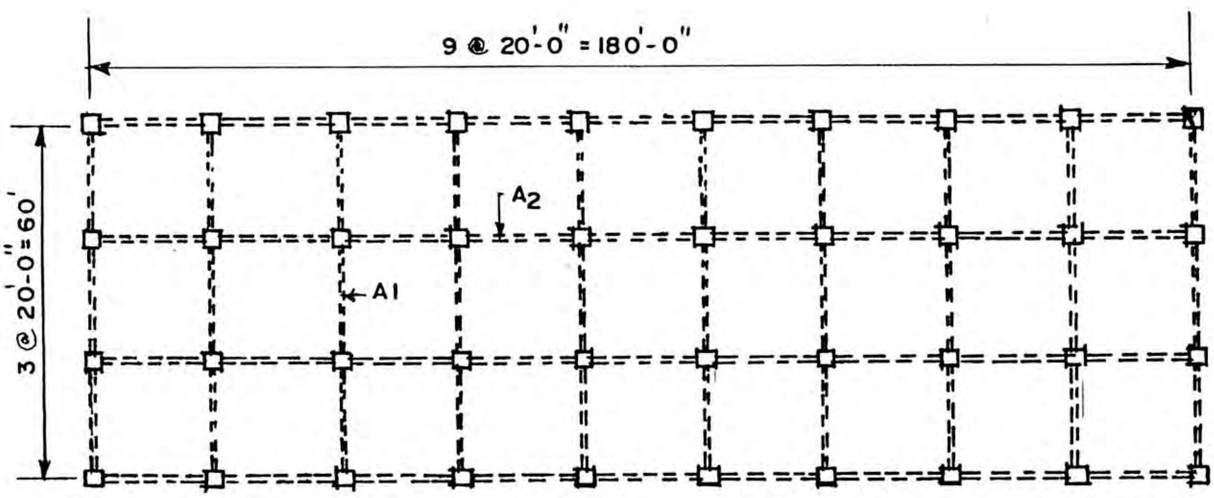


FIG. A - 1.1

Beam : A_1

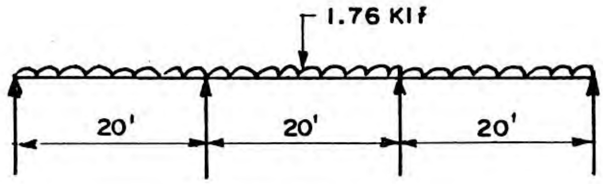


FIG. A-1.2

Loading:

From slab $\frac{120x20x2}{3}$

D.L of beam $\frac{150x10x16}{144}$

= 1766 plf = 1.76 klf

Clear span 18'-10" = 19' beam size 10"x21.5"

$-M = \frac{1.76x19^2}{10}$ = 63.5 k'

A_s = 2.9 in^2

$+M = \frac{1.76x19^2}{11}$ = 57.76 k'

A_s = 2.66 in^2

$+M = \frac{1.76x19^2}{16}$ = 39.71 k'

A_s = 1.8 in^2

Reinforcement required: (Ref. Fig. A-1.4)

#7.

3x62 = 186

14x4 = 56

242x2.044 = 494.65 lbs

#6.

2x62 = 124

4x28 = 112

236x1.502 = 354.50 lbs

#3. 5x90x.376 = 168.20 "

1017.35

=1017 lbs

Beam A_2

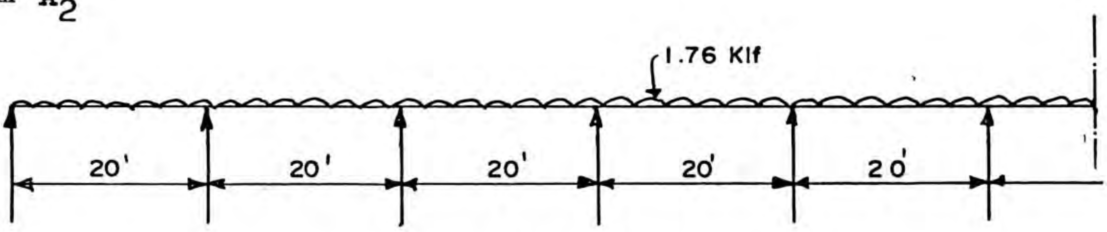


Fig A-1.3

Loading and moments same as in Beam A_2

So, reinforcement at the critical section as in Beam A_1

Beam size 10"x21.5"

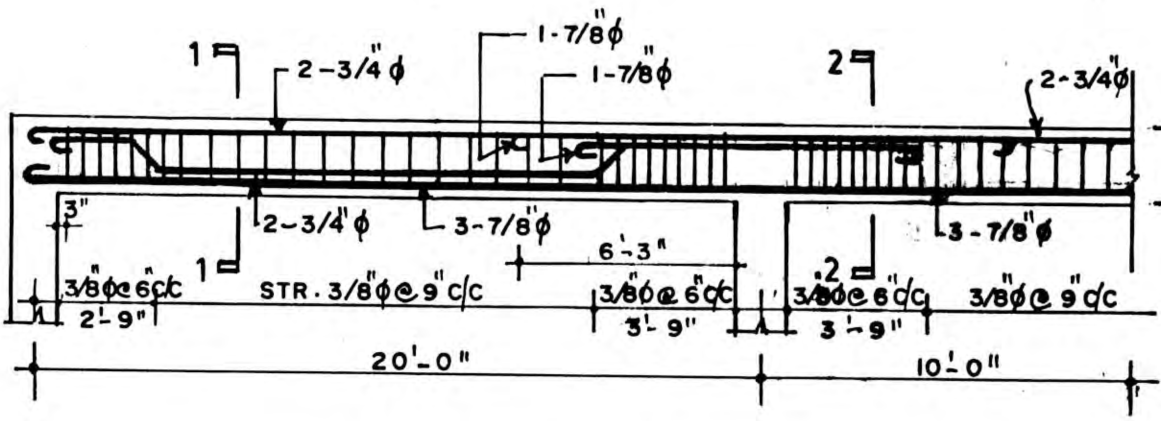
Reinforcement Required (Ref. Fig.A-1.5)

#7.

3x182 = 546

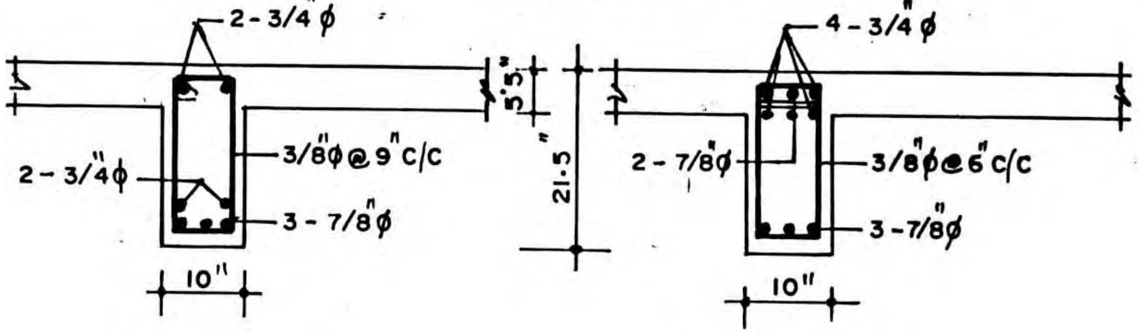
14x22 = 308

854x2.044 = 1746



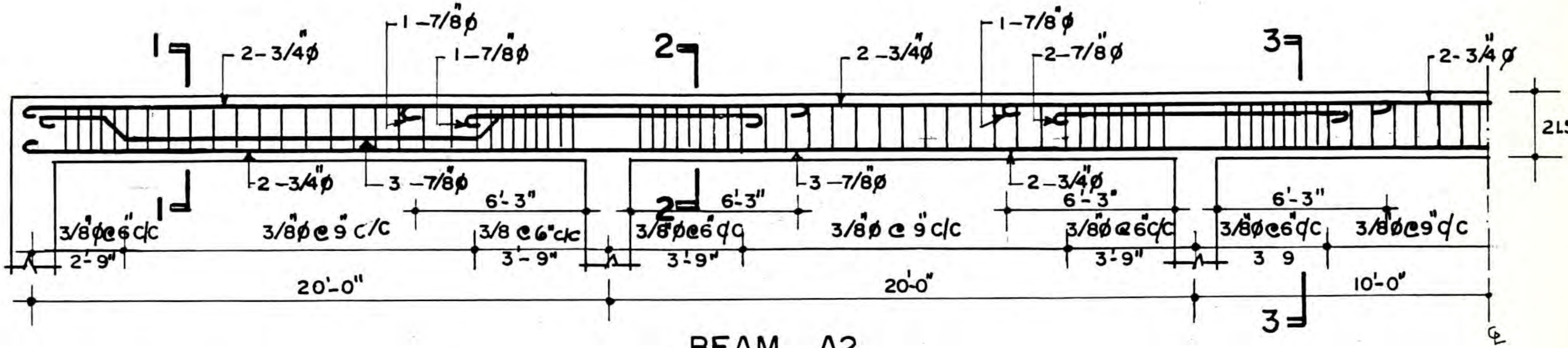
BEAM A1

Fig. A-1.4

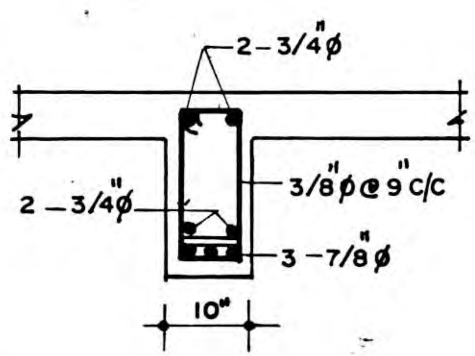


SECTION 1-1

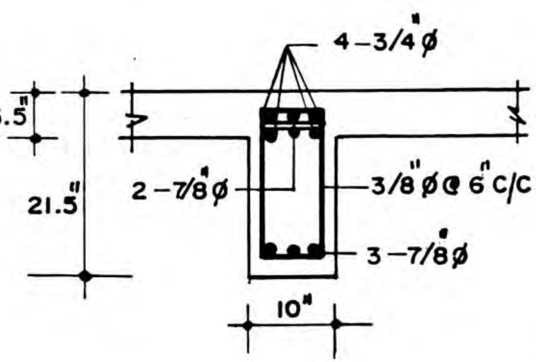
SECTION 2-2



BEAM A2



SECTION 1-1



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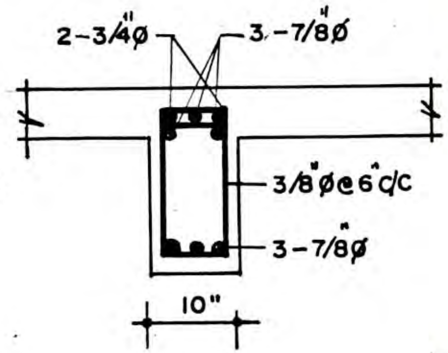
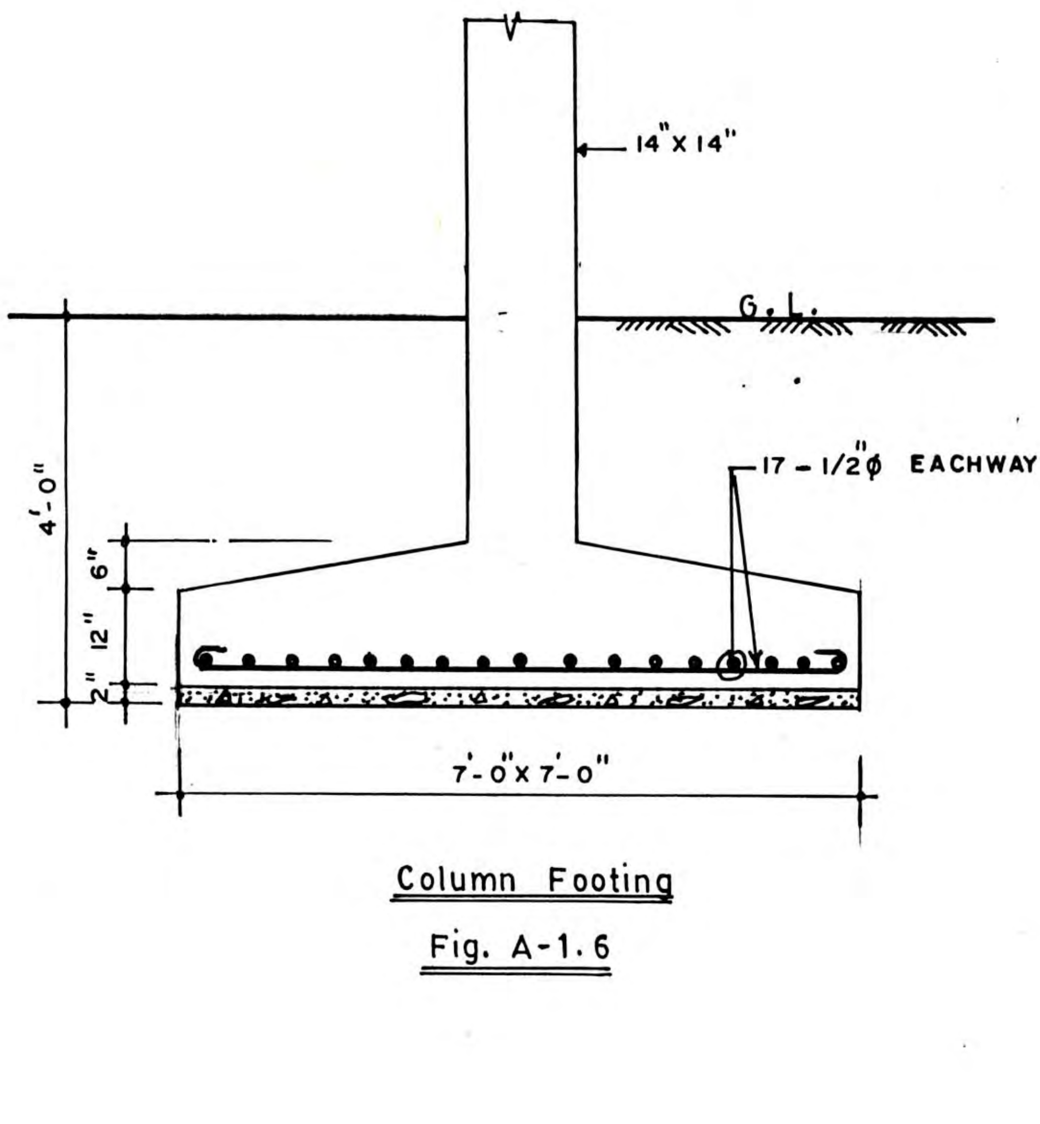


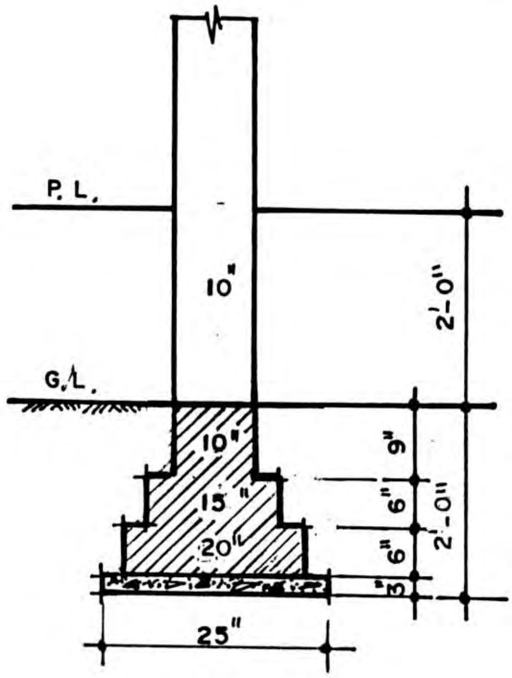
SECTION 3-3

FIG. 1.5



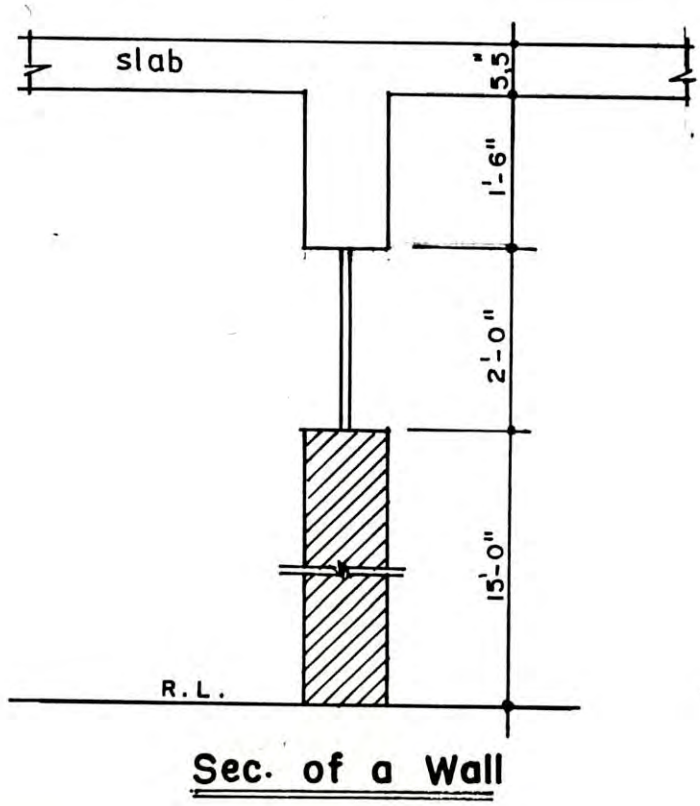
Column Footing

Fig. A-1.6



Wall Footing

Fig. A - 1.7



Sec. of a Wall

FIG. A-1.8

#6.

2x182 = 364

4x28 = 112

476x1.502 = 715

#3.

5x270x.376 = 508

2969 lbs

Column: Number of columns required = 40

Size 14"x14"

Reinforcement: 8- 5/8"Ø

Footing: Column load from super-structure

$$\text{Slab} = 120\times400 = 48{,}000 \text{ lbs}$$

$$\text{Beam} = \frac{10\times16\times38\times150}{144} = 6300 \text{ "}$$

$$\text{Column} = \frac{14\times14\times22\times150}{144} = 4490 \text{ "}$$

58,830 lbs.

Area of footing required = 7'x7'

Reinforcement required 17 - 1/2" Ø each way.

APPENDIX-A-2

ESTIMATES OF WORKS IN DIFFERENT ITEMS FOR 20'x20' GRID

a) Earthwork:

Footing $7 \times 7 \times 4 \times 40$

$24 \times \frac{25}{12} \times 3 \times 13$

9730 cft

b) Brickwork:

Foundation

Only peripherial upto P.L

$24 \times 18'\text{-}10'' \times \frac{35 \times 1}{12 \times 2}$ = 660 cft

$24 \times 18'\text{-}10'' \times \frac{10}{12} \times 3'\text{-}9''$ = 1413 "

Wall $24 \times 18'\text{-}10'' \times \frac{10}{12} \times 15$ = 5650 "

7720 cft

c) Concrete (Plain)

c.c in foundation

$40 \times 7 \times 7 \times \frac{2}{12}$

$24 \times \frac{25}{12} \times \frac{3}{12} \times 18'\text{-}10''$

556 cft

d) Concrete (R.C.C)

i) Slab

(3.5' extended beyond centre line of column)

$187 \times 67 \times \frac{5.5}{12}$ = 5743 cft

ii) Beam $\frac{10 \times 16 \times 18'10'' \times 66}{144}$ = 1339 "

iii) Column $\frac{14 \times 14}{144} \times 22.5 \times 40$ = 1225 "

iv) Footing $40 \times 7 \times 7 \times 1 + 40 \times 9.75$ = 2350 "

10657 cft.

e) Reinforcement:

i) Slab (1.3%)		= 327 cwt
ii) Beam	$\frac{1017x10+2969x4}{112}$	= 197 cwt
iii) Footing	$40x2x17x7'\text{-}6"x.\frac{667}{112}$	= 61 cwt
iv) Column	40x8x25x1.043/112	
	40x25x.376x4.25/112	= 89 cwt
		674 cwt.

APPENDIX B-1

Design of 30'x30' Grid Godowns (Ref. Fig. B-1.1)

Slab thickness: 4"

Beam	:	D.L $\frac{4}{12 \times 100}$	= 50 psf
		L.C	= 30 "
		L.L	= 20 "
			100 psf

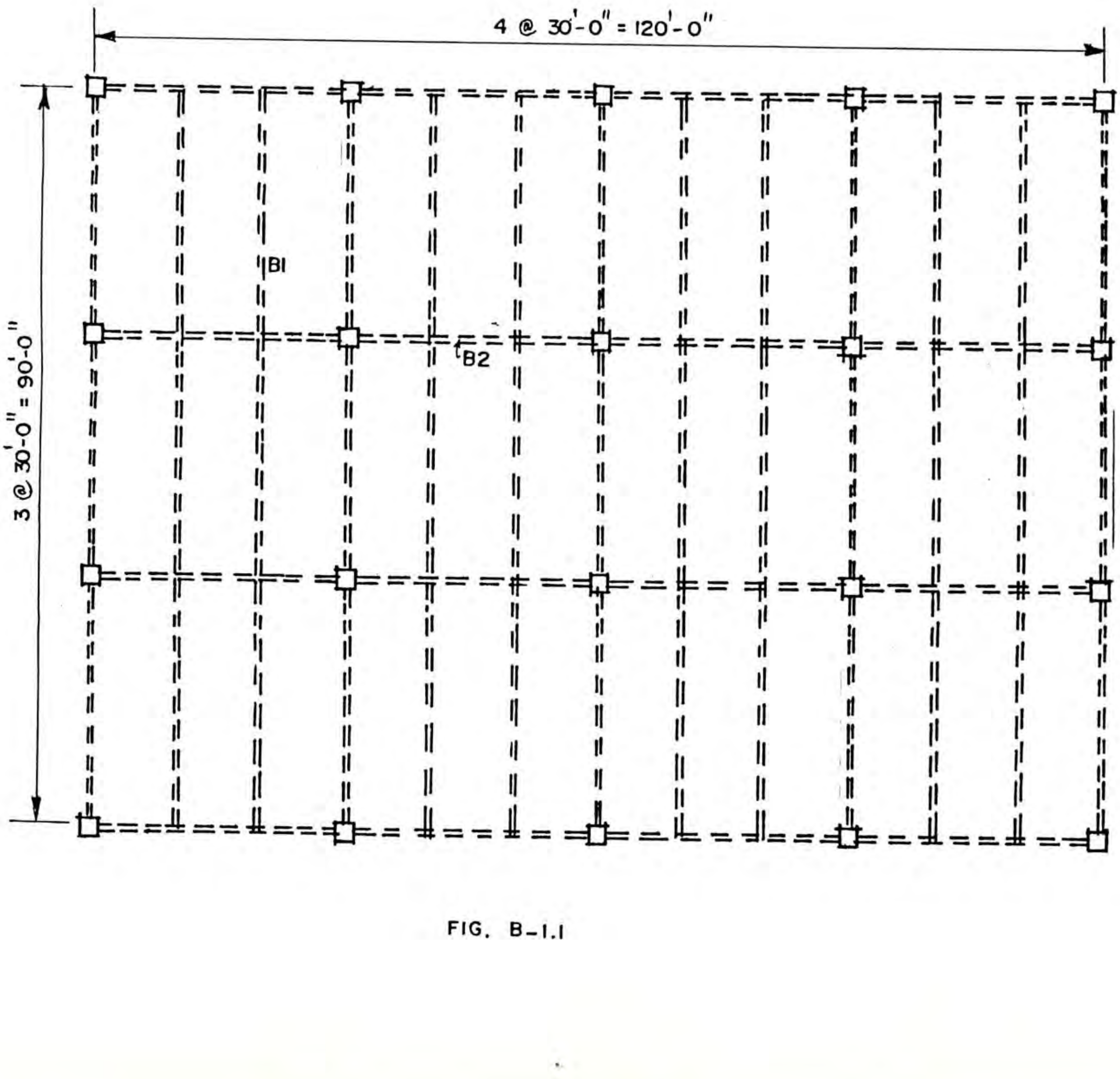


FIG. B-1.1

Beam B_1:

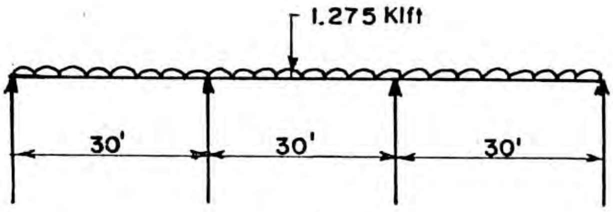


FIG. B-1.2

Clear span 28'8"

Beam size 12"x24"

Loading:

$$10 \times 100 = 1000$$

$$\frac{12 \times 22 \times 150}{144} = 275$$

$$1275 \text{ plf}$$

$- M = 107.23$ k' ($A_s = 4.14$ in^2 , $A'_s = 0.612$ in^2)

$+ M = 97.48$ k' ($A_s = 3.75$ in^2)

$+ M = 67.01$ k' ($A_s = 2.58$ in^2)

16t + b' = 76, Span/4 = 90

Centre line of beam spacing 120

First criterion controls and b is taken as 76

$+ M = 97.48$ k', As required $= \dfrac{M}{f_s(d-t/2)} = 3.61$ in^2

$p = \dfrac{3.61}{76 \times 20} = .00237$, pn = 0.02133, k= .1863

kd = 3.72   4 , The beam is not,in effect, as T beam.

$- M = - 107.23\ k',\ Rbd^2 = 94\ k'$

$M_1 = 94\ k',\ A_{s1} = 3.62\ in^2$ $\qquad A_s = A_{s1} + A_{s2} = 4.14\ in^2$

$M_2 = 13.23\ k',\ A_{s2} = .52\ in^2$

$f'_s = 2\ f_s\ \frac{k-d'/d}{4-k} = 15.256\ ksi \angle 18\ ksi$

$A'_s = \frac{13.23x12}{15.256x17} = .612\ in^2$

Reinforcement required (Ref. Fig. B-1.4)

#8. 3x92 = 276x2.67 = = 736.92 lbs

#7. 3x92 =276
6x21 = 126
4x40 = 160
562x2.044 = = 1148.728 lbs

#3. 6x132x.376 = 298 lbs

2183.648 lbs =19.5 cwt.

Beam B_2:

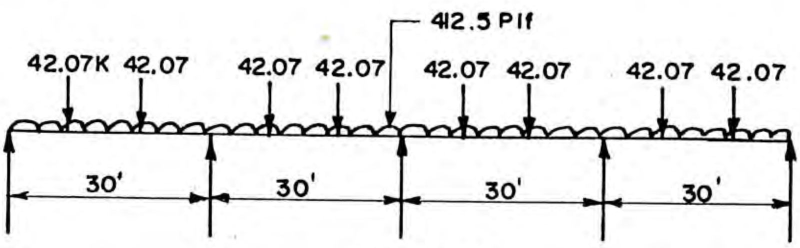


FIG. B-1.3

Clear span 28.67'

Beam size 14"x33"

Loading: $\frac{100x10x30}{1000} = 30.00\ k$

$\frac{12x22x150x30}{1444x1000} = \underline{8.25\ k}$

38.25 k

.˙. Concentrated load 38.25x1.1 = 42.07 k

Distributed load $\frac{14x29x150}{144}$ = 422.9 plf.

- M = 378.86 k'

+ M = 317.88 k'

+ M = 156.27 k'

- M = 259.18 k'

M = 378.86 k'; $M_1 = Rbd^2 = \frac{235x14x29^2}{12x10^3}$ = 230.57 k' A_{s1} = 6.12 in^2

M_2 = 148.29 k'; A_{s2} = 3.80 in^2

$\therefore A_s$ = 9.92 in^2

$f'_s = 2 f_s \frac{k-d'/d}{1-k}$ = 15.68∠18.0 k

$\therefore A'_s$ = 4.72 in^2

M = 317.88 k';

Span/4 = 90"

Centre line of beam spacing = 360"

16t + b' = 78"

Third criterion controls and b is taken as 78"

A_s required = $\frac{M}{f_s(d-t/2)} = \frac{317.88x12}{18x26}$ = 8.15 in^2

$p = \frac{A_s}{bd} = \frac{8.15}{78x28}$ = .00373

pn = .0335 t/d = .142 k = .25 j = .938

kd = 7 > t

T beam effect confirmed

Revised $A_s = \frac{M}{f_s jd}$

$= 8.068 \text{ in}^2$

$+ M = 156.27$ k' ($A_s = 4.15 \text{ in}^2$)

$- M = 259.18$ k' ($A_s = 6.85 \text{ in}^2$)

Reinforcement required: (Ref. Fig. B-1.5)

#8.

5x122 = 610

6x42 = 252

18x21 = 378

1240 x2.67 = 3310.80 lbs

#7.

2x122 = 244

4x42 = 168

8x21 = 168

580 x 2.044 = 1185.52 "

#6.

2x122 = 244x1.502 = 366.488 "

#3.

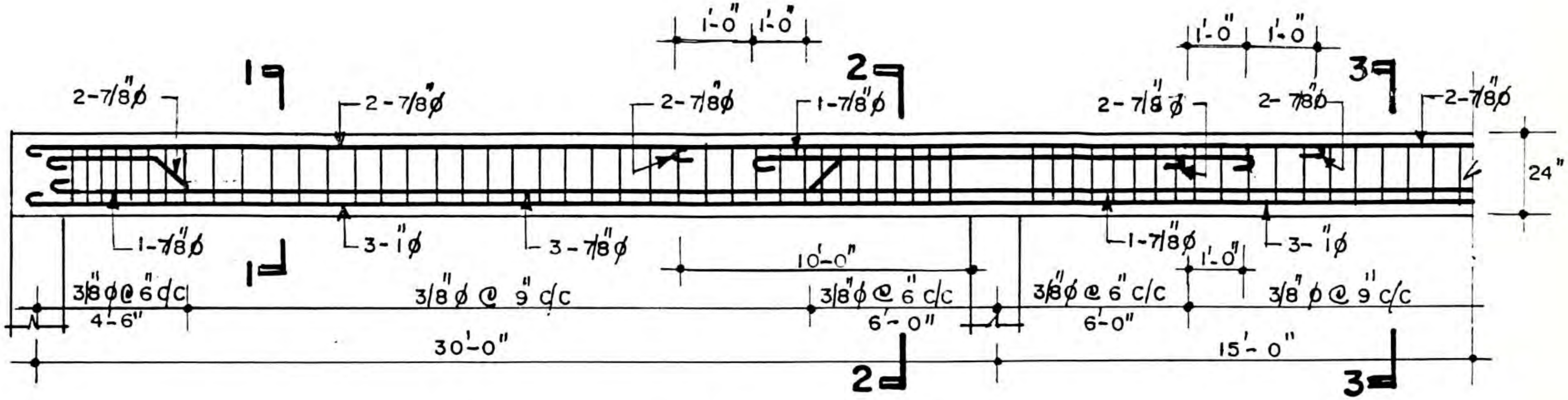
57x4x8x.376 = 685.00 "

5547.808 lbs

= 49.53 cwt.

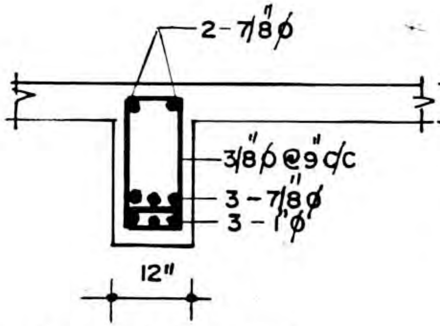
Column:

Number of columns required	20
Size	16"x16"
Reinforcement	8 - 7/8" ø

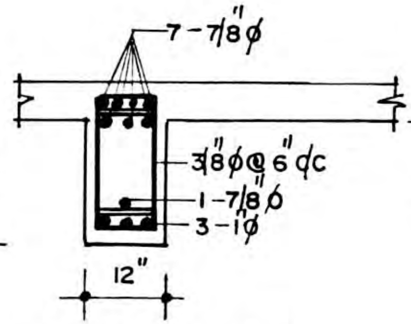


BEAM B1

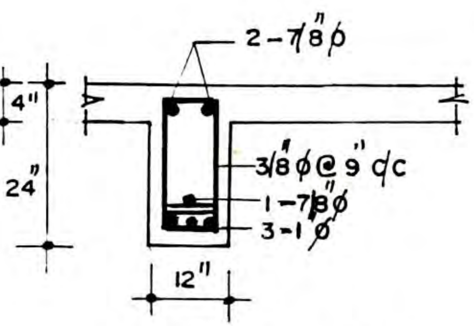
FIG. B-1.4



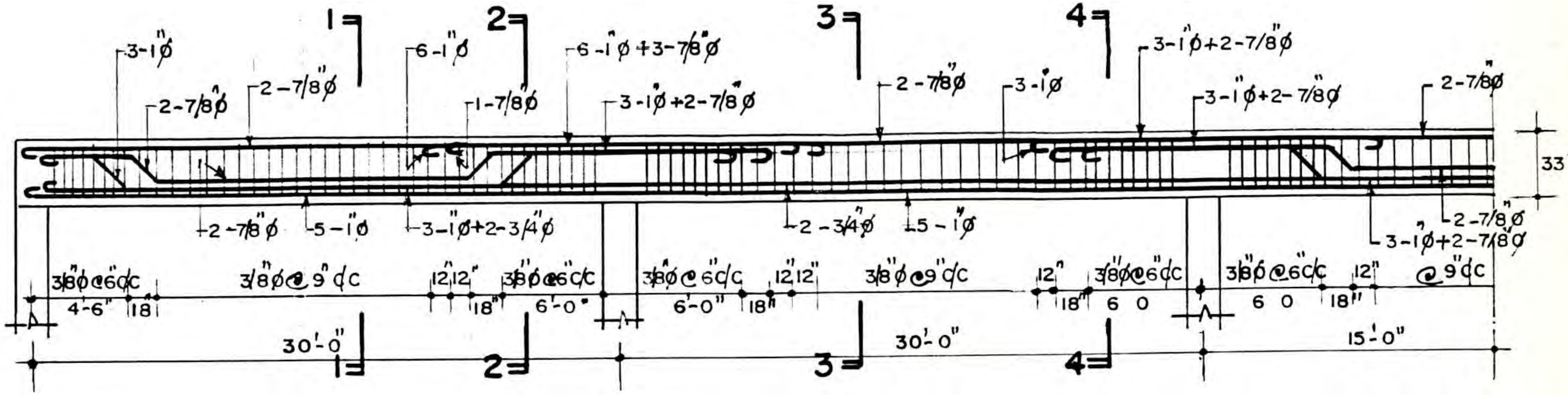
SECTION 1-1



SECTION 2-2

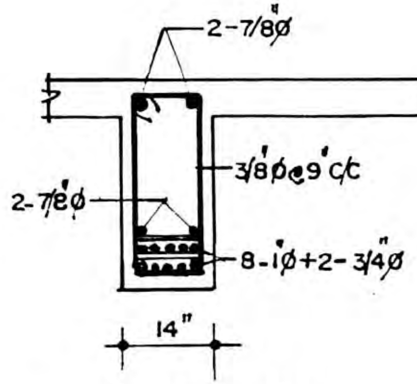


SECTION 3-3

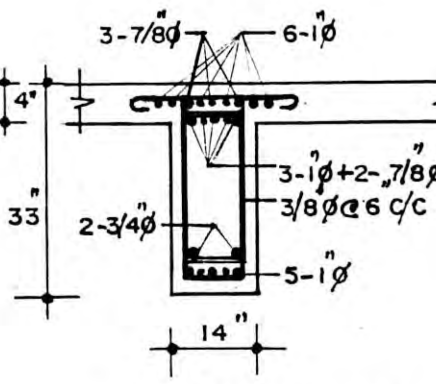


BEAM B2

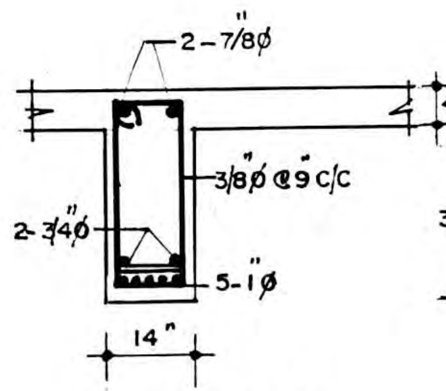
FIG. B-1.5



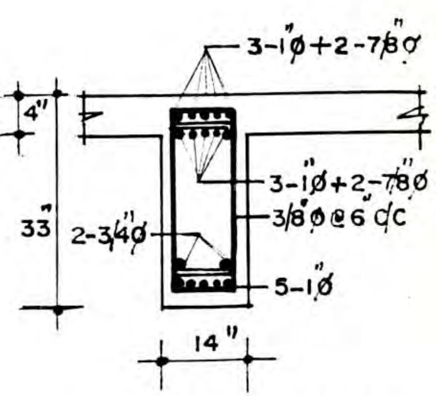
SECTION 1-1



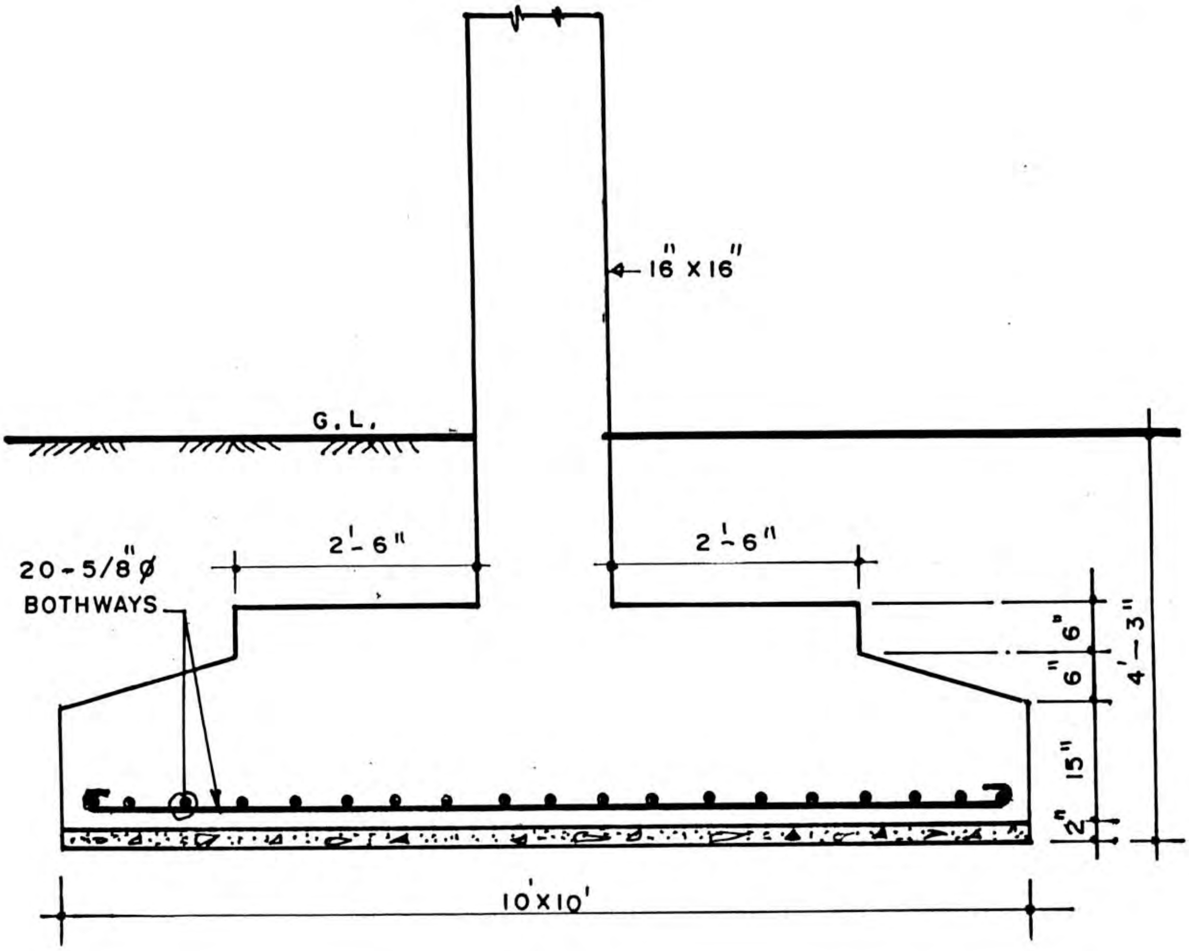
SECTION 2-2



SECTION 3-3



SECTION 4-4



Column Footing

Fig. B-1.6

Footing:

Column load from superstructure

Slab	30x30x100	90 k
Beam	$\frac{3x30x12x22x150}{144}$	
	$\frac{1x30x14x29x150}{144}$	37.43 k
Column	$\frac{16x16x22x150}{144}$	5.86 k
		133.29 k

Footing required 10'x10'

Reinforcement 20 - 5/8" Ø each way.

APPENDIX-B-2

ESTIMATES OF WORKS IN DIFFERENT ITEMS FOR 30'x30' GRID

a) Earthwork:			
Footing	20x10x10x4.25		
	$14x\frac{25}{12}x3x20$	10,250 cft	
b) Brickwork	$14x\frac{35}{2x12}x1x28.67$		
upto P.L.	$14x\frac{10}{12}x3.75x28.67$	1839 cft	
Wall	$14x\frac{10}{12}x28.67x15$	5017 "	6856 cft
c) Plain concrete:			
Footing	$20x10x10x\frac{2}{12}$		
	$14x\frac{25}{12}x\frac{3}{12}x28.67$	542 cft	
d) Concrete (R.C.C.)			
Slab	127x97x4/12	4106 cft	
Beam	13x3x28.75x12x20/144		
	$4x4x28.75x14x\frac{29}{144}$	3166 "	
Column	16x16x22x20/144	782 "	
Footing	10x10x1.25x20		
	6.33x6.33x.5x20	3578 "	11632 cft.
	33.9x20		

e) Reinforcement

Slab (1.20%)		215 cwt
Beam	13x17+4x49.53	451.62 cwt
Column	20x8x25x2.044	81.4 "
	20x5x25x.376	
Footing	20x20x2x10.5x1.043	78.22 "
		826.24 cwt
		= 826 cwt.

APPENDIX-C-1

Design of 22.5'x32' Grid Godown

(Ref.Fig. C-1.1)

Slab thickness		4"
Beam:	D.L	$= \frac{4}{12} x 150 = 50$
	L.C	= 30
	L.L	= 20
		100 psf

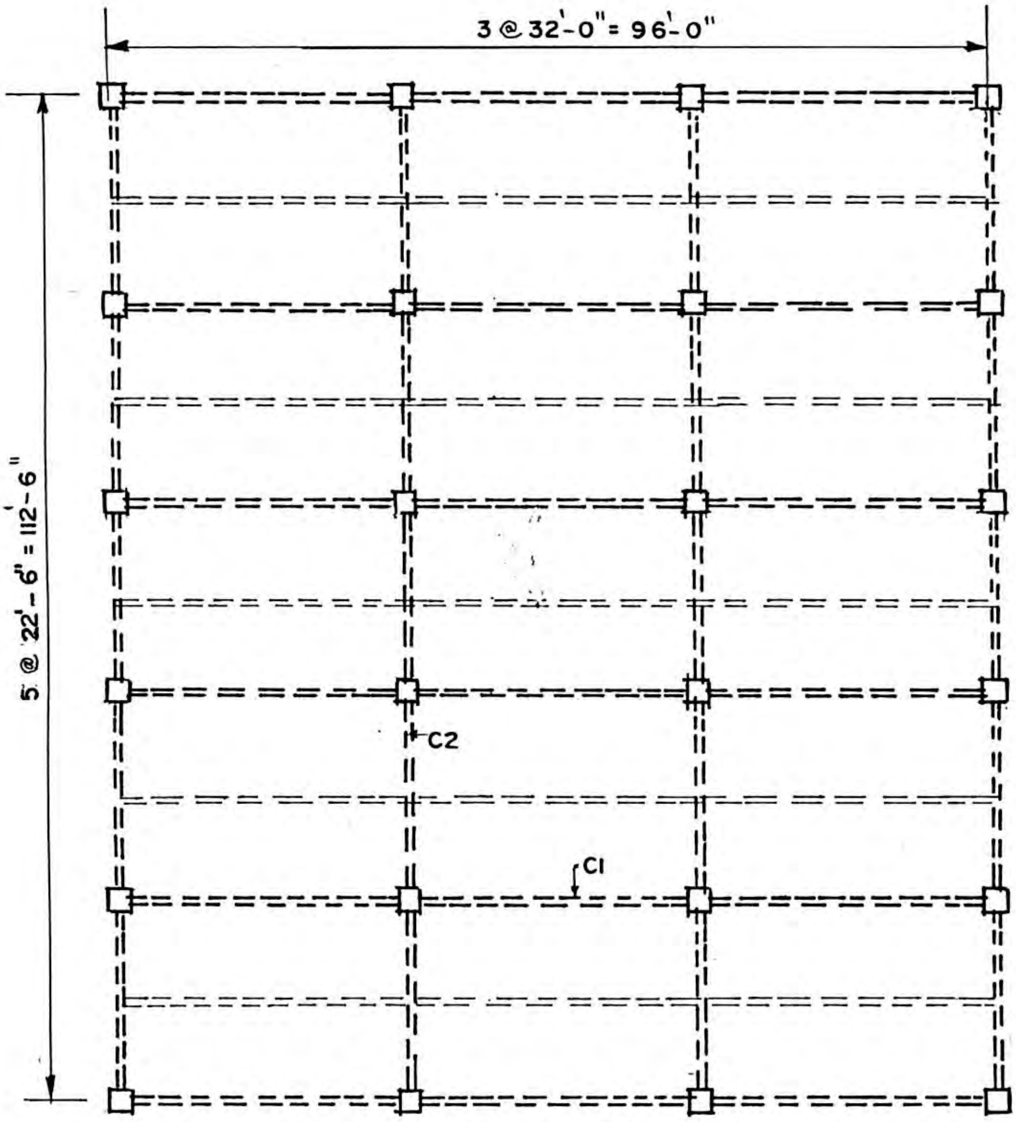


FIG. C-1.1

Beam C_1:

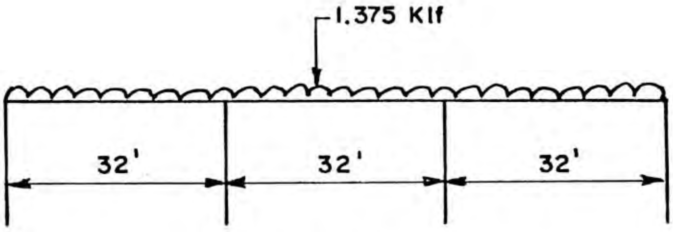


FIG. C-1.2

Clear span 30'9" = 31'

Beam size 12"x24"

Loading

$$11.25 \times 100 + \frac{12 \times 20}{144} \times 150 = 1375 \text{ plf}$$

$$-M = \frac{1.375 \times 31^2}{10} = 132.12 \text{ k'}$$

$$(A_s = 5.11 \text{ in}^2, \quad A_s' = 1.763 \text{ in}^2)$$

$$+M = \frac{1.375 \times 31^2}{11} = 126.12 \text{ k'} \ (A_s = 4.52 \text{ in}^2)$$

$$+M = \frac{1.375 \times 31^2}{16} = 82.58 \text{ k'} \ (A_s = 3.10 \text{ in}^2)$$

16t + b' = 76"

Span/4 = 96", Centre line of beam spacing 135"

First criterion controls and b is taken as 76"

$+M = 126.12$ k'

A_s required $= \dfrac{M}{f_s(d-t/2)} = 4.67$ in^2

$p = \dfrac{A_s}{bd} = \dfrac{4.67}{76x20} = .00307$

$pn = .0276$, $t/d = 0.2$, $k = .205$ and $j = .93$

$kd = 4.1 > 4.0$ in

and the beam is, in effect, a T beam as assumed.

Revised $A_s = \dfrac{M}{f_s jd} = 4.52$ in^2

Maximum concrete stress,

$$f_c = \frac{M}{(1-t/2kd)btjd} = 522 \text{ psi} < 1350 \text{ psi}$$

$-M = 132.12$ k'

$Rbd^2 = 235x12x20^2 = 94$ k'

$\therefore M_1 = 94$ k' $\quad A_{s1} = \dfrac{M_1}{f_s jd} = 3.618$ in^2

$M_2 = 38.12$ k'

$A_{s2} = \dfrac{M_2}{f_s(d-d')} = \dfrac{38.12x12}{18x17} = 1.494$

$$A_s = A_{s1} + A_{s2} = 5.11 \text{ in}^2$$

$f'_s = 2 f_s \dfrac{k-d'/d}{1-k} = 15.256$ ksi < 18 ksi

$A'_s = \dfrac{38.12x12}{15.256x17} = 1.763$ in^2

Reinforcement required (Ref. Fig. C-1.4)

#8.

4x98 = 392'

4x32 = 168'

560 x2.67   1495.2 lbs

#7.   2x98 = 196

8x22 = 176

372x2.044   760.37 "

#3.   6x3x47x.376   318 "

2573.57 = 22.98 cwt.

Beam C_2:

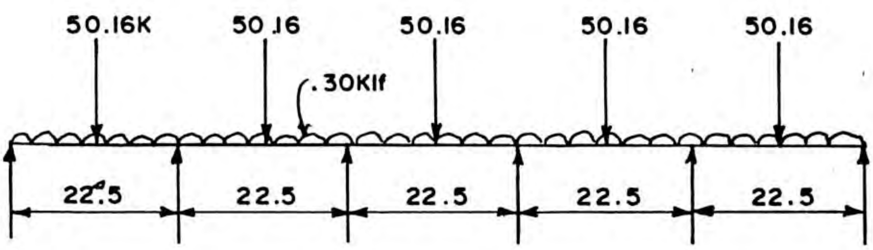


Fig. C-1.3

Clear span 21.25'

Beam size 12"x28"

Loading:

$$\frac{24\text{x}12\text{x}150\text{x}32}{12\text{x}12\text{x}1000} = 9.6 \text{ k}$$

$$\frac{100\text{x}32\text{x}11.25}{1000} = 36.0 \text{ k}$$

45.6 k

∴ Concentrated load 45.6x1.1 = 50.16 k.

Distributed load: $\frac{12x24x150}{144} = 300$ plf

$$-M = \frac{.3x21.25^2}{10} + 50.16x21.25x.158 = 181.95 \text{ k'}$$

$$M_1 = 135.36 \text{ k'}, \quad A_{s1} = 4.34$$

$$M_2 = 46.59 \text{ k'}, \quad A_{s2} = \frac{1.48}{5.82 \text{ in}^2}$$

$$A'_s = 1.62 \text{ in}^2$$

$$+M = 194.58 \text{ k'} \qquad A_s = \frac{M}{f_s(d-t/2)} = 5.89 \text{ in}^2$$

$$+M = 125.72 \text{ k' } (A_s = 3.99 \text{ in}^2)$$

$$-M = 139.15 \text{ k' } (A_s = 4.46 \text{ in}^2)$$

$$+M = 147.03 \text{ k' } (A_s = 4.66 \text{ in}^2)$$

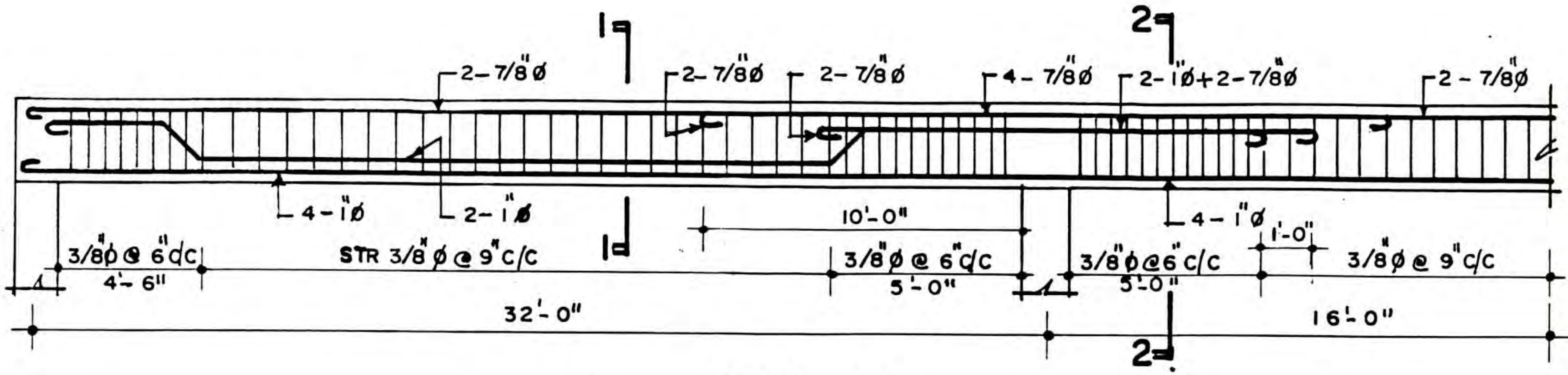
Reinforcement required (Ref. Fig. C-1.5)

#8.

	6x115	= 690	
	2x120	= 240	
	12x16	= 192	
		1122x2.67	= 2995.74 lbs
#7.	4x32 = 128x2.044		= 261.62 "
#3.	45x5x7.5x.376		= 634 "
			3891.31 "
			= 34.74 cwt.

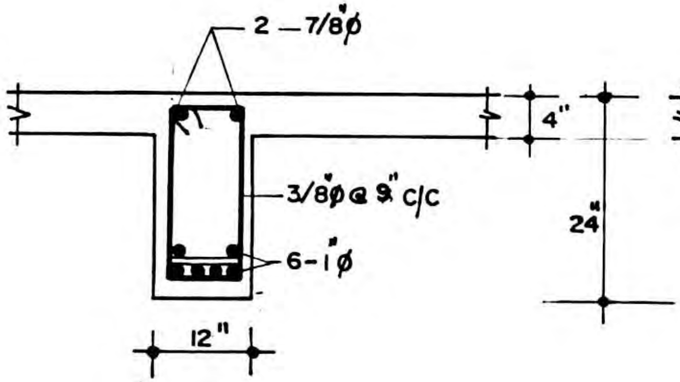
Column:

Number of column required	24
Size	15"x15"
Reinforcement	8 - 3/4" Ø.

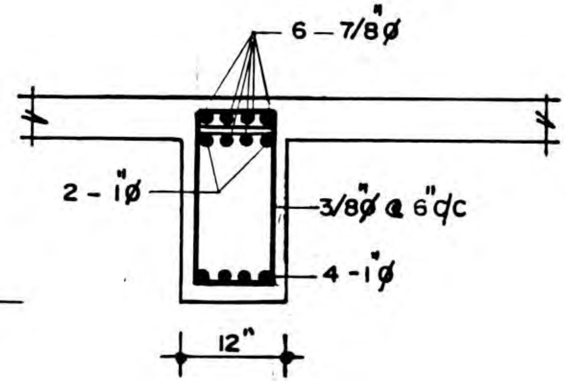


BEAM C1

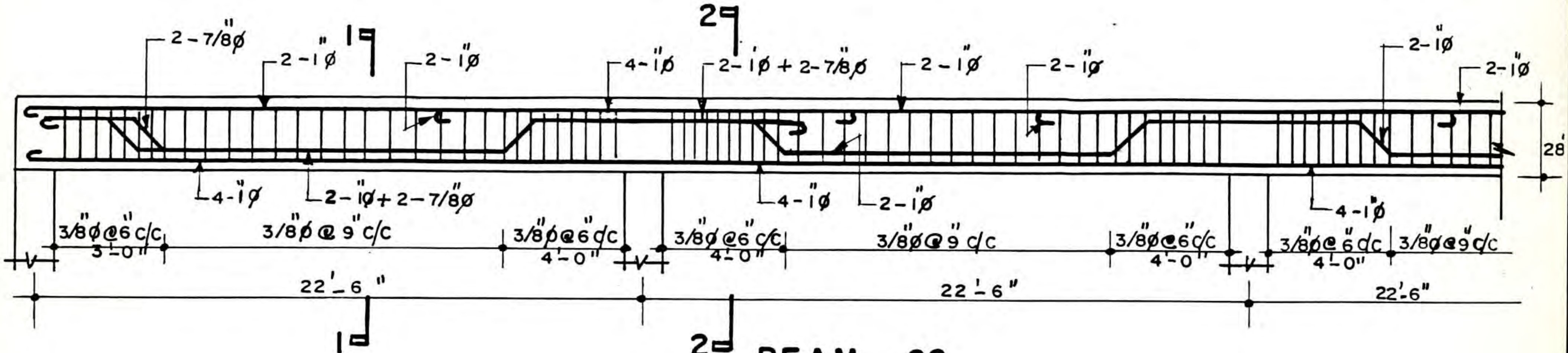
FIG. C-1.4



SECTION 1-1

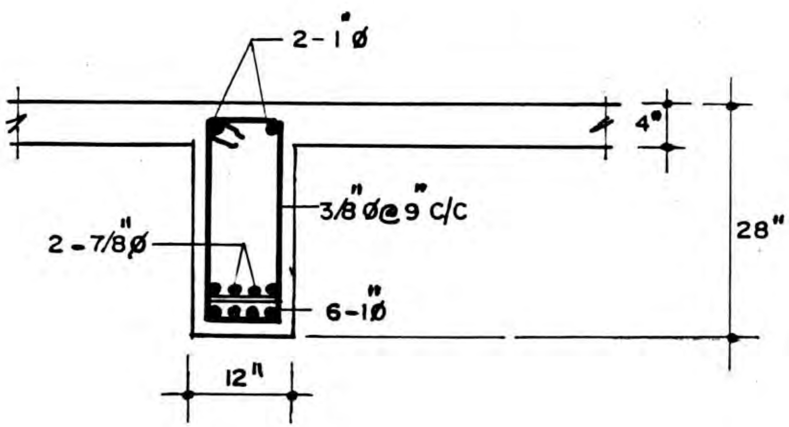


SECTION 2-2

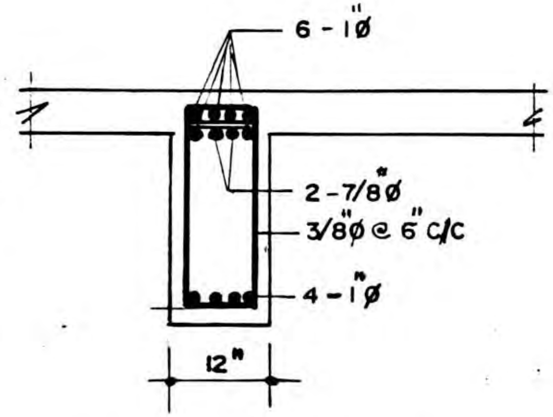


BEAM C2

FIG. C-1.5



SECTION 1-1



SECTION 2-2

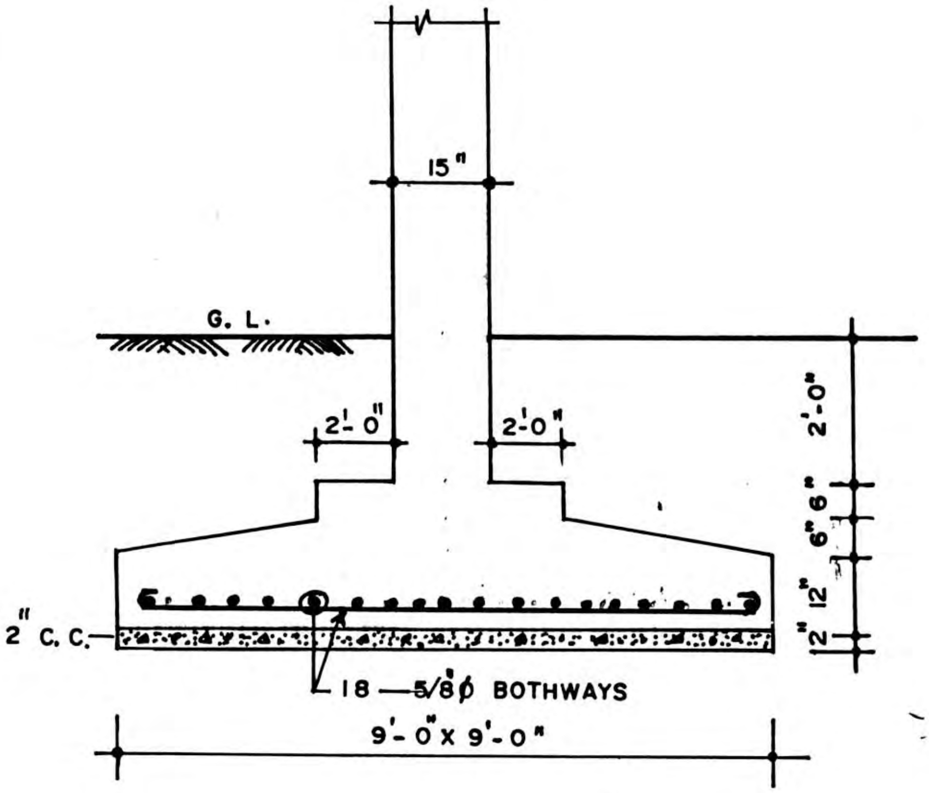


Fig. C-1.6

Footing:

Column load from superstructure

Slab	32x22.5x100	72 k
Beam	2x1x1.67x32x150	22.7 k
	1x1x2x22.5x150	
Column		
	$\frac{15 \times 15 \times 150 \times 22}{144}$	5.2 k
		99.9 k
		= 100 k

Area of footing required = 9'x9'

18 - 5/8" Ø each way.

APPENDIX-C-2

ESTIMATES OF WORKS IN DIFFERENT ITEMS FOR 22.5'x32' GRID

a) Earthwork:

Footing 24x9x9x4

10x25x3x23/12

6x25x3x13.5/12

= 9483 cft

b) Brickwork:

$6\times\frac{35}{2\times12}\times1\times30.75$

6x10x30.75x3.75/12

10x35x1x21.25/24

10x10x3.75x21.25/12

upto P.L. 1836 cft

Wall 6x10x30.75x15/12

10x10x21.25x15/12

6799 cft

c) Concrete (Plain)

Footing 24x81x2/12

$6\times\frac{25}{12}\times\frac{3}{12}\times30.75$

$10\times\frac{25}{12}\times\frac{3}{12}\times21.25$

531 cft.

d) Concrete (R.C.C)

i) Slab $\frac{119.5 \times 103 \times 4}{12}$ 4103 cft

ii) Beam

12x20x3x11x30.75/144

12x24x5x4x21.25/144 2541 cft

iii) Column 24x15x15x22/144 825 "

iv) Footing 24x81x1

24x5.25x0.5x5.25

24x25.96

2898 cft

10,367 cft

e) Reinforcement:

i) Slab (1.20%) 215 cwt

ii) Beam 22.98x11+34.74x4 391.74 cwt

iii) Column: 24x8x25x1.5/112

24x4.5x25x.376/112 73.4 cwt

iv) Footing

24x18x2x9.5x1.043 76.5 cwt

756.64 cwt

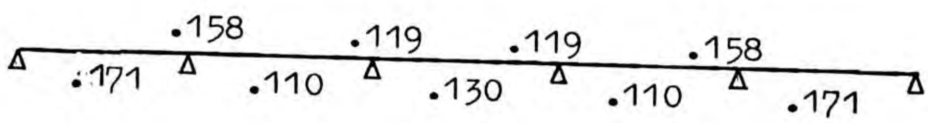
= 757 cwt.

APPENDIX-D

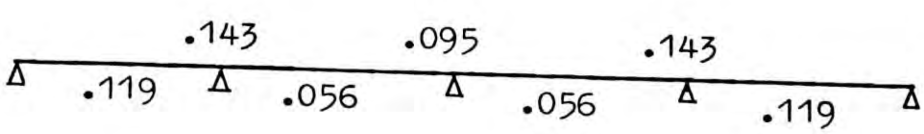
MAXIMUM BENDING MOMENT AND SHEAR FORCE COEFFICIENTS IN CONTINUOUS BEAMS OF EQUAL SPAN

Maximum bending moment coefficient:
(Beams freely supported at ends and for all spans equally loaded simultaneously).

a) Centre point load:



b) Point loads at 1/3 rd points:



Bending moment = Coefficient xWxL

W = Total load on one span

L = Effective span

Maximum shearforce in continuous beams of equal span

Maximum shear force coefficient:
Uniformly distributed load.

Shear force = coefficient x total load on one span.

APPENDIX E-1

PILE CAP DESIGN

(Three piles under 1 column)

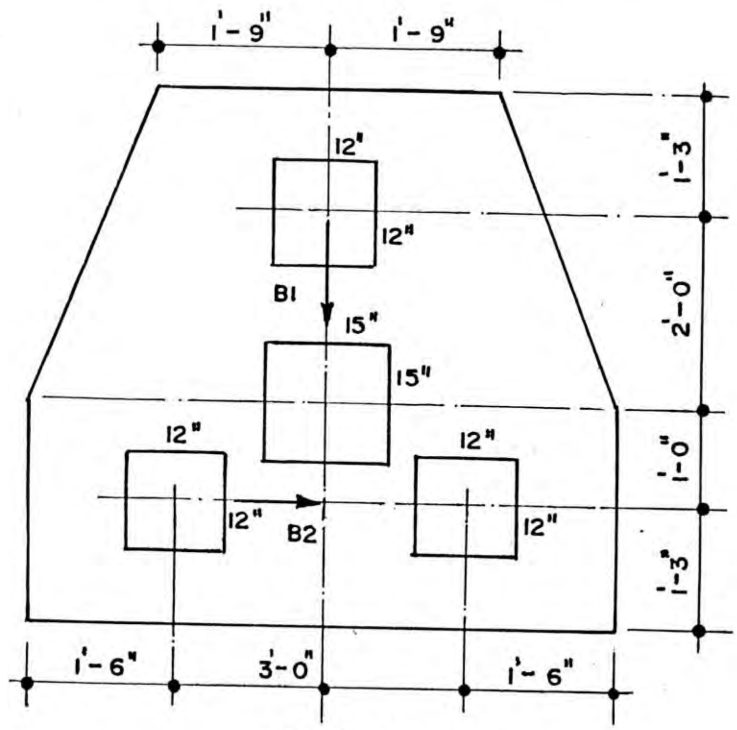


FIG. E-1.1

Load	= 100 k	
Floor load	= 14.465 k	
Self wt. of pile cap (2' depth)	= 8.679 k	
	123.144 k	= 124 k

∴ Allowable load per pile $= \frac{124}{3} = 41$ k

Total depth of pile cap assumed = 24"

Effective depth = 17"

For two way shear, the critical shear force (Ref. Fig. E-1.2) is equal to $(41 + 2 \times 8 \times \frac{41}{12}) = 95.68$ k

Shear stress $= \frac{95.68 \times 1000}{4 \times 32 \times 17}$

$= 43.96$ psi

Allowable shear stress $2 \quad f'_c = 110$ psi

Hence O.K.

For one way shear, critical line is at a distance of (17+7.5) = 24.5" from the centre of column. No pile is outside of this line. Check is not necessary.

Maximum bending moment B_1, 41x10.5 = 676.5 k"

Maximum Bending moment B_2, 41x10.5 = 430.5 k"

As required $= \frac{676.5 \times 12}{18 \times .866 \times 17} = 2.55 \text{ in}^2$

Minimum reinforcement required .0025 bt

= .0025x72x24

$= 4.32 \text{ in}^2$

Provide 14-5/8"Ø

Reinforcement details is shown in Fig. E-1.3.

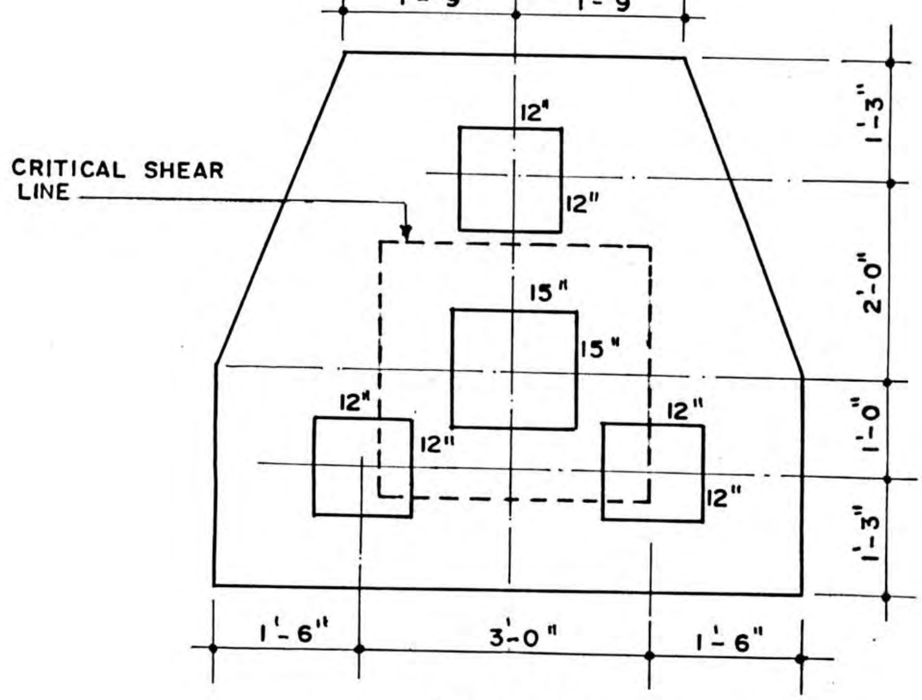


FIG. E – 1.2

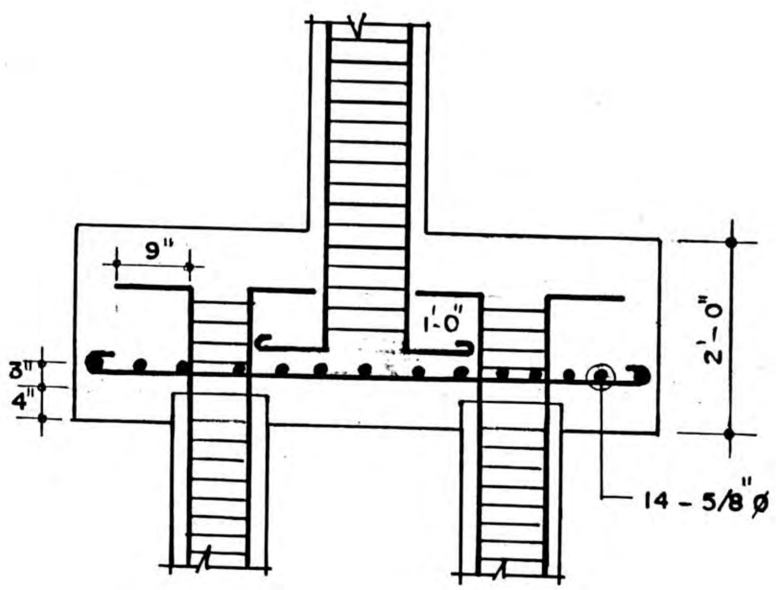


FIG. E – 1.3

APPENDIX-E-2

ESTIMATES OF NUMBER OF PILES IN DIFFERENT GRIDS

Area of pile cap (Ref. Fig.E-1.1)

= 28.93 sq.ft.

a) 20'x20' grid

Column load from superstructure	= 58830 lbs
Floor load 28.93x500	= 14465 "
Weight of pile cap (Assume 2' depth)	= 8679 "
	81974 lbs
	= 41 tons

2 piles satisfy but minimum 3 piles to be used.

∴ 40x3 = 120 piles required

b) 30'x30' grid

Column load from superstructure	= 133.29 k
Floor load	14.465 k
Wt. of pile cap(depth 2.5')	10.848 k
	158.60
	= 80 tons

3 piles of higher strength or 4 piles of the same strength needed.

∴ Total number of piles needed 20x3 = 60 of higher strength or 20x4 = 80 of the same strength as considered for other grids.

c) 22.5'x32' grid

Column load from superstructure	= 100 k
Floor load 28.93x500	14.465 k
Wt. of pile cap (depth 2')	8.679 k
	123.144 k = 62 tons

3 piles/column required

∴ Total number of piles needed 24x3 = 72.