ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

FACULTY OF TECHNOLOGY
DEPARTMENT OF CIVIL ENGINEERING

VIBRATIONAL CHARACTERSTICS OF BUILDINGS IN ADDIS ABABA .

TADESSE KEBEDE

JUNE,1999.

VIBRATIONAL CHARACTERSTICS OF BUILDINGS IN ADDIS ABABA

A Thesis Presented to the
School of Graduate Studies
Addis Ababa University

Supervisor Dr. Messele Haile.

In Partial Fulfillment
of the Requirements for the degree of
Master of science in Civil Engineering.

by
Tadesse Kebede
June,1999

ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

VIBRATIONAL CHARACTERSTICS OF BUILDINGS IN ADDIS ABABA

by
Tadesse Kebede
Faculty of Technology

Approved by Board of Examiners:

Dr. Bayou Chane

Chairperson, Department Graduate Committee

Dr. Messele Haile

Advisor

Professor Ramaswamy

Examiner

Dr. Ing. Asrat Worku

Examiner

TABLE OF CONTENTS

ACKNOWLEDGEMENT

This study was conducted under the supervision of my advisor, Dr. Messele Haile of Civil Engineering Department, Addis Ababa University. I would like to expresses my deepest gratitude to my supervisor Dr. Messele Haile, for his helpful guidance Throughout my research work and for providing me with relevant materials and his personal note book (lap-top) computer.

The author would also like to extend his gratitude to Owners of the following buildings: All Ethiopian Trade Union, Dasset Building, Oromya Regional Government Bureau, Ministry of Justice, Science and Technology Commission, Ethiopian Telecommunication Corporation, Ethiopian Grain Trade, Sunshine Builiding and Ato Mergia G/mariam for allowing me to take microtrmor Measurements on top of their buildings.

Finally I would like to thank Ato Elias Kebede, Ato Abebe Bekele, Ato Belete G/selassie and Ato Temtem for helping me in carrying the measuring instruments from one site to the other.

The research was Possible under the Incountry scholarship offered by DAAD. The author would like to take this opportunity to express his deep appreciation.

ABSTRACT

Dynamic loading acting on structural systems may result from several sources such as wind and vehicular motions, etc. The type of dynamic input, which is of greatest importance to the structural engineer undoubtedly is the one that is induced by earthquakes.

Buildings constructed in Seismic Zones are subjected to earthquake ground motion in addition to other types of loads. If one tries to generate response spectrum curves of a structure for different recorded ground motions, large variations will be observed in both the response spectral values and the shape of the spectrum curves. These variations depend on many factors, such as magnitude, source, and variation in geological formation along the path, local site condition and the nature of the building.

The recent trend of increasing height and scale of building structures accelerated the research and investigation activities in the area of Earthquake Engineering, with the aim to get rational and safe earthquake resistant design criteria. Consequently, one

of the current problems in evaluating earthquake response of a building is how to find out period of vibration of a building. Recent developments in the techniques for measuring period of vibration of building have permitted us to obtain important experimental information regarding the dynamic behavior of a building during earthquakes.

The fundamental period of buildings can be obtained by one of the following methods: -

1) Microtremor measurements: here ambient building vibrations are measured by using microtremors. These ambient vibrations called microtremors operate at a very low strain level. Properly interpreted, microtremors give the fundamental period of vibration of the building.

2) Code Method-or-Equivalent Static Analysis: this gives an approximate formula that can be used to determine the first mode period of a building.

3) Dynamic Analysis: is a sophisticated level of analysis available for finding period of vibration of buildings, that employs Dynamic Time-History Analysis or Response Spectral Analysis.

The comparison of experimental results with the results obtained by empirical formulas and dynamic analysis will facilitate the engineers' understanding of the analysis and design of building structures subject to dynamic loading.

In the "Introduction", the background and the purpose of this study are described. In the second chapter Period of vibration of selected buildings are determined by using Microtremor. In the third chapter Period of vibration of buildings are determined by using the Code Method. In the fourth chapter periods of buildings are determined by using Dynamic Analysis. In the fifth chapter Comparison of results obtained by Microtremor, Code-Method and Dynamic Analysis are done. In the last chapter, Conclusion was made based on the results obtained.

CHAPTER- 1 . INTRODUCTION.

1.1 Background

During an earthquake the ground moves in a random fashion in all directions. The earthquake that produces ground motions also exerts forces on the building. Buildings constructed in earthquake regions respond to those motions and are set into vibrations. Therefore, understanding the dynamic characteristics of building becomes an important issue in the design of building structures subjected to earthquakes.

The response of a structure (elastic or inelastic system) to dynamic loads depends on the capacity of energy dissipation and on the natural period of vibration of the system. For structures subjected to a base motion the maximum stress that the structure experience is a function of its stiffness and its mass distribution. The fundamental period of vibration of a building is a logical index to be used in determining relative base shear, moments, etc., for design purposes using Quasi-Static Analysis and is also an important parameter for Dynamic Analysis of Buildings.

The design of earthquake resistant structures involves engineering judgement and experience as well as an application of scientific principles. The essential background for practice in the field of Earthquake Engineering is the knowledge of earthquakes themselves.

Basic information on the characteristics of earthquake motions which could be used for engineering purpose were not available until the first strong motion recording accelerographs were developed. Gradually more extensive networks have been installed in Japan, the most active seismic region of the United States, Mexico, and various other parts of the world. At present, new and significant information is being obtained from studies on earthquake records. Among other things the general magnitude and nature of the motion to be expected have been determined, based on these records the nature and relative magnitude of the response spectra have been indicated.

Based on these earthquake records and developments in the understanding of earthquake phenomena, most countries prepared their own seismic codes pertinent to their design and construction practice. In Ethiopia, the seismic code gives an approximate formula for determining the natural period of vibration of buildings, which is useful to find the base shear and its distribution among the stories. The building can then be designed for this distribution of Lateral Quasi-Static forces.

The site soil effect, mainly the amplification characterstics and the damping effect, should be taken into account in determining equivalent set of lateral forces on buildings (in Equivalent Static Method) and in specifying input motions at the base in conducting earthquake response analysis of a structure(In Dynamic Analysis).

For the design of earthquake resistant structural components of multi-storey buildings different approaches are available that enable the designer to estimate design forces generated by seismic ground motions. Dynamic Analyses are the most accurate and sophisticated methods of analysis available to the designer for the purpose of predicting design forces, displacements, etc under seismic action. On the other hand these methods are complicated and especially difficult in inputing data on the characterstics of site soil.

In this study an attempt is made to determine the predominant period of buildings by using three methods, namely: -

1) Microtremor-Measurements
2) Code Method
3) Full Dynamic Analysis

Comparison of the results obtained by the different methods is also made.

1.2 Purpose of the study

The main purpose of this thesis is to determine the predominant period of vibration of some randomly selected buildings in Addis Ababa using different methods. The methods chosen are Microtremor Measurements, The Code Method or Equivalent Static Analysis* and Dynamic Analysis. Finally, recommendations will be made on the determination of period of vibration of a building for earthquake design by comparing the results obtained.

*E.B.C.S-8, 1995,Art. 2.3.3.2.2(3)

CHAPTER –2 MEASUREMENT OF PERIODS OF BUILDINGS BY USING MICROTREMORS.

2.1 INTRODUCTION

Determination of the predominant period of vibration of a building can be made by using full dynamic analysis, the code method, or by measuring vibration of buildings using Microtremors and other methods. The use of microtremors was first developed by Kanai in the 1950's (Kanai, 1951) for the study of site effects. Later microtremors were used in many research works, such as in the critical assessment of site effect parameters for strong ground motion prediction (M. Haile, 1996). It was also adopted for use in determining the vibrational characterstics of buildings. The main approach here is to employ a portable instrument package to record building vibrations produced by microtremor at a number of buildings and make Fourier Analysis using an integrated program to obtain the Fourier Amplitude Spectra from which the predominant period can be determined. Besides the use of microtremors, analytical methods(static and dynamic analysis) are used in determining the periods of the buildings.

The use of measured microtremor for determination of period of vibration of buildings is based on the principle that microtremor propagate in the building and are amplified at periods which are synchronous with the predominant period of the building.

Period distribution and spectral shapes of microtremor follow a definite pattern for a particular building and resemble building motions recorded during strong ground motion. But this conclusion has the following significant limitations:

1) Microtremors operate at a very low strain level as compared to strong ground motion, which results in higher strain levels inducing non-linearity.

2) The effect of source on microtremors is significant. Short period microtremors less than 1-sec in length are substantially affected by direct sources like traffic noise, while longer period microtremors are affected by environmental conditions like atmospheric pressure and ocean waves. Removing the effects of this source is not so direct.

Irrespective of these shortcomings microtremors show building dependent variation when measured and interpreted carefully. Acceptable level of stability both in period and amplitude is required to use microtremors for such purposes.

Many researchers have used Microtremors in various research works, highlights of some of the works are given below.

The comparison between the predominant periods in the long-period microtremors and in the strong earthquake (ground) motions and evaluation of wave amplification due to deep soil deposits (Kagami, 1968). The classification of ground by microtremors, i.e. by comparing the dynamic characterstics of the ground derived from microtremors and those expected from measured properties and geometry of the ground (Yorihiko and Ohsaki, 1978). The correlation study made between response spectra and microtremor Power Spectral Density(PSD) estimates in Nevada (Lewis, 1978). In Seismic Microzonation of Tokyo area, which gives the seismic input intensity at the base layer and damage distribution features for various levels of input earthquake intensity (Yoshihiro and Sugimura, 1982). Comparison of ground vibration characterstics among several districts mainly with microtremor measurement(Seo, 1990). In the applicability of the microtremor analysis for determination of the site response in the

In the study of undamaged buildings in Mexico City, after the earthquake of sept.19, 1985, the first successful application of the approach was made by Hiroyoshi Kobayashi and his colleagues (Kobayashi and his colleagues, 1986), their purpose was to know the general dynamic behavior of building structures, by measuring the structural vibration due to microtremors, and to determine the natural period of vibration and damping coefficient of undamaged buildings in Mexico City. The results obtained from the experiment show:

1) The relation between Natural period, T, of horizontal sway fundamental mode of building and number of stories, N, of buildings.

2) The relationship between natural torsional period of the building and number of stories.

3) The relationship between period T and damping coefficient.

And the second study was also made in Mexico City to estimate stiffness deterioration, by comparing the original story stiffness to that of story stiffness after the earthquake of sept.19, 1985.

The results obtained in the above study are shown in Fig 2.1, 2.2 and 2.3. Fig 2.1 shows the relation between period of translational motion and number of stories. Fig 2.2 shows the relation between period of torsional motion and number of stories. Fig 2.3 shows the relation between period of translational motion and damping coefficient.

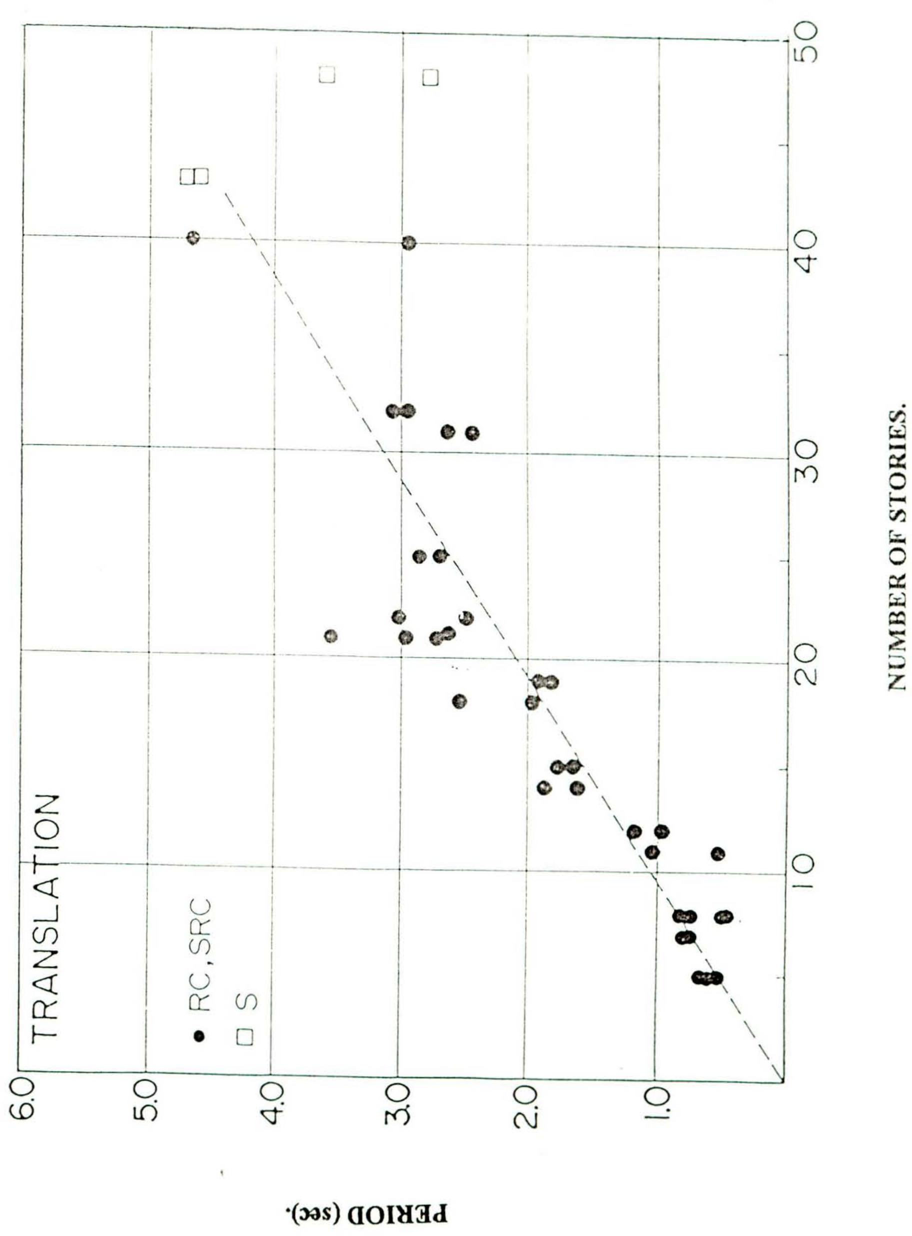


Fig. 2.1 Relation between Natural Period and Number of Stories (Kobayashi, 1986)

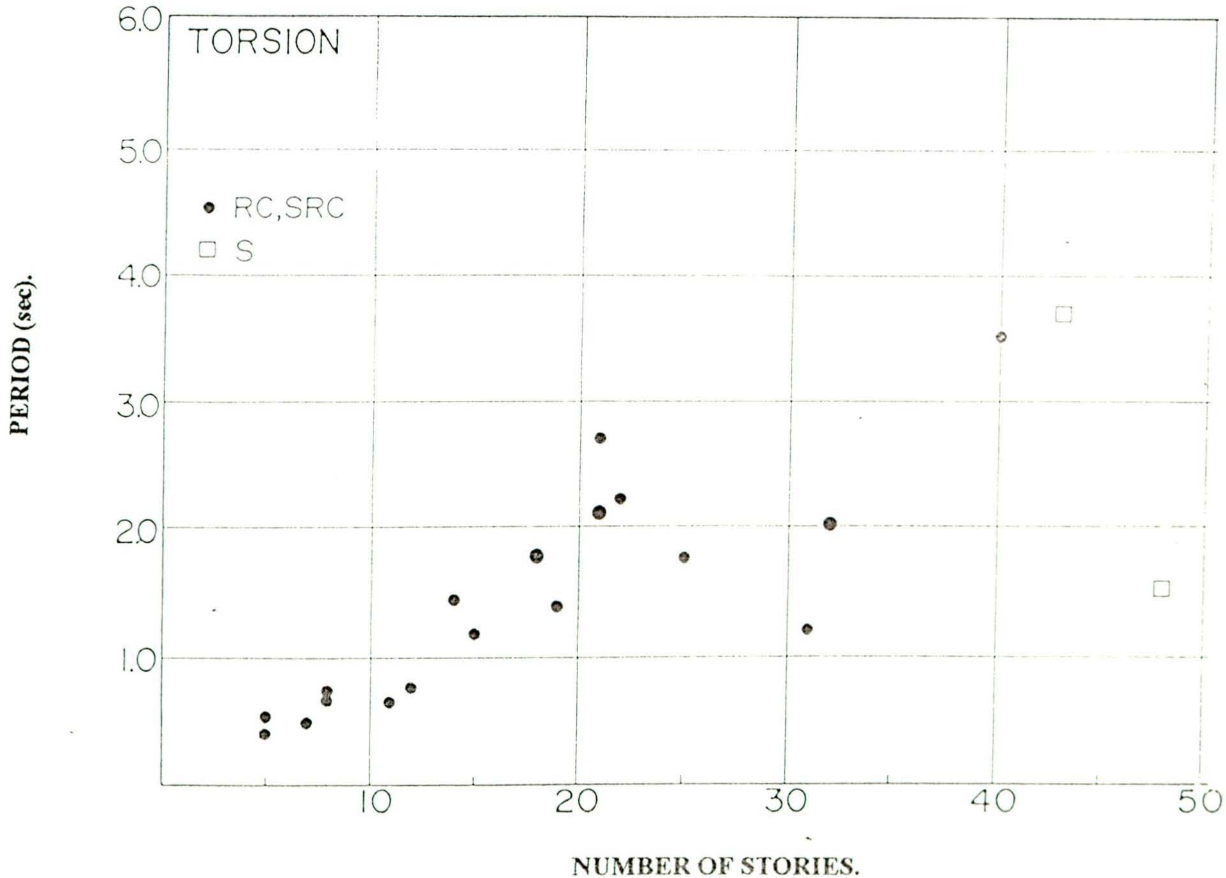


Fig. 2.2 Relation between Torsional Period and Number of Stories (Kobayashi, 1986)

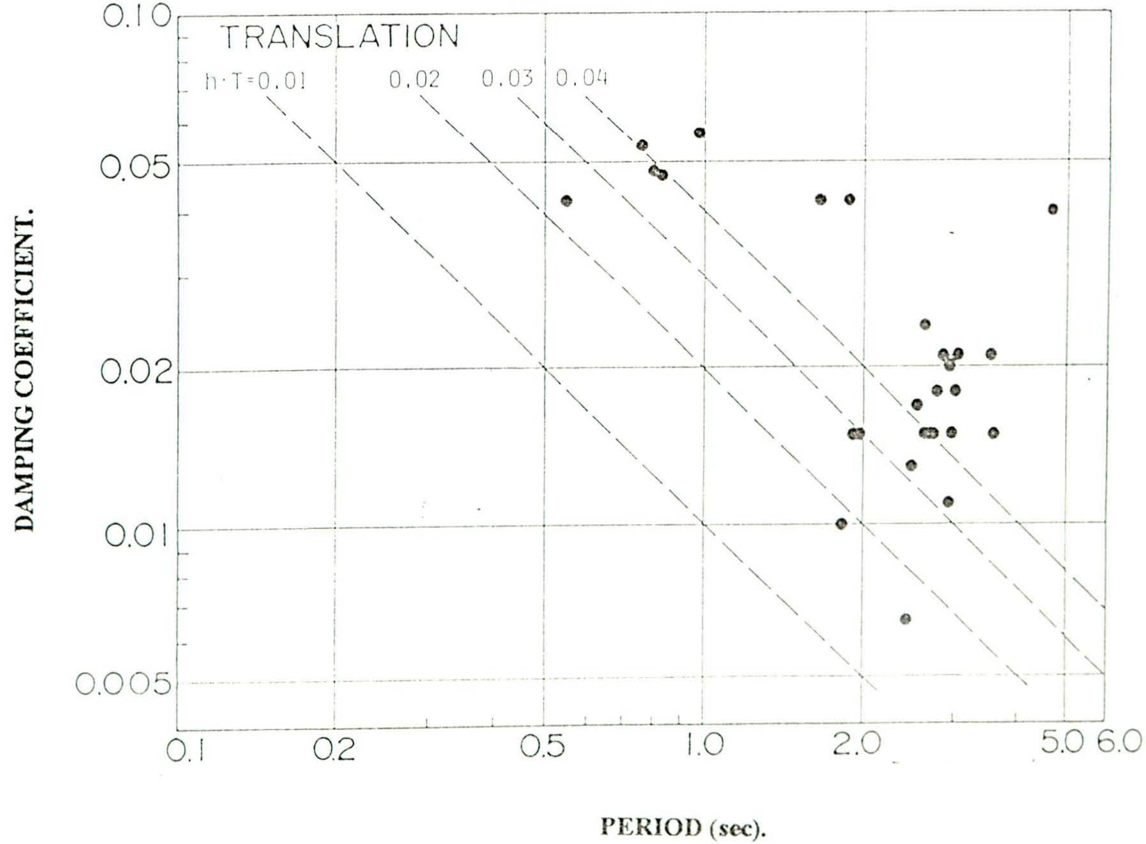


Fig. 2.3 Relation between Natural Period and Damping Coefficient (Kobayashi, 1951)

2.2 METHODS OF MEASUREMENT AND ANALYSIS OF DATA.

In this study the observation system is composed of three component-seismometer, amplifier and notebook computer with A/D converter. The seismometer used has a moving coil system having 1-sec natural period.

The pick-up was set on top of each building selected for this study and the first channel was adjusted to the lateral direction of the building, the second channel to the longitudinal direction and third channel to vertical (UD) direction, respectively. The sampling rate was set to 100-HZ and 300-sec long records were obtained.

The velocity amplitude of microtremors, which is clearer for visual observation, was measured. The obtained signals were amplified depending on the characterstics of each building. It is also possible to make on site preliminary analysis and display, enabling immediate remeasurement if the obtained data has some problem, like contamination with a high-amplitude direct noise generated by passing vehicles or a machine operating very close to the measuring point.

The records thus obtained are played back and segments with big direct noise from nearby sources are removed, and the stable part of the velocity-response is used for further Fourier Analysis. The Fourier Velocity Spectrum is computed by using Fast Fourier Transformation with Parzen's lag window with bandwidth of 0.3HZ. In the spectra, sharp peaks are found and fundamental (predominant) period can easily be recognized.

Some pictures taken on top of different buildings while taking microtremor measurements are shown in Fig 2.4, through 2.8.

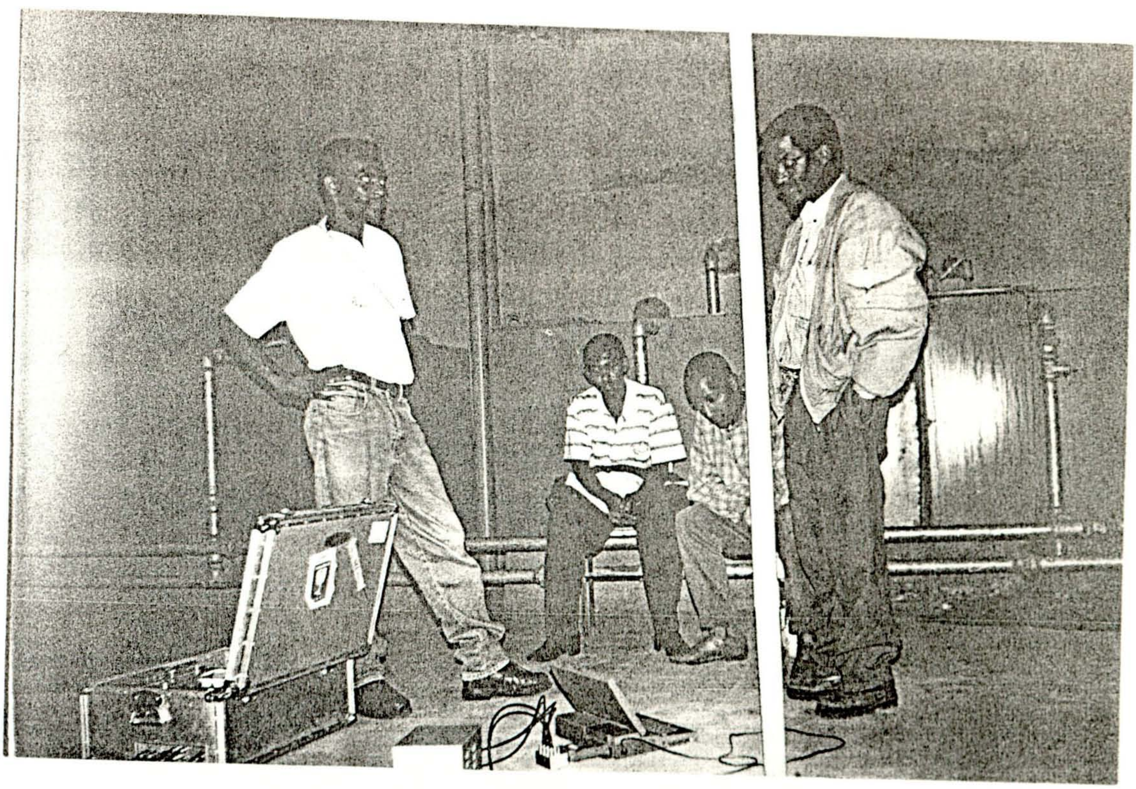


Fig. (2.4) Microtremor Measurement on top of E.A.T.U Building.

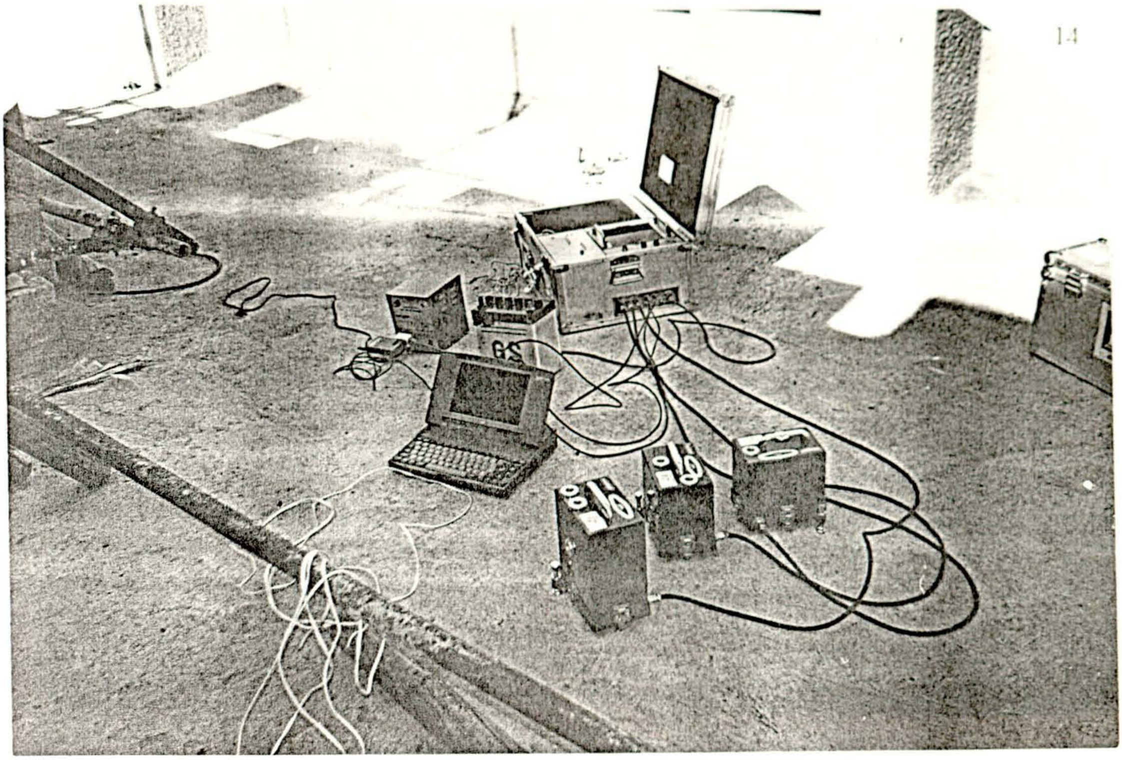


Fig.(2.5) Taking Microtremor Readings on top Oromya Regional Government Bureau Building.

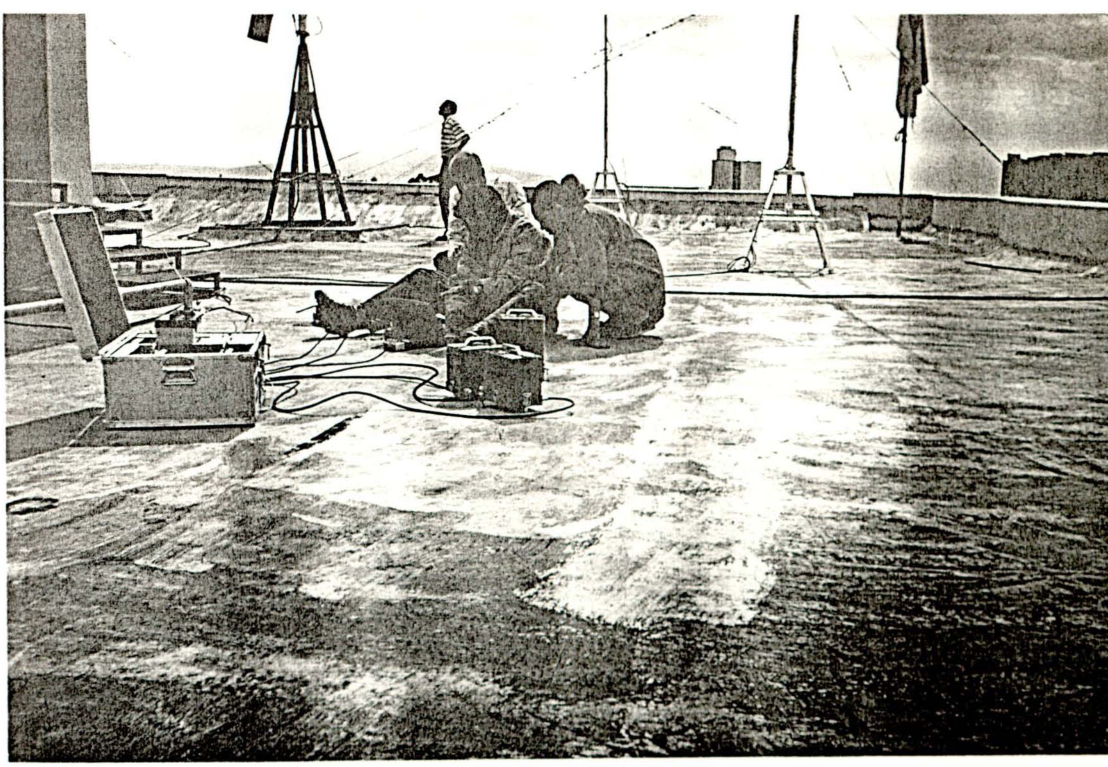


Fig.(2.6) Taking Microtremor Readings on top of sunshine Building..

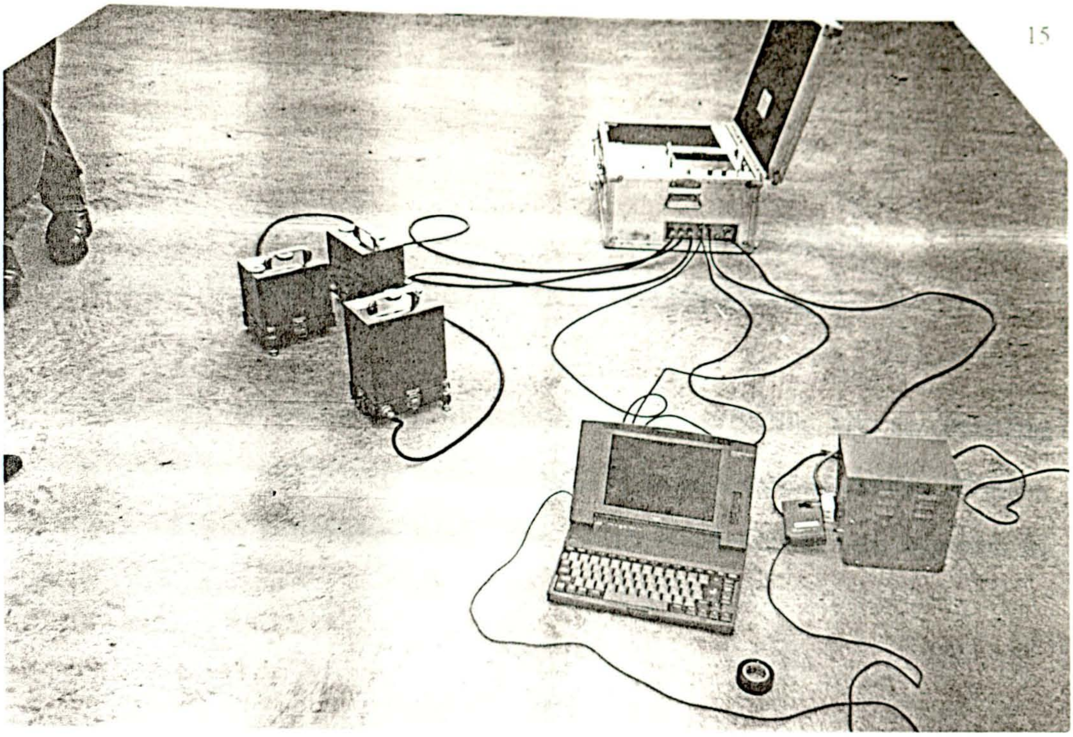


Fig.(2.7) Microtremor Readings on top of Grain Trade Building.

Fig.(2.8) Taking Microtremor Readings on top of
Science and Technology Commission Building.

2.3 DESCRIPTION OF MEASURED BUILDINGS AND THE SOIL TYPES THEY ARE LOCATED IN.

Determination of period of vibration of a building by measuring microtremors is carried on seventeen (17) buildings in Addis Ababa. The types of the buildings and the periods obtained are shown in Table 2.1.

All Ethiopian Trade Union Building (EATU) and Oromya Regional Government Bureau Building are two-way slab buildings (G^{+10}) similar in plan (10.9m * 40m) and elevation-section (40m high) and located at bole area close to each other. The predominant period of vibration of these buildings is the same and is 0.68 sec in the lateral direction. Since the sites of these two buildings are close to each other the soil condition below the base of the structure is expected to be similar. Due to this similarities (building nature and site) the period of vibration of the buildings is found to be equal.

Ato Mergia Shop Building (G^{+7}) is a flat slab building whose plan dimension is 9.5m*26.58m and a height of 29.68m rests on a 12m soil deposit is located at Kazanches. The period of vibration of this building is found to be 0.68 sec in the lateral direction, which is the same as EATU and Oromya Regional Bureau Building. This result indicates us that the building is more flexible as compared to the above two buildings. This building also rests on softer soil formation.

The microtremor measurement taken on Dasset Building (G^{+7}), having plan dimension of 10m * 30.97m and a height of 25.04m, located at Bole area shows 0.45 sec of period of vibration in the lateral direction.

The Oromya Regional Administration Bureau Building (G^{+5}), 18.9m * 18.9m in plan and 21m high, is located at Bole area. The period of vibration of this building as determined by microtremor is 0.45 sec in the lateral direction.

The Ethiopian Ministry of Justice Building (G^{+9}), 11m * 29m in plan and 33m high rests on a 21m soil deposit overlying 4m rock, is located at Kazanches. The period of vibration of the building in the lateral direction is 0.57 sec. Based on this result the building is considered as rigid when it is compared to the period of vibration of Ato Mergia's flat slab shop building.

The period of vibration of Sunshine Building (G^{+8}), 11.8m * 25m in plan and 32.4m in height rests on a 5m thick soil deposit overlying

2m thick rock, is found to be 0.5 sec by microtremor measurement in the lateral direction.

Similarly, measurements taken on the Ethiopian Grain Trade Buildings, Block-A (G^{+4}) and Block-B (G^{+3}) has shown 0.54 and 0.33sec period of vibration, respectively.

Microtremor measurements were also taken on the Ethiopian Telecommunication Exchange Buildings. These measurements are catagorized into two, namely:

1) Old Exchange Building (G^{+2} with basement): in this category we have four buildings located at four different sites, Mercato, Kera, Old airport, Bole Medhanealem. The period of vibration of these buildings are 0.28, 0.27, 0.26, and 0.20 sec respectively. The soil profile of mercato shows 8m thick soil deposit overlying 2m thick weathered rock, and a 10m thick soil deposit is found at Bole-Medhanealem site below the ground level.

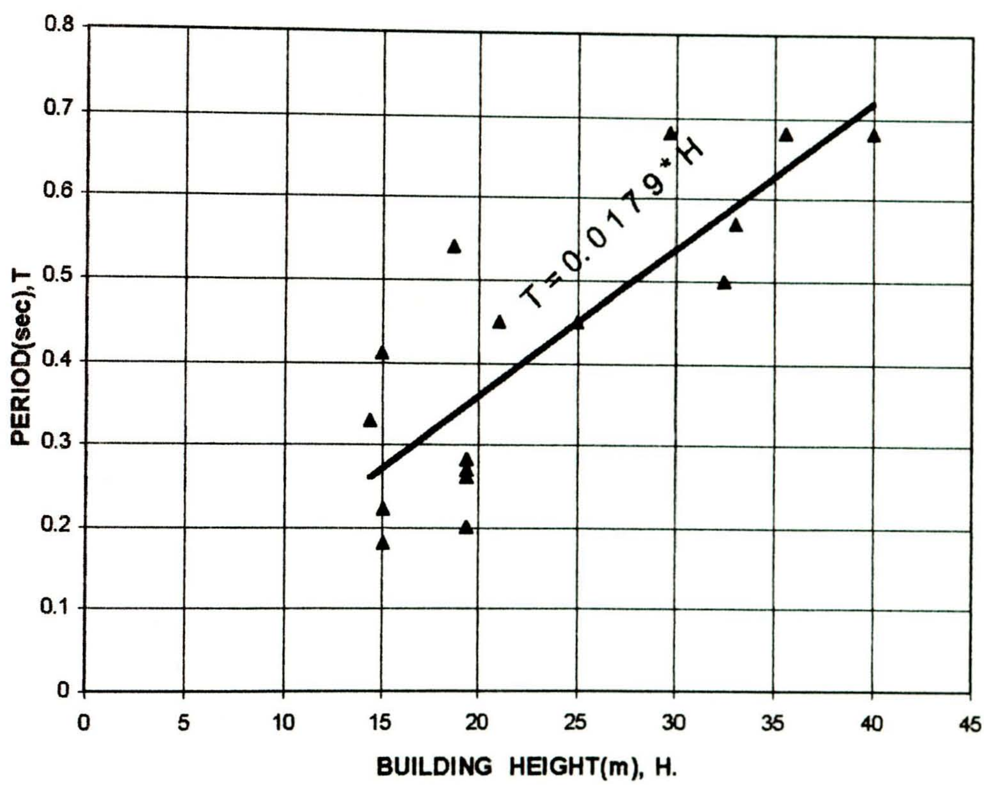
2) New Exchange Building (G^{+2}): the total number of such buildings is two and located at Nefas-silk and Shola (CMC). Period of vibration of the buildings located at Nefas-silk and Shola is 0.22 and 0.18 sec, respectively. The soil profile at Shola is 10m deposit and at Nefas-silk it is 6m thick soil deposit overlain on 6m thick sound rock.

TABLE 2.1 PERIOD OF VIBRATION OBTAINED FROM MICROTREMOR.

	NAME OF THE BUILDING	NO. OF STORIES	HEIGHT OF BLDG ABOVE BASE(m)	PERIOD OF VIBRATION(sec)	SHAPE OF THE BUILDING
1.	E.A.T.U	13	40	0.68	
2.	OROMYA REGIONAL GPOV'T	13	40	0.68	RECTANGULAR
3.	SCIENCE AND TECHNOLOGY COMMISSION	12	35.6	0.68	
4.	MINISTRY OF JUSTICE	11	33	0.57	
5.	SUNSHINE	10	32.4	0.50	
6	MERGIA SHOP BLDG.	10	29.68	0.68	
7.	DASSET BUILDING	9	25.04	0.45	
8.	OROMYA ADMNSTRATN BLDG.	7	21	0.45	SQUARE
9.	GRAIN TRADE(BLOCK-B)	6	18.72	0.54	RECTANGULAR
10.	TELECOMMUNICATION(OLD)	5	19		
	i) MERCATO TELE............			0.28	
	ii) KERA............................			0.27	
	iii) OLD AIRPORT............			0.26	
	iv) BOLE MEDHANEALEM...			0.20	
11.	TELECOMMUNICATION(NEW)	4	15.05		
	i) NEFAS-SILK.			0.22	
	ii) SHOLA...........			0.18	
12.	HIBRET	5	15	0.41	SQUARE
13.	GRAIN TRADE(BLOCK-A)	5	14.4	0.33	RECTANGLE

* For detail see Appendix B

The period of vibrations obtained by this method are shown in Fig 2.9 and 2.10. Fig 2.9 shows Period of Vibration versus Building Height and Fig 2.10 shows Period of Vibration versus Number of Stories.



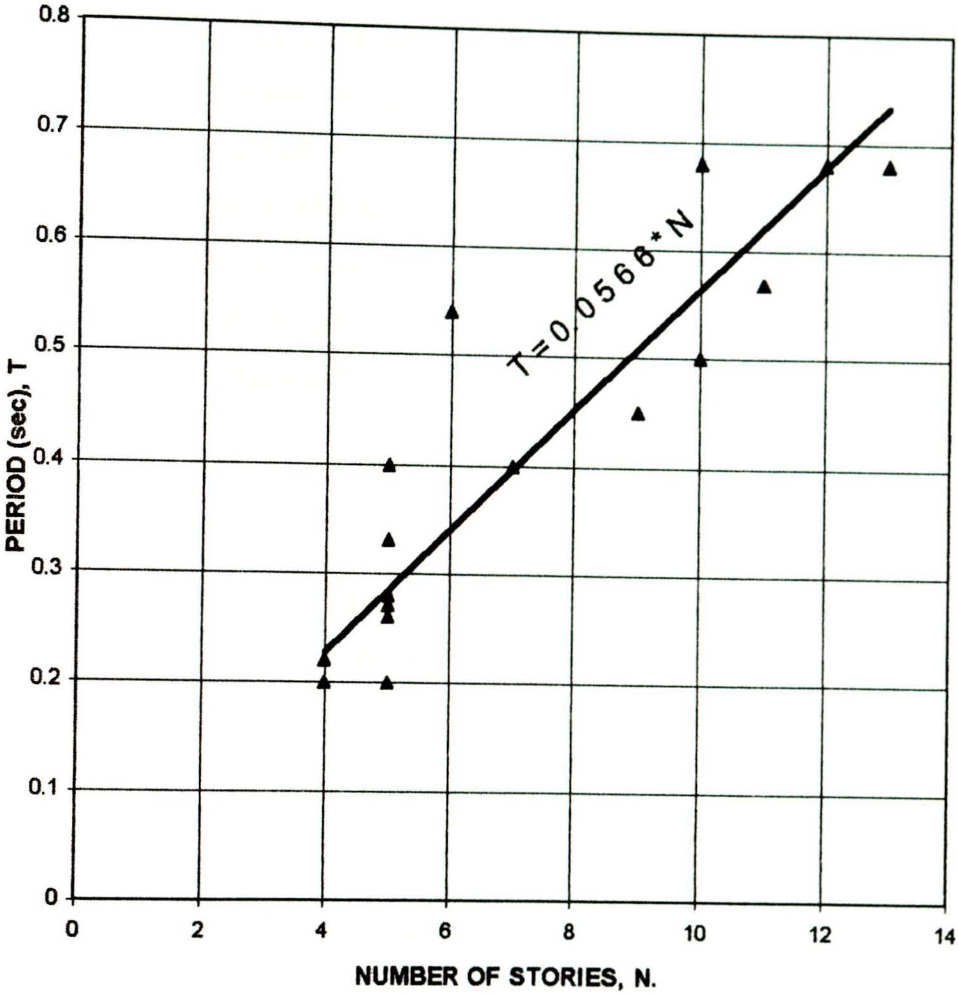


Fig. 2.10 Period of Vibration obtained by using Microtremor

2.4 CONCLUSION

1) If we consider two tall similar buildings, E.A.T.U and Oromya Regional Bureau, the period of vibration of the buildings read from the microtremor measurements are the same even if they are located at different sites. This is due to the similarity in the nature of the buildings (i.e., in plan dimension and elevation) and also soils property below the base of the building. This tells us that the period determined (read) by microtremor is stable and consistent.

2) If we take the Ethiopian Telecommunication similar buildings (Old and new) located at different sites, Mercato, Kera, Old-Airport, Bole Medhanealem, Nefas-silk, and Shola, they show variation in period of vibration. This periods are 0.28, 0.27, 0.26, 0.20 sec, respectively for the old ones and 0.22 and 0.18sec for the new ones respectively. This difference in period of vibration is due to the change of soil properties below the structure (mainly difference in depth of soil sediment). From this we can observe that even if the buildings are similar in their nature (i.e. plan dimension and elevation-section), the microtremor will not give (show) the same period of vibration.

3. Therefore, based on the above two conclusions we can say that:

- microtremor readings are mainly dependent on the type (nature) of the building structure and site condition on which the building is constructed.

- A building built on sound rock formation shows shorter period of vibration than that of a similar building built on deep soft soil formation, this is due to the amplification characterstics of the soil formation.

CHAPTER – 3 DETERMINATION OF PERIOD OF VIBRATION OF A BUILDING BY USE OF THE CODE METHOD.

3.1 INTRODUCTION

The incorporation of seismic design in building design was first adopted in general sense in the 1920's and 1930's, when the importance of inertia loadings of buildings began to be appreciated. In the absence of reliable measurements of ground accelerations and as a consequence of the lack of detailed knowledge of the dynamic response of structures, the magnitude of seismic inertia forces couldn't be estimated with any reliability. Therefore, design codes specified that about 10%- t0- 20% of the building weight to be used as design lateral force.

The above Method (Code Method) applies to the design and construction of buildings in seismic regions. Its purpose is to ensure that, in the event of earthquakes, human lives are protected, damage is limited, and important structures remain operational. The Equivalent Static Method (Code-Method) for defining seismic resistance of structural systems is still the most used method in many countries.

The capacity of structural systems to resist an earthquake motion (seismic actions) at a given point is generally represented by an elastic ground acceleration response spectrum, called 'elastic response spectrum'. The preliminary estimates of fundamental period of vibration of a building may be obtained from empirical equations, or from Rayleigh's method. After determining the fundamental period of vibration T_1 and design spectrum, we can find the total seismic base shear force F_b by using equation:

$$F_b = S_d(T_1) * W \text{ ....(EBCS-8, 1995)}$$

<u>Where:</u> W = Dead Load of the Building

$$S_d(T_1) = \alpha \beta \gamma \text{ ....Design Spectrum.}$$

α = (Bed rock acceleration of site) * (Importance factor)

$$\beta = \frac{1.2s}{(T_1)^{2/3}} \leq 2.5 \text{ ....Design response factor.}$$

γ = Behavior factor.

Empirical equations given by codes for determining fundamental period T_1 are mostly different from region to region. For example (from World List, 1996):

Australia (1993)

$$T = (h_a) / 46$$

Where: - h_a = total height of a building above base(meter).

New Zealand (1992)

$$T_1 = (0.061) * H^{(0.75)}$$

Where: - H = total height of a building above base (in meter)

Japan (1981)

$$T_1 = (0.08)n \text{ t0 } (0.13)\, n$$

Where : n = number of stories.

Canada (1995)

$$T = 0.075\, (H)^{0.75}$$

Where: - H = total height of a building above base (in meter)

U.S.A. (Uniform Building Code, 1994)

$$T = 0.0731\, (H)^{0.75}$$

Where: - H = total height of the building above base (in meter).

Eurocode (1994)

$$T \leq (0.4) * T_c \leq 2.0 \text{ sec}$$

Where: - Tc can be read from table.

Ethiopia (EBCS- 8, 1995, Art.2.3.3.2.2 (3))

$$T_1 = C_1 * H^{3/4}$$

Where: C_1 = 0.075 for concrete

H = height of the building in meter above base.

T_1 = fundamental period of vibration of a building.

The total height of a building above the base and the base shear force distribution is shown in Fig 3.1 and 3.2 below.

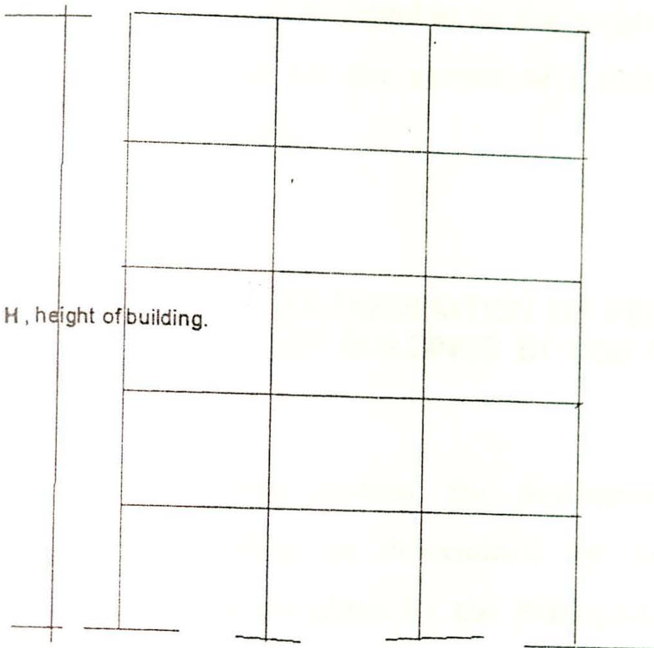


Fig. 3.1 **Elevation- Section of a building**

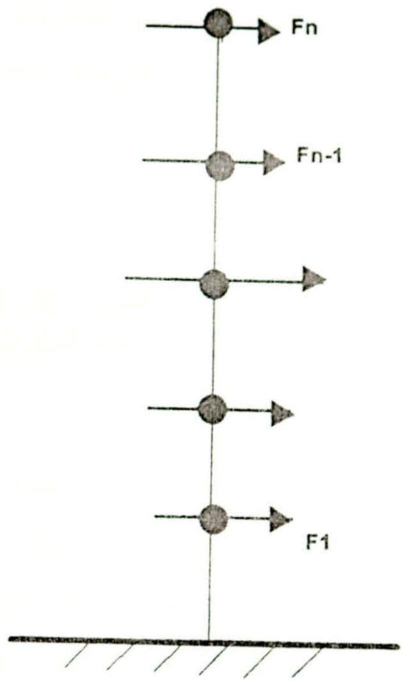


Fig. 3.2 **Base Force Distribution .**

Example:- As an illustration if we take the Ethiopian Trade Union Building and determine its period of vibration by using the above codes empirical formula (Height of the building is 40m).

Australia:-	T = 0.869 sec.
U.S.A:-	T = 1.162 sec.
Canada:-	T = 1.193 sec.
Japan:-	T = 1.03 to 1.69 sec.
Ethiopia :-	T = 1.193 sec.

As we see from the result we get three different period of vibration for the same building by using different codes. This is acceptable as the empirical formulas are developed based on the nature of building and experience of each country.

3.2 DETERMINATION OF PERIOD OF VIBRATION OF BUILDINGS BY USE OF CODE METHOD.

In this section, the fundamental period of vibration of a building is determined by using the above approximate formula given by the Ethiopian Code (E.B.C.S-8, 1995). For instance, let us see some of the results of the selected buildings obtained by the formula:-

The Ethiopian Trade Union Building, with plan dimension 10.9m * 47m and a height of 40m above the base, is the tallest of the selected buildings and gives the longest period of vibration of 1.193 sec. The smallest of all, The Ethiopian Grain Trade Building (Block-A), whose plan dimension is 18.9m * 18.9m and height is 14.4m, has the shortest period of vibration of 0.554 sec out of the selected buildings.

The results obtained are presented in Table 3.1, Fig.3.3 and 3.4. Fig.3.3 shows Period of Vibration versus Building Height and Fig.3.4 shows Period of Vibration versus Number of Stories. Both curves are obtained by Linear Regression Analysis.

TABLE 3.1 PERIOD OF VIBRATION OBTAINED BY CODE METHOD (EBCS-8, 1995).

	NAME OF THE BUILDING	NO. OF STORIES	HEIGHT OF BLDG ABOVE BASE(m)	PERIOD OF VIBRATION(sec)	SHAPE OF THE BUILDING.
1.	E.A.T.U	13	40	1.193	RECTANGULAR
2.	OROMYA REGIONAL GOV'T	13	40	1.193	
3.	SCIENCE AND TECHNOLOGY COMMISSION	12	35.6	1.093	
4.	MINISTRY OF JUSTICE	11	33	1.033	
5.	SUNSHINE	10	32.4	0.932	
6.	MERGIA SHOP BLDG.	10	29.68	0.954	
7.	DASSET BUILDING	9	25.04	0.789	
8.	OROMYA ADMNSTRATN BLDG.	7	21	0.735	SQUARE
9.	GRAIN TRADE				
	i) BLOCK-B....	6	18.72	0.592	RECTANGULAR
	ii) BLOCK-A....	5	14.4	0.554	
10.	TELECOMMUNICATION				
	i) OLD....	5	19	0.693	
	ii) NEW.....	4	15.05	0.573	RECTANGLE
11.	HIBRET	5	15	0.572	SQUARE

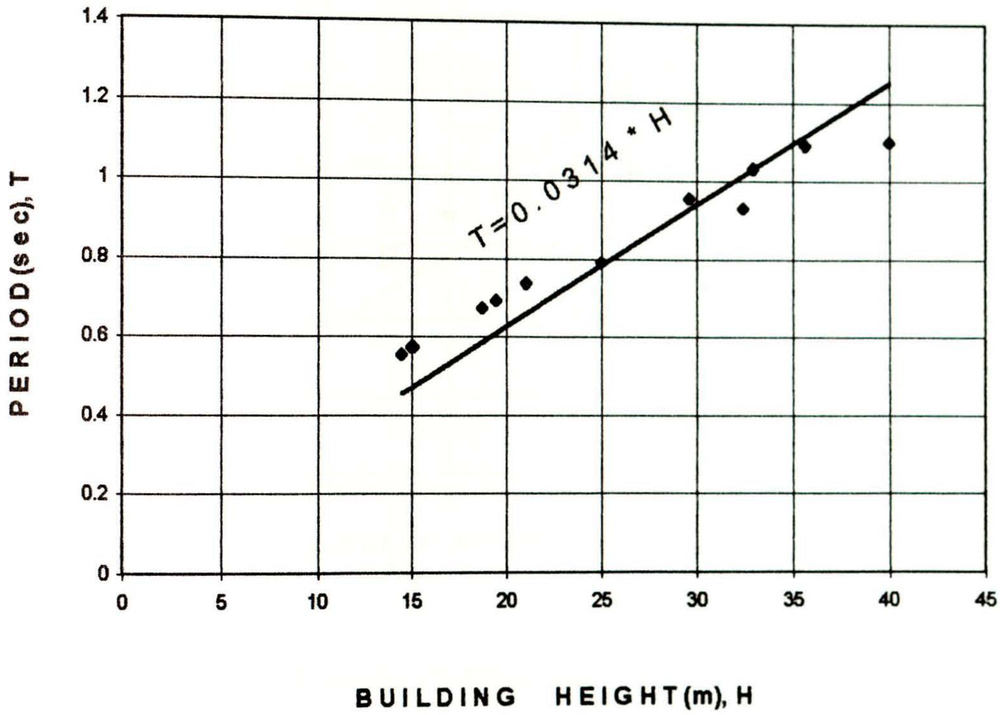


Fig. 3.3 Period of vibration of buildings obtained by using the code method

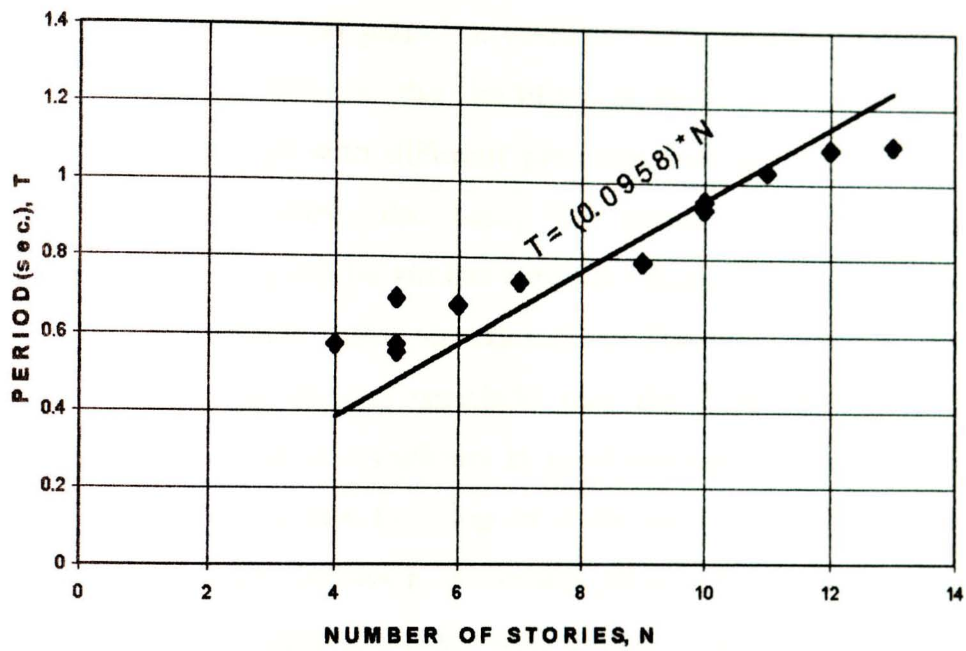


Fig 3.4 Period Of Vibration of buildings obtained by using Code Method.

3.3 CONCLUSION

As it is seen from the result obtained above, the fundamental period of vibration of a building increases as the height of the building increases. If we take two buildings with different plan dimensions but having equal height above the base, the period of vibration of the building will be similar without taking the difference in plan dimension into consideration. Therefore, based on this concept we can conclude that the fundamental period of vibration of a building is predominantly dependent on the height of the building in code method. While the actual dynamic behavior, including period of a building depends on the total geometry and stiffness of a building and soil condition. Therefore it is clear that the Code Method is at most an approximation of period of buildings in a general sense.

CHAPTER - 4 DETERMINATION OF PERIOD OF VIBRATION OF BUILDINGS BY USING DYNAMIC ANALYSIS

4.1 INTRODUCTION

The degree of importance of earthquake loading in any region is related to its probable intensity and likelihood of occurrence, i.e. to the seismicity of the region. By the 1960s accelerograms giving detailed information on the ground acceleration occurring during earthquakes were becoming more and more available. Besides, the development of sophisticated computer-based analytical procedures facilitated a much closer examination of the seismic response of multi-degree of freedom structures.

It quickly became apparent that, in many cases, seismic design to existing lateral force levels specified in codes were inadequate to ensure that the structural strength provided was not exceeded by the demands of strong ground shaking. Due to this and other reasons, currently the use of Full Dynamic Analysis becomes important. This design method is divided in to two: -

1) Inelastic Dynamic Analysis: - used as a research tool, and for investigating specific response. It may also be used in verifying anticipated response of important structures after detailed

design to forces and displacements defined by less precise analytical methods.

2) Elastic Dynamic Analysis: - this approach relies on the assumption that the dynamic response of the structures may be found by considering the independent response of each natural mode of vibration and then combining the response in some way (Square Root of the Sum of Squares, Complete Quadratic Combination, etc).

4.2 DETERMINATION OF PERIODS OF BUILDINGS BY USING DYNAMIC ANALYSIS

In this method, the predominant period of vibration of a building is determined after modeling the structure as a three-dimensional framework. All the frame-element properties in the building structure must be known and assigned prior to the determination of period of vibration of a building. And the other data required in the analysis is the time-history of the input ground motion at the base of a structure.

For the dynamic response analysis of the selected buildings, the adopted input earthquake ground motions to the building structures are capped to (0.1)*g, which is assumed as the maximum ground acceleration for Addis Ababa. The adopted earthquake ground motions are: -

1) Elcentro (0.319 g)............1940(NS)......California, U.S.A
2) Hachinohe (0.225 g).........1968(NS)........... ...... Japan
3) Kobe (0.84 g)..................1995(NS).................... Japan

Finally, a computer program (software) called SAP-90 (that can be used for both Static and Dynamic Analysis) is used in the determination of predominant period of vibration of the selected buildings. The predominant period of vibrations are shown in Table 4.1 below.

The period of vibrations obtained by this method are shown in Fig 4.1 and 4.2. Where Fig 4.1 shows Period of Vibration versus Building Height and Fig 4.2 shows Period of Vibration versus number of stories. Both curves shown in the figure are obtained by Linear Regression Analysis.

Fig 4.3, 4.4 and 4.5 show the deformed shapes of some of the buildings selected for the study (obtained from output of SAP-90). Fig 4.3, 4.4 and 4.5 show the first mode deformed shape of Dasset Building, Hebret Insurance Building and Ethiopian Telecommunication Old Exchange Building respectively.

TABLE 4.1 PERIOD OF VIBRATION OBTAINED FROM FULL DYNAMIC ANALYSIS.

	NAME OF THE BUILDING	NO. OF STORIES	HEIGHT OF BLDG ABOVE BASE(m)	PERIOD OF VIBRATION(sec)		SHAPE OF THE BUILDING
				TRANSVERSE	LONGITUDINAL	
1.	E.A.T.U	13	40	1.234	1.084	
2.	OROMYA REGIÓNAL GOV'T	13	40	1.234	1.084	RECTANGULAR
3.	SCIENCE AND TECHNOLOGY COMMISSION	12	35.6	1.228	1.024	
4.	MINISTRY OF JUSTICE	11	33	0.927	0.842	
5.	SUNSHINE	10	32.4	1.245	1.128	
6.	MERGIA SHOP BLDG.	10	29.68	1.129	1.07	
7.	DASSET BUILDING	9	25.04	1.089	1.072	RECTANGULAR
8.	OROMYA ADMNSTRATN BLDG.	7	21	0.957	0.813	SQUARE
9.	GRAIN TRADE					
	i) BLOCK-B....	6	18.72	0.636	0.347	RECTANGULAR
	ii) BLOCK-A.....	5	14.4	0.538	0.476	
10.	TELECOMMUNICATION					
	i) OLD.......	5	19	0.694	0.584	
	ii) NEW.....	4	15.05	0.532	0.452	RECTANGLE
11.	HIBRET	5	15	0.679	0.569	SQUARE

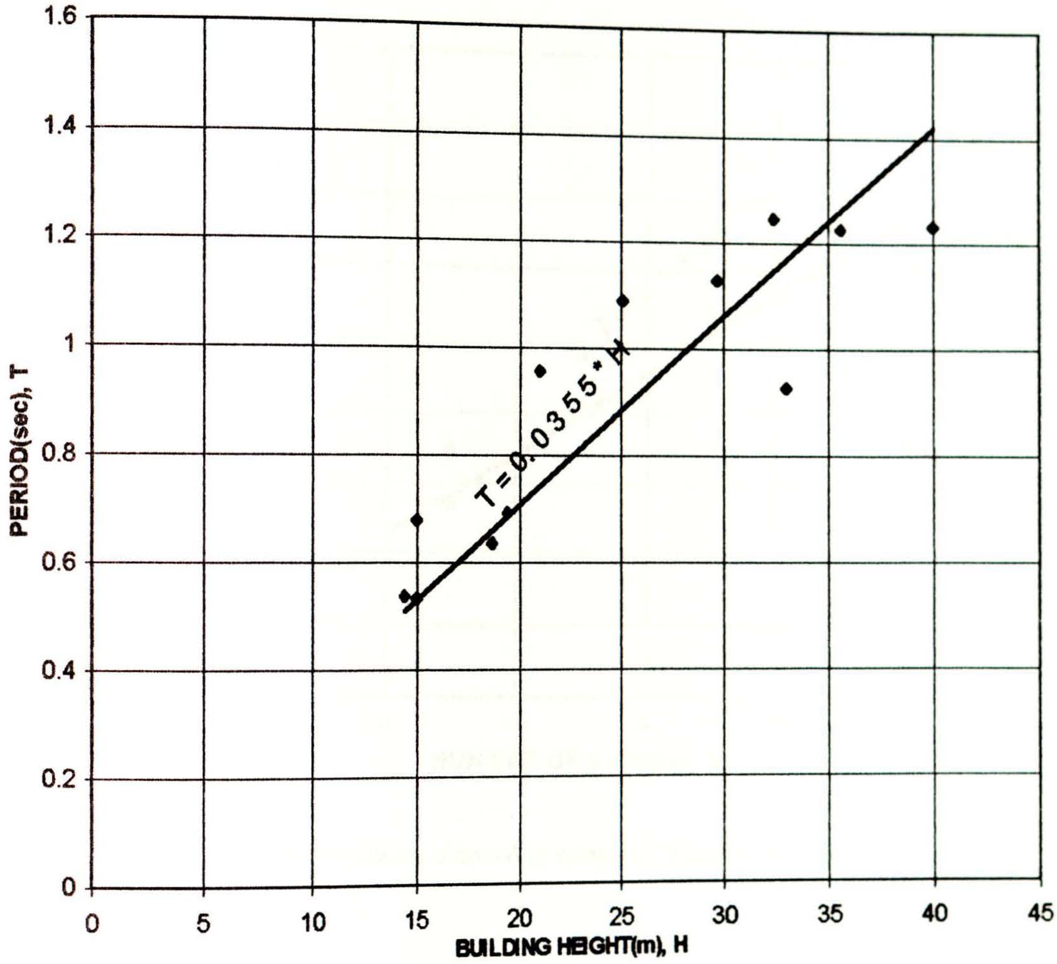


Fig. 4.1 Period of Vibration obtained by using Full Dynamic Analysis

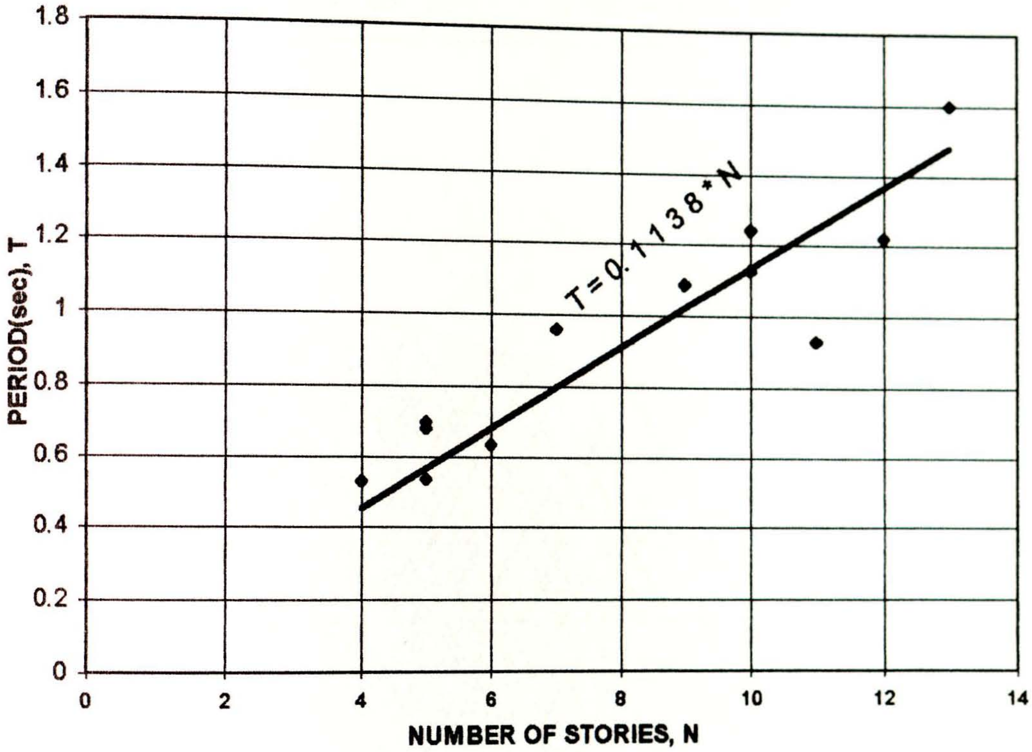


Fig. 4.2 Period of Vibration obtained by using Full Dynamic Analysis

Fig 4.3 Deformed (1st Mode) Shape of Dasset Building.

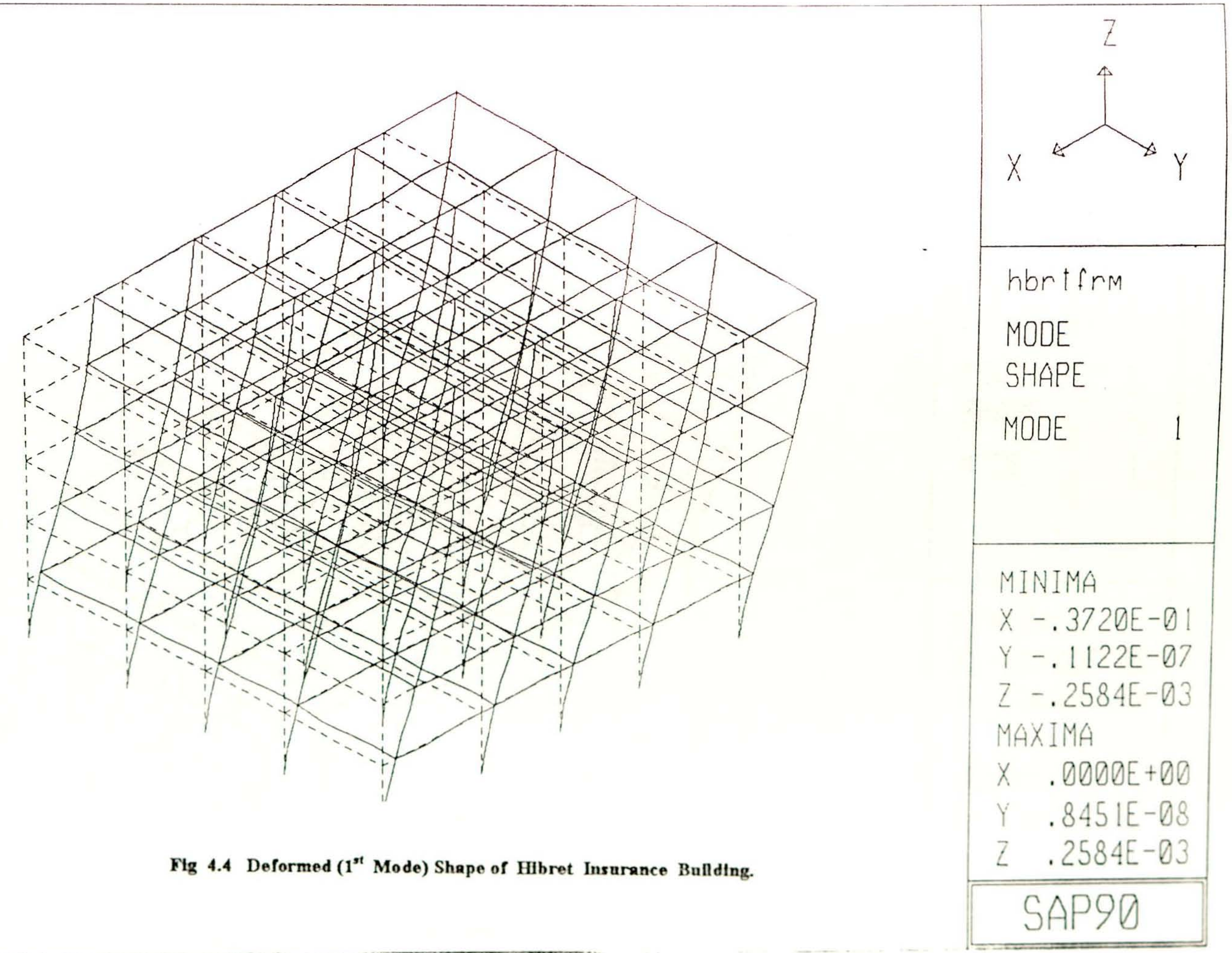


Fig 4.4 Deformed (1st Mode) Shape of Hibret Insurance Building.

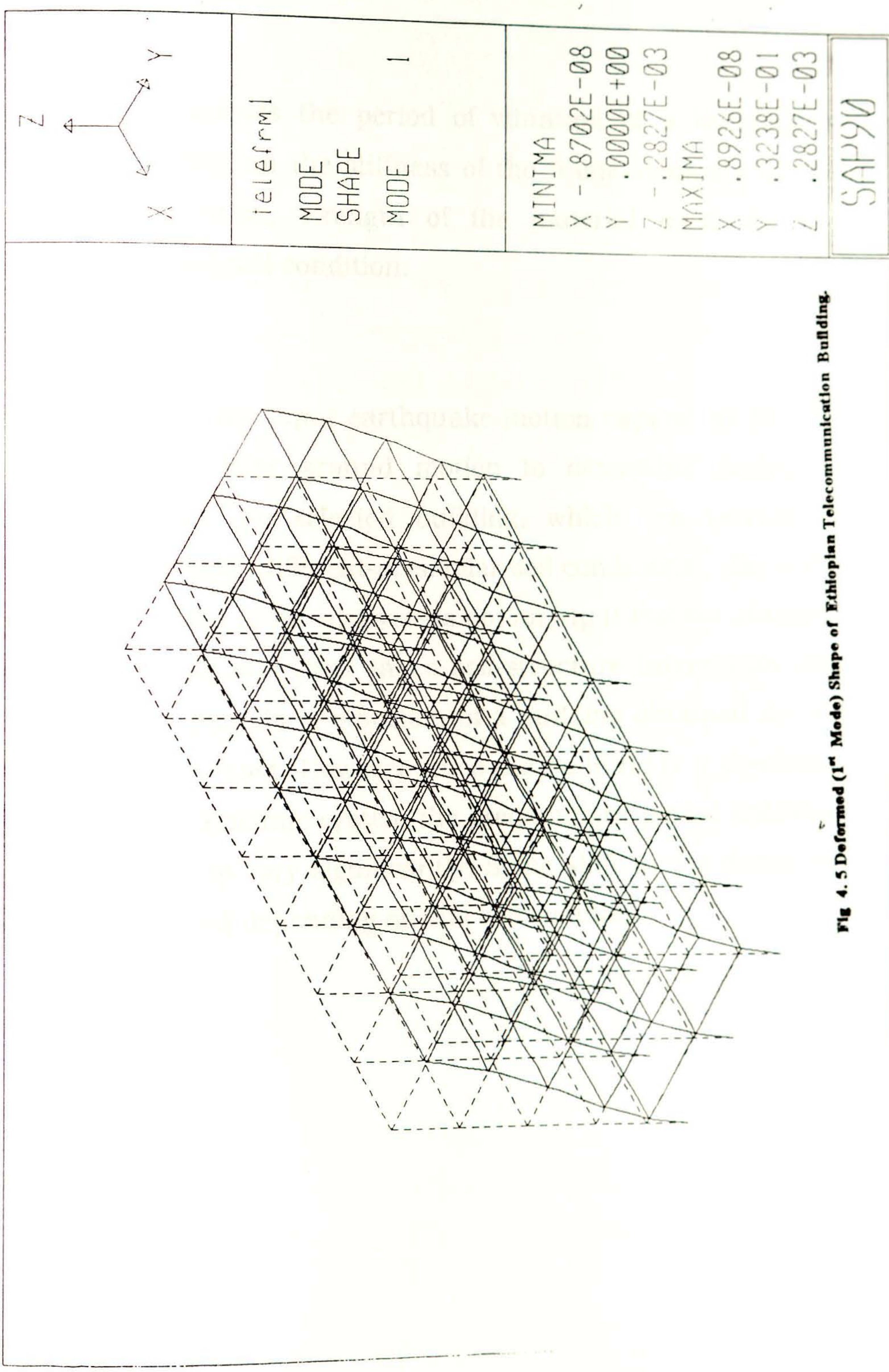


Fig 4.5 Deformed (1[st] Mode) Shape of Ethiopian Telecommunication Building.

4.3 CONCLUSION.

In Dynamic Analysis the period of vibration of a building is mainly dependent on the stiffness of the frame-elements in the direction of motion, strength of the material used for the construction and soil condition.

In the analysis, the input earthquake motion capped by (0.1)*g, is taken as a base ground motion to determine period of vibration of all the selected building, which are located at different sites (with different-or-similar soil conditions). Since the base motion used in the analysis is not an input motion obtained at each building site (that takes soil-structure interaction into account), The periods of vibration of a building obtained by the method are not exact. However since the building is a dominant element in the dynamic system the predominant period obtained is not expected to vary significantly. Some shift in the dominant period is expected depending on site soil condition.

4.3 CONCLUSION.

In Dynamic Analysis the period of vibration of a building is mainly dependent on the stiffness of the frame-elements in the direction of motion, strength of the material used for the construction and soil condition.

In the analysis, the input earthquake motion capped by (0.1)*g, is taken as a base ground motion to determine period of vibration of all the selected building, which are located at different sites (with different-or-similar soil conditions). Since the base motion used in the analysis is not an input motion obtained at each building site (that takes soil-structure interaction into account), The periods of vibration of a building obtained by the method are not exact. However since the building is a dominant element in the dynamic system the predominant period obtained is not expected to vary significantly. Some shift in the dominant period is expected depending on site soil condition.

CHAPTER-5 COMPARISON OF RESULTS OBTAINED BY MICROTREMOR , CODE - METHOD AND DYNAMIC ANALYSIS.

The results obtained by Microtremor, Code Method and Full Dynamic Analysis are shown in Fig 5.1 and 5.2. Fig 5.1 shows the relation between natural period of vibration of a building versus building height and Fig 5.2 shows the relation between natural period of vibration of a building versus number of stories.

If we compare the results of period of vibration of a building obtained by the two methods, i.e. Microtremor and Code-Method, to that obtained by Full Dynamic Analysis, we will observe that to get the period of vibration of a building obtained by Dynamic Analysis, we should multiply by a constant the periods obtained by the two methods:-

1. From Fig.(5.1)

   $T_{(dynamic)} = 1.983 * (T_{micro})$

   $T_{(dynamic)} = 1.131 * (T_{code})$

2. From Fig.(5.2)

   $T_{(dynamic)} = 2.01 * (T_{micro})$

   $T_{(dynamic)} = 1.188 * (T_{code})$

The above relation shows us that there is a possibility for developing regional empirical formula that can be used for determining period of vibration of a building (close to the dynamic) by making quick Microtremor measurements and extrapolating the results to that of Dynamic Analysis. Such fast and cheaper methods could save the enormous time required to make Full Dynamic Analysis. It should however be noted that results obtained by Microtremors are at a very low strain level.

LEGEND:
♦ Periods obtained by Code Method.
▲ Periods obtained by Microtremor
• Periods obtained by Full Dynamic Analysis

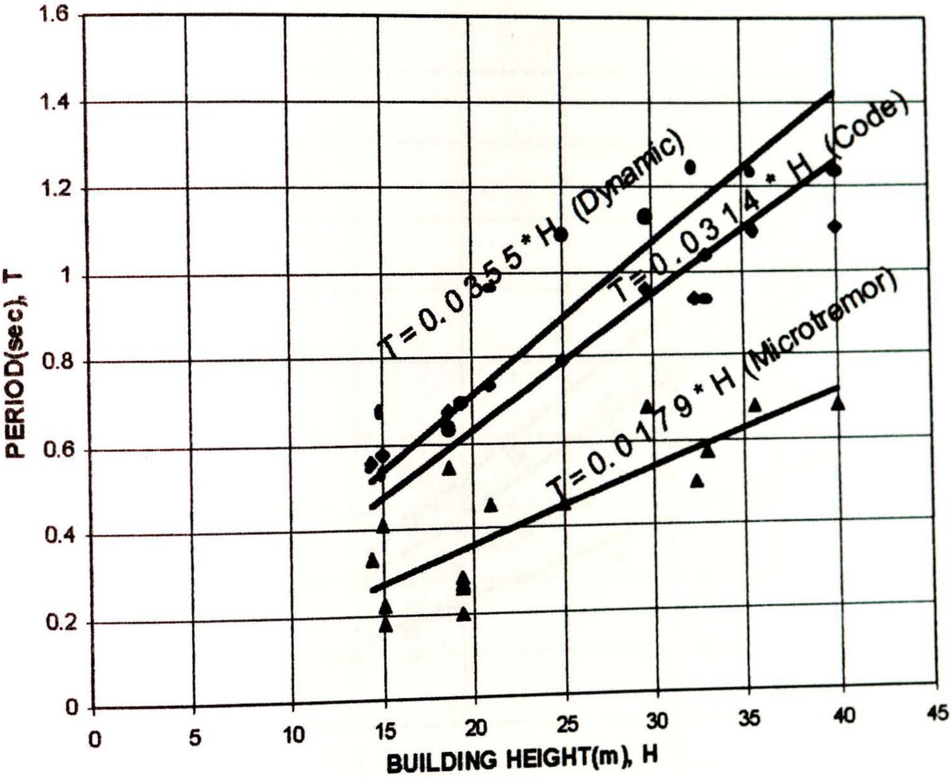


Fig 5.1 Period of Vibration (Combined).

LEGEND:

- ♦ Periods obtained by Code Method.
- ▲ Periods obtained by Microtremor
- • Periods obtained by Full Dynamic Analysis

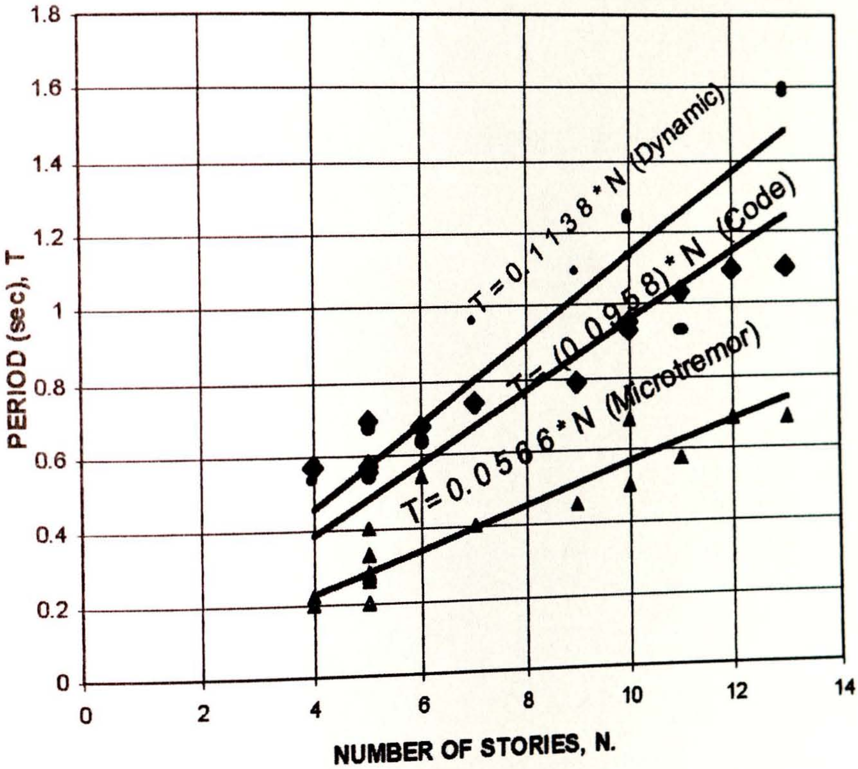


Fig 5.2 Period of Vibration (Combined).

CHAPTER – 6 CONCLUSION

1) The Code Method, i.e. the empirical formula, is mainly dependent on the height of a building to determine its period of vibration. But in reality the actual dynamic behavior of a building mainly depends on the total geometry (plan dimension and height), and stiffness of a building. Therefore it is clear that the Code Method is an approximation of period of a building.

2) In the Microtremor measurements all the parameters that influence the vibrational characterstics of a building are taken into account during measurement. But, as already mentioned earlier, micritremors operate at a very low strain. Therefore, when a building is subjected to strong ground motion that induces high strain, the periods of vibration of a buildings obtained at this time will differ from that obtained by the microtremors (which operate at a very low strain). Therefore, period of vibration obtained by this method requires some correction.

3) In Dynamic Analysis period of vibration of a building depends on the stiffness, strength of the material used in the construction and the mass distribution of the system. Since the base motion used in the analysis is not an input motion obtained at each building site (that takes soil-structure interaction into account), the periods of vibration of a building obtained by the method are not exact. However, since the building is a dominant element in the dynamic system, the predominant period of vibration obtained by Dynamic Analysis is not expected to vary significantly. Even if some shift in the period of vibration is expected depending on the site soil condition, the Dynamic Analysis method is the best of all the methods available to determine period of vibration of a building. In this method the soil response should be included for more accurate Dynamic Analysis.

REFERENCES.

1. Ethiopian Building Code Standard , Part-8, 1995.

2. Haile M., and K. seo. Analytical study of weak and strong ground motion characterstics, *San-Daigaku Symposium,* 1996, Tokyo, Japan.

3. Haile M., and K. seo. Study of site effects in Kobe area using microtremors, *Journal of physics of the earth,* Vol. 45, pp. 121-133, 1997.

4. Hiroshi K., Y. Ohta, N. Goto, and K. Kudo. Comparison with long-period accelerations at the Tokachi-oki earthquake of 1968. *Bulletin of Seismological Society of America,* Vol.68, No.3, pp. 767-779, June, 1978.

5. Hiroyoshi K. Estimated Strong Ground Motions in the Mexico City due to the Micloacan, Mexico earthquake of september19, 1985 based on the characterstics of Microtremors.

6. J. Morales, F. Vidal, J. A. Pena. Micritremor study in the sediment-filled basin of Zafarya, Granada (Southern Spain). *Bulletin of the Seismological Society of America,* Vol. 81, 2, April 1991.

7. Kanai K. Relation between the nature of surface layer and the amplitude of earthquake motions, *Bulletin of the Earthquake Research Institute*, University of Tokyo, 1951.

8. Kiyoshi K. On Microtremors, *Bulletin of the Earthquake Research Institute*, Vol. 39, pp. 97-114, 1961.

9. K. Seo, T. Samano, H. Yamanaka, S. Koyama. Microtremor measurements in the San Francisco Bay area, 1990.

10. Lewis J. Katz and Robert S. Bellon. Microtremor Site Analysis Study at Beatty, Nevada. *Bulletin of Seismological Society of America*, Vol. 68, No.3, pp. 757-765, June, 1978.

11. Regulations for Seismic Design, A World List-1996.

12. T. paulay and M.J.N. Priestley, Seismic Design of Reinforced Concrete and Masonry Buildings (1992).

13. Yorihiko Sugimura and Izuru Ohkawa. Seismic Microzonation of Tokyo Area. *3rd International Earthquake Microzonation Conference Proceedings.* Vol. 3, Seatle, U.S.A, 1982.

APPENDIX

APPENDIX-A

SOIL DATA OF SOME OF THE SELECTED BUILDINGS.

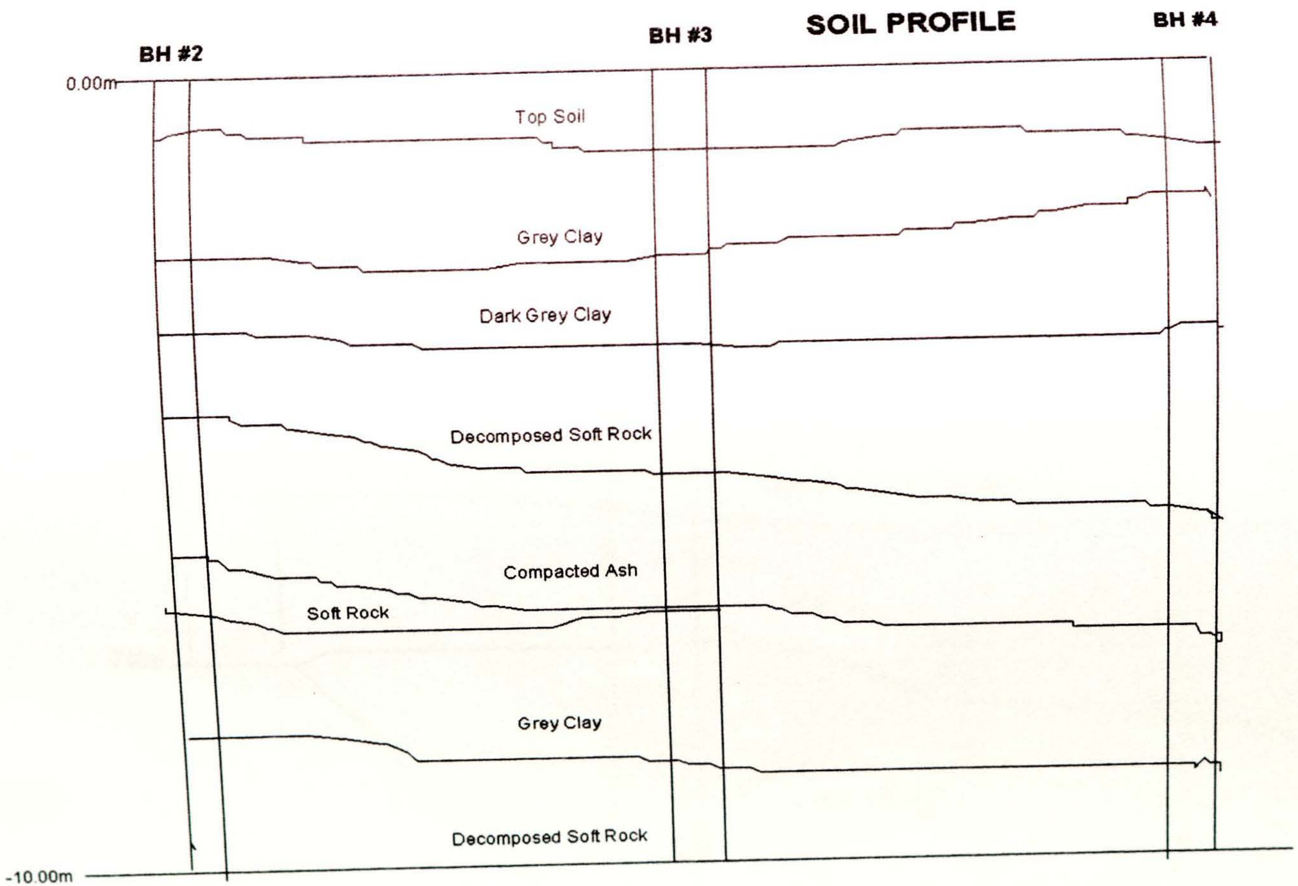


Fig A.1 BOLE TELE BUILDING.

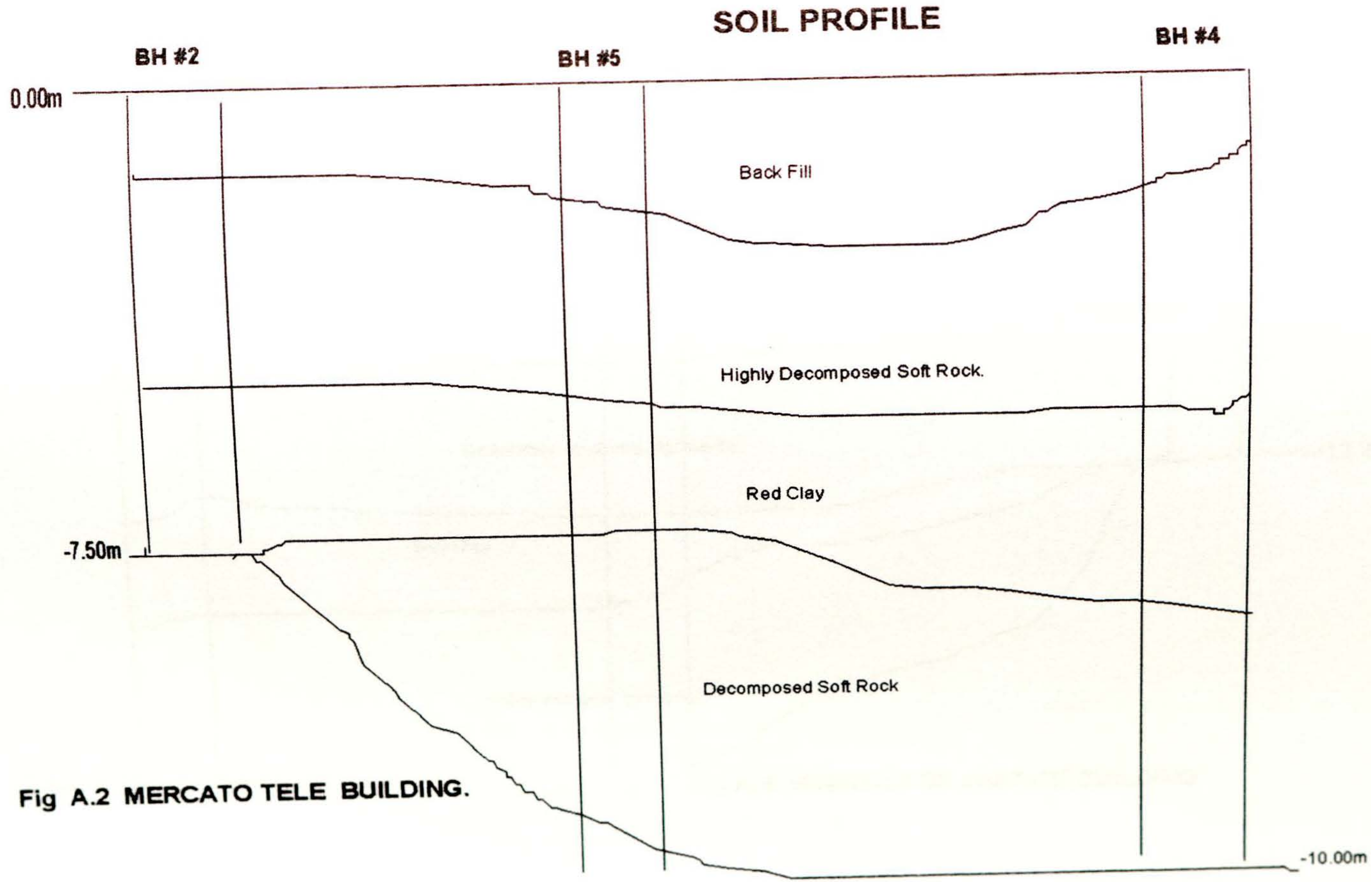


Fig A.2 MERCATO TELE BUILDING.

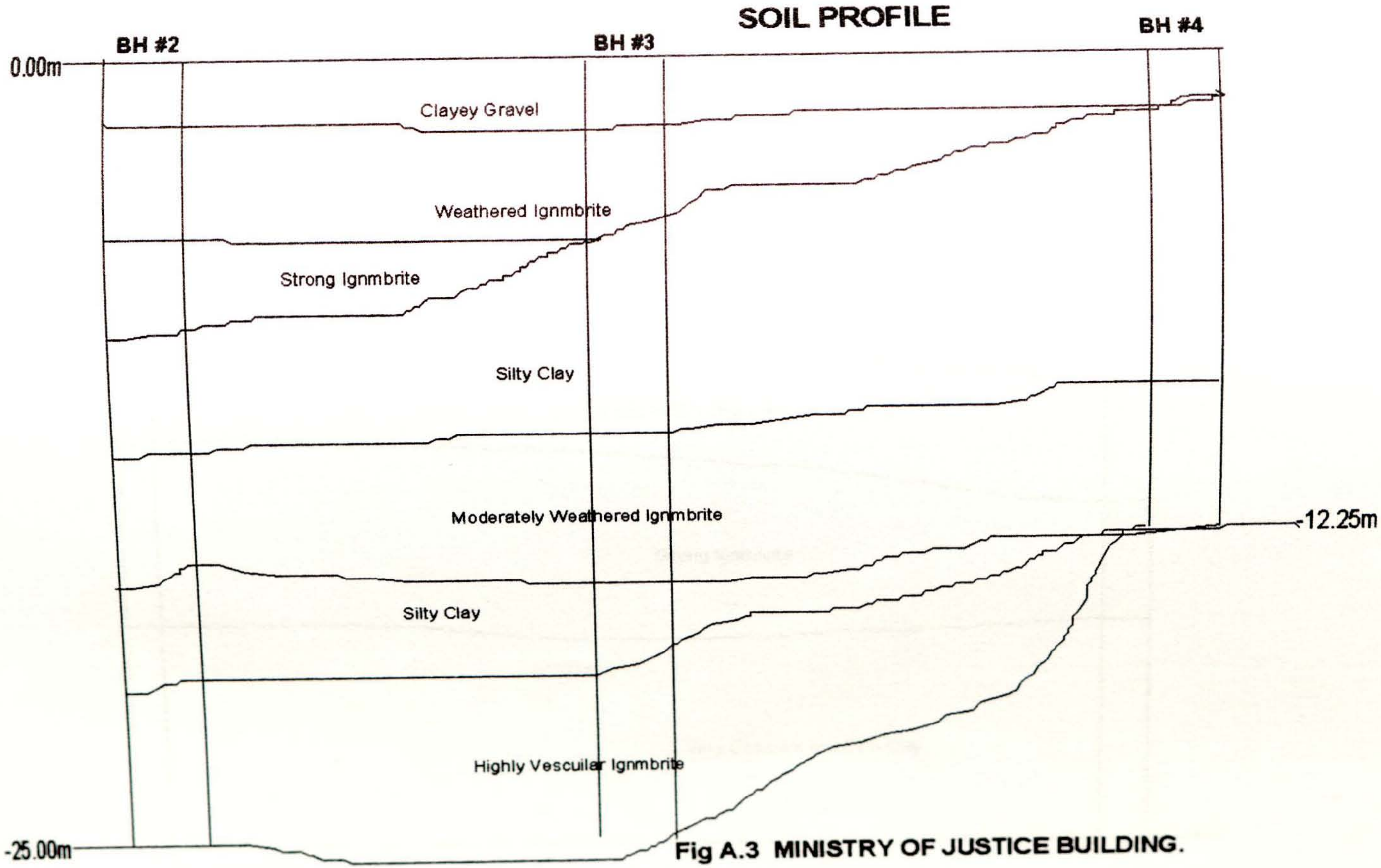


Fig A.3 MINISTRY OF JUSTICE BUILDING.

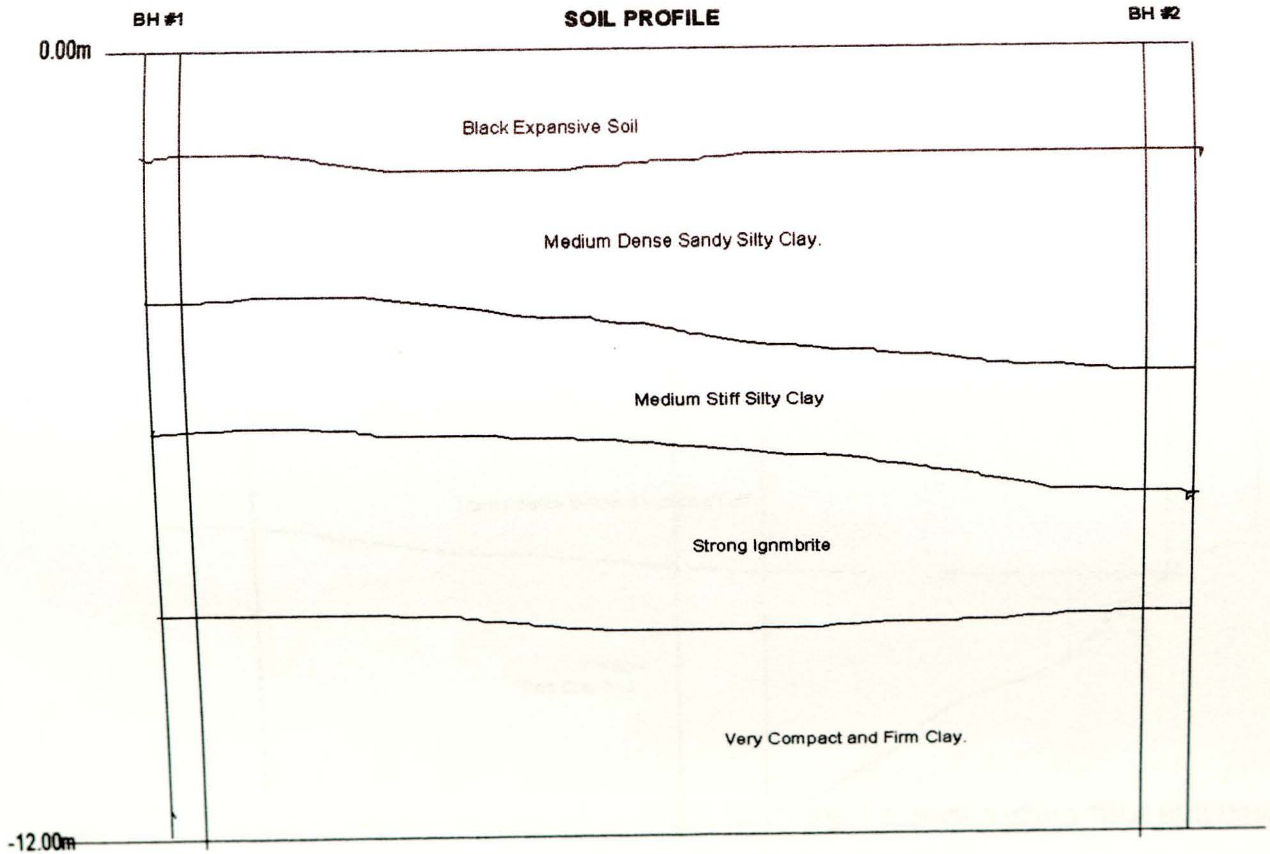


Fig A.4 MERGIA SHOP BUILDING.

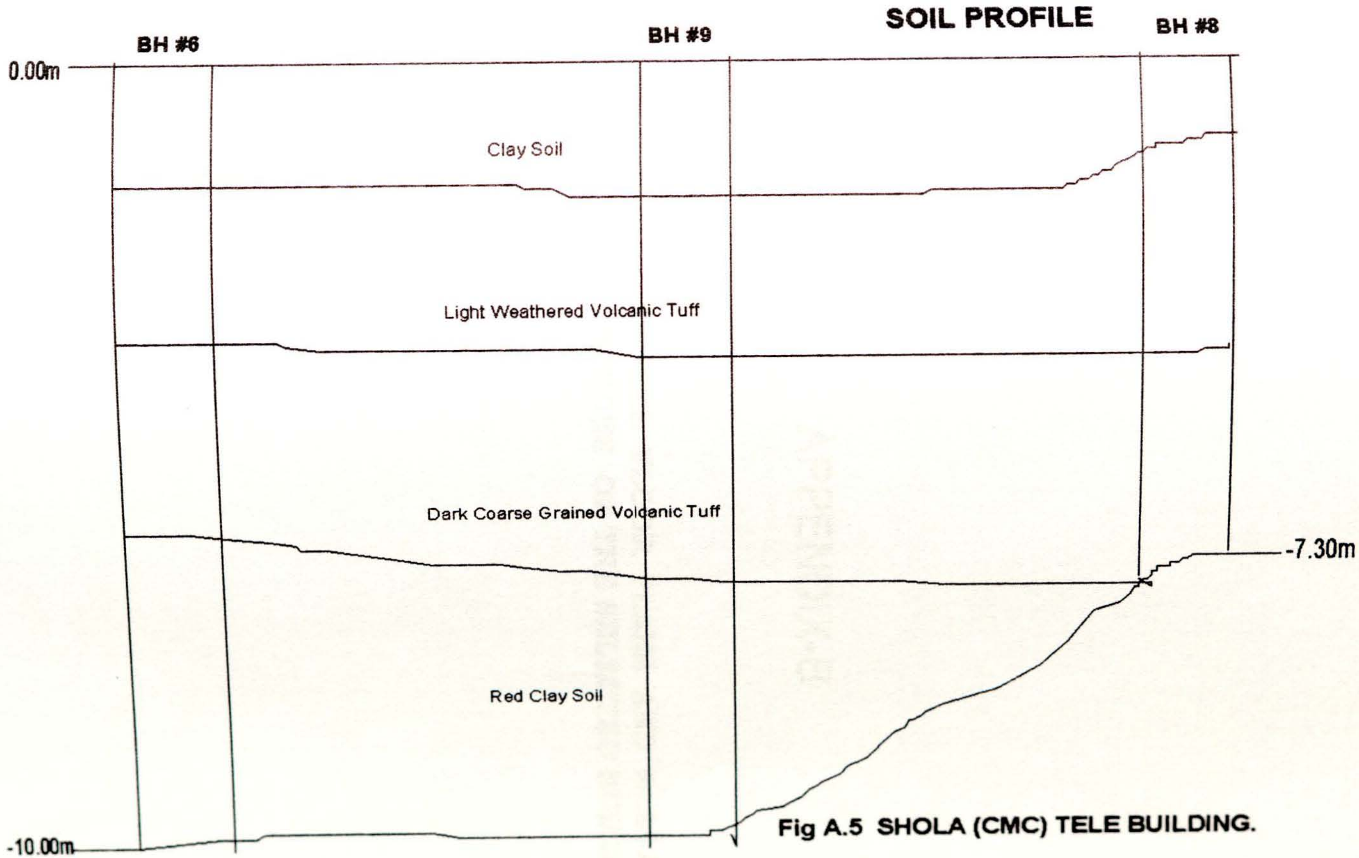


Fig A.5 SHOLA (CMC) TELE BUILDING.

APPENDIX-B

TYPICAL FLOOR PLANS AND ELEVATION-SECTIONS OF THE SELECTED BUILDINGS.

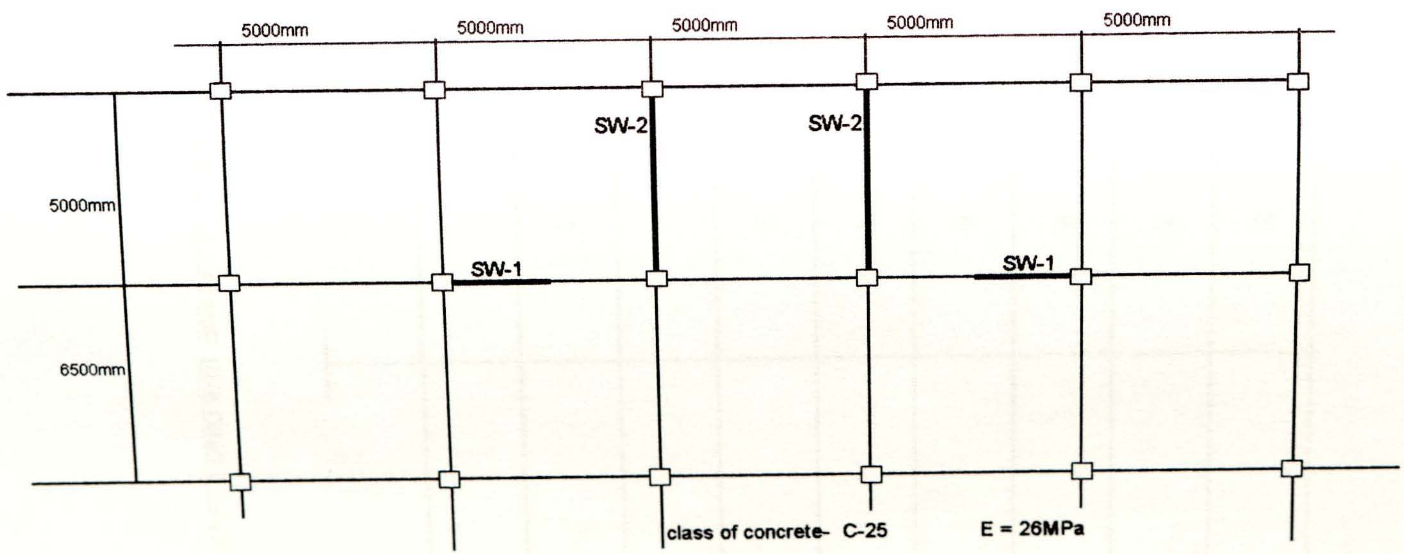


Fig B.1 SUNSHINE BUILDING FLOOR PLAN.

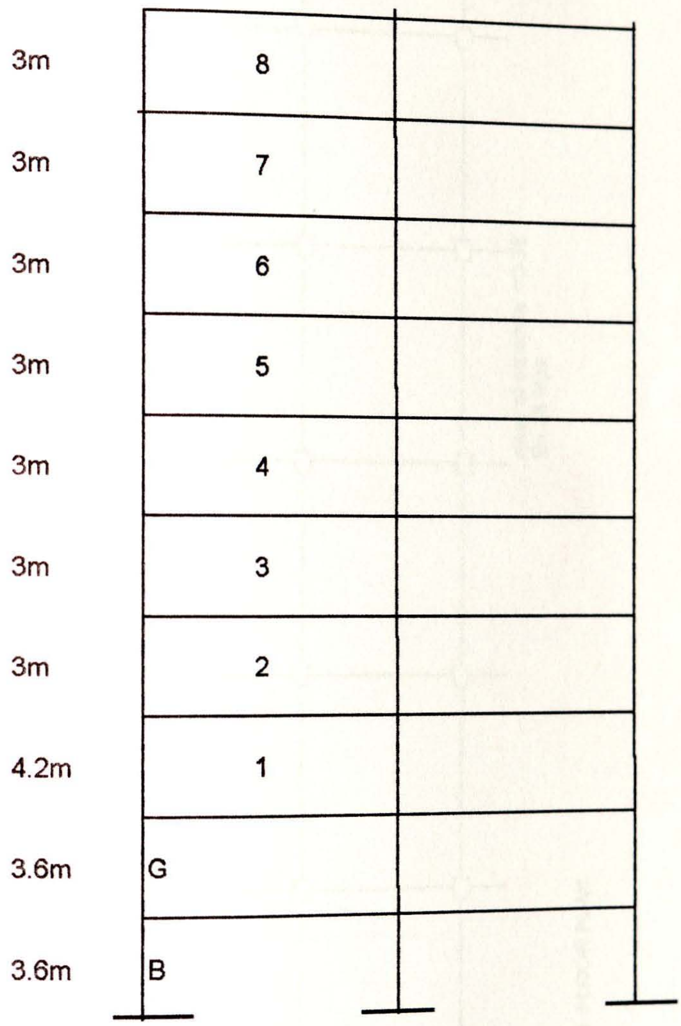


Fig B.2 SUNSHINE BUILDING ELEVATION.

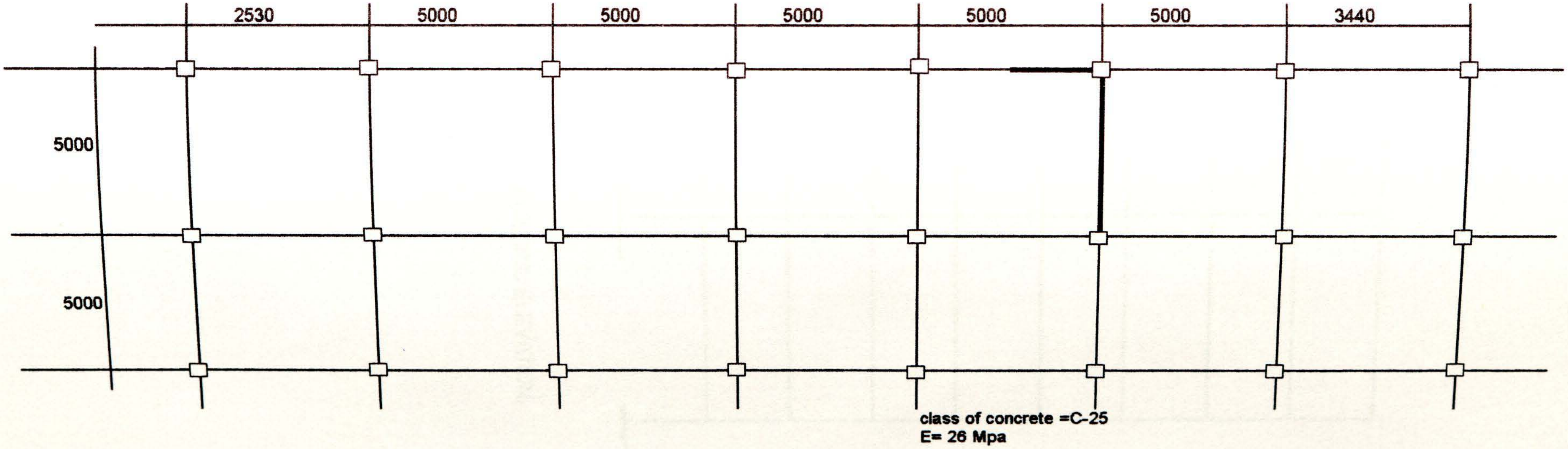


Fig B.3 DASSET BUILDING FLOOR PLAN

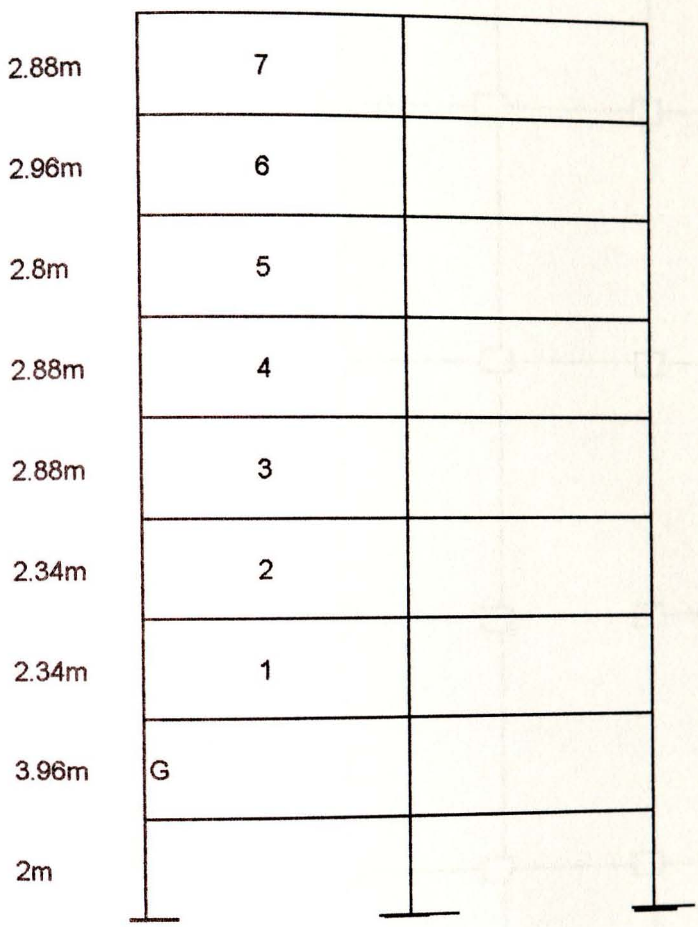


Fig B.4 DASSET BUILDING ELEVATION.

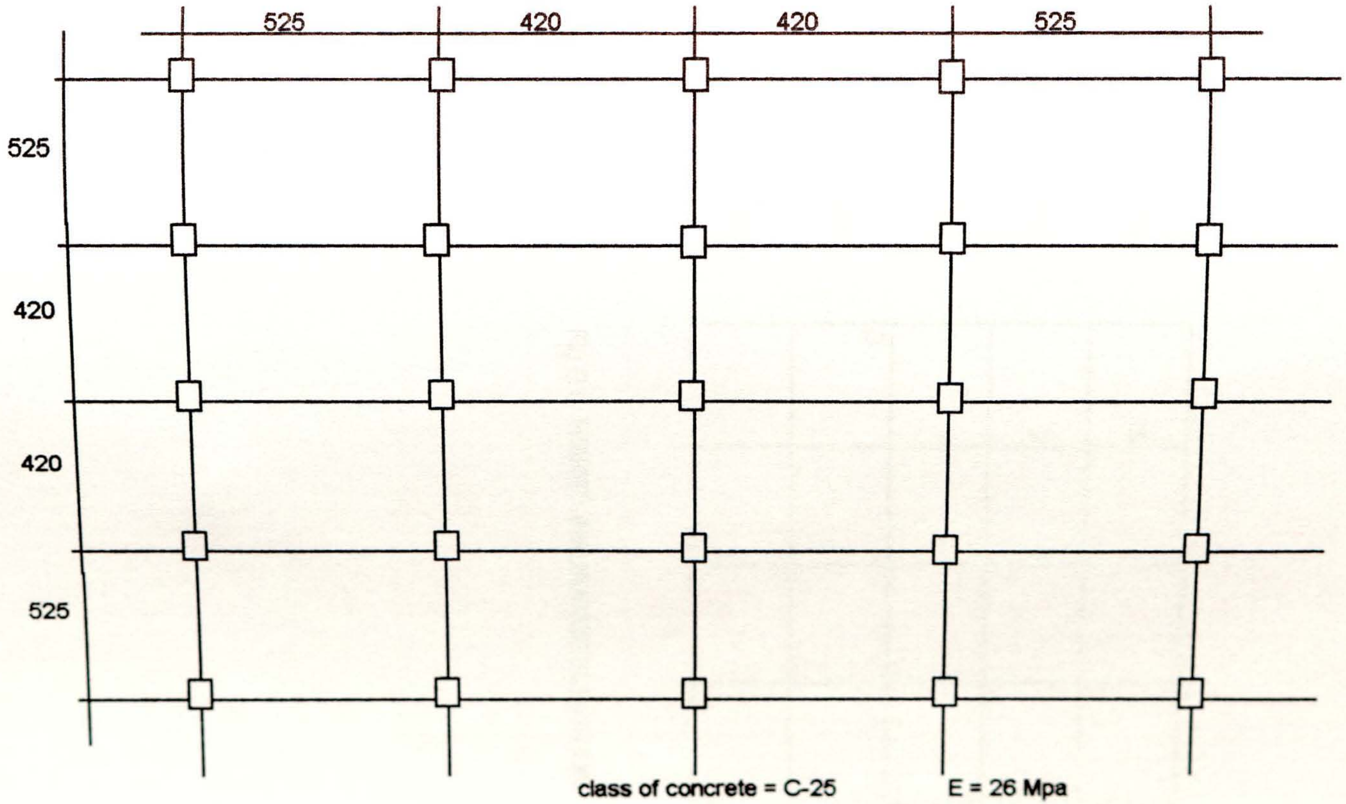


Fig B.5 HIBRET INSURANCE AND OROMYA ADMINISTRATION BUILDING FLOOR PLAN.

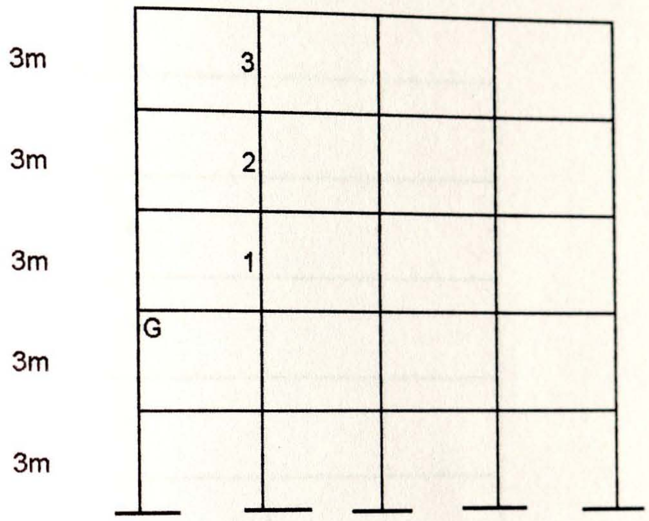


Fig B.6 HIBRET INSURANCE ELEVATION.

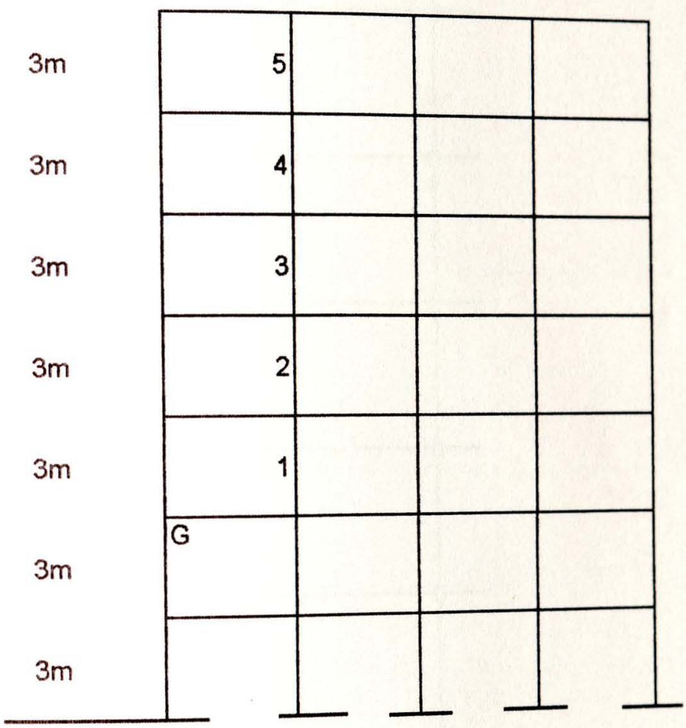


Fig B.7 OROMYA REGIONAL ADMINSTRATION BUREAU ELEVATION.

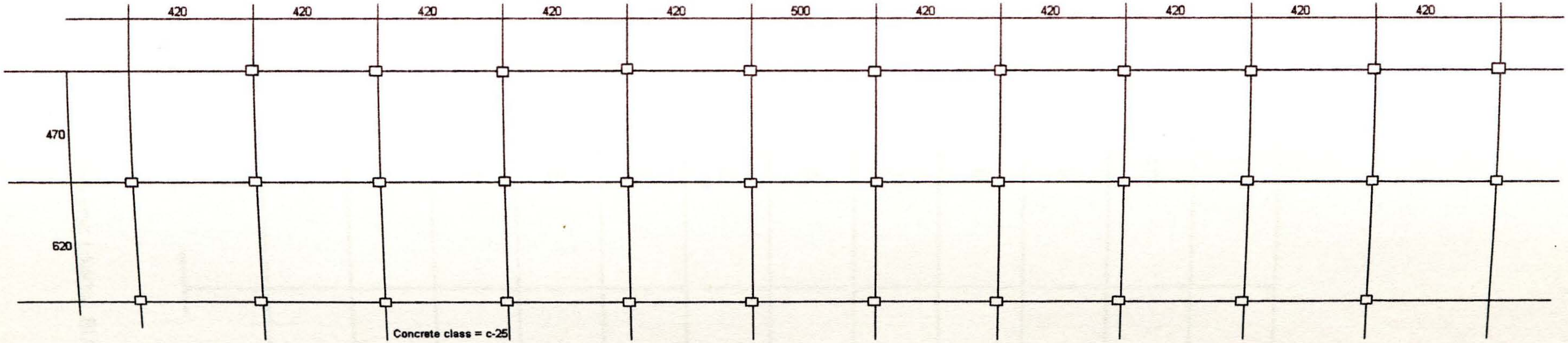


Fig B.8 ETHIOPIAN TRADE UNION FLOOR PLAN.

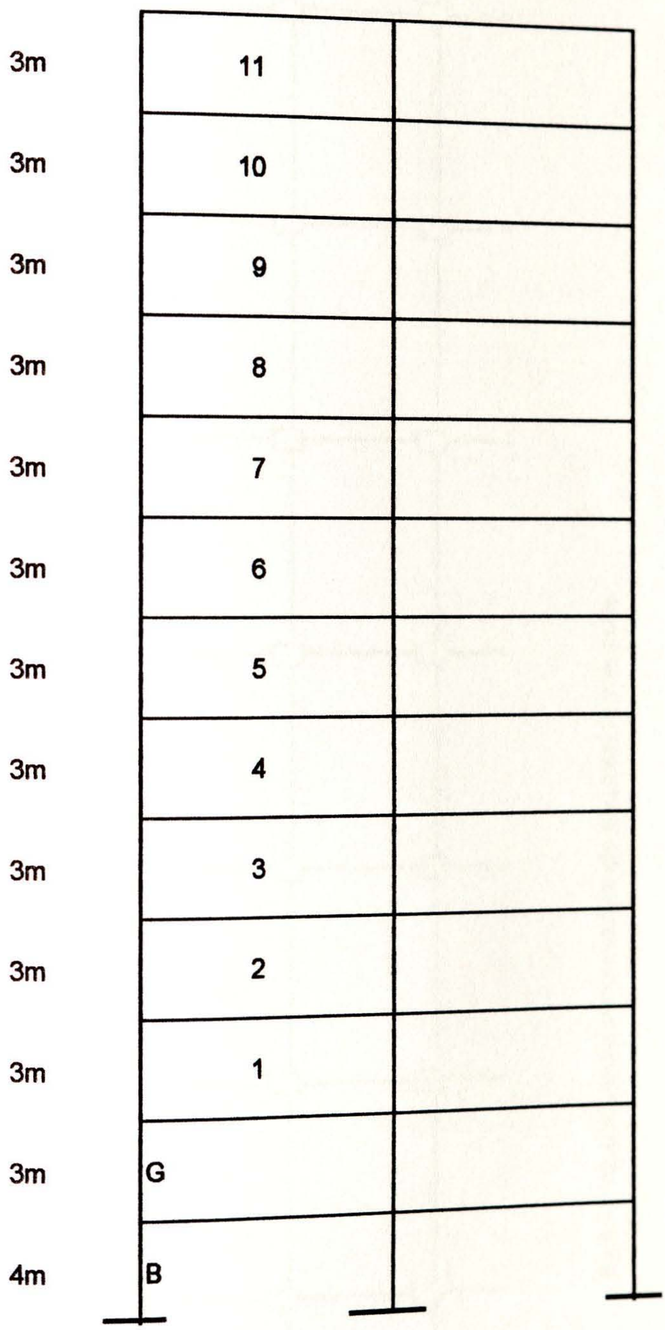


Fig B.9 ETHIOPIAN TRADE UNION BUILDING ELEVATION.

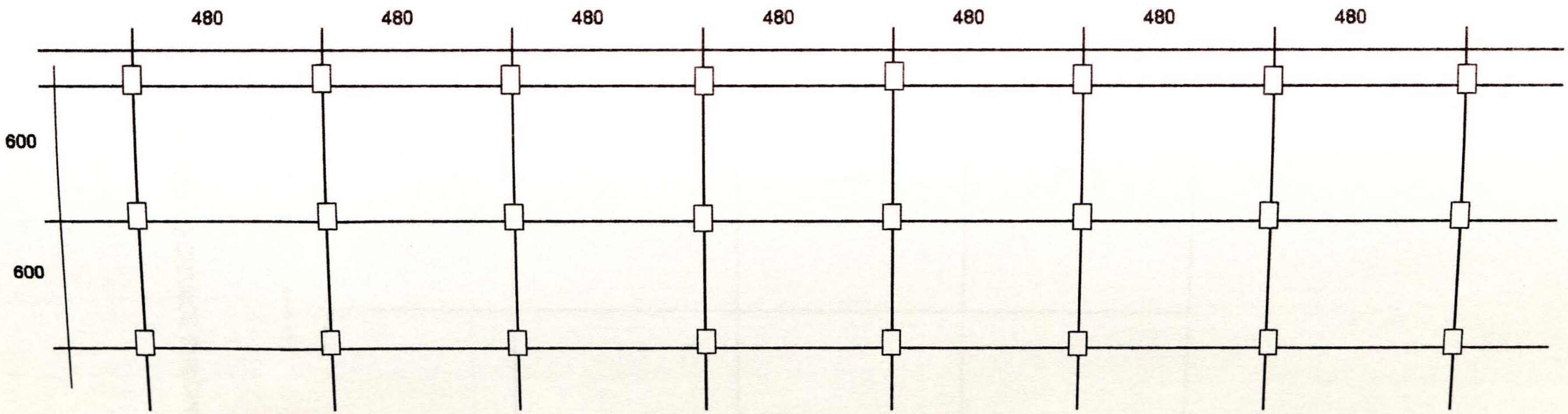


Fig B.10 TELECOMMUNICATION EXCHANGE BUILDING FLOOR PLAN.

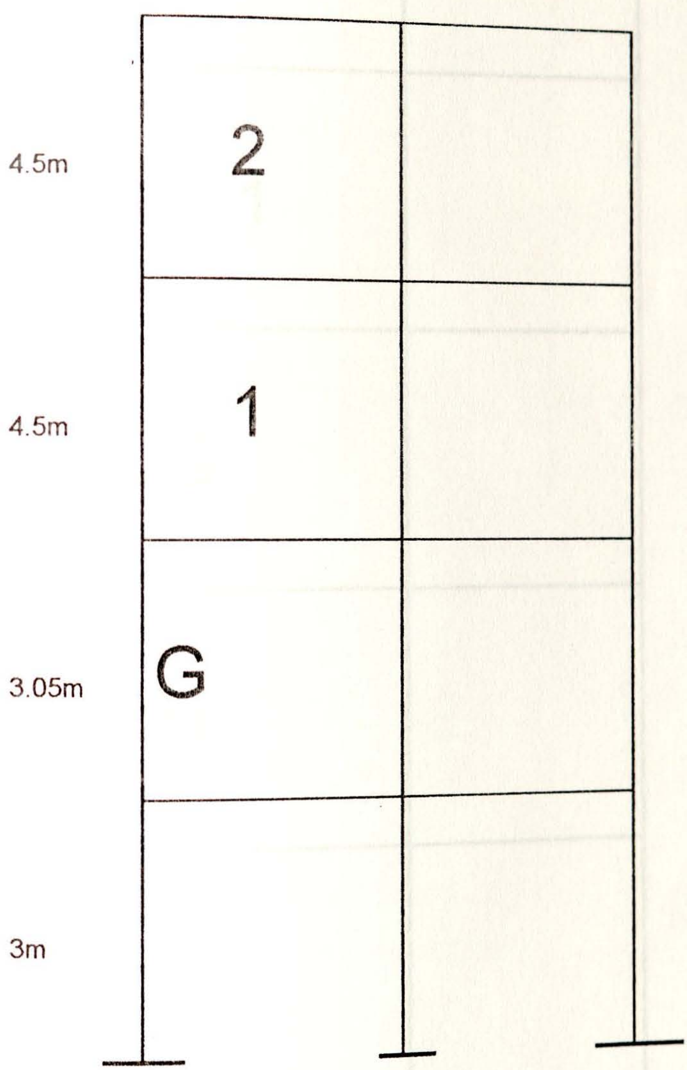


Fig B.12 TELECOMMUNICATION EXCHANGE BUILDING ELEVATION (NEW).

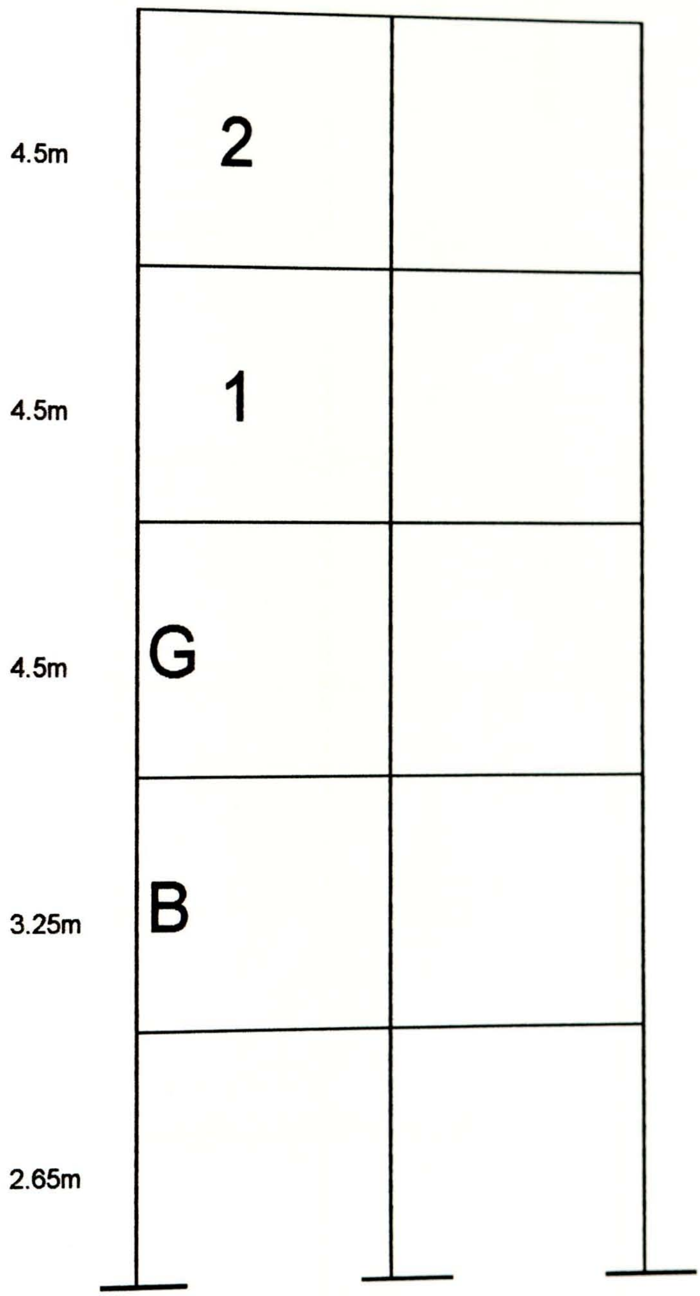


Fig B.11 TELECOMMUNICATION EXCHANGE BUILDING ELEVATION (OLD).

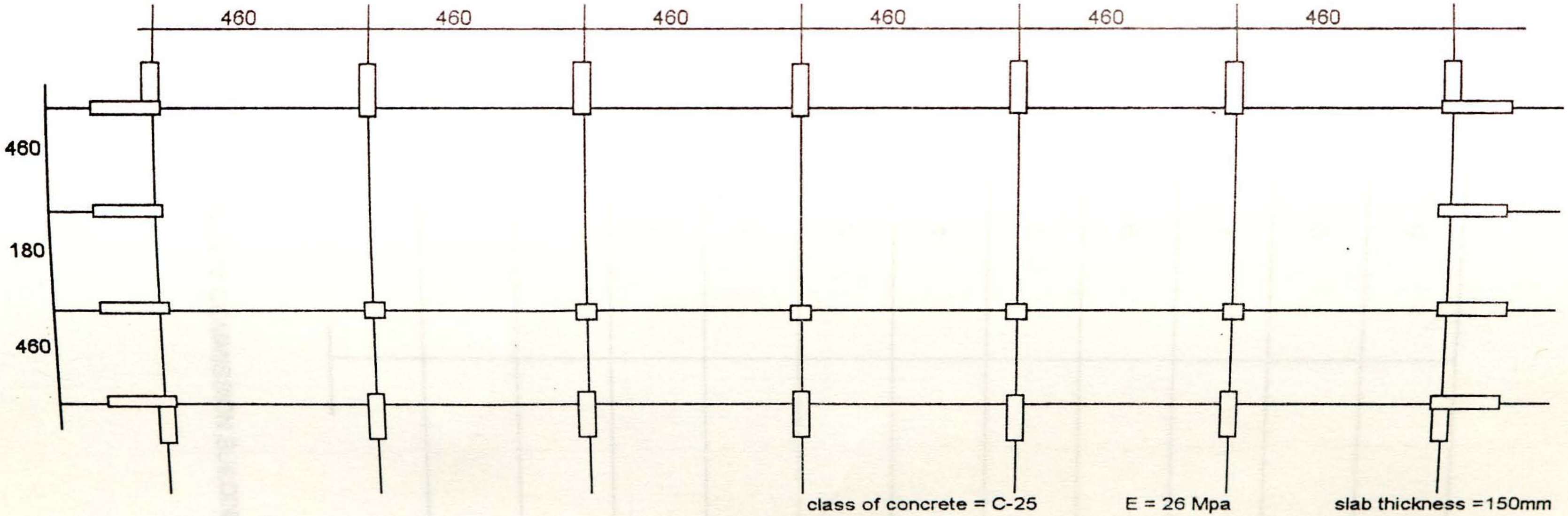


Fig B.13 SCIENCE & TECHNOLOGY COMISSION BUILDING FLOOR PLAN.

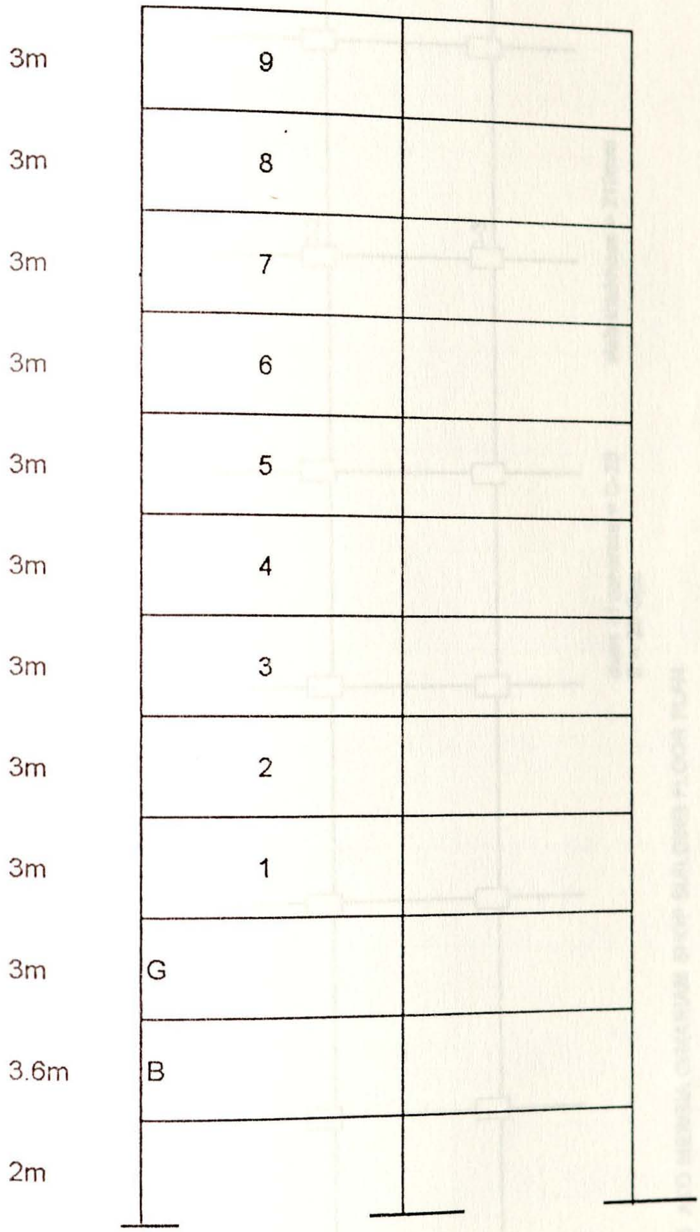


Fig B.14 SCIENCE & TECHNOLOGY COMMISSION BUILDING ELEVATION.

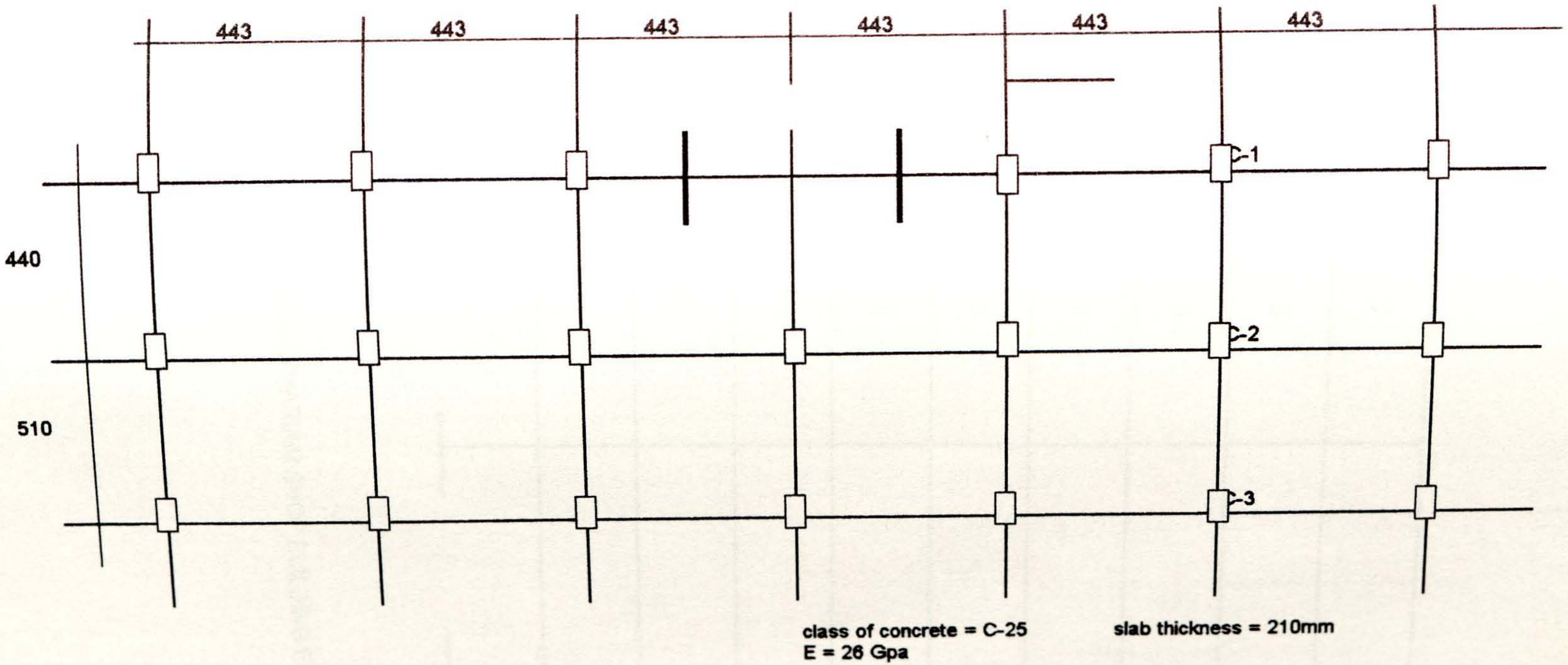


Fig B.15 ATO MERGIA G/MARIAM SHOP BUILDING FLOOR PLAN.

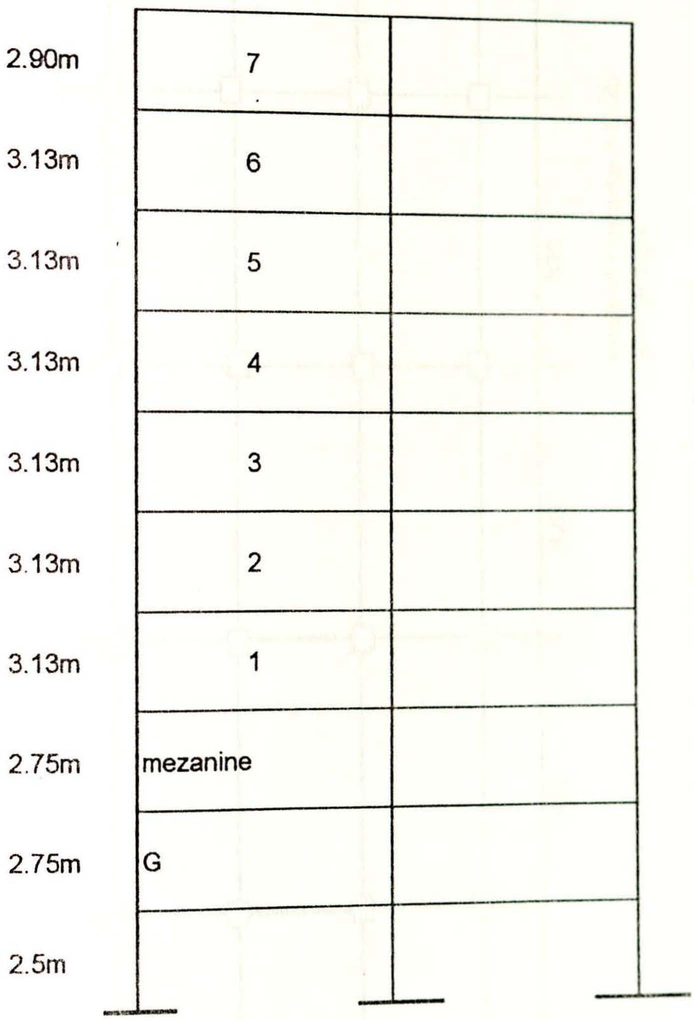
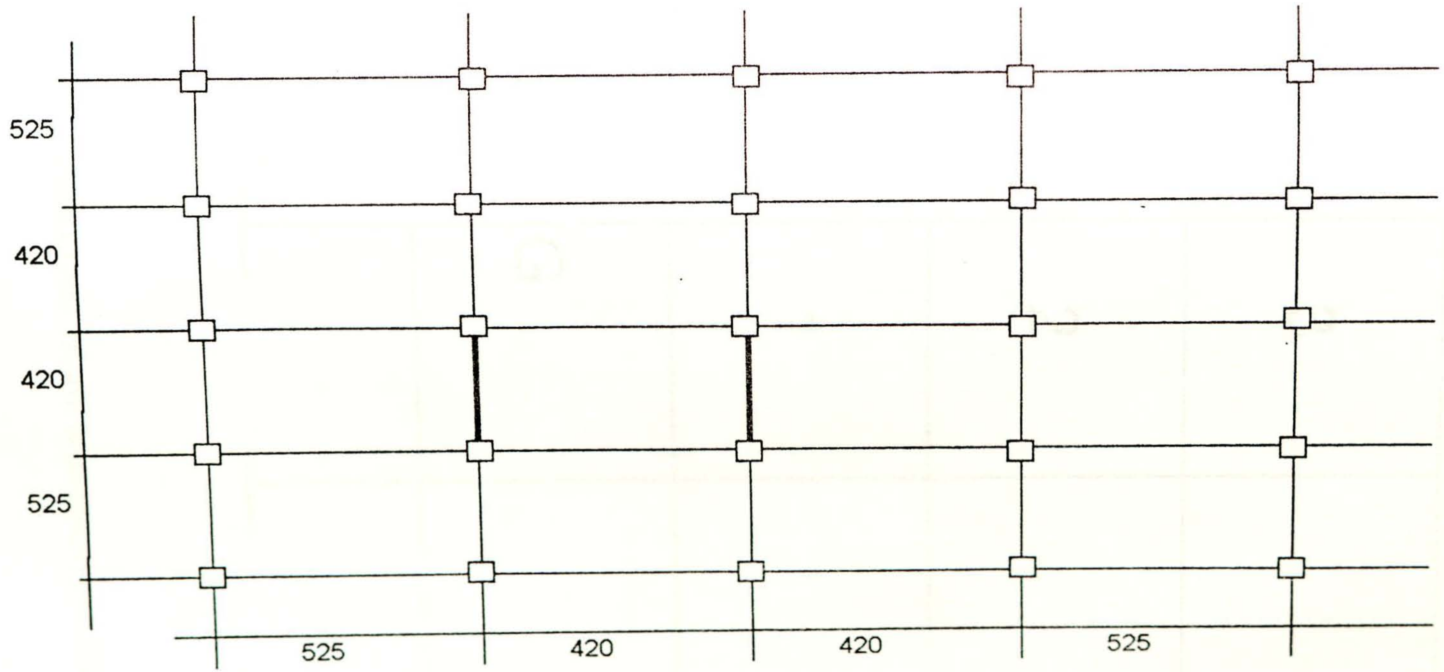


Fig B.16 ATO MERGIA G/MARIAM SHOP BUILDING ELEVATION.



class of concrete = C-25
E = 26 Mpa

Fig B.17 ETHIOPIAN GRAIN TRADE BUILDING FLOOR PLAN (BLOCK-B).

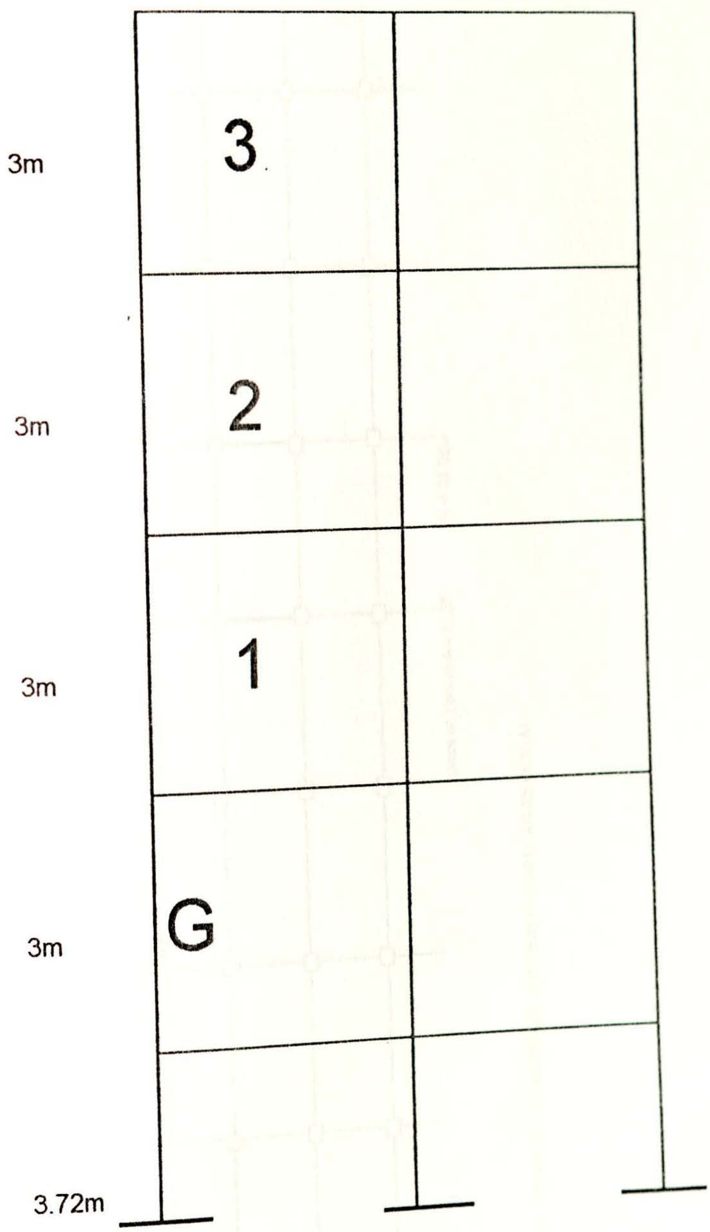


Fig B.18 ETHIOPIAN GRAIN TRADE BUILDING ELEVATION (BLOCK-B)

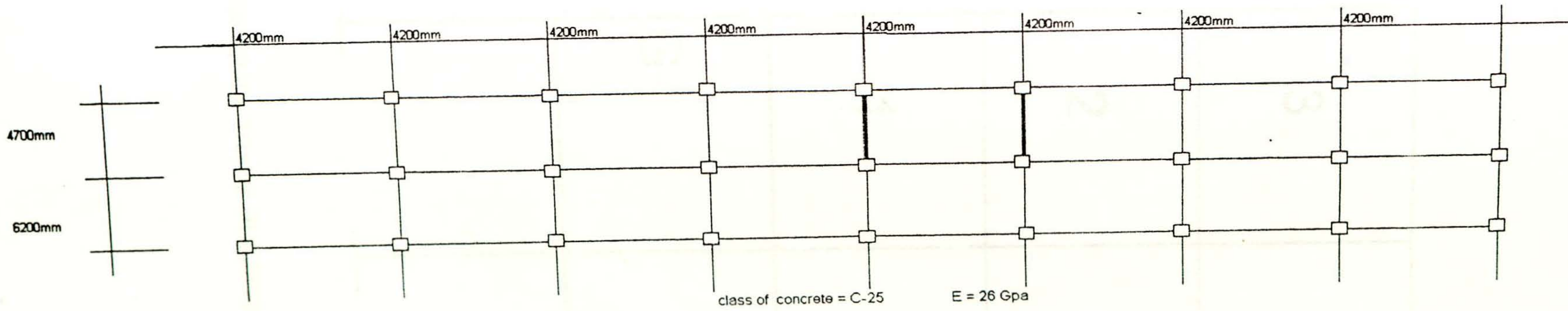


Fig B.19 ETHIOPIAN GRAIN TRADE BUILDING FLOOR PLAN (BLOCK-A).

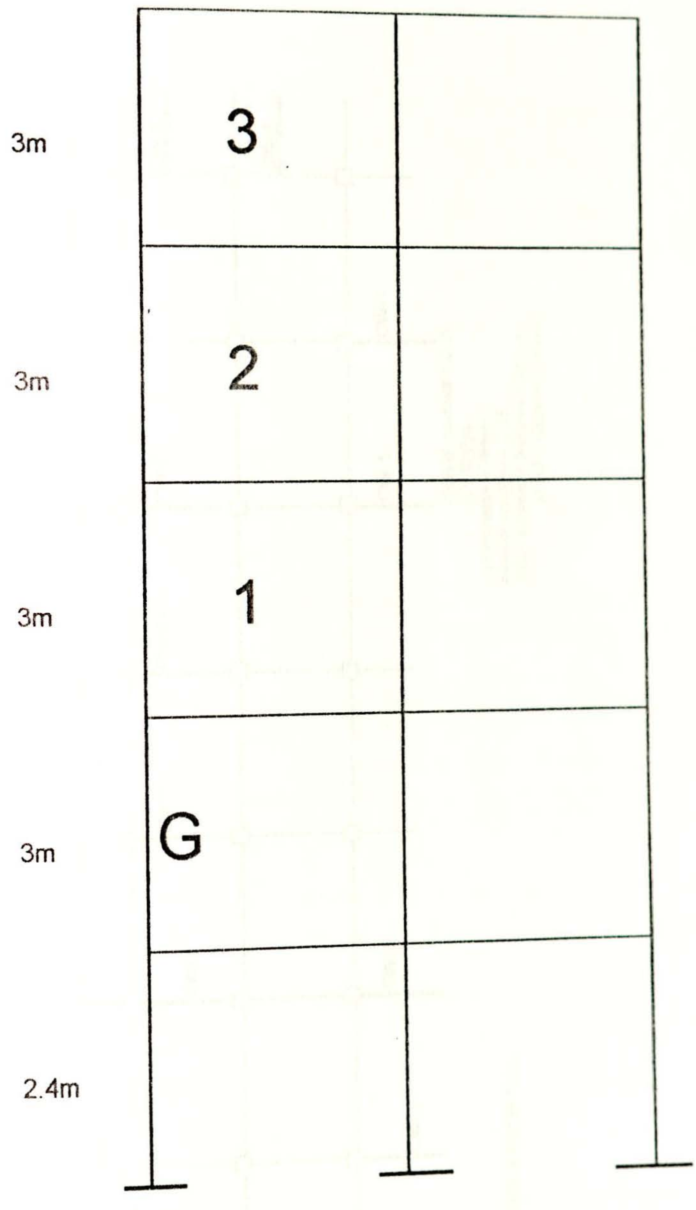
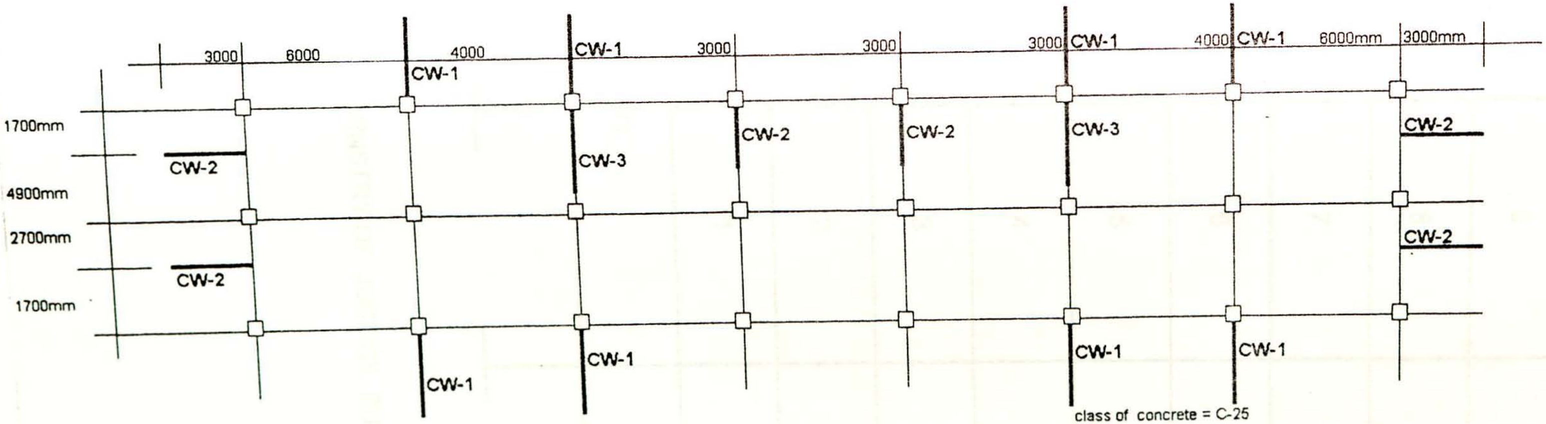


Fig B.20 ETHIOPOAN GRAIN TRADE BUILDING ELEVATION (BLOCK A)



class of concrete = C-25
E = 28 Gpa
slab thickness = 150mm
class of concrete = C-25
CW-1 & CW-4 = 3000mm * 200mm
CW-3 = 4800mm * 200mm

Fig B.21 MINISTRY OF JUSTICE FLOOR PLAN

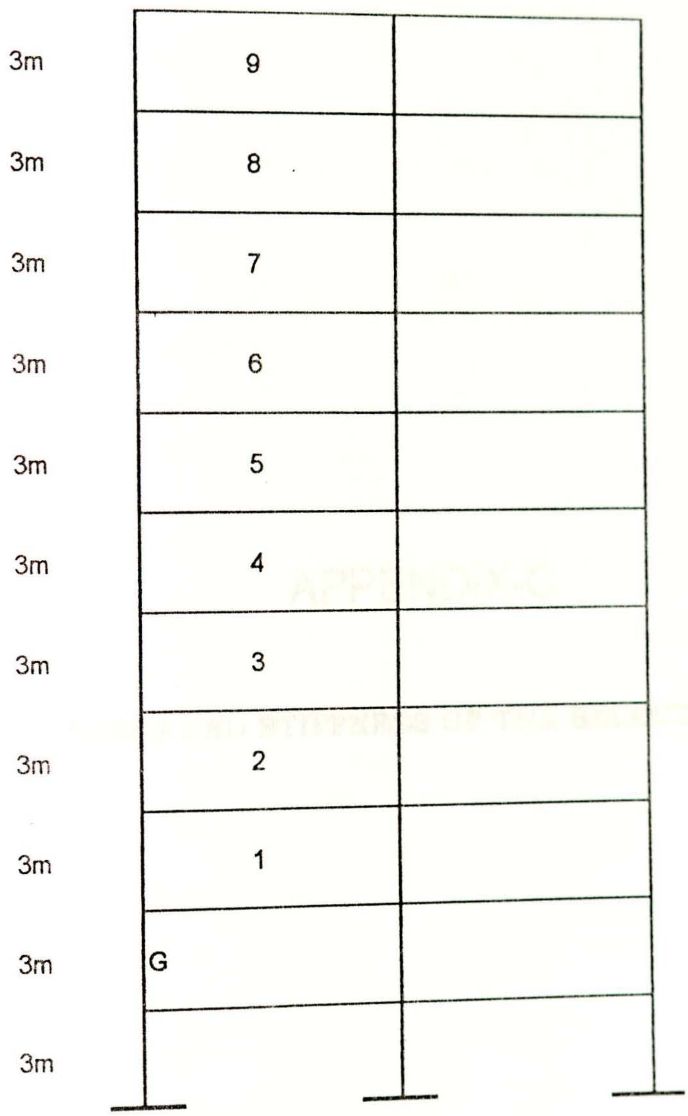


Fig B.22 MINSTRY OF JUSTICE BUILDING ELEVATION.

APPENDIX-C

MASSES AND STIFFNESS OF THE SELECTED BUILDINGS.

	TABLE C.1	Weight(KN)	Stiffness (KN/m)
	DASSET BUILDING		
1.	7th- FLOOR (Rm. Height= 2.88m)		
	COLUMN		
	0.3*0.3*2.88*12*25	77.67	
	0.4*0.3*2.88*6*25	51.84	21.3
	SHEAR WALL		
	0.2*4.6*2.88*25	66.25	
	0.2*3.45*2.88*25	49.69	1768.2
	BEAM		
	0.35*0.3*10*6*25	157.5	
	0.35*0.3*25*3*25	196.88	
	SLAB		
	25.3*10.4*0.15*25	986.67	
2.	6th-FLOOR (Rm. Height=2.96m)		
	COLUMN		
	0.4*0.3*2.96*16*25	142.08	
	0.5*0.3*2.96*2*25	22.21	31.93
	SHEAR WALL		
	(63.6+47.7)*2.96/2.88	119.16	1629.11
	BEAM		
	(151.2+189)	364.22	
	SLAB	986.67	
3.	5th-FLOOR (Rm. Height=2.8m)		
	COLUMN		
	0.5*0.3*2.8*18*25	189	66.62
	SHEAR WALL	112.72	1924.65
	BEAM	364.22	
	SLAB	986.67	
4.	4th-FLOOR (Rm. Height=2.88m)		
	COLUMN		
	0.4*0.5*2.88*18*25	259.2	81.63
	SHEAR WALL	112.72	1768.2
	BEAM	364.22	
	SLAB	986.67	

5.	3rd-FLOOR (Rm. Height=2.88m)		
	COLUMN		
	0.4*0.5*2.88*16*25	230.40	
	0.4*0.6*2.88*2*25	12	88.23
	SHEAR WALL	112.72	1768.2
	BEAM	364.22	
	SLAB	986.67	
6.	2nd-&-1st-FLOOR (Rm. Height=2.34m)		
	COLUMN		
	0.4*0.6*2.34*18*25	252.71	262.98
	SHEAR WALL	94.20	3297.46
	BEAM	364.22	
	SLAB	986.67	
7.	GROUND FLOOR (Rm. Height=3.96m)		
	COLUMN		
	0.5*0.7*3.96*18*25	623.70	107.71
	SHEAR WALL	159.41	680.36
	BEAM	364.22	
	SLAB	986.67	
8.	FOUNDATION COLUMN (2m)		
	COLUMN		
	0.6*0.6*2.*18*25	324	631.8
	SHEAR WALL	80.51	5281.25
	BEAM	364.22	
	SLAB	986.67	

	TABLE C.2	Weight(KN)	Stiffness (KN/m)
	ETHIOPIAN TRADE UNION		
1.	HIBRET INSURANCE		
	COLUMN		
	0.4*0.4*3*25*25	300	51.36 (all-floors)
	SLAB		
	19.3*19.3*0.18*25	1676.21	
2.	ETHIOPIAN TRADE UNION MAIN BUILDING		
	COLUMN	464.06	
	1.25*0.45*3*11*25	429	
	0.65* 0.4*3*21*25		285.66 (all floors)
	SHEAR WALL	127.5	
	4.25*0.2*3*2*25	51	
	3.4*0.2*3*25	72	
	4.8*0.2*3*25		3098 (all floors)
	SLAB	2245.32	
	11.55*43.2*0.18*25		

	TABLE C.3	Weight(KN)	Stiffness(KN/m)
	ETHIOPIAN GRAIN TRADE BUILDING		
1.	BLOCK—A		
	COLUMN		
	C_1 0.65*0.4*3*18*25	351	8.82(Grnd-3[rd])
	0.65*0.4*2.4*18*25	280.80	17.22(Footing)
	C_2 0.45*0.45*3*9*25	136.69	3.29(Grnd-3[rd])
	0.45*0.45*2.4*9*25	109.35	6.42(Footing)
	SHEAR WALL		
	4.7*0.15*3*6*25	317.25	1249.72(Grnd-3[rd])
	4.7*0.15*2.4*6*25	253.80	2440,86(Footing)
	BEAM		
	0.52*0.45*35.38*3*25	620.91	
	SLAB		
	35.38*10.9*0.18*25	1735.39	
2.	BLOCK—B		
	COLUMN		
	0.5*0.5*3*25*25	468.75	5.02(Grnd-3[rd])
	0.5*0.5*3.72*25*25	581.25	2.63(Footing)
	SHEAR WALL		
	4.2*0.15*3*25*2	94.50	891.8(Grnd-3[rd])
	4.2*0.15*3.72*25*2	117.18	467.74(Footing)
	SLAB		
	18.9*18.9*0.18*25	1607.50	

	TABLE C.4	Weight (KN)	Stiffness (KN/m)
	MINISTRY OF JUSTICE		
	COLUMN		
	C_1 0.4*0.8*3*16*25	384.00	16.43(all floors)
	C_2 & C_{20}		
	0.4*0.8*3*4*25	96.00	16.43(7^{th}-9^{th})
	0.5*0.8*3*4*25	120.00	20.54(4^{th}-6^{th})
	0.6*0.8*3*4*25	144.00	24.65(1^{st}-3^{rd})
	0.65*0.8*3*4*25	156.00	26.71(Grnd & Base)
	SHEAR WALL		
	SW_1 & SW_2		
	3*0.2*3*10*25	450.00	433.33(all floors)
	SW_3		
	4.8* 0.20*3*2*25	144.00	1774.93(all floors)
	SLAB		
	29*11*0.15*25	1196.25	

	TABLE C.5	Weight (KN)	Stiffness (KN/m)
	ATO MERGIA G/ MARIAM BUILDING		
	COLUMN		
	C_3 0.4*0.4*3.13*5*25	62.60	1.81(1^{st}-7^{th})
	0.4*0.4*2.75*5*25	55.00	2.67(Grd-Mezanine)
	0.4*0.4*2.5*5*25	50.00	3.55(Foundation)
	C_1 & C_2		
	0.4*0.4*3.13*7*25	175.27	1.81(5^{th}-7^{th})
	0.4*0.5*3.13*7*25	219.10	3.53(1^{st}-4^{th})
	0.5*0.5*2.75*7*25	240.63	6.51(Mezanine)
	0.5*0.5*2.5*7*25	218.75	8.67(Foundation)
	SHEAR WALL		
	3.5*0.2*3.13*2*25	109.58	605.89(1^{st}-7^{th})
	3.5*0.2*2.75*2*25	96.25	893.36(Meznine)
	3.5*0.2*2.5*2*25	87.50	1189.07(Foundation)
	SLAB		
	11.9*27.73*0.21*25	1732.43	

	TABLE C.6	Weight (KN)	Stiffness (KN/m)
	SCIENCE & TECHNOLOGY COMMISSION		
	COLUMN	60.00	10.27(7^{th}-9^{th})
	0.4*0.4*3*5*25	93.75	25.08(4^{th}-6^{th})
	0.5*0.5*3*5*25	135.00	52(Grnd-3^{rd})
	0.6*0.6*3. *5*25	162.00	30.1(Basement)
	0.6*0.6*3.6*5*25	90.00	175.5(foundatn)
	0.6*0.6*2*5*25		
	CONCRETE WALL	495.00	354.37(all floors)
	1.0*0.3*3*22*25		
	BEAM	288.75	
	0.3*0.5*11*7*25	329.63	
	0.3*0.5*29.3*3*25		
	SLAB	1138.54	
	0.15*27.6*11*25		

	TABLE C.7	Weight (KN)	Stiffness (KN/m)
	SUNSHINE BUILDING:		
	COLUMN		
	0.4*0.6*3*12*25	216.04	6.93 (2^{ND}-8^{TH})
	0.4*0.6*4.2*12*25	302.40	2.53 (1^{ST}-Floor)
	0.4*0.6*3.6*12*25	259.16	4.01 (Grnd. & Basement)
	BEAM		
	0.4*0.5*11.9*6*25	356.98	
	0.4*0.5*25.4*3*25	381.04	
	SHEAR WALL		
	SW1 0.3*2.7*3*2*25	121.46	5.85(2^{nd}-8^{th})
	0.3*2.7*4.2*2*25	170.10	2.13(1^{st}-Floor)
	0.3*2.7*3.6*2*25	145.83	3.38 (Grnd & Basmnt.)
			309.26(2^{nd}-8^{th})
	SW2 0.3*5*3*2*25	225.00	109.67(1^{st}-Floor)
	0.3*5*4.2*2*25	315.00	174.15(Grnd & Basmnt.)
	0.3*5*3.6*2*25	270.00	
	SLAB		
	11.5*25*0.18*25	1293.75	

	TABLE C.8	Weight (KN)	Stiffness (KN/m)
	TELECOMMUNICATION EXCHANGE BUILDING.		
1.	OLD BUILDING		
	COLUMN		
	0.5*0.5*4.5*24*25	648	35.67(Grnd-2nd)
	0.5*0.5*3.25*24*25	468	94.67(Basement)
	0.5*0.5*2.65*24*25	382	174.64(Foundation)
	SLAB		
	32.7*12.5*0.25*25	2452.5	
2.	NEW BUILDING		
	COLUMN		
	0.5*0.5*4.5*24*25	648	35.67(1st-3rd)
	0.5*0.5*3.05*24*25	439.2	114.56(Ground)
	0.5*0.5*3*24*25	432	120.39(Foundation)
	BEAM		
	0.5*0.39*12*8*25	449.28	
	0.5*0.39*33.6*3*25	471.74	
	SLAB		
	34.1*12.5*0.21*25	2148.3	

DECLARATION

I, the undersigned, hereby declare that this thesis is my original work carried out under the supervision of Dr. Messele Haile, has not been presented as a thesis in any other university and that all sources for this thesis are duly acknowledged.

Tadesse Kebede